Rule based Expert System in the Use of Inorganic Fertilizers for Sugarcane Crop

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ABSTRACT

This paper presents the development of rule based expert system in the use of inorganic fertilizers for sugarcane crop. Inorganic fertilizers are essential for the growth of crops. Fertilizers add nutrients and texture to soil that need to support trees, vegetables, herbs, flowers and crops. This expert system helps the farmers to decide what kind of inorganic fertilizers should be used on the basis of symptoms appeared (Due to Nutrient Deficiency) on the leaves of sugarcane crop.

Keywords- Artificial Intelligence, Expert System, Inorganic Fertilizers, Planting Season of Sugarcane Crop

1. INTRODUCTION

The expert systems are a branch of applied Artificial Intelligence (A.I.) and were developed by the A.I. community in the mind-1960s. The most commonly known type of knowledge based system is the rule based expert system in which the experience and knowledge of human expert is captured in the form of IF-THEN rules and facts which are used to solve problems. An expert system is a computer program which uses non-numerical domain-specific knowledge to solve problems with a competence comparable with that of human experts"(Doran 1988). Farmer uses inorganic fertilizers to gain maximum yield of sugarcane. The diagnosis of nutrient deficiency is an important problem in the agriculture field and it can be done on the basis of appearance of leaves. Leaves (Young leaves, old leaves, immature leaves etc) of sugarcane crop show symptoms of nutrients deficiency. This paper deals with the development of a rule based expert system in the use of inorganic fertilizers for sugarcane crop. The rules are generated with the help of symptoms appeared on the leaves of sugarcane crop, nutrient deficiency and the appropriate use of inorganic fertilizers. Author has developed a prototype of expert system for the use of nutrients (Inorganic Fertilizers) and diagnosis of nutrient deficiency. The paper includes: The Domain, Factors Considered for the Diagnosis of Nutrient Deficiency, Problem Description, Design of Expert System, Rule Based Development and Implementation.

2. THE DOMAIN

The field of Agriculture is a vast and large field with uncertainty. An Expert system is a computer program that contains stored knowledge of one or more human experts in a particular field. The field is called domain. A farmer has to face lots of problem regarding the production of sugarcane. They hardly understand the nutrient deficiency. The main aim of this research paper is to present nutrient deficiency symptoms appeared on sugarcane crop. Also this paper represents the use of inorganic fertilizers to cover up the nutrient deficiency. Inorganic fertilizer is a good domain because they are chemical additives that are directly absorbed such as nitrogen, phosphorus & potassium. In this paper, expert knowledge is acquired in the form of IF-THEN rules to find nutrient deficiency and to suggest proper ratio of inorganic fertilizers.

3. FACTORS CONSIDERED FOR THE DIAGNOSIS OF NUTRIENT DEFICIENCY IN SUGARCANE CROP

For the diagnosis of nutrient deficiency in sugarcane crop, it is important to consider the different planting seasons of sugarcane, types of inorganic fertilizers and symptoms of nutrient deficiency.

3.1 Planting Seasons of Sugarcane

In Maharashtra (India), three planting seasons are used for cultivation of sugarcane. These are **ADSALI** (Planting period is during 15 June to 15 August), **PURV-HANGAMI** or **Pre-Seasonal** (Planting period is during 15 August to 15 October) and **SURU** (Planting period is during 15 January to 15 March). Farmers may select any one planting season as per the certain circumstances like climate, availability of water, availability of labor etc.

