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A Comprehensive Review on the Application of Diagnostic Expert Systems in the Field of Agriculture

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ABSTRACT: Agriculture is the backbone of Pakistan economy and primary sector of country. Farmers require advance or experts' knowledge to take decision during; soil preparation, seed selection, fertilizer management, pesticide management, water scheduling, weed management etc., so as to get a high yield. Expert Systems play the role of agricultural engineer/expert and provide suitable information to users for decision-making. In agriculture, Expert Systems unite the accumulated expertise of individual disciplines, e.g., plant pathology, entomology, horticulture and agricultural meteorology into a framework that best addresses the specific, on-site needs of farmers. Expert System is the most powerful approach that simulates human knowledge from an expert in certain domain to assist human during decision making at a level of or greater than human expert. However, most of the diagnostic expert systems specially developed for the field of agriculture is useless for poor farming community of Pakistan, because most of the farmers who live in the rural areas of Pakistan can understand only local languages as well as they do not have facility to use expert systems on laptop/desktop computer. They use only mobile phone technology. If some modern farmers understand English language and have the facility of laptop/desktop to use expert systems but still they cannot fully assisted from this powerful tool because most of the diagnostic expert systems cannot give the confidence level to user. This paper provides a comprehensive overview on 43 Agricultural Diagnostic Expert Systems. It also present a comparative analysis of already existing studies, identify the existing areas of expert systems in the field of agriculture, identify the development tools and techniques used for building agricultural diagnostic expert systems, and also identify the gap of existing diagnostic expert systems i.e., certainty factor, local languages and mobile phone technology.

Keywords: Expert system, Diagnostic Expert system, Agricultural Diagnostic Expert system, Disease Diagnosis, Plant Disease Diagnosis, Crop Disease Diagnosis, Fruit Disease Diagnosis, Comprehensive Review.

I. INTRODUCTION

Population of rural area was reported 63.09% of the total area in 2019 in Pakistan, while 65.53% in India and 39.69% in China [1]. Agriculture is the main sector of economy of these nations. Most of the population of these countries are living in the rural areas while agriculture is their only source of income. Mostly farmers rely on the agriculture experts' assistance but proportion of agriculture experts to farmers' ratio is very low. Therefore, agriculture experts are not generally accessible for interview at the scratch of the time. As a result, the population of rural areas are always under the food security threat. To take care of this issue, an Expert System (ES) may turn into an integral asset, which is a critical need of the day for farmers, expansion laborers and government authorities. ES can give an on-line data on various crop management issues like; diagnosing and controlling poisonous and usually discovered insect-pests and diseases, crop financial matters and planning plan for irrigation and fertilization application and so forth [2].

Expert System is a special piece of software or a computer program, which holds the expert knowledge about a specific problem, frequently in the form of IF – THEN rules, which is able to resolve the problems at a level equivalent to or greater than human expert [3]. Components of Expert System are being shown in Fig. 1 [3].

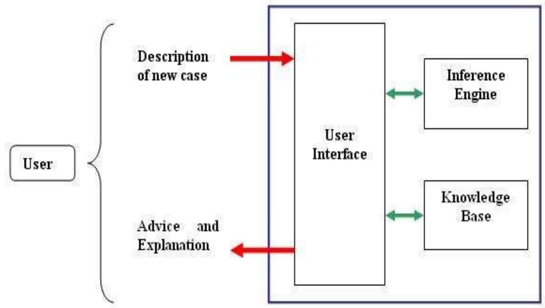

Fig. 1. Expert System Components.

According to Kaur [3] there are 3key components of an Expert System, as described below.

Knowledge Base: Knowledge base is one the most important components of Expert system which defines all the knowledge about the particular problem. It is the collection of facts and rules.

Inference Engine: The inference engine controls the overall operations of the ES according to the instructions given and selects which rules and facts to apply when trying to solve the user's query. A main feature different from the traditional software is the reasoning capability of the ES which may either be Data-driven/forward chaining or Objective-driven/backwardchaining or both.

User Interface: User interface takes the user's query in a readable form, permits it to the inference engine, and then provides the results to the user.

Main Characteristics of expert system are:

It simulates human reasoning about a problem domain, rather than simulating the domain itself. It performs reasoning over representations of human knowledge that solves problems by heuristic or approximate methods [3]. Expert system started to be utilized in the field of agriculture at the end of 1970's. After 30 years of improvement, its application domain has spread into the crops development management, establishment agriculture management, poultry raising, aquaculture movement, plant assurance breeding just as affordable decision-making system [4].

