Disease Diagnose of Rice Plants using Fuzzy-Expert Hybrid System

T.D.Nuwan Chathuranga[1], Gehan Anthonys[2]
Department of Electrical and Computer Engineering.
The Open University of Sri Lanka, Nawala
nuwanhp@gmail.com[1], ganth@ou.ac.lk[2]

Abstract – **Sustainable agriculture related research is a hot topic in modern world. In Sri Lanka, paddy cultivation is a main income method. Advantages of using these systems are that the output of such systems are very accurate and faster than analyzing the same problem by humans. This paper proposes a web based software system which has the ability to identify pest/s and their damage level to the plant by analyzing the various kinds of inputs such as damage symptoms, size of the pest, damage intensity etc. It is very helpful to identify the condition of the paddy before it becomes critical.**

1. Introduction

Agriculture in Sri Lanka mainly depends on rice production. Its main goal is to achieve an equitable and sustainable agricultural development through development and dissemination of improved agriculture technology. Aim of this project is to develop a decision support system, useful for sustainable agriculture in Sri Lanka which is to help farmers and agricultural related people to identify pests using their damage symptoms and calculate the current pest activity level using Artificial Intelligence approach called Fuzzy-Expert (Hybrid System). The System we have developed is called EXRICE.

Problem Statement

There is an optimized or maximized productive energy of the rice plant. But obviously there is an unbalanced or a difference between the maximized (optimized) potential harvest and what framers get actually. There are some varieties of rice which are very sensitive to the environmental factors and crop management factors. Generally average harvest density which we have in Sri Lankan conditions is less than half of the plant's potential maximum harvest ability. There are many reasons for this situation.

These reasons can be categorized as controllable factors[10] such as field diagnosis problems, Pest attacks, lack of water management problems and weeds control problems, feeding problems, etc. and uncontrollable factors such as flooding, wind variations, temperature changing, weather factors, drought, etc. Farmers cannot control or go against the uncontrollable factors. Because of these factors 30-40% of harvest get destroyed [9]. There are approximately about 100 problems which are very common in Sri Lankan farming society. Table 1 show the threats against paddy cultivation in Sri Lanka.

Attack Type	Quantity
Pests	28
Diseases	28
Weeds	29
Fertilizer Deficiencies	14
Total	99

Table 1: ***Threats to rice plants in Sri Lanka (Rice Research Institute Bathalagoda)***

Introduction to Fuzzy-Expert System

Artificial Intelligence (AI) can be defined as the science and engineering of making machines with intelligence. Specially making intelligent computer programs and algorithms can create intelligent robots (hardware/software fabricated brains). The main purpose in AI is to create a machine that can think like a human, i.e. human behavior and the thinking patterns are embedded in to a machine.

A fuzzy expert system is an expert system that uses fuzzy logic instead of Boolean logic and a collection of membership functions and rules that are used to reason about data. Unlike traditional expert systems, fuzzy expert systems are oriented toward numerical processing. This expert system is extended to incorporate explicit handling of imprecision in the input data and uncertainty in the embedded knowledge. This system is designed on the basis of the fuzzy expert system.

There are number of advantages of having this integrated approach. In contrast with conventional AI techniques which only deal with precision and uncertainty, the guiding principle of a hybrid system is to exploit the tolerance for imprecision, uncertainty, low solution cost, robustness, partial truth to achieve tractability, and better response to reality. By usinga hybrid approach, the complexity of its design and development are increased [1].

2. Methodology – Fuzzy Expert System

An overview of the EXRICE is shown in figure 1.

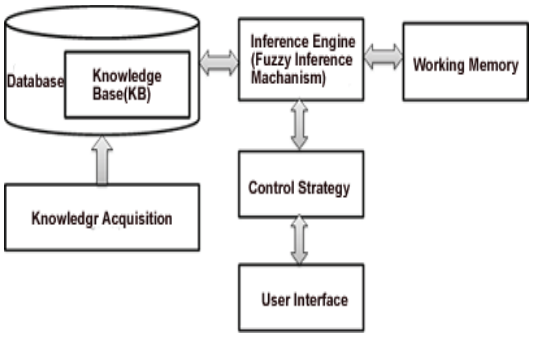


*Figure 1: **Overview of EXRICE***

Knowledge Base

This is where the knowledge of the problem domain resides. Here database is used as a knowledge base [4] of Facts and temporal data. It is the source to the working memory when using the production language. Images, Videos, Questions related to the system are stored here.