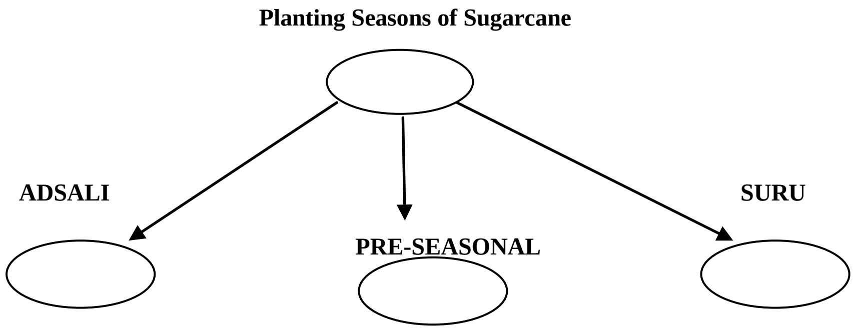

Fig.1 Tree Structure Representation of the Primary node

3.2 Classification of Inorganic Fertilizers

Fertilizers are broadly divided into organic fertilizers (composed of enriched organic matter—plant or animal), or inorganic fertilizers (composed of synthetic chemicals and/or minerals).Inorganic fertilizers are mainly classified into three types such as

a) Primary Nutrients
b) Secondary Nutrients
c) Micronutrients

Carbons, Oxygen & Hydrogen are essential elements for plant growth. They are supplied by air and water i.e. they are easily available in surrounding. Therefore they are not treated as nutrients by the fertilizer industries. The main aim of fertilizer industry is to provide the primary and secondary nutrients which are required in macro quantities.

a) Primary Nutrients:-

Primary nutrients are supplied through chemical or inorganic fertilizers. They are chemical compounds containing one or more of the primary nutrients and are generally produced by chemical reactions. The primary nutrients are nitrogen, phosphorus and potassium. Their concentration in chemical fertilizer is expressed as a percentage of total nitrogen (N), available phosphate (P_2O_5) and soluble potash (K_2O). The grade of fertilizer is expressed as a set of three numbers in the order of percent N, P_2O_5 and K_2O.

b) Secondary Nutrients:-

These are required for plant growth in relatively smaller quantities than primary nutrients. Calcium, magnesium and sulfur are called the secondary nutrients. Any deficiency of the secondary nutrients and other essential elements reduces the efficiency of primary nutrient by restricting the yield to low levels. Therefore, to gain optimum results, secondary nutrients in addition to primary nutrients have to be supplied to crops.

Calcium and magnesium are the elements that are responsible for the acidity or alkalinity of soil. They are soluble, so in regions of high rainfall they are washed from the soil. Soils in these regions are usually acid, and calcium carbonate (lime) is often added every year to make the soil less acid. In areas of low rainfall, the soil is high in calcium and magnesium and is usually alkaline.

Sulfur is present in many commercial fertilizers. As sulfate, it is highly acid and is often used to make alkaline soil acid.

c) Micronutrients :-

Micronutrients are a group of nutrients, which are essential for plant growth but are required by plants in small quantities. Selective use of micronutrients is necessary for increasing agricultural production. Micronutrients are often applied incorporated in NPK fertilizers. They may be applied directly or sprayed. Iron, zinc, manganese, copper, boron, and molybdenum are different types of micronutrients.

3.3 Symptoms of Nutrient Deficiency

By using following symptoms farmers can easily find out nutrient deficiency in sugarcane crop. The symptoms of nutrient deficiencies and toxicities can be the first sign that the particular crop has a nutritional problem. Recognizing these symptoms is an important step when designing corrective action. Further evaluation can be pursued with detailed leaf and soil sampling. Following are some symptoms, which are useful for field diagnosis of Nutrient deficiencies in sugarcane crop.

a) Nitrogen(N):-

Nitrogen deficiency is easily diagnosed in the field. Older leaves first show N deficiency. Nitrogen deficiency symptoms are

i) Yellow green colored leaves
ii) Shortening of internodes
iii) Reduction in growth
iv) Premature drying of older leaves
v) Long hairy root system

b) Phosphorus (P):-

Leaf reddening usually occurs with P deficiency when the plant is young and when growing temperatures are less than 10°C (50° F).