Agriculture production has evolved into an overwhelming business that requiring the collection and integration of information and data from numerous different sources. To stay competitive, advanced farmers regularly depends on agricultural specialists and need theirhelp during decision-making. Unfortunately, agricultural specialists' assistance is generally not accessible when the farmers are in necessity of it. To lighten this issue, Expert systems were recognized as an amazing tool with broad potential in agriculture production [3].

One of the key benefits and potential gain of using Expert System is that this has the ability to diminish the information or data that human clients need to measure, increment yield and lessen work force costs. Another benefit of Expert System is it execution, it performs errands more reliably and at some point more dependably than human experts can do. Some diagnosing Expert Systems depend upon the limit and capacity of an end client to comprehend strange symptoms of the plant and to pass on these symptoms through a textual exchange. Contingent on the client's level of appreciation of the strange perceptions, the Expert system can show up at the right analysis, if the end client deciphers the unusual perceptions in an off base way and picks a wrong textual response to an introduced question, by then the Expert System will come to wrong end result [3].

Part of the expert system in agriculture characterized in if a farmer is keen on crop development, he experiences following issues identified with data move [2].

Static Information: Information on beat production innovation put away and accessible in the difficult space uncovers that the information is static and may not change as indicated by the cultivators need. All extension literatures works simply give general proposals without mulling over every one of the factors. Consequently, by and large the information is deficient.

Integration of specialties: The majority of the extension documents manage issues identified with specific strengths: plant pathology, entomology, nutrition, production, and so on In genuine circumstances, the issue might be because of more than one reason, and may require the coordination of the information past the information remembered for various extension documents and books. Picture may require, in some cases, an expert to consolidate different factors to arrive at an exact analysis, and regardless of whether a finding is reached, the treatment of the diagnosed disorder ought to be given through extension archive.

Updating: Over a period, the extension documents become outdated which should be refreshed now and again. Changes in chemicals, their doses, and their effect on the environment should be considered while adopting the production and protection technology. Refreshing this information in the documents and dispersal of similar takes quite a while.

Information unavailability: Certain information may not be accessible in any type of media. It is accessible just from human experts, extensionists, or potentially experienced farmers. Likewise, the information move from subject matter experts and researchers to extensionists and farmers addresses a bottleneck for the advancement of crop production innovation at the public level. The issues distinguished can be settled effectively utilizing Expert Systems innovation in agriculture by utilizing its information base and thinking component through information obtained from human experts and different sources. Aside from these, the Expert System helps farmers and extension laborers to create all the applicable information and helps them in making harmless to the ecosystem and financially feasible crop management choices. Expert system in agriculture, along these lines, offers to give an important connection between both examination information and human expertise and the down to earth execution of the information.

II. MATERIALS AND METHODS

This review paper starts from the section's method of describing how the researchers conducted the analysis in their studies, analysis findings for the diagnosis of diseases in plants and crops which has been reviewed in previous studies of expert systems shows how the system can help institutions and governments in tackling diagnosis more easily with the knowledge equivalent of the experts. The purpose of this review paper is to summarize and analyze previous researches on the approach to the expert system and technology methods used. The author focuses on things that affect the approach to the goodness of the future system. The results will be proven at the level of system quality in terms of specificity, sensitivity or accuracy of the system, as well as the type of expert system that is deployed based on their respective categories. In the examining discussion, the result is how far the expert system has helped life, and in conclusion, how these studies are to find the best solution and methods for development purposes of the expert system in the future.

A. Literature Search Strategy

The review consists of selected sources from research journals, review papers, and conference proceedings. The development of research references is from the identification of the key word "expert system" and "diagnosis of diseases". This paper focuses more on expert systems about plants, crops and is proficient in diagnosing diseases. Using databases, these words were improved, such as Google Scholar. The research's literature reference search was based on title and abstract by manually filtering through the website only. The reference research findings were derived from published journals that are being written in English from 2008 to 2020.

