Journal of Oilseed Brassica, 9 (2) : 168-175, July 2018

Design and implementation of web-based expert tool for selection of climate resilient rapeseed-mustard varieties

Vinod Kumar*, Abhinav Kumar[1], AK Sharma, PD Meena and PK Rai

ICAR-Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur, India
[1]Department of Computer Science & Engineering, IIT BHU, Varanasi, India
**Corresponding author: vky20@hotmail.com, vinod.kumar6@icar.gov.in*
(Received: 05 February 2018; Revised: 09 May 2018; Accepted: 23 June 2018)

Abstract

Rapeseed-mustard grown area in India has been classified into five major agro-ecological zones. The basic climatic conditions targeted for developing the resource efficient varieties are rainfed and irrigated. Approximately 30% of total rapeseed-mustard cultivated area in the country is rainfed. In situations of erratic climatic conditions, it is imperative for the farmers to be well informed about the available technologies suitable for their regions. In India, rapeseed-mustard researchers have developed many improved varieties performing well in both rainfed & irrigated conditions. However, information about these varieties is scattered and in several forms. The challenge was to organize the information electronically so that the farmers of the country could be benefited from this information. For this purpose, a web based expert system for rapeseed-mustard crop variety selection was developed by applying knowledge engineering approaches with scientific knowledge base in backend. The system suggests the varieties of farmer's/advisors's choice based on agro-climatic conditions. The system carries detailed information about 160 notified varieties that have been stored in its knowledge base. The important feature implemented in this expert system is that it is bilingual and available in English and Hindi languages making it easily understandable by farmers of the major rapeseed-mustrad grown states.

Key words: *Domain expert, expert systems, inference engine, knowledge base, MySQL, rapeseed-mustard, web*

Introduction

India is the third largest producer of oilseeds worldwide. Oilseeds cultivated area in India is about 27 mha, out of which 72 % area is under rainfed condition. Out of the nine oilseed crops cultivated in India, Soybean (*Glycine max* (L.) Merill), Rapeseed-Mustard (*Brassica* species), Groundnut(*Arachis hypogaea L.*) and Sunflower (*Helienthus annus* L.) are the major crops and collectively contribute to more than 85% of the total oilseed cultivated area. Rapeseed-mustard is the second most important oilseed crop from production, as well as, domestic consumption point of view and comprises of about 25% of the total oilseed cultivated area (Anonymous, 2014). The rapeseed-mustard grown area in India has been classified into V major agro-ecological zones based on their climatic conditions. In India, about 55% of the net sown area is rainfed (NRAA, 2012). More than 27% area of total rapeseed-mustard is under rainfed condition which of high risk of importance. Rapeseed-mustard crop being an economically important oilseed crop, continuous efforts have been made by researchers since a long time to develop resource efficient varieties for different agro-ecological conditions. Rapeseed-mustard crops comprises of traditionally grown indigenous species of rapseed and mustard. The indigenous species of rapeseed includes, Brown Sarson (*Brassica campestris* syn. *B. rapa* var.. Brown Sarson); Gobhi Sarson *(B. napus* ssp. *oleifera* DC var. *annua*); taramira (*Eruca sativa / vesicaria* Mill.); Toria (*B. campestris* syn. *B. rapa* var. Toria); Yellow Sarson (*B. campestris* syn. *B. rapa* var.. Yellow Sarson). The species of mustard includes Indian mustard [*B. juncea* (L.) Czernj & Cosson]; black mustard (*B. nigra*); Ethiopian mustard or Karan rai (*B. carinata* A. Braun). As a result till 2015, more than 160 improved varieties of these species, suitable for different zones, have been developed by researchers under All India Coordinated Research Project on Rapeseed-Mustard (AICRP-RM) and are notified by the Government of India and State governments (Chauhan *et al.*, 2006; 2012, AICRP-RM 2015). Although, the information related to most of these varieties have been documented, however it is scattered and in several forms. Organization of this scattered information and making it accessible to the end users is a major challenge. Availability of the information to the intended users (farmer, extension personnel, student and researchers) supports in selection of varieties for their specific purposes. Variety selection is the most important decision a farmer make each year for any crop. This needs agricultural specialization and technical awareness among farmers or extension personnels to help the farmers in selecting suitable variety. The traditional system to equip farmers with latest scientific information and technological progresses is either not trustworthy or highly expensive or may not available at the time of farmers' decision making. In order to alleviate this problem, expert systems were identified as a powerful tool with extensive potential in agriculture (Hasan *et al.,* 2014; Ganesan, 2007).

