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Selection of Suitable Wheat Variety in Rainfed Areas using BEST WORST Method, DEX Method and Expert System Technology: An Integrated Approach

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ABSTRACT: Wheat is the major crop in Pakistan that accounts 8.9 % value added in agriculture and 1.6 % of GDP and cover large area of country in cultivation. Wheat is highly adopted in rainfed areas of District D.I. Khan as well as in most of the country. However, this crop suffers from low productivity due to poor agronomic practices, like; poor soil preparation, diseases, insect pests, weeds, and most importantly use of poor and not suitable wheat varieties. Mostly, farmers get information or consultation about suitable wheat varieties from extension workers or Agriculture experts. Unluckily, agriculture expert assistance is not all the time accessible. In this research work, we solve this issue by integrating Expert System's technology with Multi-Criteria Decision-Making Method (MCDM) i.e., BEST WORST Method and Multi-Attribute Decision-Making Method (MADM) i.e., DEX Method as well as comprehensively review the application of Expert system in the field of Agriculture. The system was tested for Rainfed areas of District D.I.Khan. Domain experts evaluated the proposed system showing a result of 80.9% which shows that the system is highly acceptable in the rainfed areas of District D.I. Khan. This work is not only limited to wheat variety selection but it also gives all information to farmers/users about land preparation methods, sowing dates, seed quality, sowing methods, seed treatment, fertilizer requirement, weed control, harvesting, threshing and storage method of proposed wheat variety. This research work is expected to enhance the food productivity along with improving the living standard of poor farming community.

Keywords: BEST Worst Method, DEX Method, Expert System Technology, and Wheat Variety Selection.

I. INTRODUCTION

Agriculture plays an essential role in the development of a country and has sound effects on living standard of a country. Agriculture is one of the largest sources of fulfilling human needs that covers the main part of household expenses and plays a pivotal role in solving human problems in the form of foods, shelters, fuels and numerous others. The agriculture not only fulfills the needs of humanity but also needs of about all the creatures. It will not be injustice to say that without agriculture humanity may not live a short life.

Due to the present technological development and global increase in population, values of natural resources are increasing day by day. Therefore, very soon a time will reach that those countries having agriculture products in abandoned, along with utilization of these resources in optimal ways, will be the richest countries in the world.

Pakistan is a developing country and agriculture is the foundation of Pakistan economy. According to [1] Agriculture provides 18.5% to nation's GDP and gives 38.5 % work to domestic work power however; this one stays in reverse area of the economy while huge agriculture performing is crucial to financial development and neediness easing. In course of most recent decade, the exhibition of agriculture part has missed the mark regarding alluring level, essentially because of stale profitability of exceedingly significant harvests.

Wheat interpretations 8.9 % regard included farming and 1.6 % of GDP. Wheat crop demonstrated minimal increment of 0.5 % to 25.194 million tons ended year ago's creation of 25.075 million tons yet missed the mark concerning the objective by 4.9 % [1].

According to [2] the Agriculture sector in Pakistan mostly depends upon rainfall along with canal irrigation. In rainfed area, crop production is mostly depending upon on precipitation. Rainfed agriculture assumes a substantial job in Pakistan's economy and participates about 17 % of yield developing territory in the country.

The study area of this research work is the rainfed areas of District Dera Ismail Khan. Dera Ismail Khan is the part of Khyber Pakhtunkhwa province with latitude (35.56 °N) and longitude (70.56 °E). The district lies in the arid zone where mean, minimum and maximum annual temperatures are 24 °C, 17 °C and 32 °C respectively. In district, main source of livelihood is agriculture. Wheat is dominant crop in the area during Rabi season and is sown from 1st of October to mid of November and harvested from 1st of April till the mid of May [3].

The developed zone or cultivated area of District Dera Ismail Khan is 572000 hectares the rainfed area is 195000 hectares, irrigated area is 147000 hectares and Rodkohi as 230000 hectares, a one-of-a-kind arrangement of water system with incredible potential for farming creation in Pakistan. This territory atmosphere is arid as well as semi-arid and yearly rainfall from 180 to 305 mm. In this region mostly winter temperature varies from 4^0C to 20^0C while summer 26^0C to 44^0C. Figure 1 shows the Map of District Dera Ismail Khan.

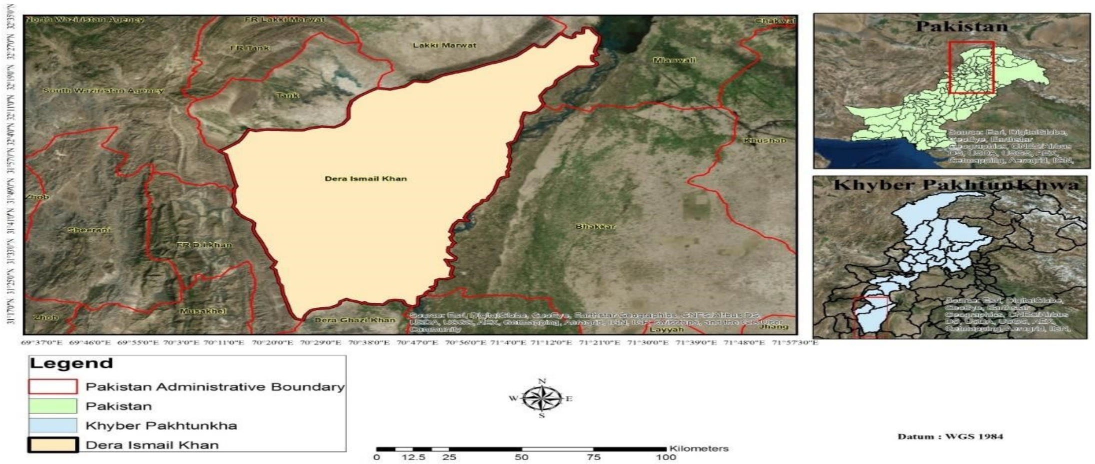

Fig. 1. Map of District Dera Ismail Khan Pakistan.