Phosphorus deficiency symptoms are

i) Length and diameter of cane stalk or stems is reduced resulting in short and slender stalks that tappers rapidly at the growing point.
ii) Tillering is affected adversely.
iii) The leaves turn to greenish blue.
iv) The leaves remain narrow and somewhat reduced in length.
v) Shoot or root ratio is decreased considerably.

c) Potassium (K):-

Red discoloration of upper surfaces of the midrib is characteristic of K deficiency.

Potassium deficiency symptoms are

i) Plant shows depressed growth yellowing and spotting of older leaves and development of slender stalks.
ii) Yellowing of young leaves starts at the base of the blade and taper towards tip.
iii) The older leaves turn orange and later brown.
iv) The leaves will start die-back from the margin and tips.

d) Calcium (Ca):-

The effects of calcium deficiency on older leaves are localized with mottling and cholorotic. Calcium deficiency symptoms are

i) Older leaves may have "rusty" appearance and may die prematurely.
ii) Spindles often become necrotic at the leaf tip and along margins.
iii) Immature leaves are distorted and necrotic.

e) Magnesium (Mg):-

Magnesium deficiency results in chlorosis as the element is an essential component of chlorophyll. Magnesium deficiency symptoms are

i) The symptoms appear on the older leaves and later change into brown.
ii) Red necrotic lesions result in a "rusty" appearance.
iii) The "rusty" appearance can spread across all leaves & may result in premature dropping of older leaves.
iv) The stems/stalks become shorter and severely "rusted" and brown.

f) Sulfur (S):-

Young leaves affected by SO_2 toxicity. Sulfur deficiency symptoms are

i) Leaf tips and margins may become necrotic within 3 to 7 days after SO_2 exposure.
ii) Leaves are narrower and shorter than normal.
iii) Stems or Stalks are slender.

g) Iron (Fe):-

The Fe deficiency symptoms first appear on the young spindle leaves and then extend to the older leaves. The iron deficiency symptoms is

i) The normal green color disappears between the vascular bundle (Veins) and such pale strips extend the entire length of the leaf blade.

h) Manganese (Mn) :-

Manganese deficiency first appears on older leaves. Manganese deficiency symptoms are

i) Pale-yellowish, green, longitudinal strips which alternate with normal green color.
ii) The entire leaf becomes bleached.
iii) Interveinal chlorosis occurs from the leaf tip toward the middle of the leaf.

i) Molybdenum (Mo):-

Molybdenum deficiency is seen on older leaves. Molybdenum deficiency symptom is

i) Short longitudinal chlorotic streaks on the apical one-third of the leaf.

j) Boron (B):-

The symptoms of B deficiency appear on young leaves of sugarcane. Boron deficiency symptoms are

i) Boron deficient plants have distorted leaves, particularly along the leaf margins on immature leaves.
ii) The apical meristem may die.
iii) Translucent lesions ("Water Sacks") along leaf margins occur.
iv) Young sugarcane plants tend to be brittle and bunched with many tillers.
v) Leaf margins become chlorotic.

k) Copper (Cu):-

Copper deficiency symptoms are

i) Green splotches are an early symptom.
ii) Apical meristems remain alive, but internodes elongation will be reduced.
iii) General vigor and tillering are reduced.

l) Zinc (Zn):-

Zinc shortage results in drastic yield reduction. Zinc deficiency symptoms are

i) A broad band of yellowing in the leaf margin occurs.
ii) The midrib and leaf margins remain green except when the deficiency is severe.
iii) Red lesions are often noticed.

4. PROBLEM DESCRIPTION

In India, particularly in Maharashtra, the sugarcane is a cash crop. To get maximum yield or profit through this crop, farmers have to provide inorganic fertilizer to this crop. But most of the farmers are unaware of how many quantity of inorganic fertilizer they have to provide to the crop. Excess use of these fertilizers is harmful to the soil, which can adversely affect the yield. So that it is necessary to develop an expert system which explains to the farmers, that how much fertilizer should have to be used for sugarcane crop. Also they could not easily understand the nutrient deficiency by observing symptoms appeared on leaves of sugarcane crop.

