A computer-based system for the management of field crop pests

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A Computer-Based System For The Management of Field Crop Pests

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ABSTRACT

This article describes an axpert system, COT-XPERT, developed for controlling insects and diseases affecting cotton crop as well as system for Rice Stem Borers (RSB) simulation. The system works in two parts. The first part addresses the issues of efficient use of knowledge for RSB problems and predicts the population build-up of RSB after a certain period of time by taking into consideration weather factor, number of larvae per square metre present earlier, fecundity of female and dispersal pattern, etc. The second part is an expert system for the management of cotton pests which diagnoses the pest problem by using information about the damage inflicted to the crop or based on its morphology and displays all technical information about the pests as well as efficient control measures for a particular pest. The paper concludes with a mention of some of the limitations and future research directions for enhancing the qualities of the system.

1. INTRODUCTION

Pakistan is an agricultural country and approximately 80% of its population directly or indirectly depends on agriculture. Agriculture is one of the major means of earning foreign exchange. In view of this, the Government of Pakistan has set up several agricultural institutes which are engaged in doing research to increase productivity in agricultural commodities.

The Entomology Group has undertaken research to develop strategies for controlling major crop pests. Here, all kinds of insects are identified, their biologies and life-cycles are studied and various methods to control their harmful effects are tested. The extensively tested technologies are then transferred to the farmers through extension workers by holding meetings/ seminars, radio and television talks, and by distributing relevant literature. However, there is a considerable debate over the ineffectiveness of the existing ways of communicating with the concerned persons. A few of the reasons are as follows:

(i) Creating and publishing new information as well as updating and maintaining existing information is very time consuming.

(ii) Locating existing information in different volumes of literature is difficult .

(iii) Existing means are limited in their capabilities to provide individualized to the growers.

The present study has been conducted for overcoming the above mentioned drawbacks and putting together all available information about cotton pests and simulating population buildup of rice stem borers (RSB).

1.1 OBJECTIVES OF THE STUDY

The objectives of this study are summarized keeping in view different aspects, for example,

- Organizational needs
- User's perspective

1.1.1 Organizational Needs

The objectives in terms of the organizational needs are briefly described under the following two headings:

(a) RSB Simulation

Its aims are twofold:

(i) To evaluate the impact of crop following rice on the populatiuon build-up of RSB in the subsequent generations.

(ii) To evaluate the impact of area under a given crop following rice on the population build-up of RSB in the subsequent generations.

(b) Cotton Pest Management

It is used to derive several important benefits, for

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example,

(i) Identify the pest problem based on the morphology of insects and crop symptoms inflicted due to insect and disease attacks.
(ii) provide a list of desirable methods of insect and disease attacks,
(iii) select a few specific insecticides for the effective control of insects,
(iv) estimate the loss occuring in yield due to insect attacks,
(v) generate automated pest control recommendations indicating which pesticide, its formulations, dose per acre, and packing should be used to optimize the grower's profit,
(vi) intimate the pest activities and pest control operations for a given month,
(vii) educate users in calibrating the spray equipment so as to apply pesticide correctly , and
(viii) provide all necessary information about the biology and seasonal cycle of insects or diseases, nutrient deficiency problems and their control.

1.1.2 User's Point of View

From the user's point of view the system should

(i) provide required information efficiently (i.e., both the time and memory requirements should be as small as possible),
(ii) provide help to users for convenience so that the user may feel comfortable while using it and should be able to operate the system after only a few trials,
(iii) be free from errors, inconsistency and redundancy, and
(iv) be able to accommodate expansion through a minimum of change in its program structure.

2. RSB AND COTTON PESTS

RSB and cotton pests are briefly described below:

In Pakistan, rice crop is attacked by five species of stem borers. They are rice stem borers, yellow stem borers, white stem borers, pink borers, and asiatic rice borers. Latif [1] reported that the stem borers damage over 70% of the crop in some parts of Pakistan. Moiz and Rizvi [2] reported that during 1957 and 1958, yellow stem borers caused almost total damage in vast tracts of rice area in Sindh province and this damage continued upto 1964. Koehler [3] reported that during 1970 the yield of Basmati rice in Pakistan declined by 25% to 30% due to the attack of stem borers. Beside stem borers, rice crop is also occaionally attacked by leaf-folders, grasshoppers and white-backed planthopper; however, yellow and white stem borers are considered to be the major pests of rice in our country.