In the era of digital technology, World Wide Web has played an important role in development of tools to augment human decision-making ability (Daryal *et al*., 2012). Web based expert system for rapeseed-mustard variety selection can assist the farmers and extension personnels by providing varietal information according to their climatic conditions. The expert system is an intelligent computer program that uses knowledge based and inference procedures to solve problems that are difficult enough to require human expertise for their solution (Kumar *et al.,* 2008; Andrew, 2014).

Related Work

As the expert system (ES) is a computer program which captures the knowledge of a human expert on a given problem, and uses this knowledge to solve problems in a fashion similar to that of an expert. The system can assist expert during problem-solving, or act in place of the expert in situations where the expertise is lacking (John Durkin, 1990). A number of stand-alone and web based expert systems have been developed for solving general and domain specific problems in agriculture. Expert systems for disease diagnosis (Yialouris *et al*., 1996; Mansingh *et al*.,2007; Boyd *et al.*, 1994; Thomson *et al*., 1998; Li *et al.*, 2002; Prasad *et al.*,2002; Mahaman *et al.*, 2002, 2003; Duan *et al.*, 2003; Zetian *et al.*, 2005; Gutie'rrez-Estrada *et al.*, 2005; Gonzalez *et al.* ,2006; Prasad *et al*., 2006; Khan *et al.*, 2008; Kumar *et al.*, 2008; Patil *et al.*, 2009; Lai *et al.*, 2010; Li *et al*., 2002; Ahmed Rafea, 2010; Ravishankar *et al.*, 2012; Kolhe *et al.*, 2011; Sarma *et al.* 2008; Pertot *et al.*, 2012; Suhartono *et al.*, 2013; Kaliuday *et al.*, 2014) and System for selecting crop variety (Joseph, 1995; Zhang *et al*.,1992; Ole *et al.*, 1997; Allan *et al*.**,** 2001**;** Edrees *et al.*, 2003; Millard *et al.*, 2009; Xiangliang *et al*., 2009; Yan-fang Liu *et al.*, 2013; Islam *et al.*, 2012; Erlin *et al*., 2014; Koonsanit *et al*., 2011; Ani Dath *et al*., 2016) have been developed for crop variety selection. Grove (2000) mentioned several factors that make the internet an ideal base for expert system delivery in contrast to stand-alone platform. These are: instant availability of internet; a common multimedia interface provided by web browsers; inherent portability of web based applications and availability of several web based KBS development tools. In order to develop an expert system in agriculture, knowledge has to be extracted from human expert or domain expert. This knowledge is then converted into a computer program. While developing it, engineer must perform task of extracting the knowledge from the domain expert, so that it can produce knowledge base. The knowledge is then represented in the form of IF-THEN rules. In this direction much work has been done, however no study has utilized this new approach for selecting climate resilient varieties of rapeseed-mustard crop. Therefore, this study was conducted with major focus on the design, implementation and application of web based variety selection system for rapeseed Mustard. The system developed in the study was named as RMSelect and it was developed at ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, the premier institute engaged in development and co-ordination of rapeseed-mustard research in India. RMSelect is a prototype system developed for rapeseed-mustard crop, but the system can be implemented for any agricultural crop especially oilseed crops as an aid in farmer decision making for selection of appropriate variety of their need. For development of web-based system, we chose the robust open source technology LAMP (Linux-Apache-MySQL-PHP), the system which is bi-lingual was recommended to use an essential tool for rapeseed-mustard variety selection in India.

Materials and Methods

The design of an agricultural expert system (ES) has to take into account two possible requirements: 1) the completeness of the information held in the knowledge base, and 2) ease of use for the intended users. Information in the knowledge base has to be as comprehensive and detailed as possible to allow for all conceivable queries. A key factor in the success of any ES is the quality and quantity of knowledge provided by the experts (David, 1987). There are several methodologies devised for development of expert system, and out of them, rule-based knowledge representation appears to be better adapted to expert systems (Lio, 2005). System design and development usually proceeds through several phases of a software development life cycle (SDLC) that includes: feasibility study (problem identification); requirements analysis (users' requirements); system design; testing; implementation and evaluation (Kumar, 2015).