The above discussion describes the importance of expert system used for inorganic fertilizers, so that the author intended to carry out his research endeavor entitled as "Development of expert system in the use of inorganic fertilizers for sugarcane crop".

Identifying the knowledge for decision making or problem solving is the most crucial component of an expert system design. The task of acquiring the knowledge in the system is identifying the nutrient deficiency, by close interaction with officers/experts in the field of agriculture in the form of interviews and questionnaire. This part can be termed as knowledge acquisition phase of the expert system development, where the parameters that influence the decision were identified and classified under various areas or nodes and listed in the form of a tree structure depicted in figure 1 & 2.

5. DESIGN OF THE EXPERT SYSTEM

"Design of the domain knowledge is the task of formalizing expert's years of experience in a tool which will then be used to solve real world problems [Holsapple and Whinston, 1989]. The current logical design of the system would lend itself to partition the decision space in a "Top-Down" approach with three major classifications namely, primary nutrients, secondary nutrients and micronutrients. After arriving at goals comprising primary nodes with possible values, the rules were framed for the tree structure using forward chaining method. With this as the basis, the rules were framed for all the nodes from primary to $(n-1)^{th}$ level and the rule base was designed. Continuing our top-down approach, we divide the primary nodes mentioned above into secondary and tertiary nodes (fig. 2).

To understand expert system design, it is also necessary to understand the major roles of individuals who interact with the system. These are:

a) **Domain Expert:** An Expert system is a computer program that contains stored knowledge of one or more human experts in a particular field. The field is called domain. The individual who are currently experts in solving problems are called domain experts.
b) **Knowledge Engineer:** The individual who encodes the expert's knowledge in a declarative form are called knowledge engineer.
c) **User:** A user presents the expert system with the specifics of a problem within the domain. The system applies its stored knowledge to solve the problem.

6. RULE BASE DEVELOPMENT

After designing of expert system, the next step is rule base development. The rule based system uses rules in the form of IF-THEN. Rule-based systems differ from standard procedural or object-oriented programs in that there is no clear order in which code executes. Instead, the knowledge of the expert is captured in a set of rules, each of which encodes a small piece of the expert's knowledge. Each rule has a left hand side and a right hand side. The left hand side contains information about certain facts and objects which must be true in order for the rule to potentially fire (that is, execute). Any rules whose left hand sides match in this manner at a given time are placed on an agenda. One of the rules on the agenda is picked (there is no way of predicting which one), and its right hand side is executed, and then it is removed from the agenda. The agenda is then updated (generally using a special algorithm called the Rete algorithm), and a new rules is picked to execute. This continues until there are no more rules on the agenda.

The primary node of the overall tree structure of the domain space takes the values as: planting seasons, different types of nutrients and symptoms of nutrient deficiency.

For the goal driven backward chaining expert system, the final goals are: Finding nutrients which have deficiency, suggesting proper ratio of Inorganic Fertilizers (Nutrients) to cover up the deficiency appeared in sugarcane crop. Any one can have 36 resulting combinations (planting seasons, types of nutrients and symptoms), based on which he/she decide which nutrient having deficiency in sugarcane crop. The system ultimately has to reach one of these goals after processing all the parameters under each node to complete the evaluation process and provide the final decision about the diagnosis of nutrient deficiency. On which system suggest appropriate ratio of inorganic fertilizers (Recommended by Mahatma Phule Krishi Vidhyapeeth, Rahuri) . Following sample rule illustrates how the knowledge base has been represented in the form of 'IF-THEN' rules.

7. RULE BASE SYSTEM IN THE USE OF INORGANIC FERTILIZERS FOR SUGARCANE CROP:

The rule base structure comprises 'Rule Master ', 'Rule Detail' and 'Message Table'.

