BIONERGIA EM REVISTA: DIÁLOGOS

A web-based expert system for diagnosis of nutritional deficiency in sugarcane

Sistema especialista para diagnose de deficiência nutricional em cana de açúcar

Basado en la web un sistema experto para el diagnóstico de deficiencia nutricional en la caña de azúcar.

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Abstract

This paper presents a web-based expert system for diagnosis of plant nutrient disorders in sugarcane. This system aims to provide a guide to identification of essential and functional plant nutrient disorders in sugarcane to avoid deficiency and to solve nutritional problems arising from the development of this culture. It is directed toward the sugarcane farmer, research scientist, extension specialist, student, and consultant. The first version of system was developed using the virtual diagnosis framework developed by Embrapa and CENA/USP. The adopted development methodology and the current status of the system for diagnosis of nutritional deficiency in sugarcane are discussed in this paper. The experience

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acquired in the development of this expert system and applications are also presented.

Keywords: Sacharum spp; nutritional lack, deductive inference, artificial intelligence, agriculture energetic.

Resumo

Neste trabalho foi desenvolvido um sistema especialista para internet visando ao diagnóstico de distúrbios nutricionais em cana de açúcar. O objetivo do sistema foi proporcionar um guia de identificação de deficiências e alterações visuais, dos principais nutrientes exigidos pela cultura da cana de açúcar, para ser utilizado como base de informações na tomada de decisão dos problemas provocados pelas deficiências nutricionais. O trabalho é dirigido aos produtores de cana de açúcar, extensionistas, estudantes, consultores e pesquisadores. A primeira versão do sitema foi desenvolvida utilizando conhecimentos de diagnose visual pela Embrapa e CENA/USP. A metodologia de desenvolvimento adotada pelo sitema atual para diagnóstico de deficiência nutricional em cana de açúcar está descrita neste documento. A experiência adquirida pelo desenvolvimento deste sistema especialista assim como as aplicações também são apresentadas.

Palavras-chave: Sacharum spp; deficiência nutricional, inferência dedutiva, inteligência artificial.

Resúmen

Este trabajo presenta una web basada en el sistema de expertos para el diagnóstico de trastornos en nutrientes de las plantas de caña de azúcar. Este sistema tiene como objetivo proporcionar una guía para la identificación de las principales nutrientes de las plantas funcionales y trastornos en la caña de azúcar para evitar la deficiencia nutricional y de resolver problemas derivados del desarrollo de esta cultura. Está dirigida hacia el agricultor de caña de azúcar, la investigación científica, de extensión de especialistas, estudiantes, y consultor. La primera versión del sistema fue desarrollado utilizando el marco diagnóstico virtual desarrollado por Embrapa. La metodología de desarrollo adoptado y de la situación actual del sistema *para el diagnóstico de deficiencia nutricional en la caña de azúcar se examina en el presente documento. Las experiencias adquiridas en el desarrollo de este sistema experto y también se presentan las solicitudes.*

Palabras clave: sacharum spp; falta de nutrición, la inferencia deductiva, la inteligencia artificial, la agricultura energética.

Introduction

In order for any crop to grow and remain healthy, certain elements must be made available to the plants from the soil and air. The nutrient requirements include C, N, P, K, Ca, Mg, S, Mn, Zn, Cu, Cl, B, Fe and fertilization among others. The diagnosis leaf as a method for assessing the nutritional status, make adjustments in the programmer of fertilizer and determine dose of fertilizer seems to have received more attention than the analysis of soil, but why large number of contributions such as: (1) Capó and his collaborators (1955); (2) Clements (1961, 1980), (2) Evans (1961), (3) Samuel (1969), (4) Beaufils (1973), (5) Elwali and Gascho (1984). The concept of critical physiological level was used by the first four, while the last two used the relationships between the elements (DRIS). H.F. Clements developed the original method of the record agronomic (crop logging). Some studies of the effect of treated mineral deficiencies in the levels of the elements and industrial components: Clements (1980) and Evans (1961) are examples. More recently there was the contribution of Anderson and Bowen (1990).

In revision now some contributions Brazil, a both of mineral requirements of macro and micro nutrients, and sometimes disability consequences of the same object were the contributions of Catani and his colleagues (1959), H.P. Haag and his collaborators (1965, 1987), Orlando Filho (1976, 1980), Salcedo and Sampaio (1984, 1988). The original contributions of Dobereiner (1973, 1992) and his collaborators of Embrapa Agrobiology showed the roles of biological fixation of nitrogen in the rhizosphere and endophytic. Also in Brazil the largest volume of work comes to diagnose leaf in several aspects - from the sampling until the effect of the rain on the composition of the leaf, varietals influence and the type of soil.