Rainfed areas of District Dera Ismail Khan is hesitant and vulnerable areas of the District, where the major source of income is only Agriculture farming. Wheat crop is highly adapted to rainfed areas of the district Dera Ismail Khan. However, this crop suffers from low productivity due to a number of biotic and non-biotic agents. These include poor agronomic practices like poor soil preparation, diseases, insect pests, weeds, and use of poor & inappropriate wheat varieties, lack of timely agriculture specialist assistance etc. As a result, the poor farmers of rainfed areas are always under food security threats.

Under rainfed environment sensible yield of wheat can be harvested through managing practices which include infiltrating and conserving moisture into the soil, selecting suitable varieties, timely sowing by recommended method, sensible use of fertilizers, controlling pest's insects and weeds and proper harvesting of wheat crop [4].

A multi-criteria decision making problem is the process of finding the best alternative from all of the feasible alternatives where all the alternatives can be evaluated according to a number of criteria or attributes [5].

A Multi-Attribute model represent a class of models used in decision analysis that evaluate options according to several, possibly conflicting, goals or objectives, In principle multi-attribute model represents a decomposition of decision problem into smaller and less complex problems [6].

In the domain of Artificial intelligence, an Expert system is a special piece of software or a computer program with ability to copycat or reproduce the tasks of humans' intelligence by making decisions just like a skilled human expert do.

Expert system is a program that holds expert information about a specific problem domain, regularly as in the event that decides that can take care of the issues at equivalent level or more prominent than human expert can. Knowledge Engineer accumulates information from area experts and afterward moves this information into production rules, and creates knowledge Base. At that point, apply inference engine and diverse knowledge acquisition strategies to acquire the information, and convey it in the form of recommendation or advice to solve issues or problems. In view of its explanation facility, it gains the choices of users' trust and utilization. The basic components of the Expert system as shown in Fig. 2 [7].

Expert system started to be utilized in the field of agriculture at the end of 1970's. After nearly the 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 [8].

Expert system plays the vital role in the field of agriculture. It joins the gathered ability of individual orders, e.g., plant pathology, entomology, horticulture and agricultural meteorology, etc. into a structure that best tends to the particular, on location needs of farming community [7].

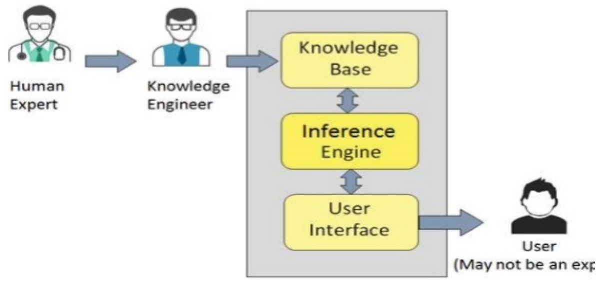

Fig. 2. Interaction between the Components of an Expert System.

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, the advanced farmers regularly depends on agricultural specialists who guides them through provides information for decision-making. Unfortunately, agricultural specialists' assistance is generally not accessible when the farmers are in dire need of it. To lighten this issue, Expert systems were recognized as an amazing tool with broad potential in agriculture production [9].
One of the key advantages and upside of utilizing Expert System is it have the capability to decrease the data or information that human users need to process, increase output and reduce personnel costs. Another advantage of Expert System is its performance. This performs tasks more consistently and reliably than human experts can do.

II. RELATED WORK

Fendji *et al.,* (2020) proposed a three-phase approach for the selection of crops concerning conventional agriculture. In first phase, they set the environmental parameters, which have higher impact on crop yield. Then they used an analytic hierarchy process to set weight of those parameters, after that they designed a rule-based expert system to determine the appropriateness of crops. Moreover, at the end, they developed a linear programming model for net income of farmers considering the working record of the different crops selected during the past stages and developed a web interface to allow farmers to benefit from the whole system. They designed different scenarios and compared these scenarios with the results of expert system and the result shows that the system can effectively help farmers to improve their net revenues [10].
Shahzadi *et al.,* (2016) proposed a cotton crop Expert system, which is based on Internet of things. The proposed system contains 3 core components the 1st component was the placement of sensors in the field. They placed different type of sensors in the fields i.e., soil sensors, humidity sensors, and temperature and leaf wetness sensors. The different Sensors, which placed in the fields, gather the information and send this information to the server, on the serve side they arrange the system i.e., expert system, which processes the data, and sends the different recommendations to the ranchers about crop. For the gathering of information waspmote agriculture sensor board was utilized since it is uncommonly intended for taking care of farming exercises. The deployment of ES done using CLIPS for recommendations to the farmer, they also developed an android app for ranchers. Ranchers install the android app on their mobiles. The server refers the recommendation to the rancher mobile. The server directs the recommendations in English language; farmers have the facility to convert the different recommendation into Urdu or Punjabi languages. The system was evaluated by the hundreds of experts from the field and found this system very helpful for the farmers [11].
Tatte & Nichat (2013) proposed a rule-based Expert system 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 [12].
Islam *et al.,* (2012) examined in their article about EXOWHEM (Development of master framework on wheat crop the board). EXOWHEM is a specialist framework and created in the Indian Agricultural Research Institute. The framework holds an assortment of general rules that conceivably applied to take care of an issue identified with wheat crop the board and is able to stretch out master guidance to the specialists and wheat-developing ranchers. The framework utilized plant protection, variety selection, cultural practices and one module for knowledge management. Plant protection module sub-separated into pathological aspects, and entomological perspectives. In pathology, the framework recognizes small-scale sicknesses, for example, leaf rusts, scourges and so on. In entomology, the framework distinguishes pest / insects influencing plants and suggests control measures [13].
Negied, (2014) developed an Expert system 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 [14].
Mansour & Abu-Naser (2019) proposed a rule-based Expert system for wheat crop. The system developed using languages i.e., CLIPS and Delphi XE10.2 programming language with forward chaining technique. The system 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 [15].

Dath & Balakrishnan (2016) 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 [16].

Singh & Sharma (2014) 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 [17].

Islam *et al.,* (2012) developed Fuzzy-Based Expert System for the optimization of fertilizer. This Expert System have capacity to figure that 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 [18].

Khan *et al.,* (2008) developed a system for the selection of suitable wheat variety. The system is web-based Expert System and developed using programming languages i.e., Active Server Pages (ASP) technology and two scripting languages VBScript® and JScript™. The system has a variety selection module with a scientific knowledge base in the backend. This module recommends a most suitable wheat variety to farmer or user according to their requirements. The system carries complete data about three hundred-wheat varieties that are stored in the knowledge base of this system [19].