Rule Master:- It is a set of expected outputs (for the primary and secondary nodes) for the given inputs (leaf nodes). The rule master contains the rule number, rule description and expected output.

Table-1 Rule Master(Primary)

Rule Number	Description	Result
A	Type of Planting Season	ADSALI
B	Type of Planting Season	PURV HANGAMI or Pre- Seasonal
C	Type of Planting Season	SURU

Table-2 Rule Master(Secondary)

Rule Number	Description	Result
1	Primary Nutrient	Nitrogen (N)
2	Primary Nutrient	Phosphorus (P)
3	Primary Nutrient	Potassium (K)
4	Secondary Nutrient	Calcium (Ca)
5	Secondary Nutrient	Magnesium (Mg)
6	Secondary Nutrient	Sulfur (S)
7	Micronutrient	Ferrous/ Iron (Fe)
8	Micronutrient	Manganese (Mn)
9	Micronutrient	Molybdenum (Mo)
10	Micronutrient	Boron (B)
11	Micronutrient	Copper (Cu)
12	Micronutrient	Zinc (Zn)

Rule Detail:-It is a set of conditions required to generate output. The rule detail table contains the rule number-1 and 2, the conditions and their values. The conditions mentioned are all the leaf nodes.

Table-3 Rule detail

Rule Number-1	Rule Number -2	Conditions	Value
A	1	Yellow green colored leaves	Observed
A	1	Shortening of internodes	Observed
A	1	Reduction in girth	Observed
A	1	Premature drying of older leaves	Observed
A	1	Long hairy root system	Observed
A	2	Length and diameter of cane stalk or stems is reduced	Observed
A	2	Tillering is affected adversely	Observed
A	2	The leaves turn to greenish blue	Observed
A	2	The leaves remain narrow and somewhat reduced in length	Observed
A	2	Shoot or root ratio is decreased considerably	Observed
A	3	Plant shows depressed growth yellowing and spotting of older leaves	Observed
A	3	Yellowing of young leaves starts at the base of the blade and taper towards tip	Observed
A	3	The older leaves turn orange and later brown	Observed
A	3	The leaves will start die-back from the margin and tips	Observed
B	1	Yellow green colored leaves	Observed
B	1	Shortening of internodes	Observed
B	1	Reduction in girth	Observed
B	1	Premature drying of older leaves	Observed
B	1	Long hairy root system	Observed
C	1	Yellow green colored leaves	Observed
C	1	Shortening of internodes	Observed
C	1	Reduction in girth	Observed
C	1	Premature drying of older leaves	Observed
C	1	Long hairy root system	Observed

Message Table: It is a set of all the possible messages that are required by the system to display as and when arrives at the outcome of processing any of the nodes.

8. SAMPLE RULES FOR USE OF INORGANIC FERTILIZERS TO SUGARCANE CROP:

Rule # A1

If Planting Season Is ADSALI and Symptoms Observed are:

- Yellow green colored leaves
- Shortening of internodes
- Reduction in girth
- Premature drying of older leaves