B. Eligibility Criteria

The author first opted for the reference journal based on the title from the collected reference search. It was then filtered out material based on abstract, objectives, methods and results. The following criteria were also the main focus for the selection of contents: (1). Research should cover this sector in the field of information technology (2). Research objectives have to be a system with expert systems associated with plants and crops. (3). Research results which include the following conditions: (a). the journal obtained is to be used exclusively in the diagnosis of plant/crop disease only, (b). Studies have methodologies in applying expert systems.

C. Literature Survey on Diagnostic Expert System in the Field of Agriculture

Based on our literature survey, overview of the diagnostic expert systems developed in the field of agriculture are presented here:

Edrees *et al.,* [5] Presents an ES for the production of paddy and its management. The system provides consultation to paddy cultivators in Egypt to enhance production. This system holds 2-principle parts i.e., strategic part and the tactic part. The strategic part contains four sub systems to be specific: variety selection, irrigation, land preparation & planting, and fertilization and tactic part contains two sub systems to be specific: diagnosing the disorder and its treatment. The paddy ES created at CALES and implementing utilizing Knowledge Representation Object Oriented Language (KROL) shell under Windows 98. The system was tried and checked in CALES.

Khan *et al.,* proposed an ES for the diagnosis of pests and diseases in Pakistani wheat. The system is web-based ES developed using a shell i.e., e2gLite™ expert system shell. This system was the case study of Pakistan because Wheat is the most significant crop in Pakistan and it is cultivated in a vast area and rank 1st as a cereal crop in the whole country of Pakistan. This system shelters the two key aspects of problems that are diseases and pests, which normally experienced in this crop. The results of the system are correct and reliable [6].

Abu-Naser *et al.,* developed a rule-based expert system using CLIPS for plant disease diagnosis with descriptive and graphical representation methods. The system was evaluated and the results showed that the graphical representation method has positive impact [7].

Sarma *et al.,* Presents the architecture and design and development technique of an ES for diagnosing the diseases of rice. This rule-based system was developed using ESTA (Expert System Shell for Text Animation). The system they developed has an integrated knowledge base of common symptoms of rice plant and it has a picture database of diseases, which attack the rice plant due to the picture database the user/farmer can see the disease and easily diagnose it. From this system the user can be assisted to easily diagnose the common diseases of rice plant [8].

Li *et al.,* developed web based intelligent diagnosis system for cotton disease control. The main species and characters of cotton diseases were listed classified in the study and a database was established for this purpose. BP neural network as a decision-making system was used to establish an intelligent diagnosis model. An experiment scheme was designed for the system test, in which 80 samples, including 8 main species of diseases, 10 samples in each sort were included. The result showed the rate of correctness that system could identify the symptom was 89.5% in average, and the average running time for a diagnosis was 900ms [9].

Wu *et al.,* developed expert system called TPPADS: An Expert System Based on Multi-branch Structure for Tianjin Planting Pest Assistant Diagnosis using ASP.NET, C# and Microsoft SQL server 2008 database. The system included about more than 300 species of green plant pests. Diagnosis knowledge was obtained from Tianjin Institute of Plant Protection. TPPADS can be used as a diagnosis tool and information database both for plant protection professionals and for farmers [10].

Tefera proposed an ES, which presents variety selection and disorder diagnosis for teff crop in Ethiopia. The system has three sub modules; the first module is variety selection module, the second module of this ES is disorder diagnosis module, and the third module is disorder treatment module. The variety selection module assists user in selection of suitable teff varieties for their agro-ecological zone and the interests of the farmer, and second sub module offers the user with a diagnostic disorder, which is caused by insect and disease problems on the production of the crops. The third module provides the user with the treatment of disorders after being verified or identified by the diagnosis module. Finally, the system recommends possible measures to be taken [11].

Sarma established a rule-based ES for Rose plant. In this rule-based system, the system takes the symptoms as input, generates the exact disease with all the facts, and rules that matches with in the knowledge base. The knowledge representation language was a high-level language in this ES, which permits a user to build a knowledge base. They used forward chaining method to execute this rule-based system [12].

Munirah & Rozlini developed a rule-based expert system with forward chaining inference engine for diagnosis of Oyster Mushroom Diseases. The main goal of this expert system is to get the appropriate diagnosis of oyster mushroom diseases and get the correct treatment. This system consists of four types of modules, which includes main module, diagnosis module, information module, and admin module [13].