Edress *et al.,* (2003) proposed an Expert System 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 [20].

According to Islam *et al.,* (2012) [18] NEPER was one of the wheat expert systems, which created at CLAES in Egypt. The NEPER system has 6 main parts, each part signifies an individual Expert System, which are able to run alone or integrated with other parts. These different parts are variety selection, land preparation, planting, irrigation, and fertilization and harvest sub systems. NEPER was developed and implemented using Generic Task tool, and built by using Smalltalk language and run under the VisualWorks environment.

Singh *et al.,* (2013) proposed web-based ES for Barley variety selection. The system developed using programming language i.e., Active server pages (ASP), Two scripting languages Java Script and VB Script to develop inference engine, and MS-ACCESS used as a knowledge base of the system with forward and backward chaining technique. This proposed system has special variety selection module and varietal selection module provide variety based on state, zone, type of barley i.e. malt barley, food barley, fodder barley etc. Farmers, extension workers and technicians can use the program as an expert for instructive purposes for quicker dispersal of expert counsel at distant areas [21].

Ravisankar *et al.,* (2018) proposed web-based Expert System on Indian Tobacco Varieties using a tool Agridaksh in N-tier architecture in the method of static web pages and ontology-based system. The users through user-friendly menus can access this system at any location and point of time and ontology-built inference system using Internet. The module allows the user to enter into question-answer session in text mode leading to identification of tobacco varieties suitable to different areas with their images and yield potentials [22].

A. Summary

Various Expert Systems in the field of agriculture were developed, especially about wheat crop but could not find the exact problem and approach being adopted in this study to solve the problem. In addition, the Expert Systems that reviewed in this study were designed for specific regions or countries because wheat crop varieties and their factors for selection are different from country to country. Moreover, within a country, wheat varieties are different from area to area. Most of the Expert systems that reviewed are not freely available and accessible to users/farmers. The proposed Expert system is a rule-based system that can be accessed at anytime and anywhere without any cost. The proposed Expert System is of conventional nature that can be used in some other rainfed conditions of the world with minor changes in the knowledge base. That is why there is a need of the day to develop and implement the

ESWCRA (Expert System for Wheat Cultivation in Rainfed Areas).

III. PROPOSED METHODOLOGY

In order to achieve the objective of this research study, the methodology of design science research was used. Design science research methodology is the most adopted and recommended methodology to find the solution of identified problems. This research work involves various stages to achieve our objective. In the first stage, domain experts were selected using purposive sampling technique, relevant knowledge for selection of wheat crop variety was acquired from these domain experts along with literature study and a list of criteria for wheat variety selection was selected. In second stage, selected criterion was assessed through MCDM method i.e., BEST WORST Method to know which criteria is most important and which criteria is least important for selection of a suitable wheat variety. In third stage, the rainfed wheat verities were evaluated through using MADM method i.e., DEX method on the basis of selected criterion. At the last stage, a prototype rule-based Expert System named as ESWCRA **(**Expert System for Wheat Cultivation in Rainfed Areas) was developed. which was tested for Rainfed areas of District Dera Ismail Khan. Proposed Methodology of the research work is being shown below in Fig. 3.

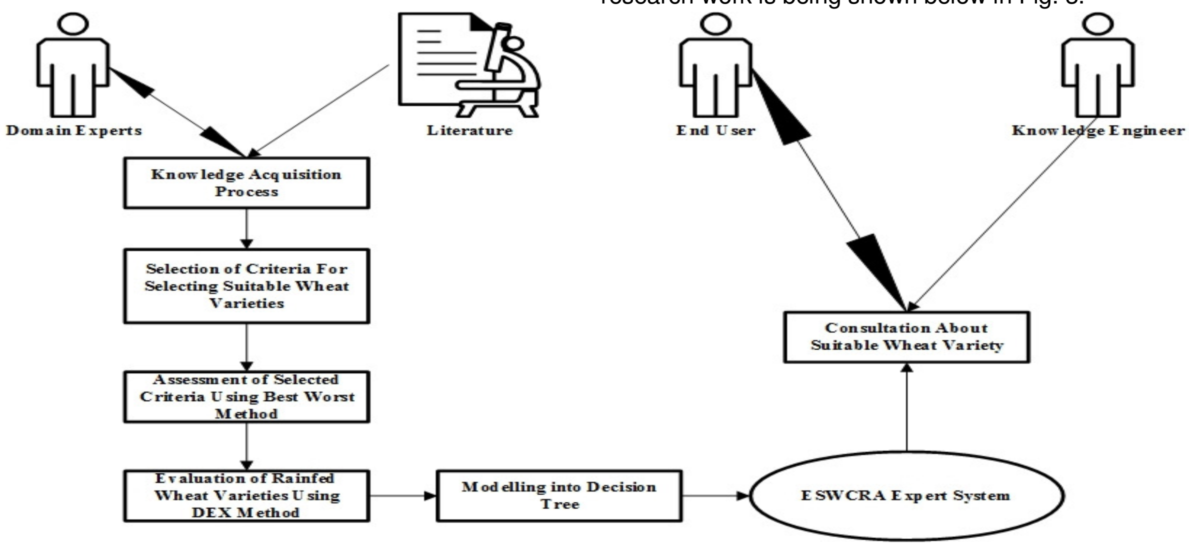

Fig. 3. Proposed Research Work Methodology.

A. Knowledge Acquisition

The process of knowledge acquisition includes some straightforward activities such as acquiring the necessary knowledge, analyzing the acquired knowledge, identifying the importance of criteria for wheat variety selection. In order to acquire desirable knowledge for this study both secondary and primary sources of knowledge are used. The techniques used to extract relevant knowledge from these sources are:

- Reviewing related documents, books, articles and research reports
- Interviewing domain experts

The purposive sampling technique was used for selecting domain experts. The selection of domain experts for this research study was based on the expertise level. Total six wheat crop specialists were selected as domain experts, two from Agriculture Research Institute, Ratta Kulachi, Dera Ismail Khan and four Agriculture experts were selected from Faculty of Agriculture, Gomal University, Dera Ismail Khan Pakistan.