Cotton, like rice, also plays an important role in the economy of Pakistan. It is grown on almost 10% of the total cultivated area and earns about 40% of foreign exchange through its export. Cotton crop is attacked by a number of insect and disease pests and it is estimated that about 30% of its total yield is lost annually due to these pests. In cotton growing areas every farmer sprays at least 4 to 5 times to save his crop from the ravages of the pest. Although the use of pesticides on cotton has increased production, it has created many associated problems, namely,

- environmental contamination
- pest resurgance
- health hazards, etc.

For this purpose, correct identification of the pest and its life cycle information is necessary. There are about 168 registered pesticides in Pakistan and the user is often confused as to which one should be used to increase his profit.

3. DESCRIPTION ON THE SYSTEM

The system provides the following two main functions:

- RSB simulation
- Cotton pest management (COT-XPERT)

3.1 RSB Simulation

The simulation of RSB is discussed considering the following factors:

(a) Inputs and main processing

(b) Data entry checks

(c) Data file

(d) Output reports

The user first inputs the starting year and the number of years for which he wants to predict the population build-up of RSB. At present, the user can predict results upto 12 years.

There are three options for data entry:

(i) Data Remains Constant Throughout the Selected Time Period

In this case, the user enters data only once, i.e., for the initial year and the calculations proceed with the same figures except for the number of larvae/sq. metre which is entered for the starting year, and for rest of the years it is calculated as follows:

$$L = L1/FZ$$

where L = No. of larvae/sq. meter for the next year, L1=No. of larvae for fourth generation of the proceeding year and FZ= Farm size.

(ii) Data Changes Yearly

In this case, the user enters data for every year except for number of larvae/sq. metre which is entered only once and for rest of the years it is calculated as in (i) above.

(ii) Data Changes for Some Years But Remain Constant for a Subperiod

In this case, the user enters the starting and ending years of the subperiod for which the data remain constant. For this subperiod, the data will be entered only once but for the rest of the years the user enters data for every year.

After selecting one of the above options, the user selects the unit of area in which the farm size alongwith the area under crops will be entered. After each input screen the user has the following three options:

- Make corrections
- Continue
- Return to the main menu

When the user made all necessary corrections, the recent values of all the fields of that particular input screen are displayed for confirmation and then a summary statistics report is generated.

The next input screen prompts for the user to enter the dispersal pattern, fecundity of female, hatchability and egg parasitism. The number of larvae is calculated as follows:

$$L = Fem \times Hat \times (1-Ep)$$

Where L = No. of larvae, Fem = No. of females, Fec = Fecundity of female, Hat=Hatchability and Ep =Egg parasitism.

The next thing to be entered by the user is the food for first generation larvae for which density and survival are given. The user enters his choice and hence the number of larvae for the first generation is calculated. The last input screen prompts for the population growth rate for each of the next three generations. Thus all the four generations of the year are calculated. Finally, a summary report is generated which shows all the four generations and the number of larvae/sq. m. for each year and the preceding years.

Different checks are provided in the system to cater for the risk of inputting wrong data.

Three output screens for each year are displayed by the system which include:

(a) The Number of RSB Larvae in Various Crops for the Proceeding Year

A screen showing the number of RSB larvae for various crops for the starting year appears in Table1.

TABLE 1. RICE STEM BORER LARVAE IN VARIOUS CROPS FOR YEAR 1990

CROP	AREA (ha)	LARVAE/CROP	LARVAE/m^2
BERSEEM	1.00	100000	10
CONVENTIONAL TILLAGE WHEAT	1.00	100000	10
NO TILLAGE WHEAT	1.00	100000	10
FALLOW	1.00	100000	10
FALLOW/PLOUGHED	1.00	100000	10
GRAM	1.00	100000	10

(b) A summary statistics report for each simulation including simulation number, farm size, winter weather, % survival, tillage systems, area under each crop and the total number of moths on the farm. Based on the input values, the system displays the summary statistics for the first simulation shown in Table 2.

(c) A summary statistics report including the number of larvae for all the four generations and number of larvae per square metre at the end of the proceeding year is updated for the subsequent years .

Table 3 below is the screen display of the final summary statistics report which shows (the number of larvae for all the four generations of each year) the number of larvae/sq. metre.