Actually, the soil tests and tissue analysis complement the diagnosis process giving support to define a proper fertilization schedule. Diagnosis is a traditional focus of attention in Artificial Intelligence. Expert systems for diagnosis in the general agricultural domain are already being explored in several works (Huber& Doluschitz, 1990; Durkin, 1994; Yialouris & Sideridis, 1996; Mahaman, et. al., 2003). No system specialist in nutritional deficiency in the cultivation of sugar cane brings a synthesis of historical knowledge of their physiology, mineral nutrition and soil fertility made by researches, which were organized in the form of logical rules and that reflects on last analysis, the guidance of fertilization of a reedbed. In this way, structured is a comprehensive guide that provides the computerized identification of nutritional disorders in sugar cane.

Although, the expert systems for diagnosis of deficiency nutritional in plants are limited. Most reasoning frameworks have been based on inference from the consequences to the causes, in a deductive manner, as the ones employed in the systems cited above.

On the other hand, the evolutions in the telecommunications area and computer science are bringing modifications in the agricultural information dissemination, mainly with the coming of the Internet and the services it provides. Such circumstances demand that new technologies transfer channels are proposed (Risdon, 1994; Hill *et al*., 1996). The potentiality of Internet has attracted the attention of researches because its easiness of use and reach a significant portion of the population (Leiner *et al.,* 1997). This communication resource has become an excellent form to spread technologies, products and services.

The necessity for improving the current diagnosis process of nutritional deficiency in plants linked to the easiness supplied by the Internet motivated the development of this work. However, to develop such applications for a diversified public it is crucial that information technology and the communication infrastructure are integrated.

The version of this web-based expert system for diagnosis of deficiency diseases in sugarcane was developed using the virtual diagnosis framework developed by Embrapa. The first system developed under of this framework was an expert system for diagnosis of corn diseases (in http://diagnose.cnptia.embrapa.br/milho). This framework also allows users to get in contact with the domain experts by e-mail, chat, discussion list among others services (Massruhá et al, 1999).

The adopted development methodology and the current status of the system are discussed in this paper. The experience acquired in the development of this expert system to diagnose nutritional sugar cane is already available on the site http://diagnose.cnptia.embrapa.br/cana/, free access and a tool for assisting rural extension services. This system is aimed at producers of sugar cane, researchers, extension workers, students and consultants. Works basic and applied to sugar cane on the various aspects of mineral nutrition have been studied in Brazil and other countries.

Methodology

The focus of the project of a conventional system is the "data" while the project of an expert system (ES) is the domain "knowledge" (In site: **http://diagnose.cnptia.embrapa.br/cana/**). This process is interactive and incremental; that is, the programmer creates a prototype of the system, tests it, and then modifies the knowledge of the system to satisfy the user new requirements (Durkin, 1994). The development process of this expert system included six phases (Figure 1). The *assessment* phase involves a study of the system's requirements. The second phase is *knowledge acquisition* which represents the bottleneck in the development of an expert system. A classification model of the nutritional deficiency diseases was generated in this phase. In the *Design* phase, the structure and organization of the knowledge was modeled in the form of a decision tree, the methods to process this knowledge were also defined, as well as the software tool to be used in the implementation of the system. In following, were generated production rules from decision tree and the expert system was implemented from production rules (IF <effects> THEN <causes>). An example of this production rules are showed bellow:

IF part="leaf" THEN question = "q1"
IF part="root" THEN question = "q2"
Q1: IF leaves = "top plant" and leaves = "dead tip" THEN "calcium deficiency"
q2: IF roots = "lateral" and roots ="insufficiently" THEN "Aluminum deficiency"

The *test* phase is continuous, that is, the engineer of the knowledge tests the prototype with the domain expert, the user introduces new knowledge and a new prototype is generated and tested again, and so forth. In this phase the test plan and the user evaluations were registered formally.

In the *documentation* phase, a document was elaborated with a "knowledge" dictionary and the resolution procedures of the problems adopted.

The *maintenance* phase will begin when the system are in production. The expert system is not static, but it develops periodically. Therefore, the evolutions of the system will be contemplated in this phase.