Rule Structure of the Knowledge Base

rule_base (
rule_id , //Unique ID to identify the rule
rule_section, // section which the rule belong to
question, // Question Ask from the user to confirm the current fact and to find goal, if not firing the next rule.
goal, // Pest /s
inputs, // Reply method for a question (YES,NO)
des_if_yes, // Next rule if the condition TRUE of the
des_if_no, // Next rule if the condition FALSE of the current rule
question_type, // Main question (=1)or a sub question(=0)
help_1, // Help is to guide the user may be images, videos etc
help_2,
help_3,
help_4,
help_5,
help_6

)

Working memory

For the working memory, we used a "Hash Map" data structure. Hash-Map has many facilities than other data structures. A Map is like a dictionary in other languages. It has a key and we look-up a value using that key. The Hash-Map uses a hash of the key for lookups. EXRICE working memory is shown in Figure 2. It has a <Key,Value> pair. Here it is assigned as Key = rule_id and other information except rule_id to value. Then it becomes;

<rule_id, [rule_section, question ,……,help6]>

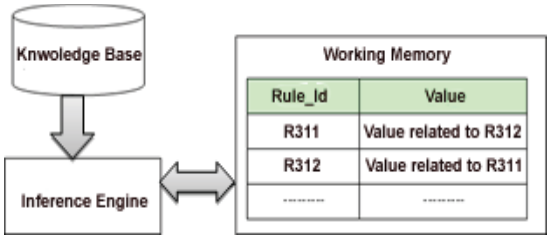


Figure 2: Working Memory

Inference Engine

An inference engine is a computer program that tries to derive answers from a knowledge base. It is the "brain" that expert systems use to reason about the information in the knowledge base for the ultimate purpose of formulating new conclusions. EXRICE inference Engine [5][6] process the forward chaining method of inference.

In order to execute a rule based expert system using the method of forward chaining here merely need to fire actions whenever they appear on the action list of a rule whose conditions are true. This involves assigning parameters to attributes, evaluating conditions, and checking to see if all of the conditions in the rule are satisfied.

The steps are as follows;

- Read parameters and assign to attributes
- Evaluate conditions
- Fire rules whose conditions are satisfied

Rules are fired in the order of sequence. There are several activities to do within an inference engine.

- Check input parameters against the conditions contained in rules.
- Fire sub rules after the main rules.
- Explanation given against the inputs.
- Select most suitable rule when the conflict set is found.
- Support advanced analysis method which is mining the KB for one goal

Decision Tree

Decision Tree gives the sequence of the rule firing. Each rule is chained to another rule. That rule may be a Goal rule or not. Chaining of the rules are done according to the solution of the problems which have occurred in Similar-Symptom cases. A sample decision tree for Mode-3 Filed pattern of damage (Around the field edge) is shown in Figure 3.

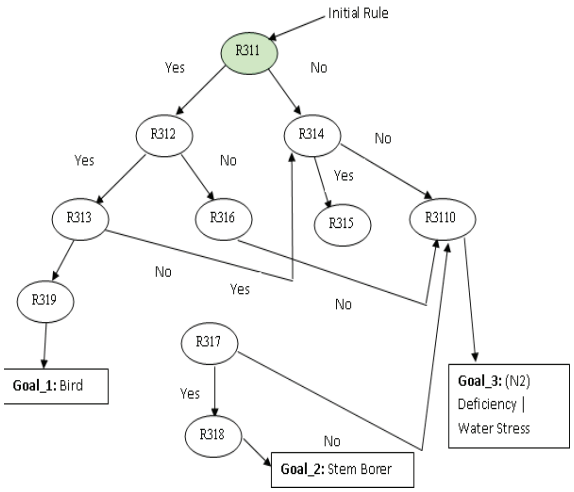


Figure 3: Decision tree for mode-3(Filed pattern of damage)

Fuzzy Logic Methodology

The major tasks in fuzzy logic system involve fuzzification, fuzzy inference and defuzzification. Fuzzification is the process of converting input and output values in to their membership functions. The real values fed into the system are converted into linguistic variables. Using linguistic variable definition then a membership function graph is drawn. The membership function graph is a result of fuzzification process. Fuzzy Inference is an inference engine which consists of fuzzy rules for the system. Inference Engine receives the output of the fuzzification and applies fuzzy rules to produce fuzzy outputs. Then crisp outputs are produced from the fuzzy outputs through defuzzification. The flow of the fuzzy logic methodology [1] use in EXRICE is shown in Figure 4.