Tatte & Nichat proposed a rule-based ES to detect and diagnosing disease in rice crop. The system checks the crop of rice and the disease of rice crop presence in the database and conveys the arrangement of diagnostic measure as for the sickness that crop have. The proposed system encourages various parts including decision-support module with intelligent user interface for identification of diseases. The system incorporates an organized knowledge base that holds data about manifestations and treatments of infections in the rice plant showing up throughout their life expectancy [14].

Prakash *et al.,* proposed Fuzzy-based agriculture ES for soyabean named as “Prithvi” for Soybean. Author used modular development approach and divided complete expert system in to five modules namely Detection of Nutrient Level in Soil, Farm Size Calculation, Sowing Period, Sowing Method and Rain Fall, Variety Selection and Advice Generation. For the development of this system, Fuzzy-logic used as machine learning technique and considered forward chaining technique for knowledge representation in simple IF-THEN rule form [15].

Derwin Suhartono *et al.,* developed the ES for detecting coffee plant diseases. For development of this system, the method of Fuzzy logic used with decision tree using a hierarchical classification with forward chaining technique. In this system, all the knowledge about the plant of coffee, the coffee symptoms and its diseases extracted from expert, transformed it into decision tree and then they applied Fuzzy logic for detecting coffee plant diseases. This systemevaluation accuracy was about 85% [16].

Kaura *et al.,* pointed out that detection of the plant sickness is typically a very complex job and it requires plant pathologist or expert person to perfectly explain the case. Furthermore, some diseases having related symptoms, it is difficult for non-experts like uneducated farmers to distinguish accurately such diseases. For this purpose, they developed web-based ES using image-processing techniques.This system uses the color images and also textual input to identify and diagnose the leaf diseases of cereals such as wheat, rice and maize [17].

Dewanto & Lukas developed a Rule-based ES for diagnosing the pests and diseases of fruit plants. This system developed using Corvid Exsys with backward chaining technique. Results of this system indicated that the advancement of this ES used to help users in distinguishing the kind of pests and diseases in various natural fruit plants [18].

Negied developed an ES for wheat yield protection. It is a desktop application developed using MATLAB and SQL server. This system gives the proper diagnosis of pest insects that can damage wheat yields. ESWYP is a system that empowers the rancher to classify insect diseases. Analyze of the insect pests is a perplexing and touchy task, and must be performed by an expert of the farming sciences. This system is Knowledge-Based System intended to copy the farming expertise for insect pest issue analyze and to empower a computer to act as a farming expert to separate the kind of pest started to influence the wheat harvests and afterward advice the best treatment for it. The system also offers a reasoning capability that permits the operator to look into the diagnosis and cure details [19].

Singh & Sharma developed Fuzzy-Based ES for the optimization of fertilizer. This ES have capacity to diagnose the estimation of NPK fertilizers required in soil for wheat crop, subsequent to knowing the degree of NPK levels present in soil. Applying definite and essentially right proportion of NPK composts required in soil in like way into gather would urges ranchers to get in the best returns from his yields and furthermore lessen the manure costs. Decreasing fertilizers consumption in like manner will diminish fertilizers admission. Besides, would forestall over fertilization, which harms crop yield, and make soil corrupted [20].

Dubey, developed Fuzzy based expert system for integrated disease management of chickpea using PHP and MYSQL. The system uses Mamdani inference method to draw inferences. This system has two modules one for information system and second for disease diagnosis. The system was in initial stages of development in Hindi language at that time that will facilitate the Indian farmers to make better use of the software [21].

Hasan *et al.,* developed an expert system using Web 2.0 standards and accessibility features to diagnose disorders in sugarcane called CaneDES, caused by various biotic and abiotic stresses. System consists of 231 textual symptoms and 256 visuals to diagnose