The main components of an ES are: a) knowledge base, b) inference engine, c) user interface, d) Knowledge engineering. The Fig. 1 below shows the system design architecture. The knowledge base is a core component of the expert system for which knowledge was acquired from the experts. Building a knowledge base with the help of an expert as a trusted source of information is the most important thing in the expert system so that the result will be correct and valid. In this case, several methods were conducted, such as direct interviews with some experts of the rapeseed-mustard (Breeder, Agronomist, Extension personnel, etc.); examination of published document about rapeseed-mustard; and surveys of farmers to formulate rules for identification of a variety based on desired condition/characteristics (Kumar *et al.*, 2012). All these criteria were developed during a requirement analysis by knowledge engineers and subject matter specialists.

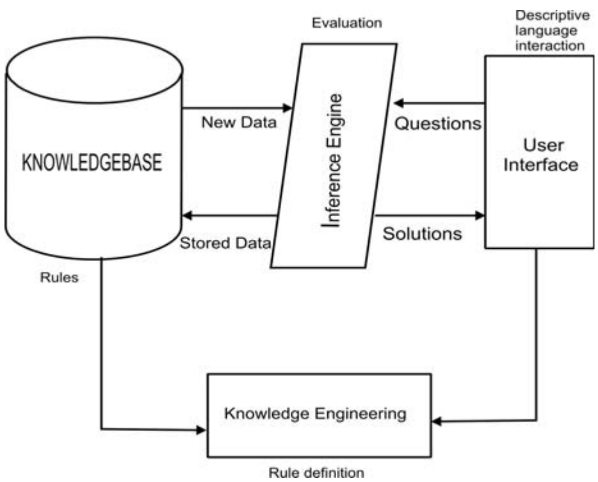

Fig 1: System Design architecture.

The inference engine is guided by the logical reasoning and inference mechanism. 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 be modified easily 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 in form of rules to develop rule-based system. The rules are in the form of "IF... then ELSE". The "IF" part mainly contains the conditions like location, sowing condition, sowing time, yield disease resistance, other quality parameters, etc.

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 (Ani Dath *et al*., 2016). These rules are normally in the form given below:

If [zone] = "Zone-III" and

[state]="Rajasthan" and

[district]="Bharatpur" and

[Sowing Condition]="rainfed" and

[sowing time]="timely" and

[maturity]="medium"

Then [suitable variety] = "V1 OR V2..."

Since, unlike the other crops, the produce of rapeseed-mustard growers' are purchased by the agencies considering several factors such as seed size, oil contact, etc., depending on their local market. Therefore, it is not sure that the farmers will get more return if they produce more using high yielding varieties. Therefore, system has been designed to include farmer's preference before drawing final conclusion by the machine in selecting variety according to their situation.

As the target users are farmers, extension persons, students and researchers, therefore, for user friendliness; the system has been developed in Multilanguage mode (presently in Hindi & English). To overcome with platform dependence, the system uses most appropriate **U**nicode **T**ransformation **F**ormat **8**-bit (UTF-8) Unicode character set for encoding the variety information in different language. UTF-8 encodes each Unicode character as a variable number of 1 to 4 octets, where the number of octets depends on the integer value assigned to the Unicode character. It is an efficient encoding of Unicode documents that use mostly US-ASCII characters because it represents each character in the range U+0000 through U+007F as a single octet. UTF-8 is the default encoding for XML and has become the dominant character set on the Web (http://www.utf-8.com/).

An open source platform consists of LAMP (Linux, Apache, MySQL and PHP/Perl/Python) has been deployed with the standard web based client/server architecture to design and implement the system (Lee and Brent, 2002; Kumar *et al.* 2012; 2013).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, oil content, seed size, response to disease and insects.

Results and Discussion

System design and operation

The web based system developed for selecting rapeseed-mustard variety used widely adopted methodology of expert system development that is rule-based knowledge representation. The expert system derives its answers by running the knowledge base through an Inference Engine. Forward chaining inference mechanism is used; this method involves checking the condition part of a rule (using IF-THEN) to determine whether it is true or false. If the condition is true, then the action part of the rule is true. This procedure continues until a solution is found or a dead end is reached. Forward chaining is commonly referred to as data-driven reasoning; it begins with known facts and an attempt to moves towards the desired goal (Akande Ruth *et al.*, 2015). The process of knowledge acquisition was done by interviewing experts of the rapeseed-mustard (Breeder, Agronomist, Extension personnel, Farmers, etc.,). The system consists of information on 20 attributes of more than 160 rapeseed-mustard varieties so far notified by the government agencies till 2015. (Chauhan *et al.*, 2006; 2012; AICRP-RM, 2015). Table1 is the crop wise distribution of varieties in knowledge base.