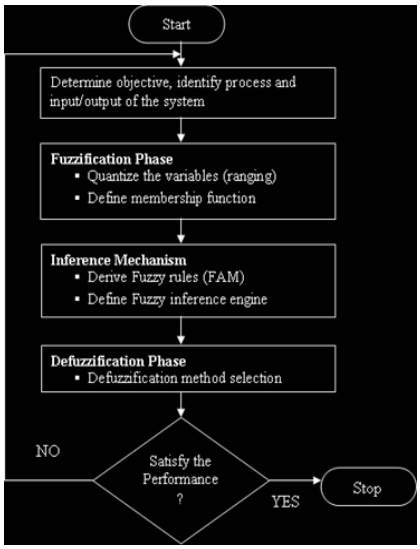


Figure 4: Fuzzy Logic Methodology

Fuzzy Logic Module input/output

It is very crucial to identify clearly the input and output variables to the fuzzy logic part of the system which are entered by the user. Input to the fuzzy system is shown in Table 2 and the output from the fuzzy system is shown in Table 3.

Linguistic Variable: Number of pests (NOP)		
Linguistic Value	**Notation**	**Numerical Range**
few	FEW	[0,3]
many	MANY	[5,13]
too_many	TOOMANY	[>=15]
Linguistic Variable: Damage Intensity to the Plant (DI)		
Linguistic Value	**Notation**	**Numerical Range**
low	LOW	[0.00,0.25]
medium	MEDIUM	[0.35,0.65]
high	HIGH	[0.75,1.00]
Linguistic Variable: Size of the Pest (SOP)		
Linguistic Value	**Notation**	**Numerical Range**
small	SMALL	[0.00,0.25]
medium	MEDIUM	[0.35,0.65]
big	BIG	[0.75,1.00]

Table 2: ***Fuzzy logic system input***

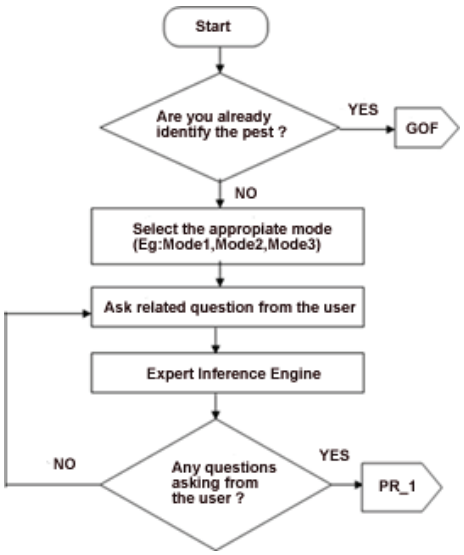
Linguistic Variable: Pest Activity Level (PAL)		
Linguistic Value	**Notation**	**Numerical Range**
low	PAL_LOW	[0.00,0.25]
medium	PAL_MEDIUM	[0.35,0.65]
high	PAL_HIGH	[0.75,1.00]

Table 3: ***Fuzzy logic system output***

3. Analysis

Gathered knowledge in the knowledge acquisition phase is well analyzed and organized in this phase. For an example in EXRICE there are modes in the expert system as Mode-1 (Based on plant factors), Mode-2 (Based on crop symptoms) and Mode-3 (Based on field pattern of damage). These modes and the related rules are a result of this analysis phase.

At present farmers fill-out an observation sheet with observation results. This observation information helps to diagnose the disease and help to calculate the pest activity level. Then finally EXRICE work the same way as the way of consultation information to the farmers with treatments and suggestions as done by the rice research institute. The System is embedded with inference engine, knowledge base, working memory to emulate the human expert's ability. Figure 5 shows the general workflow of the EXRICE Fuzzy expert system.