3.2 Cotton Pest Management (COT-XPERT)

There are three main functions of this part:

(a) Diagnosis of the pest

(b) Detailed textual information

(c) Control recommendations

3.2.1 Diagnosis of the Pest

Each type of pest can be identified through some key questions. A number of possible answers are presented to the user out of which one has to be selected. The answer selected determines the next question to be asked. This series of questions and answers leads to a certain conclusion. The system then intimates the user about the probable identity of the pest. At present, 26 pests damaging cotton can be identified. If the user is familiar with the pest, he needs not to through the key questions and is simply required to enter the name of the pest. If the system knows about that pest, a detailed information about it can be accessed.

TABLE 2. SUMMARY STATISTICS

SIMULATION NO 1
FARM SIZE = 6.00 HECTARES
WINTER WEATHER : HIGH RAINFALL HIGH TEMPERATURE
PERCENT SURVIVAL = 20%

TILLAGE SYSTEM	AREA (HECTARES)	% SURVIVAL	NO. OF LARVAE SURVIVED (PER SQ. METER)
BERSEEM	1.00	80%	1.60
CONVENTIONAL TILLAGE WHEAT	1.00	15%	0.30
NO TILLAGE WHEAT	1.00	20%	0.40
FALLOW	1.00	80%	1.60
FALLOW/PLOUGHED	1.00	70%	1.40
GRAM	1.00	40%	0.80

TOTAL NUMBER OF MOTHS ON THE FARM = 54900

TABLE 3. SUMMARY STATISTICS

YEAR	GENERATION 1	GENERATION 2	GENERATION 3	GENERATION 4	LARVAE/m^2
1990	13.18	19.76	29.65	8.89	9
1991	11.72	17.58	26.37	7.91	8
1992	10.42	15.63	23.45	7.03	7
1993	09.27	13.90	20.86	6.26	6

3.2.2 Detailed Textual Information

The system also provides information in the form of text about the pest. It may be an information regarding the injury, cause, symptoms, economic importance of the pest and its general control measures. The information about the pest activites and necessary control tactics during a particular month of the year is also available.

3.2.3 Control Recommendations

The third major function is the generation of automated control recommendations.

In this part the system asks the user for input data concerning total yield per acre of crop without inscet or disease attack, decline in yield by 1% pest infestation, total percentage of infestation, price of cotton per kg, dose per acre, application cost, number of sprays which the user wants to do and acreage. These inputs are used in computations on which the recommendations of the system are based. The user is provided with a table that includes information about suitable pesticides for the identified pests, their formulation, their prices based on packing sized and the manufacturer's name.Thus, the entire list of pesticides that are effective against the identified pest is available to the user and he can choose the one which suits him. Information about the pesticide name, amount and dose/acre to be utilized, application cost per acre, packing sizes, number of packs required, total price, control cost per acre, net cost and net profit are calculated and displayed.

If the user so desires, the system also gives its own recommendations. The three best pesticides that can be used are presented by the system. The tabular information about these pesticides is then displayed alongwith the option to have it printed.

The last part of the control recommendations is the pesticide calibration/standardization to have the crop treated at the desired rate. The following types of pesticide calculations are mostly needed while using pesticides:

(a) Litres of Spray Per Acre

It is essential to apply the correct volume of spray per acre when treating a field. If the spray volume is too low, the plants will not be properly covered, and if it is too much, the pesticides will run of the foliage and be wasted.

(b) Number of Sprayer Loads

It is important to determine the number of sprayer loads to be used per acre.

(c) Percentage Concentration

It is used to calculate the percentage concentration of the pesticide of a given formulation.

(d) Rate When the Percentage Concentration is Known

It is used to calculate the dose of a pesticicde when the concentration of the pesticide is known.

(e) Rate When Recommendations are Pased on kg ai per Acre

It is used to calculate the amount of commercial preparations of a pesticide when its dose is given in kg ai (active ingredient) per acre.

(f) Applying Pesticide Granules

It is used to calculate the amount of commercial preparations of granular pesticides when the rates are given in kg ai/acre.

The quantities required in these calculations are obtained from the user at run time.

4. KNOWLEDGE BASE STRUCTURE FOR COT-XPERT

The knowledge base consists of rules which usually enable deductions to be made from the given facts, so adding newly deduced facts to the knowledge base.