This cycle was adopted in the development of this web- base expert system for diagnosis of nutritional deficiency diseases in sugarcane. Before using the nutrition system verify that at least 2 of the criteria below are in the description of the symptoms of its planting. If does not, probably not suffer from planting their nutritional deficiency but perhaps of disease or pest.

1 º Criterion - Generalisation symptom of the crop: If disability, the symptoms usually appear in large areas (tracts, plots, blocks), not being in either plant or in several plants.

2 º Criterion - vertical gradient of color in the plant: The elements have varying degrees of mobility in plants, some are redistributing more (N, P, K, Mg, Cl and Mo), others less so (S, Cu, Fe, Mn, Zn), other practically nothing (Ca, B), this makes the symptoms of an element of redistribution easy appear first on older leaves if disability; to the contrary, the nutrients of redistribution cause minor symptoms of grace in the leaves (or organs) in first place, in any event there is always a gradient in the intensity of disability.

3º Criterion - Symmetry side in the plant: When do deficiency or excess, the two leaves of a pair or the sheets must present the typical symptom; this observation, as the previous (gradient), also helps to distinguish the symptoms of lack or excess caused by the pests and diseases.

The web-based expert system for diagnosis of deficiency disease in sugarcane has also been based on deductive inference and its theory base is the order first logic. The knowledge base of this system contains production rules derived from a decision tree (Figure 2).

This tree was generated from interviews with the experts and literature in the area (Anderson & Bowen, 1990) and it was revised by researchers of Embrapa, Universidad of San Paulo and **International Potash Institute** – IPI.

This virtual diagnosis framework was developed using the ServCLIPS tool to support the building and the running of expert systems by web. The ServCLIPS uses the inference engine and the programming language of the CLIPS to develop the expert systems (Riley, 2006). Thus, a human expert only needs to knowledge the CLIPS language to develop his expert system. More details are described in Moura & Cruz (2001).

The main features or the version 1.0 of the web- based expert system for diagnosis of nutritional deficiency in sugarcane is described in following. The system is structured in four modules (Figure 3): *Consultations, Glossary, Contact us* and *Help*. The *Consultations* module is the expert system implemented in ServClips (Figure 4). The session starts with a sequence of questions are asked such as "Which location did the symptoms appear?", "What kind of lesions did it appear?", "What time did the symptoms appear?", and so on (Figures 5 and 6). Then, the system dynamically adjusts the flow-of-control between the rules based on the user's answers to questions and at the end, a diagnosis is provided (Figure 7). The *Contact us* is an optional module that facilitates discussions between experts and producers. The module Glossary contains a small dictionary of the area. The *Help* module contains basic information for the use of the system. This first version of the system is not connected to databases. Therefore, this system will be able to interface with databases in the next version.

Identification key of nutritional disorders in sugar cane

When the nutritional deficiency is pronounced, the plant showed typical symptoms that are described in key identification, adapted and expanded, ANDERSON & BOWEN (1990), which is incorporated in the rules of this system. Resulted that when the symptoms usually appear productivity has been affected economically. For some nutrients (such as copper and zinc) the sugar cane shows the process of "hidden hunger", in other words, disability is not severe enough to show the symptoms, but it reduce the production. Therefore, in this system uses an association of visual symptoms of deficiency of a particular nutrient, with the chemical analysis of soil and the plant that are key tool to evaluate soil fertility and diagnose leaf, consequently, the need for fertilization of sugar cane. For the interpretation of the results of calibration curves exist that relate the levels of the nutrient in the soil, obtained with a specific solution extractor, and the production, obtained from experimental studies. There are also tables that allow specific economic recommendations of fertilization, which limits for occurrence of disabilities vary with the extractors used and that are in the system and summarized in key identification.

In sugar cane, leaves diagnosis means the use of the chemical composition of any plant tissue (leaf blade, sheath, internodes) for the purpose of assessing the nutritional status of the plant and recommendation for fertilization. From the practical point of view, in the units producing sugar cane in Brazil, the chemical analysis of soil is much more used to diagnose leaf that, in assessing the needs of nutrients by culture. The limits to diagnose leaf used in the system to occurrence of defects were average production sugarcane from various regions of the globe, adapted from ANDERSON & BOWEN (1990) and MALAVOLTA, (1982), for different nutrient.