disorders of sugarcane with confidence factor caused by 50 major insect-pests, diseases and nutrient deficiencies factors. The system has five major modules, which includes Sugarcane crop, Sugarcane Advisory, Disorder Diagnosis, Glossary, and Login. Developed system also have a unique e-learning platform in sugarcane and available in both English and Hindi languages on web platform for remote accessibility. User can check the website (www.iisr.nic.in) of Indian Institute of Sugarcane Research, Lucknow for its accessibility [22].
Shahzadi *et al.,* suggested that nowadays sensors have been progressively conveyed Agriculture to observe ecological and climatic changes. Temperature and moistness are very important things, which influence the crop growth. According to them temperature sensor, humidity sensor, light sensor and growth sensor play the important role in the area of Agriculture. ES is utilized in the field of Agriculture to give data about the disease management and solution for the crop, soil management, water system level to be kept up for yield, to recommend sensible seed variety, amount of fertilizers to be utilized lastly to discover the predictable yield crop. Their aimed is to building up a semantic web-based expert system for wheat with a programmed sensor interface [23].
Dath & Balakrishnan Suggested a rule-based system for coconut variety selection and disease management. The system developed using programming languages i.e., Active server pages (ASP) technology and SQL server. This system has two modules one for disease diagnosis and other for suitable variety selection. The disease management module of coconut ES created to give the management rehearses that followed for getting greatest returns by recognizing the disease at a beginning phase and the variety selection module used to choose the appropriate assortments based on the qualities required by the end user for getting the extreme returns [24].
Almadhoun & Abu-Naser proposed a knowledge-based system for the purpose of diagnosing and treating Banana diseases. This knowledge-based system was developed using the language CLIPS and the user interface created with Delphi 10.2. The proposed system was specialized in diagnosing total 9 diseases. The results of this system are acceptable in breaking down instances of tried banana diseases and helping the system to decide the right conclusion in all cases [25].
Elqassas & Abu-Naser developed an ES for diagnosing the diseases of mango. CLIPS and Delphi languages was used for the development of this system. The aim of proposed system was presented to help agricultural engineers and farmers to treat plants with 12 different possible mango diseases. Agricultural engineers and farmers can get a quicker and more exact diagnosis than customary diagnosis. The system was evaluated and tested by farmers, students, agriculture instructors and others interested people in mango production finding this system to be very useful [26].
Musleh & Abu-Naser developed a rule-based ES for diagnosing and treating potatoes problem. This system was developed using CLIPS and Delphi language with forward chaining technique. The key objective of this ES was to get the suitable and proper diagnosis of potato diseases and their correct management. The proposed system was specialized in diagnosing only eleven potato diseases. Farmers, Agricultural experts and teachers of Agriculture, evaluated the proposed system and found it to be very useful [27].
Barhoom & Abu-Naser proposed an ES for diagnosing Black pepper diseases using CLIPS and Delphi languages with forward chaining reasoning technique. The key objective of this system was to acquire suitable diagnosis of black pepper diseases and their accurate management. The Proposed system was specialized in diagnosing total seven black pepper diseases. Farmers, Agricultural experts and Agriculture teachers, evaluated the proposed black pepper diseases diagnosis expert system; resultantly they were satisfied with its performance [28].
Muludi *et al.,* developed an android-based ES with forward chaining and certainty factor method for tomato disease identification. This expert system consists of 16 data of tomato diseases, 53 data of symptoms, and 20 variety of rules. Forward chaining is used as a reasoning method to get the result of disease identification. Certainty factor is used as a calculation method to obtain accuracy degree of identification results. Testing has been done through two stages, internal and external. The result from internal testing shows that tomato expert system works properly and fit perfectly in various android devices. External testing is done by filling a questionnaire by 44 respondents. The result of the collected data showed that these respondents categorized the tomato expert system as "good" [29].
Abu-Nasser & Abu-Naser proposed an ES for diagnosing diseases of watermelon. The system was developed using CLIPS and Delphi XE10.2 languages with forward chaining reasoning technique. The key objective behind developing this system was to assist farmers in detecting watermelon diseases and solutions. The proposed system was specialized in diagnosing total seven diseases and get their appropriate diagnosis. Group of farmers evaluated this system and they were satisfied with its performance [30].
Alajrami & Abu-Naser proposed a rule-based ES for diagnosis diseases, disorder, and treatment for onion. The system was developed using CLIPS and Delphi languages with data-driven strategy of reasoning. The key objective behind developing this system was to assist farmers in detecting onion diseases, disorder and its solutions. The Proposed system was specialized in diagnosing total seven diseases and get their appropriate diagnosis. Students of Faculty of Agriculture at Al-Quds Open University tested and evaluated this proposed system. They were satisfied with its performance, efficiency, user interface and ease of use [31].

AlZamily & Abu Naser developed a cognitive system for diagnosing *Musa acuminata* Disorders. The system was developed using CLIPS and Delphi languages with forward chaining reasoning technique. The main goal of this expert system is to get the appropriate diagnosis of *Musa acuminata* disease and the correct treatment. The proposed expert system was specialized in diagnosis of nine *Musa acuminata* diseases. Farmers, agricultural experts and agriculture teachers evaluated the proposed system and they were satisfied with its performance [32].