4.1 Representation of Facts Inside the Program

A fact is a statement whose validity is accepted. The facts are elementary components of knowledge and are about particular objects and are therefore subject to some changes. Rule structure is as follows:

NAME: Rule
STRUCTURE

FILED	Rulename	Query	Optionlist	Rule namelist
TYPE	String	String	List of Strings	List of Strings

In Prolog, it is declared as,

rule(string, string, list, list)

Assume that it is instantiated as,

rule(Rulename,Query,Optionlist, Rulenamelist)

The variable **Rulename** identifies a particular rule; each rule has a unique name by which it is accessed. It has been declared as a string so that it may contain digits, alphabets or both. The variable **Query** contains the question that the system intends to put to the user. It usually consists of one or two sentences to help the user understand which information is being asked for. The variable **Optionlist** is a list of two or three strings. Each string represents a possible answer that can be chosen to reply the question put in query. One of these strings can be selected to answer the question. The variable **Rulenamelist** is also a list of strings: each string represents the name of the rule to be processed next. Corresponding to every option in the **Optionlist** there is a rule in the **Rulenamelist** which will be processed next, depending upon the option selected. For conclusion rules both lists will be empty.

Examples

(i) rule)"x10", "Appearance of plant", ["plant top dying, bolls with larvae whitish, covered with blace spots", "Note as above"], ["xconclude 10", "x11"])

(ii) rule ("xconclude 10", "spotted bollworm", [ ], [ ]).

4.2 Structure of Records

A number of records have been used to keep relevant data in an organized manner. All records are kept in a file called "Records. dbf" which contains two kinds of records, namely,

- pesticide records
- pesticide efficacy records

4.2.1 Structure of rice Records

NAME: price-rec

PURPOSE: To keep information about the packing size, packing unit and price per unit of a pesticide.

NUMBER OF RECORDS

It depends on the number of available packing sizes.

STRUCTURE

FIELD	Packing	Unit	Price	Perunit
TYPE	Real	String	Real	String

In Prolog, it is declared as,

Price-rec (real, string, real, string)

and may be instantiated as,

Price-rec (Packing, Unit, Perunit)

The value of the variable **Packing** is a real number which represents the packing size of a pesticide, the variable **Unit** contains a string to describe the units in which the packing is being measured such as L for litre and Kg for kilogram, the variable **Price** represents the price ot the pesticide in Rupess/ unit and this unit is contained in the variable **Perunit.**

The Example

Price-rec(4.0, "L", 550.00, "/L")

shows a price record in which the price for a packing of 4 litres is Rs. 550 per litre.

4.2.2 Structure of Pesticide Records

NAME: pest-rec

PURPOSE To store information about the name, formulation, manufacturer's name, dose per acre, and price records of a pesticide.

STRUCTURE

FIELD	Insecticide	Formulation	Company name	Dose	Price Record
TYPE	String	String	String	String	List of Price records

In Prolog, it is declared as,

pest-rec(string, string, string, string, plist)

and may be instantiated as,

pest-rec(Insecticide,Form,Company,Dose,p-reclist)

In the declaration of pest-rec, **plist** is a list of price records, the variable **Insecticide** is used for the name of the insecticide, the variable **Form** describes the formulation of the insecticide, the variable **Company** shows the name of a company that manufactures or sells the pesticide, the variable **Dose** contains the dose of insecticide to be sprayed (the dose per acre is usually taken as a range which shows the minimum and aximum recommended does) and the variable **P-reclist** contains one or more price records whose structure is already described.

Example

pes-rec("arrivo", "10EC","AGRO CHEMICALS LTD., KARACHI", "0.3-0.5L", [price-res(1,"L",125,"/L"), price-rec(5,"L",120,"/L"), price-res(210,"L" 105,"/L")])

4.2.3 Structure of Pesticide Efficacy Records

NAME: eff-pest

PURPOSE: To keep information about the pesticides which can be used against a pest.

STRUCTURE

FIELD	Type	Pesticide list
TYPE	Symbol	list o strings

In Prolog, it is declared as,

eff-pest (symbol, list)

and may be instantiated as,

eff-pest(Type, Pestlist)

The variable **Type** represents the type of a pest or the category to which the pest belongs and the variable **Pestlist** is a list of strings, which has the names of pesticides that are effective against the pests of the type represented in **Type**.

Example,

eff-pest("bw",["ambush","arrivo", "cymbush", "decis D", "sumicidin", "politrin C", "zolon DT", "Sevin", "gusathion-M"]).

The knowledge base of COT-XPERT can be updated by adding, modifying or deleting the records in it. A specially written program "Modify.pro" for this purpose makes the user's job easier and it does not require him to be familiar with the language or even know how the records are stored.