B. Selection of Rainfed Wheat Varieties

After acquiring all relevant knowledge from domain experts, we selected four rainfed wheat varieties for this research study and prototype Expert System. These varieties are highly adopted in the rainfed area of District Dera Ismail Khan Pakistan. The list of rainfed wheat varieties selected for this research study is presented in the Table 1 below.

Table 1: List of rainfed wheat varieties.

Sr. No.	Rainfed Wheat Varieties
1	Shahid-16
2	Israr Shaheed
3	Hashim-07
4	Amin-08

C. Criteria Selection for a Suitable Wheat Variety

The selected experts are professionals in wheat crop breeding, management and production who are involved in teaching and research for the last many years. Based on their professional expertise, these experts identified that the criteria for wheat variety selection that affects the yield of wheat crop in District Dera Ismail Khan under rainfed condition is Soil Moisture, Sowing Time, Disease Resistance, Days to Maturity and Yield. These experts recommended suitable wheat variety to the farmers or wheat growers based on these criteria.

D. Assessment of Criteria Using BEST Worst Method

After selection of criteria above for the selection of suitable wheat variety for rainfed areas of District Dera Ismail Khan Pakistan, we used BWM [23] for assessment of selected criteria to know which criteria is most important and which criteria is least important.

For this purpose, we used spreadsheet based BWM solver. The BWM is used to generate weights of the criteria using least comparisons, which is the advantage of this method over other MCDM techniques. The method only requires two the comparison vectors of the best with other criteria and the other with worst criteria. This decreases the decision-making time and complexity. The decision-making process of BWM for assessment of criteria for selecting suitable wheat crop variety in rainfed areas of District Dera Ismail Khan Pakistan comprises of the following steps.

Step 1: Determine a set of inputs. In this step, we identify m inputs $\{I_1, I_{2,}.., I_m\}$ being determined on the opinion of domain experts.

Step 2: Determine the best (e.g. most desirable, most important) and the worst (e.g. least desirable, least important) input according to the decision-maker perspective. However, in this study the best and worst criteria determined on the perception of domain experts instead of decision-makers. This is only a selection; no quantitative task or comparison is done in this step.

Step 3: Determine the preference of the best input over all the other inputs, using a number between 1 (input a is equally important to input b), and 9 (input a is extremely more important than input b). The result is a best-to-others (BO) vector:

$A_B = (a_{B1}, a_{B2}, .., a_{Bm})$, where a_{Bj} indicate the preference of the best input *B* over input *j* and $a_{BB} = 1$.

Step 4: Determine the preference of all the inputs over the worst input, using a number between 1 (input a is equally important to input b), and 9 (input a is extremely more important than input b), which results in the others-to-worst (OW) vector:

$A_w = (a_{1w}, a_{2w}, .., a_{nw})T$, where a_{jw} indicates the preference of the input *j* over the worst input *W* and $a_{ww} = 1$.

Step 5: Find the optimal weights $(w_1^*, w_2^*, \ldots, w_n^*)$

The aim is to determine the optimal weights of the inputs, such that the maximum absolute differences $\{|w_B - a_{Bj}w_w|, |w_j - a_{jw}w_w|\}$ for all *j* is minimized, which is translated into following min-max model:

$$\min \max_j \{|w_B - a_{Bj}w_w|, |w_j - a_{jw}w_w|\}$$

s.t.

$$\sum_j w_j = 1 \qquad (1)$$

$$w_j \geq 0, \text{ For all } j$$

Problem (2) is transferred to the following linear problem:

$$\min \xi^L$$

s.t.

$$|w_B - a_{Bj}w_j| \leq \xi^L, \text{ For all } j$$

$$|w_B - a_{Bj}w_w| \leq \xi^L, \text{ For all } j$$

$$\sum_j w_j = 1 \qquad (2)$$

$$w_j \geq 0, \text{ For all } j$$

Solving problem (3), the optimal weights $(w_1^*, w_2^*, \ldots, w_n^*)$ and ξ^{L*} are obtained. ξ^{L*} is considered as a consistency index. The consistency ratio value nearer to' 0' is more consistent, while values nearer to' 1' are less consistent [23-24].

The weights of the criteria for selecting suitable wheat variety in rainfed areas of District Dera Ismail Khan Pakistan can be identified in the same manner by following all the steps of Best Worst Method.

Following the step 1 the identified criteria for selection of suitable wheat variety is shown in table 2.

The step 2 allows determining best (e.g. the most desirable, the most important) and the worst (e.g. the least desirable, the least important) criteria based on the opinion of the domain experts are shown in table 3.

The steps 3 and 4 allow domain experts to give their preference of best criterion to others (BO) and others to worst (OW) criteria as shown in Table 4.

Following the step 5 and solving the linear programming model through spreadsheet based BWM solver, the optimal weight of criteria is identified. Table 5 shows the identified weights of criterions.

Table 2: Identified criteria for selection of suitable wheat variety.

Criteria Number = 5	**Criterion 1**	**Criterion 2**	**Criterion 3**	**Criterion 4**	**Criterion 5**
Names of Criteria	Yield	Soil Moisture	Sowing Time	Disease Resistance	Days to Maturity

Table 3: Best and Worst Criteria for Selecting Suitable Wheat Variety.

Select the Best	Soil Moisture
Select the Worst	Days to Maturity

Table 4: Preference of Best Criteria to Other and Other to Worst Criteria.

Best to Others	Yield	Soil Moisture	Sowing Time	Disease Resistance	Days to Maturity
Soil Moisture	2	1	4	3	8

Others to the Worst	Days to Maturity
Yield	4
Soil Moisture	8
Sowing Time	2
Disease Resistance	3
Days to Maturity	1

Table 5: Identified weights of criterions.