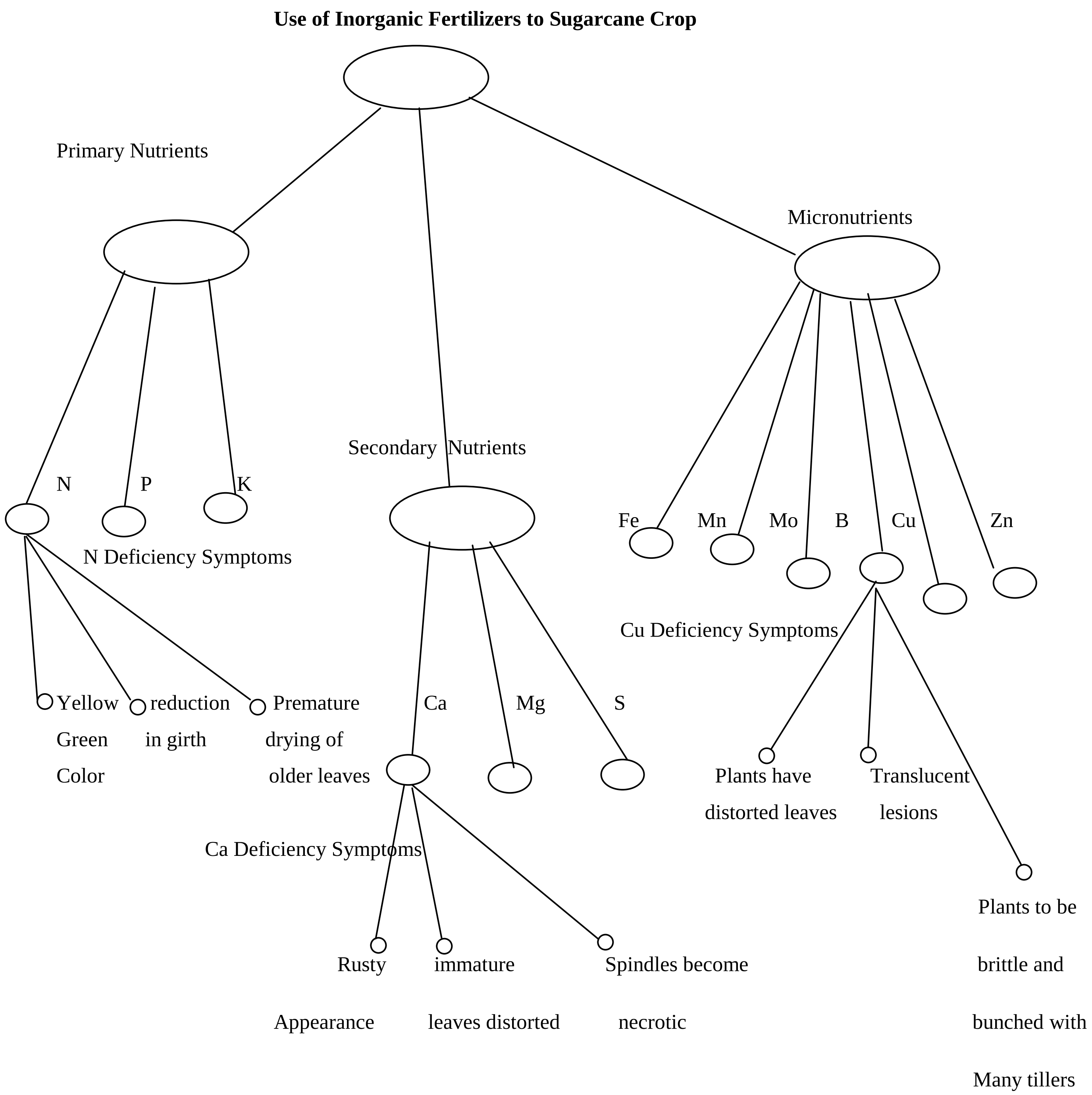

Fig. 2 Tree Structure Representation of the Primary, Secondary and Tertiary nodes

- Long hairy root system

Then Goal #1 Display Message #A

The message is a detailed description of the findings as outcome of appraisal of each node and its secondary, tertiary and leaf nodes. i.e. Nitrogen (N) Deficiency observed

Rule #A1.1

If Nitrogen Deficiency observed

Then Goal #1.1 Display Message #A.1

The message is description about the ratio of suggested inorganic fertilizer (Nutrient).i.e. Use 400 Kg/Hector of Nitrogen

In this way following rules are prepared:

Rule # A2

If Planting Season Is ADSALI

And Symptoms Observed are:

- Length and diameter of cane stalk or stems is reduced
- Tillering is affected adversely
- The leaves turn to greenish blue
- The leaves remain narrow and somewhat reduced in length
- Shoot or root ratio is decreased considerably

Then Phosphorus (P) Deficiency observed

Rule # A2.1

If Phosphorus Deficiency observed

Then Use 170 Kg/Hector of Phosphorus

Rule # B1

If Planting Season Is PRE SEASONAL

And Symptoms Observed are:

- Yellow green colored leaves
- Shortening of internodes
- Reduction in girth
- Premature drying of older leaves
- Long hairy root system

Then Nitrogen (N) Deficiency observed

Rule # B1.1

If Nitrogen Deficiency observed

Then Use 340 Kg/Hector of Nitrogen.