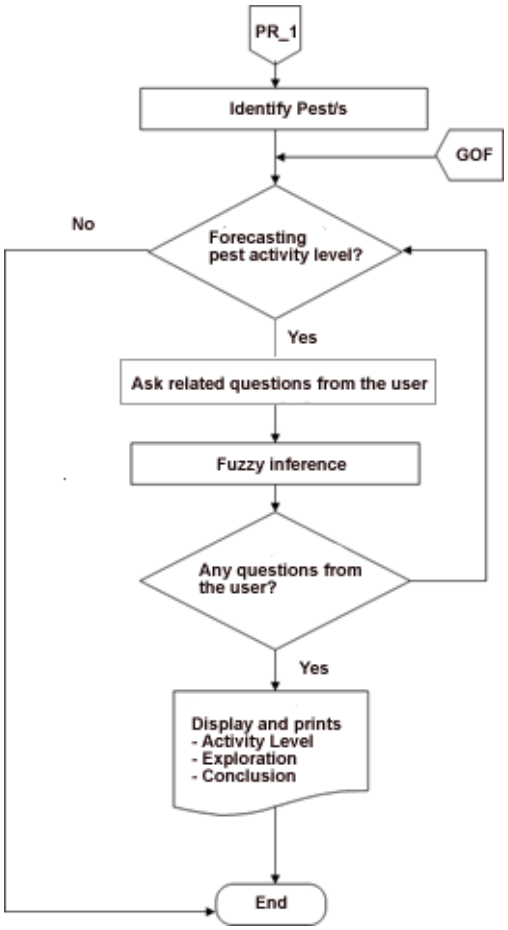
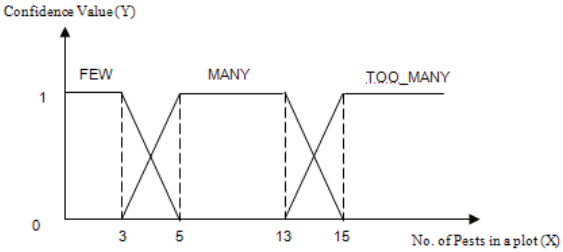


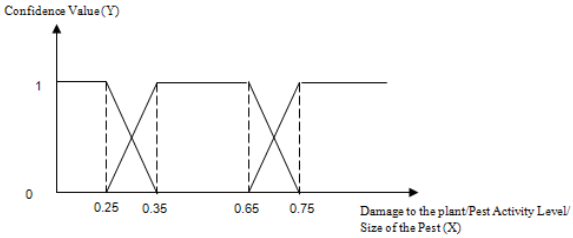
Figure 5: General Workflow of the EXRICE Fuzzy-Expert System

4. Mathematical Background

Form linguistic variable definition, a membership function graph can be drawn. Given below are the results of the fuzzification process, which describe the degree of membership of different values in different fuzzy variables. Here a mathematical formula is defined for each portion of the graph. Figure 6 (a),(b) shows the input membership function and fuzzification algorithms respectively. Damage Intensity and size of the pest membership function and formulas are identical and also the output membership is identical as latter two functions [3].



(a)



(b)

FEW Portion => Y=1 when $(0 \le X \le 3)$
$Y = (2.5 - 0.5X)$ when $(3 < X < 5)$
$Y=0$ when $(X \ge 5)$

MANY Portion => $Y=0$ when $(0 \le X \le 3)$
$Y = (0.5X - 1.5)$ when $(3 < X < 5)$
$Y = 1$ when $(5 \le X \le 13)$
$Y = (7.5 - 0.5X)$ when $(13 < X < 15)$
$Y=0$ when $(X \ge 15)$

TOO_MANY Portion => $Y=0$ when $(0 \le X \le 13)$
$Y = (0.5X - 6.5)$ when $(13 < X < 15)$
$Y=1$ when $(X \ge 15)$

LOW/SAMLL Portion => $Y=1$ when $(0 \le X \le 0.25)$
$Y = (3.5 - 10X)$ when $(0.25 < X < 0.35)$
$Y=0$ when $(X \ge 0.35)$

MEDIUM Portion => $Y=0$ when $(0 \le X \le 0.25)$
$Y = (10X - 2.5)$ when $(0.25 < X < 0.35)$
$Y = 1$ when $(0.35 \le X \le 0.65)$
$Y = (7.5 - 10X)$ when $0.65 < X < 0.75)$
$Y=0$ when $(X \ge 0.75)$

HIGH/BIG Portion => $Y=0$ when $(0 \le X \le 0.65)$
$Y = (10X - 6.5)$ when $(0.65 < X < 0.75)$
$Y=1$ when $(X \ge 0.75)$

Figure 6: (a) Membership functions for number of pest.
(b) Size of the pest, damage intensity

5. Rule Evaluation

The fuzzy inference is implemented using FAM (Fuzzy Associative Memory).These rules are located in the rule base. Here the FAM matrix is constructed by using "min" fuzzy operator with Single inference structure. Since there are 3 inputs, the hierarchical fuzzy inference mechanism is used.