	Yield	Soil Moisture	Sowing Time	Disease Resistance	Days to Maturity
Weights	0.229508197	0.448087432	0.114754098	0.153005464	0.054644809

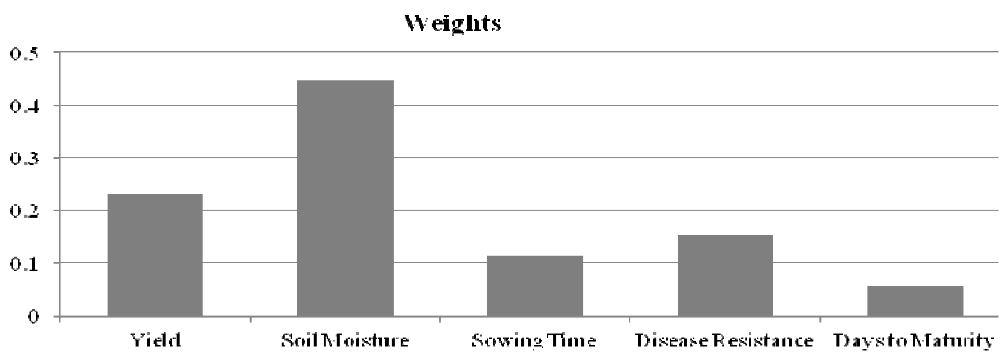

Fig. 4. Analysis Result of Best Worst Method.

The value of ξ^{L*} = 0.010928961 which means consistency ratio value ξ^{L*} nearer to' 0' that is why it is more consistent. The analysis result of Best Worst Method is shown in figure 4.

Fig. 4 shows the analysis results of BEST WORST method, BEST criteria means which have higher impact on crop yield and WORST criteria means, which have very little, or no impact on crop yield in rainfed areas of District Dera Ismail Khan.

E. Evaluation of Rainfed Wheat Varieties Using DEX Method

Evaluation of rainfed wheat varieties using DEX Method done through DEXi software, DEXi software implemented in Delphi and runs on Microsoft windows platforms. DEXi [6] is a computer program for multi-attribute-decision models and the evaluation of options. This is valuable for supporting complex decision tasks, where there is a need to choose alternative from set of possible ones in order to fulfill the objectives of the decision maker. Multi-attribute models decompose decision problems into a tree (or an acyclic graph) structure. The top attribute in such models represents the overall problem, while the attributes below the top attribute represent sub-problems, which are smaller and less complex than the overall problem. Each attribute assigned a value. The set of values for an attribute referred to as the scale of the attribute [25].

DEXi supports definition of discrete ordinal scales, where each step typically consists of a textual description. An example of an ordinal scale is (Unacceptable; Acceptable; Good; Excellent). The attributes in the model are either basic or aggregate attributes. Basic attributes represent the inputs to the multi-attribute model. They have no child attributes. The value of a basic attribute is determined solely by the input to (or selected value for) the attribute. Aggregate attributes have child attributes (which may be basic or aggregate). The value of an aggregate attribute is a function of the values of its child attributes. This function called the utility function of the attribute. The utility function of each aggregate attribute defined by stating,

for each possible combination of its child attribute values, what is the corresponding value of the aggregate attribute [25].
In summary, developing a DEXi model involves the following:

- Identify the attributes and structure.
- Define the scale for each attribute.
- Define the utility function for each aggregate attribute.
- Description of options
- Evaluation & analysis of options

Identification of Attributes and Structure
The first stage is the identification of attributes to be measured decision. At this stage, the experts start to determine the attributes to measure options by using DEX. In this study, the attributes already determined for the problem (i.e. selecting suitable wheat variety in rainfed areas of district Dera Ismail Khan). The attributes have only one level of hierarchy. The hierarchy structure of attributes shown in Fig. 5.

Definition of Attributes Scale
The second stage is the definition of the scale against attributes by the domain experts. Each attribute in hierarchy defined as a discrete variable taking values from set of symbols. These symbols need to be set for each attribute separately by model developer and usually consist of words such as good, excellent, acceptable, and so on. Scales in implementation has very difficult to easy level. Under Table 6, definition of the attributes scale set in the DEX evaluation model defined.

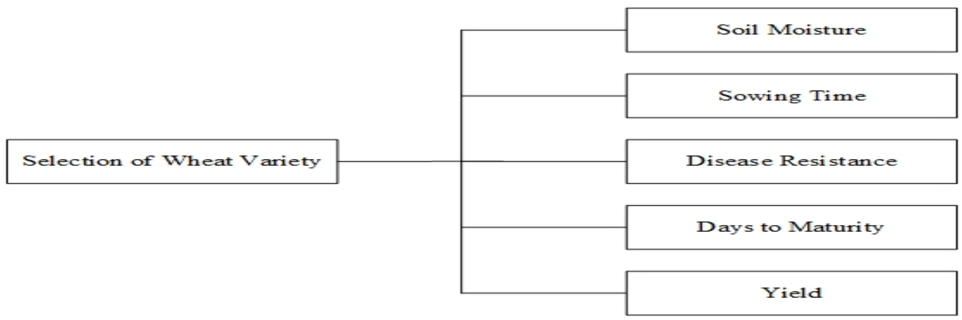

Fig. 5. Hierarchy Structure of Attributes.

Table 6: Attributes scale in DEX model.

Attributes	**Scale**
Selection of wheat Variety	Unacceptable, Acceptable, Good, Excellent
Soil moisture	Low, Medium, High
Sowing time	Late, Mid, Early
Disease resistance	No, Medium, High
Days to maturity	Late, Medium, Early
Yield	Low, Medium, High

Definition of Utility Function
In DEXi [23] Utility functions are the components of the multi attribute models that define the aggregation aspect of option evaluation. For each aggregate attribute *Y,* whose descendants in the tree of attributes are *X1, X2,….,Xn,* the corresponding utility function *f* defines the mapping:

$f.X1*X2*Xn \longrightarrow Y$

In DEXi, a utility function maps all the combination of the lower level attributes values into the values of *Y.* The mapping represented in a table, where each row gives the value of *f* for one combination of the lower level attribute values. Rows also called decision rules, because each row interpreted as if-then rules.
The aggregation made by these decision rules is rule defined by decision maker, with an aggregated function declared point by point for all possible combinations of attribute values. In this study, decision rules defined in DEXi with the help of domain experts which were defined on the basis of results obtained by BEST WORST method. Figure 6 shows set of decision rules for selection of suitable wheat variety under rainfed condition.