Key identification of nutritional disorders in sugar cane in leaves older or new or roots, with attestation by interpretation of soil and leaf tissue:

Parts of the plant Disorders

A1. Older leaves affected.

B1. Widespread effects on the whole plant; in senescence of older leaves.

C1. Blades uniformly green-leaf clear to yellow; stems are shorter and thinner; delay in the vegetative growth.

D1. Tips and margins of older leaves become necrotic prematurely...**deficiency of N**
D1.1. Confirmation by leaf analysis of nitrogen……......................................N% <1.5%. D2. Short longitudinal chlorotic streaks on the apical one-third of the leaf. Symptoms are similar to mild infections of Pokkan Boeng disease……………………………................………………**deficiency of Mo**

D.2.1. Confirmation by leaf analysis of Mo: Mo (ppm) <0.10.

C2. Blades leaf-green to dark blue-green, red or purple appears frequently, particularly in tips and margins directly exposed to sunlight; leaves finer, more narrow and shorter than normal; older leaves yellow, possibly a in senescence from the tips and along the banks; stems smaller and thinner; tillering scarce or absent …..**deficiency of P**

C.2.1. Confirmation by analysis of soil by different extractors of P: : P-resin < 16 mg/dm3 ; P-Mehlich 1(ppm) < 12-6 mg/dm3 (depending on the clay content) or P- H_2SO_4 0,5N (ppm) <30.

C.2.2.Confirmation by leaf analysis of P: (%) P <0.08.

B2. Effects located with mottling or chlorosis.

C1. Borders and tips of the leaves show chlorosis yellow-orange; injuries chlorotic located between the ribs along the sides and tips of the leaves, leaves older can become totally brown or burnt stems thinner; red discoloration on the upper surface of the leaves; leaves newest usually remain green-dark; cartridge distorted, producing "top hand," or appearance of "range"...**deficiency K.**
C.1.1. Confirmation by analysis of soil and K by different extractors:K- resin (meq/100 ml) < 0,07-0,15 ; K -Mehlich 1 or P- H_2SO_4 0,5N (ppm) < 40.
C.1.2. Confirmation by leaf analysis of potassium: K (%) <0.65.

C2. Appearance mottling or clorotic starting in tips and along the banks; necrotic lesions resulting in red appearance of "rust". The bark of the stem can show brown internally…...................................……......**deficiency of Mg.**
C2.1. Confirmation by analysis of soil of Mg (meq / 100 mL) < 0,4.
C.2.2. Confirmation by leaf analysis of Mg: <0.08 g / kg.

C3. Leaves older may submit appearance of "brown or orange color" and may die prematurely (see A2.B1.C1) ....**deficiency of Ca**

C.1.1.Confirmation by analysis of soil calcium (meq / 100 mL) < 1,0.

C.1.2. Confirmation by leaf analysis of Ca (%) <0.20.

B3. Small white patches circular (mackerel), more severe in older leaves; tillering scarce; premature senescence of leaves older …………..............…..**deficiency of Si**

A2. Leaves new affected

B1. Death of the apical meristem; immature leaves are twisted and become necrotic.

C1. Leaves new wound up down, giving an appearance of "hook" when the disability is acute, the cartridges become necrotic on the tips and along the banks;-sensitive training center with necrotic lesions chlorotic that later become to brown or red color; stems become soft, thinner, rapidly toward the point of growth (see A1.B2.C3). ....**deficiency of Ca**

C.1.1. Confirmation by analysis of soil calcium (meq / 100 mL) < 1,0.

C.1.2. Confirmation by leaf analysis of Ca (%) <0.20.

C2. Leaves twisted; injuries translucent or in the form of "bags of water" between the ribs; plants with many new tillers, leaves tend to brittle; leaves the cartridge can become chlorotic and later necrotic; often called the disease of false "Pokkah boeng "; also similar to the damage caused by some herbicide …………………………………………………………………….**deficiency of B**

C.1.2. Confirmation by leaf analysis of B (ppm) <2.

B2. Apical meristem remains alive; immature leaves become chlorotic and wilted, however, without necrotic spots.

C1. Green spots ("islands"); leaves discolored that eventually become thin as paper and rolled when the disability is severe; stems and meristem lose turgidity (disease of the "top fallen") and acquire appearance similar to rubber, reduced tillering...................................…..............................**deficiency of Cu**

C.1.1. Confirmation by analysis of soil copper (ppm)   < 0,5 (Mehlich 1).
C.1.2. Confirmation by leaf analysis of Cu (ppm) <5.