Fuzzy inference can be implemented in two ways using if-then statements or directly using Fuzzy Associative Memory (FAM). Since the rules are connected with 'and' operator here the 'min' fuzzy operator is used. In the table 2, it is shown the FAM table for SOP and NOP. Table 4 shows the general FAM Structure for the system.

Attribute-1 \ Attribute-2	ATT2VAL-1	ATT2VAL-2	ATT2VAL-3
ATT1VAL-1	OVAL-1	OVAL-2	OVAL-3
ATT1VAL-2	OVAL-4	OVAL-5	OVAL-6
ATT1VAL-3	OVAL-7	OVAL-8	OVAL-9

Table 4: ***General FAM structure***

Rules for the above FAM are as follows

If (Attribute-1 is ATT1VAL-1) and If (Attribute-2 is ATT2VAL-1) then (PAL is OVAL-1)
If (Attribute-1 is ATT1VAL-1) and If (Attribute-2 is ATT2VAL-2) then (PAL is OVAL-2)
If (Attribute-1 is ATT1VAL-1) and If (Attribute-2 is ATT2VAL-3) then (PAL is OVAL-3)
If (Attribute-2 is ATT1VAL-2) and If (Attribute-2 is ATT2VAL-1) then (PAL is OVAL-4)
If (Attribute-2 is ATT1VAL-2) and If (Attribute-2 is ATT2VAL-2) then (PAL is OVAL-5)
If (Attribute-2 is ATT1VAL-2) and If (Attribute-2 is ATT2VAL-3) then (PAL is OVAL-6)
If (Attribute-3 is ATT1VAL-3) and If (Attribute-2 is ATT2VAL-1) then (PAL is OVAL-7)
If (Attribute-3 is ATT1VAL-3) and If (Attribute-2 is ATT2VAL-2) then (PAL is OVAL-8)
If (Attribute-3 is ATT1VAL-3) and If (Attribute-2 is ATT2VAL-3) then (PAL is OVAL-9)

Then the rule is constructed as a 3-dimensional model (a rule cube).The cubic rule base is shown in Figure 7.

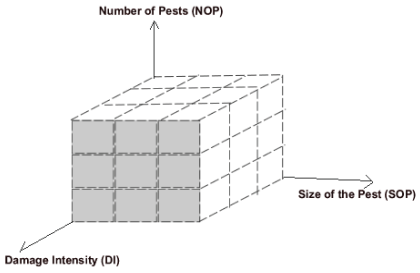


Figure 7: Rule Base (Rule Cube)

6. Defuzzification

Defuzzification Phase

Defuzzification or decomposition is the final phase regard to the fuzzy part of the system. The output of the defuzzification gives the pest activity level. There are several method of defuzzification and for EXRICE Disease Diagnose system the Sugeno method is used. Here Pest Activity Level is given by the Weighted Average (WA). Figure 8 shows the sugeno defuzzification approach.

$$W = \frac{\mu(k1)*k1+\mu(k2)*k2+\mu(k3)*k3}{\mu(k1)+\mu(k2)+\mu(k3)}$$

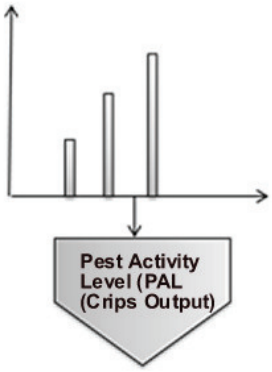


Figure 8: Sugeno Deffuzification

7. Results

In EXRICE information system, consultation and the pest identification facility is given by the expert system and the particular pest activity level is given by the fuzzy logic approach. Therefore this system is intended to facilitate as a warning system, so farmers can make early treatment to avoid high losses resulting from complete damage. Since more number of attributes is preferable in predicating the pest activity level, this system explorers using more than one attributes to perform a pest activity forecasting. The attributes involves number of pests (NOP), Damage Intensity (DI) and Size of the pest (SOP).