Table1: Crop wise distribution of varieties

S.No.	Condition	% of Varieties
1.	Indian mustard	60.0
2.	Toria	12.5
3.	Yellow sarson	9.4
4.	Gobhi sarson	6.9
5.	Taramira	3.8
6.	Brawon sarson	3.1
7.	Karan rai	2.5
8.	Black mustard	0.6

Expert system conceive the query and deliver the desired result. All notified varieties developed for different agro-ecological zones have been classified in three climatic conditions viz varieties for rainfed, irrigated and suitable for both irrigated and rainfed conditions. Table 2, shows the percentage of varieties grown under different climatic conditions.

Table2: Varieties under different climatic conditions

S.No.	Condition	% of Varieties
1.	Rainfed	30
2.	Irrigated	50
3.	Rainfed & irrigated	20

As the crop is generally cultivated in Rabi (September to March) season in India, therefore the temperature at the time of sowing and maturity, plays a very important role. Therefore all varieties are also sub-classified as early, timely and late sown varieties. The percentage of varieties classified according to sowing conditions are shown in table 3.

Table3: Percentage of varieties sown under different climatic conditions

Condition	% of Varieties
Early	30
Timely	60
Late	10

Three-tier approach of selecting varieties

The RMSelect uses three-tier approach in selecting desired variety. At tier level -I, the system provides options for choosing area and specific condition of growing the crop. At tier-II, the system suggests the number of varieties notified for the specific situation. Unlike other expert systems developed for variety selection, RMSelect selects the variety based on knowledge base considering all the varieties for a specific condition. RMSelect, at the final level, offers the option of farmer preference for selecting more suitable variety such as head-to-head comparison of selected varieties, variety is in seed chain or not and convenience of availability of seed. Therefore, farmer/ extension person can take decision of selecting the variety easily. Fig.2 depicts the three-tier approach RMSelect uses in selecting the appropriate variety.

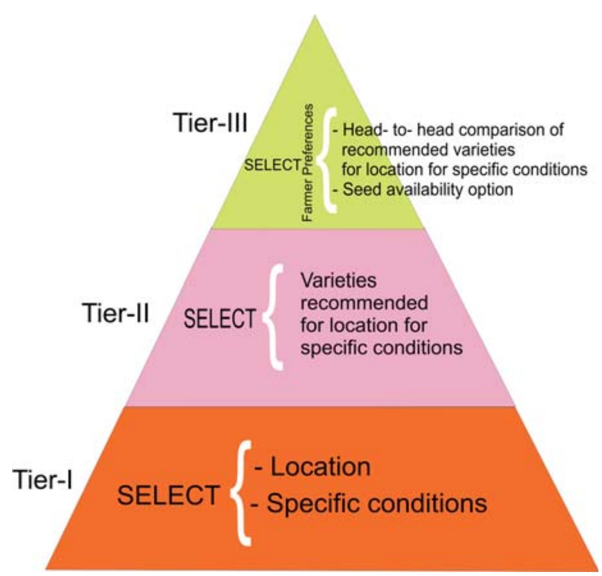

Fig. 2: Three-tire approach for selecting variety

Multi language support (MLS)

To make the system user-friendly and actually useful for farmers and extension personnels, it has been designed with multi-language support facility. The multi language support can be achieved using Machine Translation (MT) and by Human Translation (HT). Both these techniques have some advantage and disadvantage in the domain of language translation (Scoot Baas, 1999) .

In this application, there is no dynamic information acquisition. The pre-defined scientific terminology for describing characteristics of rapeseed-mustard varieties have been used for selecting appropriate variety for a specific condition. As the translation made by language expert may have more accuracy as compare to MT, therefore the system uses pre-translation by human (PTH). The knowledge base has been created by translating characteristics of varieties form English to Hindi languages, which is widely spoken or easily understood in the major mustard growing states (Rajasthan, UP, MP, Gujarat, Punjab, Bihar and West Bengal), where 90% of rapeseed-mustard is produced in India. The advantage of this PTH technique is the accuracy of translation and ease of understanding local dialects. Over the several advantage of PTH, it is slow and takes more space in creating knowledge base by storing the information in the database in separate column for different language.

System accessibility and user interface

The system is available on the website of DRMR and can be accessed with URL http://www.drmr.res.in/rmselect/.