4.3 Text Files

Corresponding to each insect and disease there is a text file contains the detailed information about the particular insect or disease. Also there are text files associated with the monthly management routine.

4.4 Query Method

Whenever the user wants to choose an option or answer out of a number of possible once, a program "cmenu. pro". is called in which the menu selection technique is implemented.

The predicate menu has the following structure:

FIELD	Row	Column	List of options	Choice
TYPE	Integer	Integer	List of strings	Integer

In Prolog, it is declared as,

menu(integer, integer, list, integer)

and amy be instantiated as,

menu(Row, Column, Listofoptions, Choice)

The variables **Row** and **Column** determine the position on the screen where the window containing options will be placed and the variable **Listofoptions** is a list of strings which represents the possible options. Each string is displayed on a separate line. The position of the selected option is returned in the integer variable **Choice**. The program can then proceed according to the selected option.

Example

menu (4,10, ["Insects","Diseases",Operating system", "Return to main menue"], Choice).

4.5 Inference Enginne

Inference engine is that part of the knowledge base that contains the inference and control strategies. For example, the inference engine of MYCIN [4] uses the rule of modus ponens which is:

If A is true and If A—> B

then B must be true.

4.5.1 Identification of a Pest

To identify a particular pest, the user has to go through a number of rules. The structure of rules has been described in sec. 4.1. To infer from these rule a predicate handle -rule having the following declaration is used:

handle-rule(string, symbol)

which may be instantiated as,

handle-rule (Rulename, Pesttype)

where the variable **Rulename** determines the rule to be invoked and the variable **Pesttype** contains the type of pest which is either a disease or an insect. The variable **Pesttype** actually has no function in this predicate but it is passed on to other predicats which uses it. Suppose the user wants to identify a diseas and selects the option of disease through the menu. Then the handle -rule has the following values,

handle-rule("y1", disease)

where y1 is the name of the first rule to be processed. So, a rule named y1 is picked which has the following values:

rule("y1","Appearance of plant", ["Stunted growth, leaves and stems discoloured", " Not as above"] ["y2","y3"]).

The predicate handle-rule picks the query in the rule and displays it on the screen. In this case it displays,

"Appearance of Plant"

Now the possible answers to this query are written on the screen throuth the predicate menu,

menu(10,10["Stunted growth, leaves and stems dis-coloured", "Not as above"], Reply)

and the system waits for the user's srsponse. The predicate menu returns the number of the selected option. If the user selects "Not as above", the variable **Reply** will contain a value of 2. This number is passed to another predicate n-element which finds the nth element of a list.

It has been declared as,

n-elements(list, integer, string)

Assume that it is instantiated as,

n-element(Rulenamelist, Reply, Next rule).

The variable **Rulenamelist** contains "y2" and "y3" it elements. The second element of **Rulenamelist**, i.e., y3 is searched and is instantiated to a variable Nextrule. This value is now passed to the predicate handle-rule to impose recursion:

hundle-rule (Nextrule, Pesttype).

The process continues until a conclusion rule is reached which has both its lists empty and the name of the identified pest as its second argument. For example,

rule ("yconcludel","Stunting",[ ], [ ]) .

In the above example, the name of the identified disease is Stunting.

To understand the working of the handle-rule predicate, let us go through the identification sequences, Harheed[5]

Suppose a user wishes to identify an insect which is infesting a cotton field. After selecting "COTTON", "Insects", and "Identification" from subsequent menus, the identification sequence is reached. The handle-rule predicate is given the name of the first rule for the identification of cotton insects, i.e., "x1".

Suppose, the insect to be identified has the following effects on the appearence of plant:

Leaves not normal, bolls healthy, lower surfaces of the leaves are silvery or shinny brownish .

Then the portion of the program containing rules to identify this insect is given below:

rule("x1", "Appearence of plant",

["Plant top drying, easily pulled out from soil, termites feeding on roots", "Not as above"], ["xconclude1","x2"])

rule ("x2","Appearence of plant",

["Plants defoliated, insect damage obvious on stems and leaves", Not as above"], ["x3", "x4"]).

rule ("x4", "Appearence of leaves and bolls",

["Leaves not normal, bolls healthy", "Leaves normal, bollsdamaged"], ["x5", "x10"]).

rule ("x5" ," Colour of leaves",

["Lower surfaces of the leaves are silvery or shinny-brownish","Not as above"],["xconclude5","x6"]).

rule('xconclude5", "thrips",[],[]).