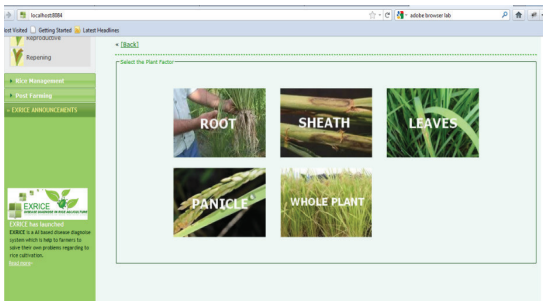


Figure 9: Diagnose according to the plant factors

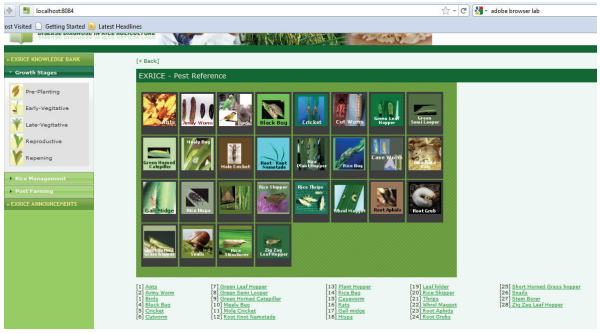


Figure 10: Pest Reference

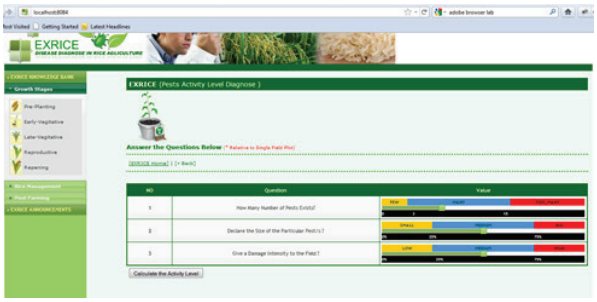


Figure 11: Input variables to find Pest Activity Level

8. Conclusion

This expert system gives the functionalities to filter the suspected pest/s, while fuzzy logic approach improves the quality of the system. It also calculates the pest activity level. Potential harvest is not collected by farmers because of various kinds of threats. Insects/Pests are major category of such threat. Inexperience farming also reduces harvest because decisions were not taken at the right time.

Fuzzy logic approach reduces the imprecision decisions taking by inexperienced farmers, since farmers are warned by the system before the threat becomes critical. In modern World, computer technology is a useful tool in day to day life. In Sri Lanka paddy cultivation is mostly spread over villages. There are many computer centres in Sri Lanka like "Nanasala", where rural people can access computers. EXRICE can be made popular among those village level computer centers as it will be of a great help for farmers.

In summary EXRICE is a web based computer solution which is useful for sustainable agriculture using two Artificial Intelligence approaches (as a hybrid system).

References

[1] Zimmerman,H.J. (1991), Fuzzy *Set Theory and its applications(2nd edition)*, Kluwer Academic publishers

[2] A., El-Azhari, S., Hassan, E. (1995). *Integrating Multimedia with Expert Systems for Crop Production Management.* Proceedings of the Second International IFAC Workshop on Artificial Intelligence in Agriculture, Wageningen, The Netherlands.

[3] Asoka S. Karunanada, (2004), *Artificial Intelligence*, Tharangi Publishers.

[4] Saini, H.S., Kamal,Raj and sharma,A.N. (2000). *Web Based Fuzzy Expert System for Integrated Pest Management in Soybean*, International Journal of Information Technology, Vol8, No.1

[5] Ahmed Rafea, Expert System Applications: Agriculture,2000. Central Laboratory for Agricultural Expert Systems, Egypt.

[6] Durkin,J. (1996). Expert Systems: *A View Of the Field*, IEEE Expert.IEEE Publication.

[7] Singh,O.P. and Singh,K.J.(1990). *Insect Pests of Soybean and their Management, Indian Farming*, Jan.1990:pp.9-38.

[8] Expert System Manual http://generation5.com Date Accessed:28 August 2010.

[9] Sri Lankan Rice Research Institute Website http://www.agridept.gov.lk/ Date Accessed:20 July 2010.

[10] International Rice Research Institute http://www.irri.org Date Accessed:14 September 2011.