Decision rules

	Soil Moisture	Sowing Time	Disease Resistance	Days to maturity	Yield	Variety Selection
	9%	1%	42%	1%	48%	
1	*	*	No	*	*	Unacceptable
2	*	*	*	*	Low	Unacceptable
3	<=Medium	*	>=Medium	*	Medium	Acceptable
4	*	*	Medium	*	Medium	Acceptable
5	Low	*	>=Medium	*	High	Good
6	<=Medium	<=Mid	>=Medium	*	High	Good
7	<=Medium	*	>=Medium	<=Midium	High	Good
8	*	*	Medium	*	High	Good
9	High	*	High	*	Medium	Good
10	>=Medium	Early	High	Early	High	Excellent
11	High	*	High	*	High	Excellent
12	High	*	High	>=Midium	>=Medium	Excellent
13	High	>=Mid	High	*	>=Medium	Excellent

Fig. 6. Set of Decision Rules.

Description of Options

Options (are also called alternatives) are basic entities studied in a decision problem. Depending on the problem, they can represent different objects, solutions, course of actions etc., which evaluated and analyzed by multi attribute model [6].

At the final stage, the expert will make assessment on each option based on existing criteria. For the case study, four samples of wheat varieties selected as shown in Fig. 7.

Option	Shahid-16	Israr Shaheed	Hashim-07	Amin-08
Soil Moisture	Medium	High	Medium	Low
Sowing Time	Early	Mid	Late	Mid
Disease Resistance	High	High	Medium	High
Days to maturity	Midium	Midium	Early	Midium
Yield	High	Medium	High	Medium

Fig. 7. Description of Wheat Variety Options.

Evaluation & Analysis of Options

The farmers need to make decision from four types of wheat varieties, which are suitable to cultivate under rainfed condition. By comparison, criteria using DEX and predefined rules in figure 6, the figure 8 shows the evaluation & analysis of options.

The following figures show some charts that obtained in DEXi from the evaluation of rainfed wheat varieties using wheat variety selection model.

In Figure 9 shows a Bar Chart represents the evaluation results according to one evaluation dimension. In this case, the root attributes are various wheat varieties; therefore the chart shows overall evaluation of four rainfed wheat varieties. In the given scenario in Figure: 10 the Israr Shaheed variety touching the scale of Excellent, which means it will performed excellent under rainfed condition of District Dera Ismail Khan Pakistan.

In Fig. 10, i.e., in Scatter Chart, you can see the evaluation results according to two selected dimensions. In this case, the selected dimensions are variety selection and soil moisture. In given scenario in Fig. 11 it shows that if the soil moisture is high then Israr Shaheed variety performed excellent.

In figure 11: In Radar chart, you can see the evaluation results according to three or more dimensions. The radar chart shows the evaluation of wheat varieties using the six attributes i.e., Variety Selection, Soil Moisture, Sowing Time, Disease Resistance, Days to Maturity and Yield.

Option	Shahid-16	Israr Shaheed	Hashim-07	Amin-08
. Variety Selection	Good	Good;Excellent	Good	Acceptable
.. Soil Moisture	Medium	High	Medium	Low
.. Sowing Time	Early	Mid	Late	Mid
.. Disease Resistance	High	High	Medium	High
.. Days to maturity	Midium	Midium	Early	Midium
.. Yield	High	Medium	High	Medium

Fig. 8. Evaluation & Analysis of options.

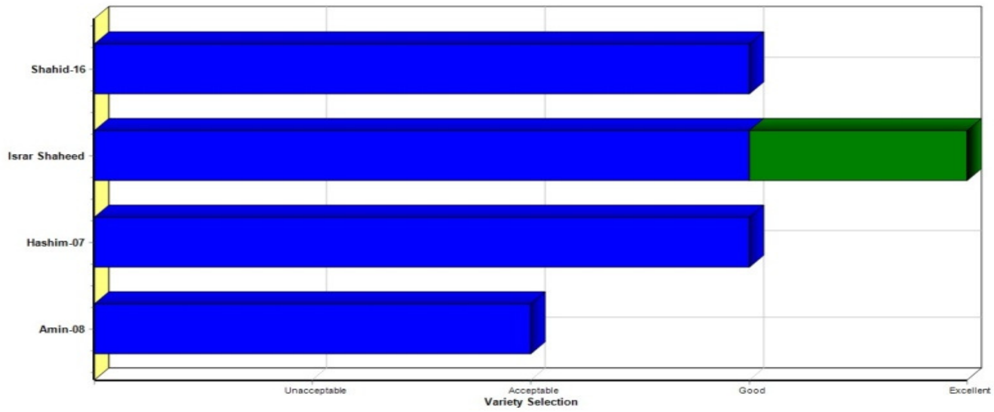

Fig. 9. Bar Chart of Wheat Variety Selection Model.

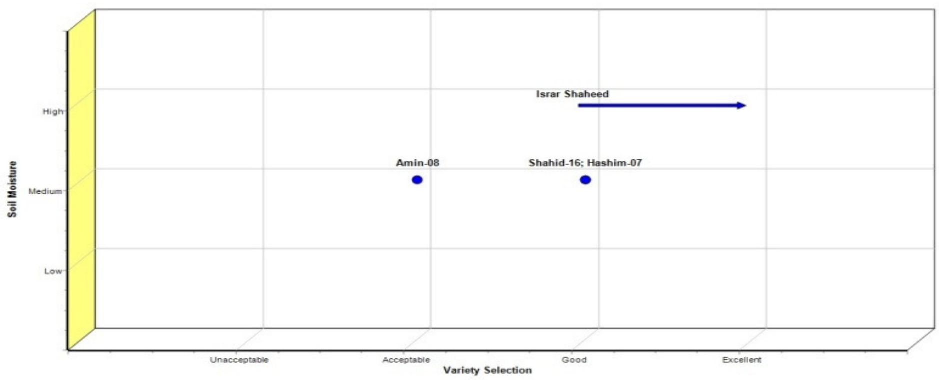

Fig. 10. Scatter chart of Wheat variety selection Model.