Rule # C1

If Planting Season Is SURU

And Symptoms Observed are:

- Yellow green colored leaves
- Shortening of internodes
- Reduction in girth
- Premature drying of older leaves
- Long hairy root system

Then Nitrogen (N) Deficiency observed.

Rule # C1.1

If Nitrogen Deficiency observed

Then Use 250 Kg/Hector of Nitrogen

In this way, 36 rules are generated to find out which nutrient has deficiency? And to cover up these deficiencies, this rule base system suggests appropriate ratio of nutrients. From these rules, it is clear that number of different parameters is considered in the diagnosis process. These parameters have values like Observed or Not Observed. When most of the parameters (Symptoms) are observed then corresponding nutrient is considered as the nutrient with deficiency. Whenever the system arrives at a value for any node, it proceeds to the message table and picks up the appropriate message and stacks in the stack.

9. IMPLEMENTATION

For the proposed expert system, author has a choice of several expert system shells. The shell is a piece of software which contains the user interface, a format for declarative knowledge in the knowledge base and an inference engine. The knowledge engineer uses the shell to build a system for a particular problem domain. Author referred VIDWAN, a expert system shell to build this system because it support IF-THEN rules for representing domain knowledge in the rule base, its inference engine supports forward chaining explanation facility and rule base can be created using any conventional text editor.

Author developed a rule based system in ASP.net as front end. The Microsoft .net framework is a software framework for Microsoft windows operating systems. It includes a large library & it supports several programming languages, which allows language interoperability. ASP.net is a web application framework to allow programmers to build dynamic web sites, web application & web services. The rule based system has been implemented and its sample output is enclosed.

Here the rule base contains the set of rules which represents the knowledge about the domain. Working memory contain the information about the appearance (symptoms appeared on) of leaves of sugarcane crop which being diagnosed. The inference engine uses the prior information about the problem being solved. The system starts with a forward chaining by decomposing a problem into sub problems and solving each one of them since number of possible initial states are compared to the number of goal states, forward chaining is used for diagnosis purpose.

9. CONCLUSION

The expert system developed for the use of inorganic fertilizers to sugarcane crop will be helpful for farmers. They can easily find out nutrients which have deficiency. Also while using inorganic fertilizers for sugarcane crop, they will use this system. Initial feedbacks collected by author from farmers and agricultural experts, have been positive. With further work, the scope of the expert system can be widened.

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Sample Output :-

The Applicant/Farmer: - S. J. Yelapure Located at A/p:-Rethare Bk. Tal:- Karad Dist:-Satara

Planting Season is Adsali

The outcome of the evaluation done by the Expert System is as follows

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THE EXPERT SYSTEM IN THE USE OF INORGANIC FERTILIZERS FOR SUGARCANE CROP USES ABOVE DATA AND PARAMETERS PROVIDED AND ON THE BASIS OF WHICH IT WAS FOUND THAT:

THE NITROGEN DEFICIENCY IS OBSERVED

HENCE IT IS ADVICEABLE TO SUGGEST USE 400 KG/HECTOR OF NITROGEN

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Assessment of following parameters show that the deficiency of Nitrogen is Observed

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The nutrient deficiency symptoms observed on sugarcane crop are

- Yellow green colored leaves
- Reduction in girth
- Premature drying of older leaves
- Long hairy root system

These symptoms suggest Nitrogen deficiency.