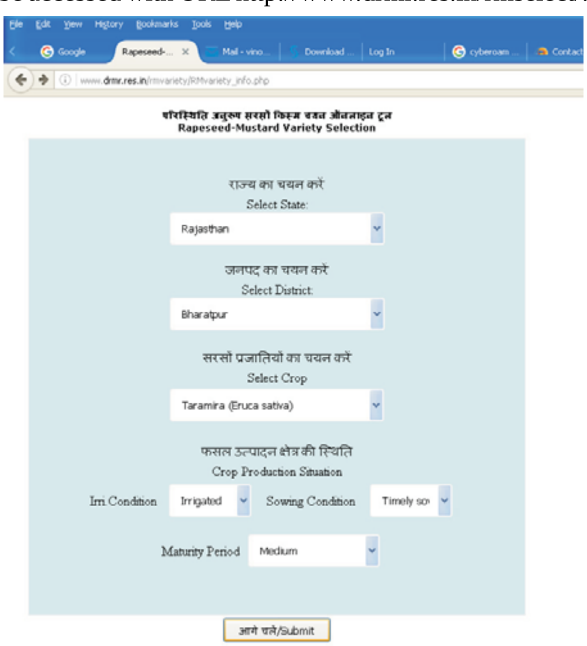

Fig.3: Interface for selecting location and crop condition

Java script, Hypertext Markup Language (HTML), CSS is used in conjunction with PHP to give aesthetically pleasing web interface for users (Kumar *et al.*, 2013, Hustinawaty *et al.*, 2014). User interface was developed with a drop-down box with user options and prompts users for selections at each stage in logical steps sequence. After input of location and conditions, system display the suitable varieties . The user then selects any of the varieties from the shortlist and is directed to a digital version of the variety information sheet. This allows for more intensive and rapid interrogation of variety characteristics and ultimately, better variety selection (Ramburan *et al.*, 2010). Some of the bi-lingual screenshots of RMSelect for user interacting with system are given below. System allows user to select their location, crop and growing conditions using bi-lingual interface (fig. 3)

After selecting the location, system provides the number of varieties which are most suitable at farmer's conditions. System provides option to the farmers to compare the varieties on several attributes of their preferences (fig 4).

Details of the particular selected varieties can be viewed by clicking on the name of variety or by clicking view details icons. Availability of seed may also be obtained through seed chain status (fig. 5).

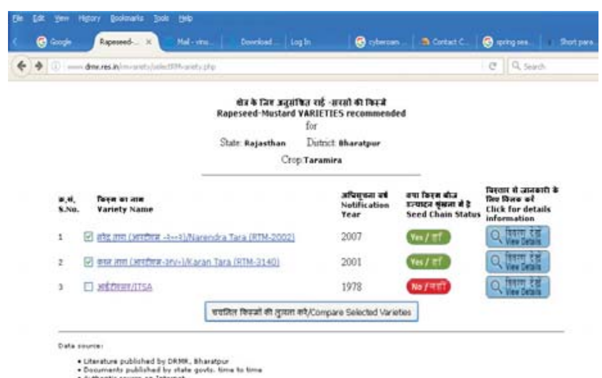

Fig4: Interface for selecting varieties comparison

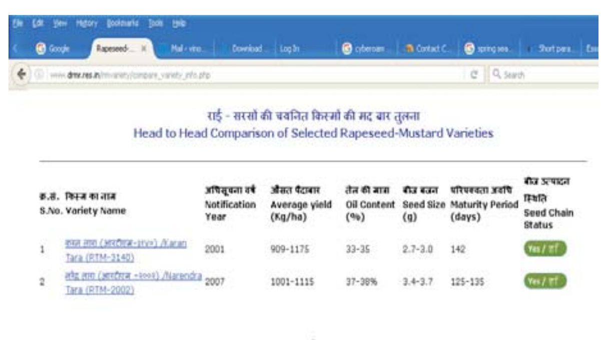

Fig.5: Interface for head-to-head comparison

Evaluation of the system

The RMSelect was evaluated to measure the attitude of the farmers, students, extension personnel and researchers who were the intended users of the system toward the user acceptance of system. Awareness about the system among the users was created through news in newspaper, system URL mailed to concerned stakeholders, leaflet publication, etc. The users were requested to give the opinion on attributes, system completeness, usability and user friendliness. Feedback shows that users were satisfied with both design and performance of the system.