Dheir & Abu-Naser developed an expert system for diagnosing Guava Problems. The system was developed using CLIPS and Delphi languages with forward chaining reasoning technique. The main goal of this expert system is to get the appropriate diagnosis of guava diseases and get the correct treatment. The proposed expert system was specialized in the diagnosis of seven guava diseases. Many agricultural engineers, agricultural teachers and agriculture students tested and evaluated the proposed system who showed satisfaction with its performance [33].

Developed An expert system for diagnosis of coffee diseases was developed using CLIPS and Delphi languages with forward chaining reasoning technique. The main goal of this expert system is to get the appropriate diagnosis of coffee diseases and to get the correct treatment. The proposed expert system was specialized in diagnosis of nine coffee diseases. A group of farmers, people interested in coffee tree production and agricultural teachers tested the proposed system and found it very useful [34].

For wheat crop a rule-based ES system was developed using CLIPS and Delphi XE10.2 programming languages with facts-driven strategy of reasoning. The system was developed for helping farming community to diagnose 13 different possible diseases of wheat crop. Through this Expert System, the poor farming community may be able to diagnose the diseases of wheat crop easily and more accurately. This system was evaluated by students and others interested people in wheat production, farmers, and agriculture instructors and they were happy with its exhibition, effectiveness, user interface and convenience [35].

For diagnosis and treatment of Grapes an ES system developed using CLIPS and Delphi languages with forward chaining reasoning technique. The key objective behind the system was to acquire the accurate identification of 14 grapes diseases. The students of the Faculty of Agriculture at Al-Quds Open University and Faculty of Agriculture at Al-Azhar University evaluated and tested this proposed system and found it very useful because of its performance, efficiency, user interface and ease of use [36].

Rule-based system for Safflower disease diagnosis the system developed using CLIPS and Delphi languages with forward chaining reasoning technique. The key objective behind system for developing was to catch the correct identification of nine safflower diseases. Agricultural specialists tested this proposed ES and found very useful because of its performance, efficiency, user interface and ease of use [37].

An ES for diagnosing Coconut diseases using CLIPS and Delphi languages with forward chaining reasoning technique. The key objective of this system was to catch the proper diagnosis of diseases and their right cure with pictures to the user. The Proposed system was specialized in diagnosing a total of five diseases**.** Agriculture Engineers evaluated this expert system who were satisfied with its performance [38].

Khalil *et al.,* recommended a knowledge-based system for diagnosing the different disease of Apple. The recommended system developed using CLIPS and Delphi languages with forward chaining reasoning technique. The key aim behind this system was to acquire the correct diagnosis of diseases and their exact cure. The proposed system was specialized in diagnosing with diagnosing twelve apple diseases. Farmers, Agricultural experts and teachers of the Gaza School of Agriculture, evaluated this expert system who were satisfied with its performance [39].

An ES for diagnosing diseases of Papaya plant a system was developed using CLIPS and Delphi languages with forward chaining reasoning technique. The key objective behind this system was to catch the precise diagnosis of diseases and their true cure. The Proposed system was specialized in diagnosing six diseases and get their appropriate diagnosis. Farmers have evaluated this system and individuals keen on developing papaya and have given acceptable results [40].

A web-based ES for diagnosing the diseases of Date palm was develop a rule-based advisory system for early diagnosis of diseases of date palm. In this system, the web interface has been designed and built by using the PHP language and supported by Java Script and CCS. MYSQL selected as system relational database. Domain experts evaluated this Expert system. The results indicated that the system succeeded in estimating the correct diagnosis [41].

Salman & Abu-Naser designed an ES using CLIPS and XE10.2 languages. The fundamental goal of this system was to design for capacity of agriculture engineers to recognize and analyze five diseases of castor. This system offers the disease symptoms, endurance and spread, ideal conditions and picture for every disease. The system was evaluated and tested by group of farmers and agriculture experts and they were happy with its exhibition, effectiveness, user interface and usability [42].

El-Mashharawi & Abu-Naser recommended an ES for sesame disease diagnosis and the system was developed by using CLIPS and Delphi languages. The key objective of this ES was to get the suitable diagnosis of diseases and the right treatment. The proposed system was specialized in diagnosing only the four diseases. Farmers and agricultural experts evaluated the system. They were satisfied with its excellence of performance and simplicity [43].