C2. Young leaves in elongation wither especially on hot summer days and sunny, however, the phenomenon is reversible, usually recovering to the night (see A3.B2)..…..**deficiency of Cl**

C3. Apical meristem remains alive; immature leaves have varying degrees of chlorosis, but not wither.

D1. Chlorosis internerval the tip to the middle of the leaves; chlorotic streaks may become white and necrotic and the leaves may to shred per share of the wind ………………… ....**deficiency of Mn**
D.1.1. Confirmation by leaf analysis of Mn (ppm) <40.

D.2.. Chlorosis internerval the tip to the base of the leaves and the whole plant may become clorotic or white when the disability is severe.....**deficiency of Fe**
D.2.1.Confirmation by leaf analysis of Fe (ppm) <30.

D.3. Chlorotic grooves in leaf blade, unite and forming a wide band of tissue clorotic on each side of the midrib, but not extending to the edge of the page, except in cases of severe disability; chlorosis starts up vascularly; longitudinal strips green-clear to the along the margins of leaves and dark-green along midrid and margins, is the leading edge to the middle of the blade; tissues internerval remain green initially, but soon the whole leaf blade can become clorotic, extending up for the foundation, leaves perceptibly short and wide at the media and asymmetric; necrosis on the edge of the leaf when the disability is severe, progressing from basic to the tip of the leaf blade; reduced tillering and shorter internode, thin stems that can lose turgidity(elastic)
…………………………………………………………………**deficiency of Zn**
D.3.1. Confirmation by analysis of soil zinc (ppm) < 0,8 (Melihch 1).
D.3.2. Confirmation by leaf analysis of Zn (ppm) <15.

D4. Young leaves evenly chlorotic; may develop color purple-clear; leaves

smaller and closer that normal; stems very fine ……..……….. **deficiency of S**
D.4.1. Confirmation by leaf analysis of s (g / kg) <0.05.

D.5. Chlorotic mottled grooves occurring throughout the length of the leaf blade; tips and margins of the leaves may become necrotic; symptoms show up between 3 to 7 days after exposure; older leaves are not affected …………………………………………….................................**toxicity of SO_2**

D.6. Chlorosis in tips and margins of the leaves of the new basis for progressing the tip of the leaf blade; finally, the chlorosis extends to the older leaves; tissue clorotic quickly becomes necrotic; tips of the leaves may become severely burned...**toxicity of B**
D.6.1.Confirmation by leaf analysis of B (ppm)> 50.

A3. Roots affected

B1. Forming Up few lateral roots and those which exist in present tips abnormally thickened; damage to the roots resemble those caused by nematodes, plants become highly susceptible to water stress and deficiency of phosphorus ………………………………………………………………………………**toxicity of Al**

C.1. Confirmation by analysis of soil aluminum (meq/100ml) > 0,5.

B2. Roots abnormally short; increase in the number of lateral roots...............**deficiency of Cl** *B3. Roots abnormally short, with very little lateral branching* ....**toxicity of Cl**

Results and Discussions

Although this system is a conceptually simple and powerful tool, it hasn't been disseminated yet. However, an expert system is not static. Hence, evolutions of the system are being contemplated from some user's observations. It is expected that this system is used in large scale. This should contribute to improve the agricultural research quality and productivity.

The future work in the context of the Artificial Intelligence will be to evaluate and possibly to develop diagnosis models that are more adaptable for this problem and which improve the efficacy of the development process of ES. The diagnosis reasoning of deficiency nutritional en sugarcane can be seen as cognitive process that embraces generic knowledge about flaws and explanations for these flaws (a diagnosis model), as well as the knowledge on a private domain and specific heuristics of the domain. We propose to structure the knowledge from the causes to effects (abductive inference) in counterpart to the deductive inference model in which the knowledge is structured in from effects to causes (Massruhá et al, 2005). In this focus, the future work will seek to evaluate several alternatives on possible diagnosis models for nutritional deficiency nutritional in plants, and to develop specific heuristics for the domain of application.

Conclusion

This system aims to provide a guide to identification of essential and functional plant nutrient disorders in sugarcane and the results of plants and soil analysis. It is directed toward the sugarcane farmer, research scientist, extension specialist, student, and consultant.