Conclusion

Web based system developed under the name of RMSelect is the modern tool for rapeseed-mustard farmers, as well as, extension persons for selecting appropriate variety according to their conditions. The rapid development of internet technology has changed the way of expert system development. It is easy to access the system via the internet. The system is bi-lingual and provides the information for both researchers/students and farmers/extension person. Researchers can select the genotypes for future study and farmers are able to select the variety according their condition and information on availability of seed. Therefore, RMSelect can save the resources of farmers also. There is sufficient inbuilt flexibility in this system so that it can be adapted by other crops. The feedback collected from the end-users who analyzed the system shows that they were satisfied with both design and performance of the system. For more practical use, the system needs to be developed in many regional languages and may be further updated to accommodate new developed varieties in future. Further refinement and augmentation of the capabilities of the application in response to user feedback is important to enhance the quality of the software.

References

Ahmed R. 2010. Web-Based Domain Specific Tool for Building Plant Protection Expert Systems, Expert Systems, Petrica Vizureanu (Ed.), ISBN: 978-953-307-032-2, InTech, Available from: http://www.intechopen.com/books/expert-systems/web-based-domain-specific-tool-for-building-plantprotection-expert-systems

AICRP-RM. 2015. Annual Progress Report 2014-15, ICAR-Directorate of Rapeseed-Mustard Research, Sewar, Bharatpur-321303

Akande R, Amosa B, Sobowale A and Hameed MA. 2015. Web based expert system for diagnosis and management of kidney diseases. *Intl J Curr Res Acad Rev* **3**: 9-19.

Allan LJ. 2001. Building a web-based information system for variety selection in field crops—objectives and results. *Comp Electroni Agric* 32: 195-211.

Andrew K. 2014. An evaluation of web based expert system as a catalyst for maize production in Kenya. *Comp Eng Intellig Sys* **5**: 86-97.

Ani D and Balakrishnan M. 2016, Expert System on Coconut Disease Management and Variety Selection. *Intl J Adv Res Comp Commun Eng* **5**: 242-246.

Anonymous. 2014. Status Paper on Oilseed, Oilseed section, Department Agriculture & Cooperation, Govt. of India (http://nmoop.gov.in/Publication/Status_Paper.pdf).

Boyd DW and Sun MK. 1994. Prototyping an expert system for diagnosis of potato diseases. *Comp Electron Agric* **10**: 259-267.

Chauhan JS, Singh KH and Kumar V. 2012. Compendium of Rapeseed-Mustard Varieties Notified and Breeder Seed Production Scenario in India (2006-2012), AICRP-RM, Directorate of Rapeseed Mustard Research, Bharatpur, pp. 72.

Chauhan JS, Singh K H and Kumar A. 2006. Compendium of Rapeseed-Mustard Varieties Notified in India, Directorate of Rapeseed-Mustard Research, Bharatpur pp. 125.

David S Prerau.1987. Knowledge Acquisition in the Development of a Large Expert System. *AI Magazine* **8**: 43-51.

Dryal HH,Timothy M and Harvey H. 2012. Web-Based Support of Crop Selection for Climate Adaptation, *In Proceeding of the 45th Hawaii International Conference on System Sciences*, 04 Jan - 07 Jan 2012, Maui, HI, USA, pp 1227-1236.

Duan Y, Zetian F and Daoliang L. 2003. Toward developing and using Web-based tele-diagnosis in aquaculture. *Exp Sys Applic* **25**: 247–254.

Edrees SA, Ahmed R, Fathy I and Yahia M. 2003. NEPER: a multiple strategy wheat expert system. *Computer and Electronics in Agriculture* **40**: 27–43.

Erlin A., Kudang S. and Muhamad S. 2014. Development of Expert System for Selecting Tomato (Solanum Lycopersicon) Varieties, In proceding: 3rd Intl Conf on Adaptive and Intelligent Agroindustry (ICAIA), Bogor, Indonesia, 3-4 Aug 2015

Ganesan V. 2007. Decision Support System "Crop-9-DSS" for Identified Crops, *Intl J Biol, Biomol, Agril, Food and Biotechnol Eng* **1**: 186-188.

Gonzalez A J L, Fernandez Q C, Izquierdo J and Urbano JM. 2006. SIMCE: An expert system for seedling weed identification in cereals. *Comp Electron Agric* **54**: 115–23.

Grove, RF. 2000. Internet-based expert systems. *Expert Systems*: 129–136.