The rule "xconclude5" is the conclusion rule.

Semantic Network

A part of the semantic network based on a program segment is shown in Fig.1.

The entire network consists of about 58 rules. The application of the handle-rule predicate to the conclusion rule results in the following message:

"The insect is probably Thrips."

The path taken by the system is clearly shown in the figure by dotted line.

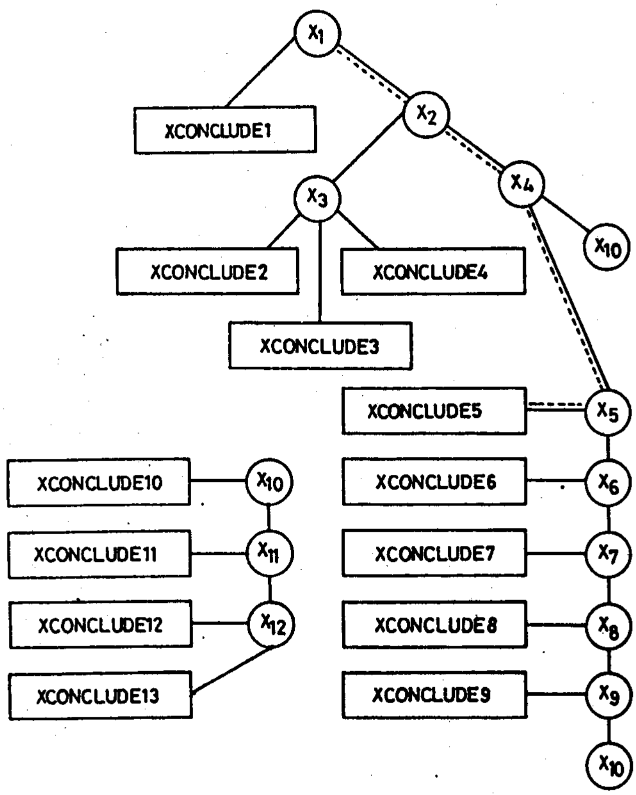

FIG. 1

4.5.2 Text Files

The name of the identified pest is passed on to a predicate detail having the following declaration:

detail(string, symbol)

Assume that it is instantiated as,

detail(Pest, Pesttype)

The variable **Pest** contains the name of the pest identified in the preceding part of the program. The variable **Pesttype** has the same meaning as in the handle-rule predicate. A predicate select-file is used to pick a text file for a particular pest. It has been declared as,

select-file("Trips", Filename2)

For every pest, there is a select-file fact present in the Factbase. When the name of the pest has been identified by the system, it reaches the select-file predicate through the predicate detail. Using this name, it can get the desired file name suppose there is a fact,

select-file("Thrips", "Thrips.dbf")

present in the program. The system matches this fact with the select-file predicate. Thus the variable **Filename2** is instantiated to "Thrips.dbf".

The system checks the existence of that file on current drive by passing the variable **Filename2** to another predicate check-file. If the file exists, another predicate file-str is used to pick the file from the disk and convert it into a string. If file-str ("Thripsdbf",Text) is applied, it results in the conversion of "Thrips. dbf" into a string called **Text**. It can then then be printed using write (Text) or displayed on screen using display (Text).

A similar procedure is applied to monthly management files, but the selection in the case is based on the month number.

4.6 Control Recommendation Procedures

After the display of information about the identified pest, the predicate detail passes control to another pedicate control having the structure:

control (string, symbol)

Assume that it is instantiated as,
control (Pest, Pest type)

In case of diseases, the control procedure are ignored because there are no pesticidal treatments available. The cultural and other methods of control are given in the text files. The pesticidal recommendations are generated only for insects.

4.6.1 Generation of Pesticide Table

This involves a predicate which is declared as,

make- table(string, list)

Assume that it is instantiated as,
make-table (Insect, Inslist)

The variable **Insect** contains the name of the identified insect and the variable **Inslist** has the names of insceticides that can be used against that Insect.

A number of pesticide records are present in the system knowledge base. All pesticides are not suitable for every pest; therefore there is a provision to include only those pesticides in the calculations that are effective against the identified pest.

After obtaining the desired information, the system displays a table of all suitable insecticides Tabl e 4.