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FIGURES:

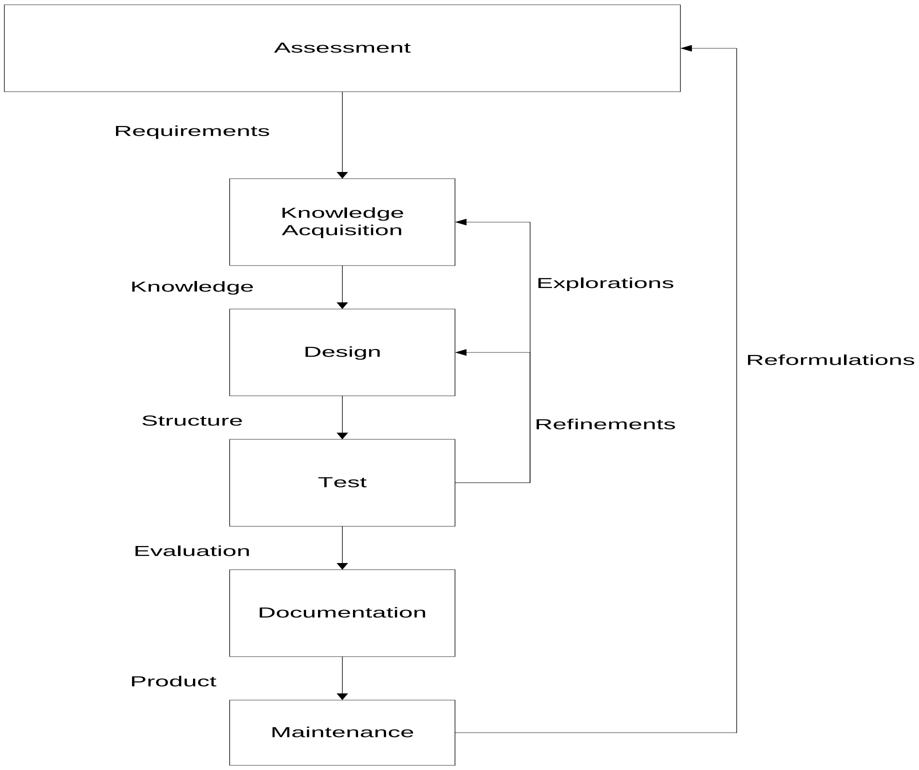
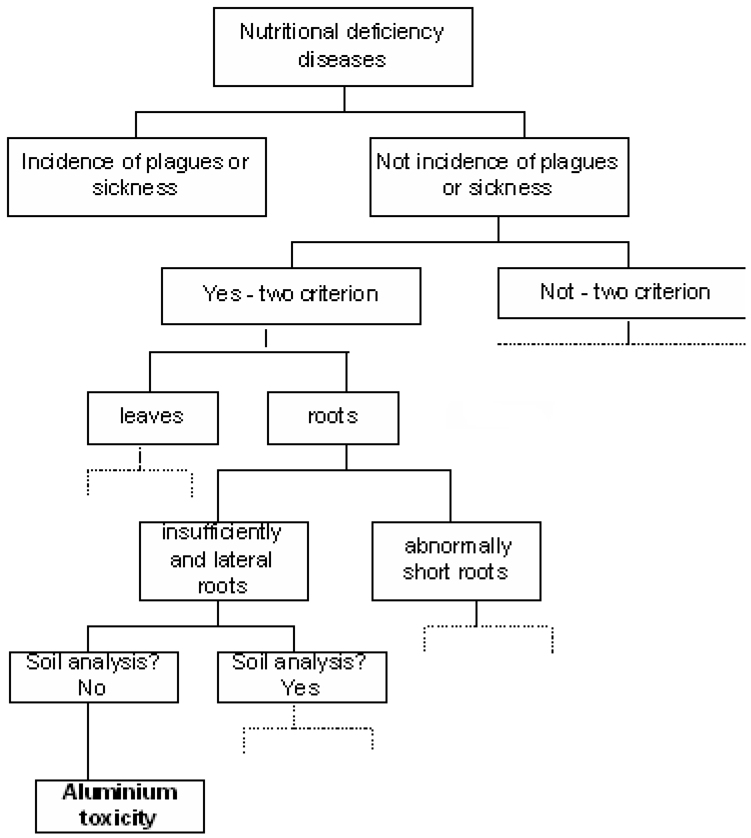


Figure 1: Life cycle of an expert system



Website: http://diagnose.cnptia.embrapa.br/cana

Figura 2: Decision tree of the expert system for nutritional diagnosis of sugarcane.