Elsharif & Abu-Naser proposed a rule-based ES, which was developed using CLIPS and Delphi languages with forward chaining technique. The purpose of ES being developed was to diagnose the major diseases of sugar cane crop in a timely manner to reduce losses. The proposed system was specialized in diagnosing 10 sugar cane diseases. The system tested and evaluated by group of farmers fascinated in generating sugarcane crops and found this system very useful [44].

Aldaour & Abu-Naser proposed an ES for diagnosing Tobacco diseases using CLIPS and Delphi languages. The key objective of this ES was to help users in diagnosing 11 tobacco diseases. The proposed system that is tobacco diseases diagnosis expert system evaluated by the students of engineering and found this system very positive and useful [45].

Saleem *et al.,* developed an expert system for diagnosing mobile and immobile nutrients deficiency of plants. The system was developed using ESTA as a development tool and Decision Tree used for hierarchal classification. The key objective of this research study was to develop and practically implement an expert system that can help the farming community of rural areas as well as researchers to timely diagnose plant nutrients deficiency. Farmers, Agricultural experts and Agriculture teachers, evaluated the proposed system who were satisfied with its performance and ease of use [46].

Saleem *et al.,* Developed an expert system for diagnosis and management of okra diseases. The system was developed using ESTA as a development tool and Decision Tree used for modeling purposes. The main objective of this research study was to diagnose diseases of Okra in a timely manner and give accurate management practices to reduce losses and boost productivity in Pakistan. Agricultural experts, different students and group of farmers took interest in testing and evaluating the proposed Expert System, which was found interesting and useful for them as a result [47].

III. RESULTS AND DISCUSSION

Table 1 shows the comparative analysis of different diagnostic expert systems in the field of Agriculture that are reviewed in Literature survey.

Table 1: Comparative Analysis of Diagnostic Expert Systems in the field of Agriculture.

Reference	Disease/ Pest Diagnosed	Techniques/Methods Used	Development Tools	Results	Limitations
[5]	Paddy Diseases	Not defined	Object Oriented Language (KROL) Shell under Windows 98	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[6]	Wheat Diseases	Web-Based, Rule-Based	e2gLite™ Expert System Shell	Correct & Reliable	Not in Local Languages
[7]	Plant Diseases	Rule-based with Descriptive & Graphical Representation Method	CLIPS	Graphical representation method has positive impact	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[8]	Rice Diseases	Rule-based	ESTA (Expert System Shell for Text Animation)	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[9]	Cotton Diseases	BP Neural Network	Not defined	Rate of correctness to identify the symptom was 89.5% in average, Average running time for a diagnosis was 900ms.	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[10]	Tianjin Planting Pest	Not defined	ASP.NET, C# and Microsoft SQL server 2008	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[11]	Teff Crop Diseases	Not defined	Not defined	Good Results	Certainty Factor, Not in Local

					Languages, Not useable on Mobile Phone
[12]	Rose plant Diseases	Rule-based with forward chaining method.	High-level language	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[13]	Oyster Mushroom Diseases	Rule-based with forward chaining method.	Not defined	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[14]	Rice Crop Diseases	Rule-based	Not defined	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[15]	Soyabean Diseases	Fuzzy-logic with forward chaining method and production rules	Not defined	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[16]	Coffee Plant Diseases	Fuzzy-logic, Decision Tree, Forward chaining	Not defined	85% Accuracy	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[17]	Leaf Diseases of Cereals: Wheat, Maize, Rice	Image processing techniques	Not defined	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[18]	Pests & Diseases of Fruit Plants	Backward Chaining	Corvid Exsys Shell	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[19]	Pests & Diseases of Wheat Crop	Not defined	MATLAB, SQL server	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[20]	Diagnose the Estimation of NPK Fertilizers required in soil for wheat crop	Fuzzy Logic	Not defined	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[21]	Chickpea Diseases	Fuzzy Logic, Mamdani Inference Method	PHP and MYSQL	Good Results	Certainty Factor, Not useable on Mobile Phone
[22]	Sugarcane Disorder	Web-based	Web 2.0 standards	Good Results	No Limitation
[23]	Wheat	Semantic web-based, Sensors	Not defined	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[24]	Coconut Diseases	Rule-based	ASP, SQL Server	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone