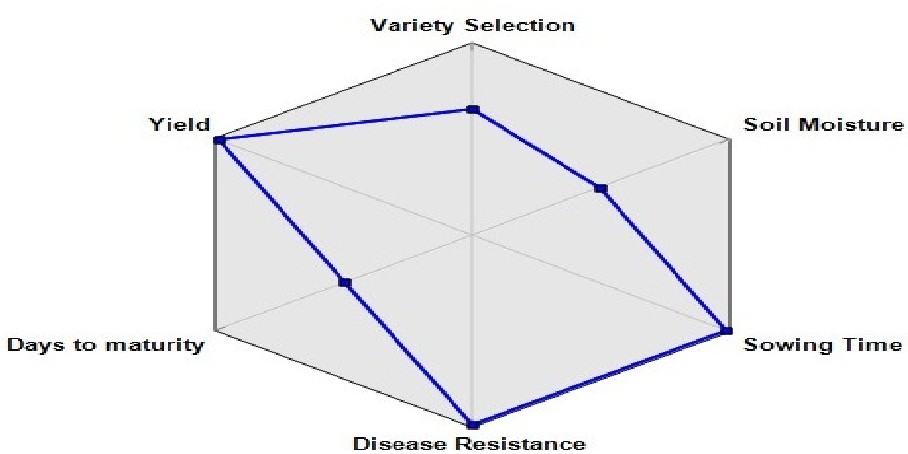

Fig. 11. Radar Chart of Wheat Variety Selection Model.

F. Development of ESWCRA

The Expert System for Wheat Cultivation in Rainfed Areas (ESWCRA) has five core components, which are depicted through Fig. 12.

These components are as User's interface, Control System Inference Machine, Set of knowledge bases, DEX Method and BEST WORST Method. As described previously, the BEST WORST Method being used for the assessment of criteria. i.e., which criterion is most important and which criterion is least important for the selection of suitable wheat crop variety. After the assessment of criteria, the DEX Method used for the evaluation of rainfed wheat varieties by making decision rules these decision rules based on importance of criteria. All the decision rules stored in the knowledge base of ESWCRA. Knowledge base provides knowledge (rules, or different conditions about any situation), while the Control system inference machine uses these rules of the knowledge base to control which advice is to be delivered to the expert system user to initiate other actions. The expert system user gets consultations from the ESWCRA through Consultation sub-system using the knowledge base, and knowledge engineer creates the knowledge base through the user interface, and control system inference machine respectively. The ESWCRA as the capabilities of

explanation of taking various decisions by pressing **why** and **how**, and **explain** buttons in the menu.
The ESWCRA has capabilities of an intelligent system as having the ability to give answer to questions, like “WHY” and “EXPLAIN” to the Expert system user at all moments. The Expert system can be easily installed and run on any PC, Laptop and compatible microcomputers. Any amendments are possible at any time, even during its execution. The expert user may discontinue the execution by pressing the “stop” button, and after making necessary changes, the program may be restarted from the point with the selection of “continue consultation” from the “consult menu” in the Expert System.

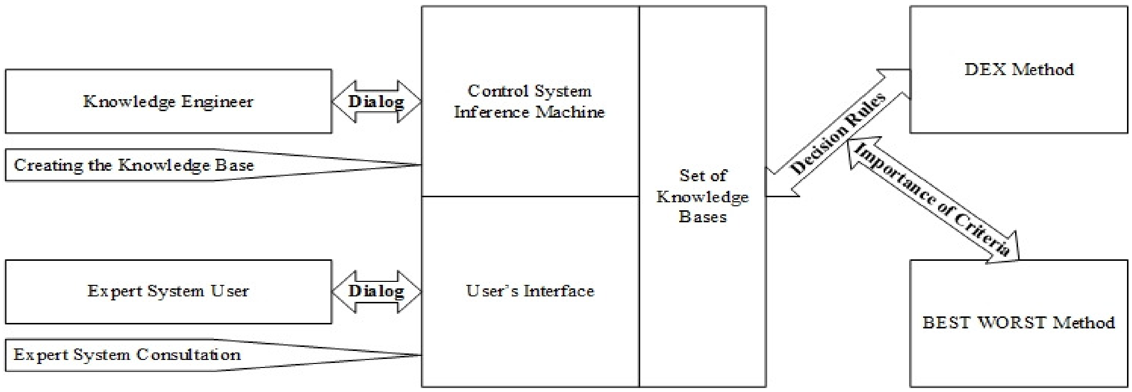

Fig. 12. Components of ESWCRA.

F. Consultation of ESWCRA

Consultation begins with pressing beginning consultation in the Expert System. Sample screen shot of the consultation process have been represented through figures as under.

In Fig. 13, the expert system requests the user to select the soil moisture of land. Which criteria is most important criteria for selecting suitable wheat variety? The user can get information about the importance of soil moisture for wheat cultivation under rainfed condition. In addition, the user can get idea of recommendation about “which level of soil moisture is suitable for cultivation in rainfed areas of District Dera Ismail Khan Pakistan” through explanation facility. If the user does not have any idea about soil moisture, he can select “don’t know” option and get information about different methods of estimating soil moisture.

Fig. 13. Select Soil Moisture of Land.

Similarly, the proposed system asks questions from users about sowing time, disease resistance, days to maturity and yield, for decision-making and then give final advice to user about suitable rainfed wheat variety along with Average yield, land preparation method, sowing date, seed rate, sowing method, seed treatment, fertilizer requirement, weed control, harvesting, threshing and storage method of proposed wheat variety. Figure 14 shows the Final advice of the consultation session.

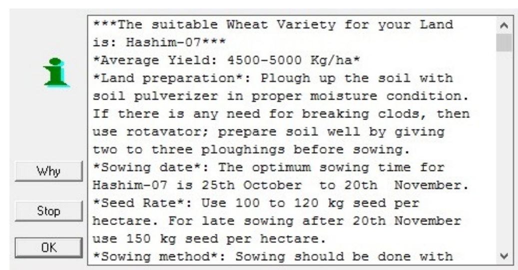

Fig. 14. Final Advice of ESWCRA.