Gutie´rrez-Estrada JC, De Pedro Sanz E, Lo´pez-Luque Rand Pulido- Calvo I. 2005. SEDPA, an expert system for disease diagnosis in eel rearing systems. *Aquacul Eng* **33**: 110–125.

Hasan SS and Isaac RK. 2011. An integrated approach of MASCommon KADS, Model–View–Controller and web application optimization strategies for web-based expert system development. *Expert Sys Appl* **38**: 417–428.

Hustinawaty and Randy A. 2014. The Development of Web Based Expert System for Diagnosing Children Diseases Using PHP and MySQL. *Intl J Comp Trends and Technol* **10**: 197-210.

Pertot I, Kuflik T, Gordon I, Freeman S and Elad Y. 2012. Identificator: A web-based tool for visual plant disease identification, a proof of concept with a case study on strawberry, *Comp Electron Agric* **84**: 144-154

Islam S, Kundu S, Shoran J, Sabir N, Sharma K, Samir, Farooqi, Singh R, Agarwal H O, Chaturvedi K K, Sharma R K and Sharma A K. 2012. Selection of wheat (*Triticum aestivum*) variety through expert system. *Indian J Agril Sci* **82**: 39–43.

John Durkin. 1990. Application of Expert Systems in the Sciences. *OHIO J Sci* **90**: 171-179,

Joseph G. Lauer. 1995, SELECT! : Crop Variety Selection Software for Microcomputers. *J Prod Agric* **8**: 433-437.

Kaliuday B, Satyanvesh D, Sampath NVSSP, Varma KTN, Baruah P K. 2014. AgPest : An Efficient Rule-Based Expert System to prevent Pest Diseases of Rice & Wheat Crops, In Proc. *IEEE 8th Intl Conf on Intelligent Systems and Control, Coimbatore*, India, 10-11 January 2014.

Khan FS, Razzaq S, Irfan K, Maqbool F, Farid A, Illahi I and Amin-ul T. 2008. Dr. Wheat: A web-based expert system for diagnosis of diseases and pests in Pakistani wheat. *In: Proc World Cong on Eng (WCE 2008)*, London, U.K., July 2-4.

Kolhe S, Kamal R, Saini HS and Gupta GK. 2011. A web-based intelligent disease-diagnosis system using a new fuzzy-logic based approach for drawing the inferences in crops. *Comp Elec Agric* **76**: 16–27

Koonsanit K, Jaruskulchai C, Miphokasap P, and Eiumnoh A. 2011. Plant Varieties Selection System, *Intel J Biol, Biomol, Agril, Food Biotechnol Eng* **5**: 524-528.

Kumar V. 2015. Design and implementation of an agricultural publication information system using metadata description: A web-based documentation and performance evaluation approach. *Informat Dev* **31**: 349–357.

Kumar V, Lehri S, Sharma AK, Meena P D and Kumar A. 2008. Image based rapeseed-mustard disease expert system: An effective extension tool. *Indian Res J Ext Edu* **8**: 10-13.

Kumar V, Kumar A and Chattopadhyay C. 2012. Design and implementation of web-based aphid (*Lipaphis erysimi*) forecast system for oilseed *Brassicas. Indian J Agril Sci* **82** : 608–614.

Kumar V, Singh K H, Chaturvedi KK and Nanjundan J. 2013. Design and implementation of web-based database of rapeseed-mustard germplasm using Linux - Apache -MySQL - PHP (LAMP) technology. *Afr J Agril Res* **8** : 2733-2743.

Lai J, Ming B, Li S, Wang K, Xie R and Gao S. 2010. An image-based diagnostic expert system for corn diseases. *Agril Sci China* **9**: 1221-1229.

Lee J, Brent W. 2002. Open Source Web Development with LAMP: Using Linux, Apache, MySQL, Perl, and PHP. Addison Wesley. P. 496.

Li D, Fu Z and Duan Y. 2002. Fish-Expert: A web-based expert system for fish disease diagnosis. *Exp Sys Appl* **23**: 311–320.

Liao S. 2005. Expert system methodologies and applications - a decade review from 1995 to 2004, *Exp Sys Appl* **28**: 93-103.

Mahaman BD, Harizanis P, Filis I, Antonopoulou E, Yialouris CP and Sideridis AB. 2002 A diagnostic expert system for honeybee pests. *Comp Elect Agri* **36**: 17–31.