[25]	Banana Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[26]	Mango Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[27]	Potatoes Diseases	Rule-based with Fact-based reasoning technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[28]	Black Pepper Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[29]	Tomato Diseases	Android-based, Forward Chaining, Certainty Factor	Not defined	Good Results	Not in Local Languages
[30]	Watermelon	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[31]	Onion Diseases & Disorder	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[32]	Musa Acuminata Disorders	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[33]	Guava Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[34]	Coffee Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[35]	Wheat Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[36]	Grape Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[37]	Safflower Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone

[38]	Coconut Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[39]	Apple Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[40]	Papaya Plant Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[41]	Date Palm Diseases	Rule-based	PHP, Java script, CSS, MYSQL	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[42]	Castor Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[43]	Sesame Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[44]	Sugarcane Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[45]	Tobacco Diseases	Rule-based with forward chaining technique	CLIPS, Delphi Languages	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[46]	Plants Mobile & Immobile Nutrients Deficiency	Rule-based with both forward & backward reasoning strategies, Decision Tree	ESTA (Expert System Shell for Text Animation)	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone
[47]	Okra Diseases	Rule-based with both forward & backward chaining strategies, Decision Tree	ESTA (Expert System Shell for Text Animation)	Good Results	Certainty Factor, Not in Local Languages, Not useable on Mobile Phone

IV. CONCLUSION

It is concluded from Table 1 that the main limitations of the 43 agricultural diagnostic Expert systems being reviewed in this study are: 42 Agricultural diagnostic Expert Systems are not in local language and most of the farmers who live in the rural areas of Pakistan can understand only local languages. 39 Agricultural diagnostic expert systems cannot useable on mobile phone and almost all farmers use only mobile phone technology they do not have facility to use expert systems on laptop/desktop. Certainty factor was also missing in 40 agricultural diagnostic expert system as a result if few modern farmers understand English language and have the facility of laptop/desktop to use expert systems but still they cannot fully assisted from this powerful tool because they cannot give the confidence level to user to give answers. Fig. 2 Shows the Bar chart of Diagnostic Expert systems in the field of agriculture.

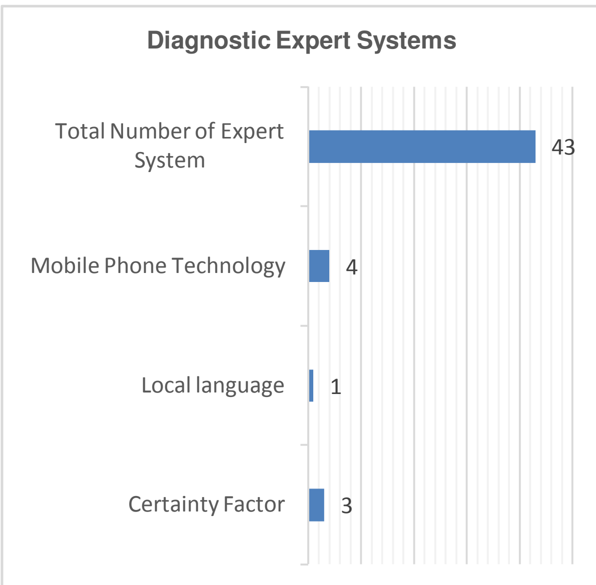

Fig. 2. Bar Chart of Diagnostic Expert systems in the Field of Agriculture.

One of the main challenges in agriculture industry is to transfer latest updated information to farmers. Expert systems are better option over traditional systems. However, most of the expert systems are in English language and most of our farmers in Pakistan are less educated so expert systems should be developed in National languages, with use of mobile phone technology and to include more audio-visual aids to help them problem understanding to increase crop production. The user interface of diagnostic expert systems should provide users to represent their degree of confidence in a response with a numerical scale whenever necessitate to avoid user uncertainty.
As a whole, the testing and evaluation of about all Expert Systems being studied in this review showed satisfactory results.

V. FUTURE SCOPE

Following points should be considered for developing agricultural diagnostic expert systems as they could practically help the farming community:
A: The diagnostic expert systems in the field of Agriculture should be developed in local languages of farmers.
B: Mobile phone technology should be considered with facility of audio & video forms.
C: Should provide degree of confidence to diagnostic expert system users in a response with numerical scale whenever necessary to avoid user uncertainty.

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