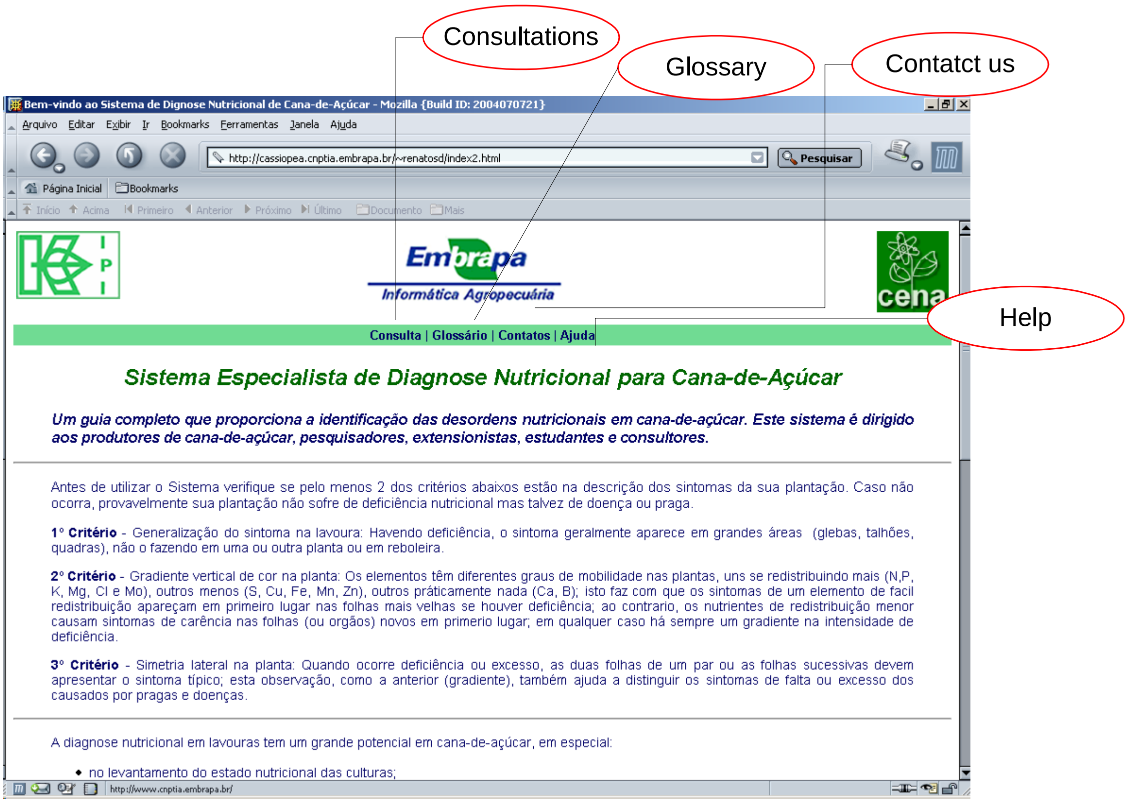


Figure 1: Expert system for nutritional diagnosis of sugarcane.