TABLE 4. COT-EXPERT

PESTICIEDE	FORM	DOSE/ ACRE	PACKING	COST (RS.)	COMPANY NAME
Temik	10 G	5-5.3 KG	1 KG 22.68 KG	80 / KG 75/ KG	JAFFAR BROTHERS LTD.
Solvirex	10 G	4.9-5 KG	25 KG	24/ KG	SANDOZ (PAKISTAN) LTD.
Disyston	10 G	5-5.2 KG	25 KG	26/KG	BAPCO LTD., KARACHI.
Anthio	25 EC	0.4-0.5 L	1 L 5 L	114/L 101/ L	SANDOZ (PAKISTAN) LTD.
Azodrin	40 WSC	0.4-0.5 L	5 L 1 L	180/ L 185/L	PAKISTAN BURMAH SHELL LTD.
Perfekthion	40%EC	0.3-0.5 ML	1 L 5L 210 L	125/ L 120/L 105/L	AGRICIDES LTD., KARACHI.

4.6.2 System Recommendations

The system, in putting forward its recommendations, calculates cost benefit ratios for those pesticides which are suitable for the control of the identififed pest. These ratios alongwith pesticide names are kept in a list in the descending order. The first three pesticides which are the most economical choices are picked from the list and conclusions about them are conveyed to the user. The system issues its recommendations only at the user's request and the request is made only if the number of suitable pesticides against a pest is greater than three.

4.6.3 Pesticide Calculations

Six types of pesticide calculations are mostly needed and they are mentioned in sec.3.2.3.

5. SOFTWARE AN D HARDWAR REQUIREMENTS FOR THE SYSTEM

Out of the various languages used for the development of expert systems, Turbo Prolog is selected due to its powerful features suitable for describing and handling both facts and rules. Turbo C is selected for performing numerical computations because it provides a variety of mathematical functions.

An IBM PC (or compatible) Microcomputer with 640k of RAM, keyboard, monitor (coloured if possible), a printer and a drive (floppy or hard disk) are the essential hardware required for using the system .

6. LIMITATIONS AND FUTURE RESEARCH

Since RSB simulation system has been developed for the first time in the third world countries, it has its limitations. However, we hope that it might form the basis of a more comprehensive system by adding more features.

The following improvements are suggested to enhance the capabilities of RSB simulation system and COT-XPERT:

(i) Calculation of Population Growth Rates

The present system accepts the Population Growth Rate (PGR) from the user for each of the three generatins for calculating the number of larvae per square metre for the next generation.

The number of larvae per square metre for the next generation is calculated using the following formula:

$$NL = NL1 \times PGR$$

Where NL = Number of larvae per square metre in the next generation, NL1= number of larvae per square metre in the previous generation and PGR = population growth rate for the next generation.

Recent reseach in RSB simulation reveals that PGR depends upon the temperature and rainfal. If the system takes into account the contributions of temperature and rainfall towards the PGR in the form of numerical calculations, the system will predict PGR itself every time the data is entered.

(ii) Expanding Tillage Systems

The present system is operational for the four crops grown after rice, namely, berseem, conventional tillage wheat, no tillage wheat and gram. Two other options that the system provides in this respect are farm lying fallow and fallow/ ploughed. However, system can be modified to cater for more crops.

(iii) Addition of New Rules

There is a provision for adding new rules for some other pests and diseases so that the system may manage all possible insects and diseases of the cotton crop.

(iv) Probabilities

COT-XPERT is deterministic and does not include probabilities. To cater for stochastic reasoning, the following concepts have to be added:

(a) Statistical probabilities

(b) Certainty(Confidence) Factors

In case of certainty factors, numerical weight is given to a fact or relationship. In general, methods for manipulating certainty factors are more informal than approaches to combining probabilities. If any one of the concepts in introduced, COT-XPERT will provide more credible and flexible results.

CONCLUSIONS

The user is required to enter the estimated yield, decline in yield by 1% pest infestation, total percent infestation, price of cotton, cost of pesticide application per acre, number of sprays the user wants to do and the total area to be streated. The above data alongwith the data stored in the pesticide record are used to draw some conclusions about this pesticide The conclusions can be about:

- Pesticide selected by the user
- Pesticides recommended by the system

In both cases, the method used is the same, the only difference is that for the pesticide chosen by the user, the dose per acre is also entered by the user. When the system recommends itself, it uses the minimum per acre dose in the range.

The predicate conclusion calculates the amount of insecticides that is required, and for each type of pesticide packing it give the control cost per acre, net cost for the entire field and the net profit.

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