Mahaman BD, Passam HC, Sideridis AB and Yialouris CP. 2003. DIARES-IPM: A diagnostic advisory rule-based expert system for integrated pest management in solanaceous crop systems. *Agril Sys* **76**: 1119–1135.

Mansingh G, Reichgelt H and Bryson KMO. 2007. CPEST: An expert system for the management of pests and diseases in the Jamaican coffee industry, *Exp Sys Appl* **32**: 184-192.

Millard D, Croft B, Cox M and Payne D. 2009. Development of a web-based decision-support tool and information resource for sugarcane varieties in the Australian sugar industry, *Proc Aust Soc Sugarcane Technol* **31**: 316-325

NRAA. 2012. Prioritization of Rainfed Areas in India, Study Report 4, NRAA, New Delhi,India 100p. (http://nraa.gov.in/pdf/Rainfed-final.pdf)

Ole Q. Bojer NS Murali, Bo JM Secher and Birgitte DB. 1997. SORTINFO: An information and decision support system for variety selection, In Proc. *First European Conf Information Tech in Agri, Copenhagen* 15-18 June, 1997

Patil SS, Dhandra BV, Angadi UB, Shankar AG and Joshi N. 2009. Web based expert system for diagnosis of micro nutrients deficiencies in crops. *In: Proc. World Congress on Engineering and Computer Science* (WCECS 2009), San Francisco, USA October 20-22.

Prasad R, Kumar RR and Sinha AK. 2006. AMRAPALIKA: An expert system for the diagnosis of pests, diseases, disorders in Indian mango. *Knowledge Based System* **19**: 9-21.

Prasad R, Sinha AK and Ranjan R. 2002. KISAN: An expert system for soil nutrient management. AFITA 2002: Asian agricultural information technology and management. *In: Proc. 3rd Asian Conference for Information Technology in Agriculture, Beijing,* China 26-28 October, 2002.

Rajendra MS. 2007. An application development framework using expert system approach ICISTM-2007. *Information Systems,Technology and Management*, Allied Publishers Pvt Ltd pp 20–30.

Ramburan S, Paraskevopoulos A, Saville G and Jones M. 2010. Development of a Variety Selection Decision Support System: Genotype X Environment Analyses and System Validation. *Proc South Afr Sug Technol Ass* **83**: 80 - 91.

Ravisankar H, Sivaraju K, Krishnamurthy V and Raju C A. 2010. Expert system for identification and management of abiotic stresses in tobacco (*Nicotiana tabacum*). *Indian J Agril Sci* **80** : 151–4.

Sarma SK, Singh KR and Singh A. 2008. An expert system for diagnosis of diseases in rice plant *Intl J Artif Intell* **1**: 26–31.

Sarma SK, Singh KR and Singh A. 2008. An expert system for diagnosis of diseases in rice plant, *Intl J of Artif Intell* **1**: 26–31.

Scoot B. 1999. Machine vs. Human translation. Advance Language Translation Inc. (http://www. advancedlinguage.com)

Suhartono D, Aditya W, Lestari M, and Yasin M. 2013. Expert System in Detecting Coffee Plant Diseases. *Intl J Elect Energy* **1**: 156-162.

Thomson AJ, Allen E, and Morrison D. 1998. Forest tree disease diagnosis over the World Wide Web. *Comp and Elect Agri* **21**: 19-31.

Xiangliang Wu , Julin Gao , Yvdong Zhao , Lijun Li , Man Li , Zhigang Wang. 2009. Design and Implementation of dynamic knowledge model for suitable variety selection and sowing time Determination Of Soybean, In IFIP international federation for information processing, volume 294*, Computer and Computing Yechnology in Agriculture*, eds D. Li Z. Chunjiang (Boston Springer) pp 847-852.

Yan-fang Liu, Qing-mei Huang, Jian-hua Zhang, Xiao-hong Yang, Yangang Li , Ye Wang, Jiang-min Wang, Hui Zhang, Jun-jiao Guan.2013. Application of Information System of Varieties of Common Knowledge in PVP, *AASRI Procedia* **4** : 236 – 242

Yialouris CP and Sideridis, A B. 1996. An expert system for tomato diseases, *Comp Elect Agri* **14**: 61-76.

Zhang, M and Shroyer JP. 1992. WHEATWIZ, An expert system for wheat variety selection: modifications and applications in Kansas. Paper presented at the *4th Inernational Conf on Computers in Agriculture*, pp 153–8. American Society of Agricultural Engineers, Orlando, Florida, USA.