IV. SYSTEM EVALUATION

Expert system evaluation is the process of determining the quality of the Expert System and the consultation/advice it provides. Evaluation is important for any software development efforts to ensure correctness of the out puts and user satisfaction with the product in solving the given problem.
The questionnaire was designed in the context of Expert System for wheat cultivation in rainfed areas of District Dera Ismail Khan (ESWCRA).
To evaluate the usability of the system we used total six (6) domain experts that were selected for this research study. We provided 7 different system evaluation questions for the respondents. The respondents were required to evaluate the system using ordinal scale from strongly disagree (rating 1) to strongly agree (rating 5). The values are given as Excellent = 5, Very good = 4, Good = 3, Fair = 2 and Poor = 1. The Table 7 indicates the feedbacks obtained from the domain experts (evaluators) on systems interaction as calculated based on the given scales.
As Table 7 indicates, 16.7% of the respondents reply easiness to use and to interact with the prototype as good and the same number of the respondent also rated that easiness to use and to interact with the prototype as excellent. However, the highest number (66.7%) rated easiness to use and to interact with the prototype

as very good. In case of attractiveness of the prototype 83.3%, the respondents reply the prototype as very good and the remaining 16.7% evaluated the attractiveness of prototype as good. In case of time efficiency, the same number of evaluators (i.e., 16.7%) rated as good as well as very good and the remaining 66.7% rated as excellent.

Additionally, 16.7% of the respondents evaluate the prototype as good and 83.3% as very good at deciding accurate description and treatment during selecting suitable wheat variety. In the same way for criteria of the prototype, incorporating sufficient knowledge, 33.3% the evaluator rated as good and the remaining 66.7% evaluated as very good. Similarly, in terms of the prototype providing right information about land preparation method, sowing date, seed rate, sowing method, seed treatment, fertilizer requirement, weed control, harvesting, threshing and storage method, 33.3% respondents evaluated as good, very good and excellent. Finally, concerning the significance of the ESWCRA prototype knowledge-based system, 83.3% of the evaluators responded as very good and 16.7 responded as excellent.

Table 8 indicates number of responses obtained for each of options that the respondent's rate to evaluate the prototype.

Table 7: Evaluation Results of ESWCRA.

No	Questions	1	2	3	4	5	Average	%age
1	Is the ESWCRA Expert System 'easy to use and interact with it?	0	0	1	4	1	4.0	80%
2	How do you rate ESWCRA attractiveness?	0	0	0	5	1	4.2	84%
3	Is' the system more efficient in time?	0	0	1	1	4	4.5	90%
4	How accurately does a system reach a decision in Selection of suitable wheat variety in rainfed areas of district Dera Ismail Khan?	0	0	1	5	0	3.8	76%
5	Does the system incorporate sufficient and practical knowledge?	0	0	2	4	0	3.6	72%
6	Can the system give right information about land preparation method, sowing date, seed rate, sowing method, seed treatment, fertilizer requirement, weed control, harvesting, threshing and storage method of proposed wheat variety?	0	0	2	2	2	4.0	80%
7	How do you rate the significance of the system in the domain area?	0	0	0	5	1	4.2	84%
		Total average					**4.04**	**80.9 %**

Table 8: Users' Feedback on Closed Ended Questionnaire.

Evaluator who respond as	Total number of responses for each option of all seven questions	%age
Poor (1)	0	0
Fair (2)	0	0
Good (3)	7	16.7%
Very good (4)	26	61.9%
Excellent (5)	9	21.4%
Total average	**4.04**	**80.9%**

As shown in the above (Table 8), based on closed ended questions as evaluation criteria, the domain experts reply the prototype as very good twenty-six times (61.9%). The experts also respond the prototype as excellent nine times (21.4%). The least response is good seven times (16.7%) regarding the prototype on its easiness, incorporation of sufficient knowledge.

As a whole, the evaluation results of the system was 80.9%, which shows that the system is highly acceptable in the rainfed areas of District Dera Ismail Khan Pakistan, and will enhance food security and improve the living standard of poor farming community.

V. CONCLUSION

Combining agricultural experts' knowledge with ICT gives valuable advantage for farmers to enhance the yield of crop production. Expert system can be one of the most useful tools to provide farmers with day-to-day, integrated decision support needed to grow their crops. Developed countries of the world used Knowledge Based System as a better mechanism to disseminate agricultural expert knowledge.

However, in Pakistan especially in rainfed areas of District Dera Ismail Khan Pakistan agricultural expert's assistance is not easily available. There should be a mechanism to make this assistance available to users. One of such mechanism is the Expert System for wheat cultivation in rainfed areas of District Dera Ismail Khan Pakistan that may fill this gap especially in wheat production.

This system will help user's especially farmers and agricultural extension workers in District Dera Ismail Khan who are mediator between farmers and agricultural researchers to provide immediate expert's assistance easily and quickly. The proposed system i.e., ESWCRA proposed a new integrated approach in this study for building Expert Systems and in selection of suitable wheat variety.

The proposed research work not only solves the problem of selecting suitable wheat variety under rainfed condition also give information to user about land preparation method, sowing date, seed rate, sowing method, seed treatment, fertilizer requirement, weed control, harvesting, threshing and storage method of proposed wheat variety. It also implements new technology in agro management. This will expand the production and the national gross pay, on one hand, and lessening the production cost on the other hand.

To assess its performance and users' acceptance in the domain area, the ESWCRA was evaluated using users' feedback through a Questionnaire. After the users were exposed to interact with system, their opinion and suggestions were gathered. According to evaluators, such system can be useful in rainfed areas, which are the rural areas of District Dera Ismail Khan Pakistan where agriculture expert's assistance is not easily available; the system can reduce the existing knowledge gap.

The thought behind developing this Expert system is that, the system empowers many persons to get benefit from the knowledge of one expert in domain specific problems. Therefore, ESWCRA was developed in this research, which is applicable and promising to apply the judgment and experiences of domain experts in selecting suitable wheat variety and providing the relevant information about problem domain.

This research work is novel because BEST WORST Method and DEX Method was not integrated with Expert system technology. It will be a new field of research for researchers.

VI. FUTURE WORKS

To improve the quality and to expand the system, the following points should be considered:

- The work needs to be extended for other rainfed areas of Pakistan and for the whole World.
- System concerns only one major crop i.e. Wheat which needs to incorporate other cereal crops like; maize, sorghum, teff, barley and rice crops, fruits and vegetable crops.
- Customize the system for other local languages like Urdu, Saraiki, and Pashto other than English.
- Mobile based application needs to be considered, which will provide facility to farmers about weather forecasting, pests and disease attack warning through SMS, and query response through voice.

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