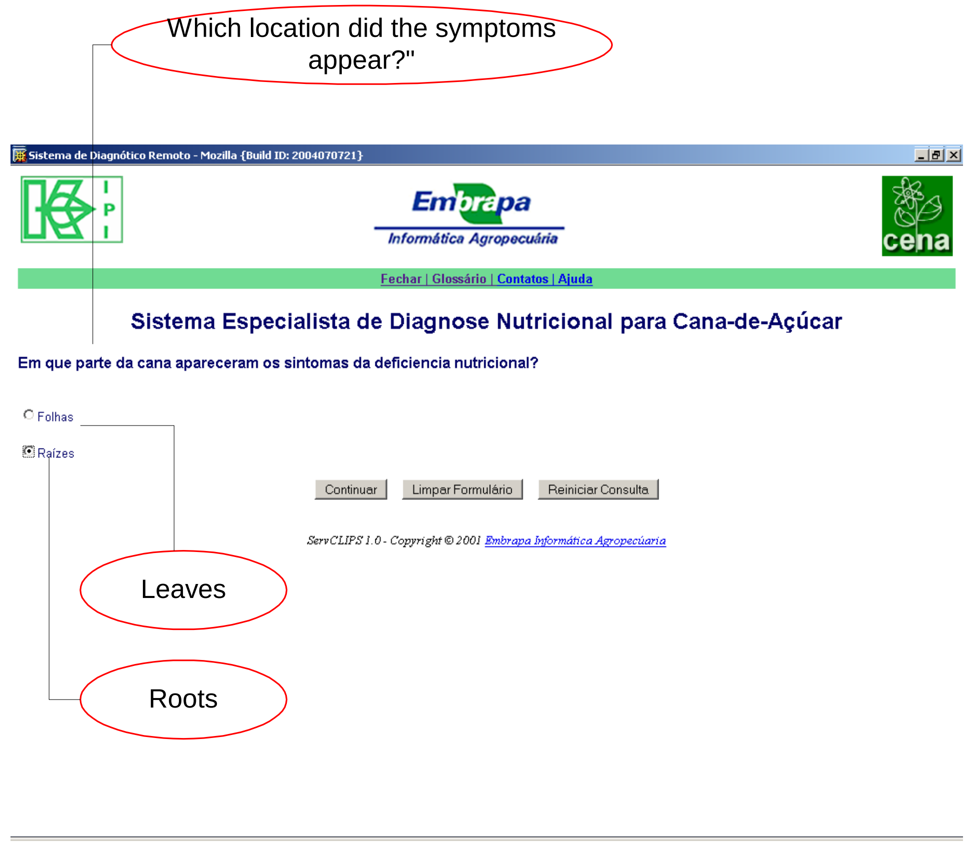


Figure 2: The *Consultations* module of the expert system for nutritional diagnosis of sugarcane.

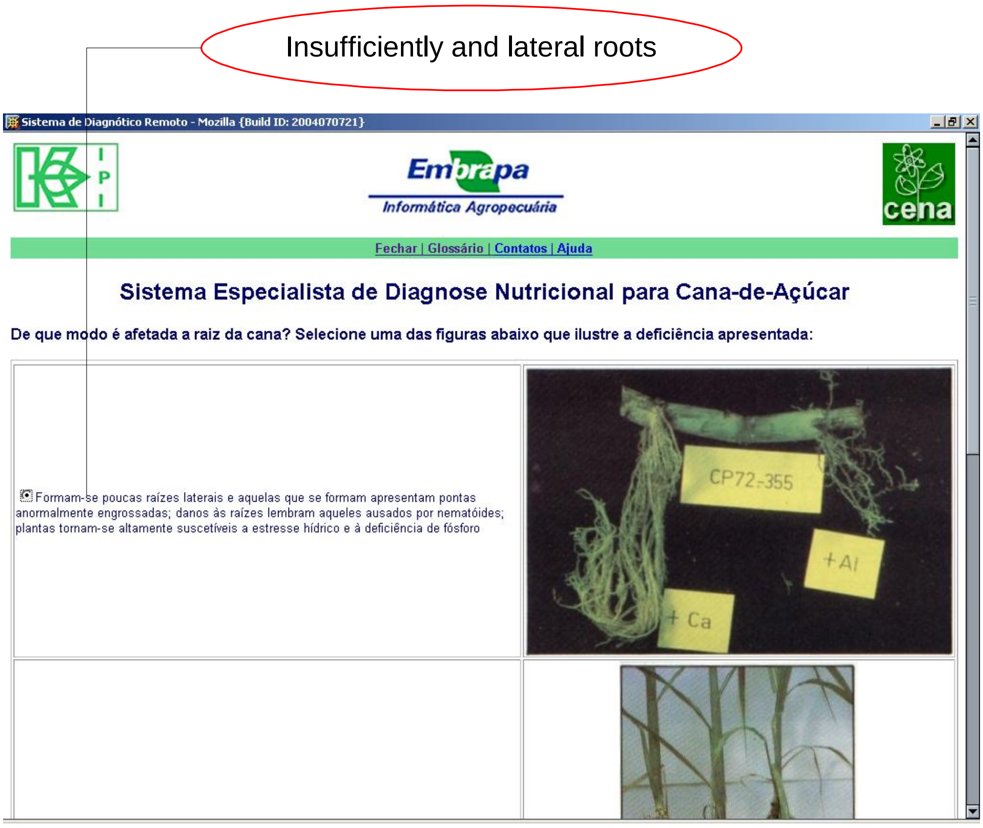


Figure 3: An example of question in diagnosis process.

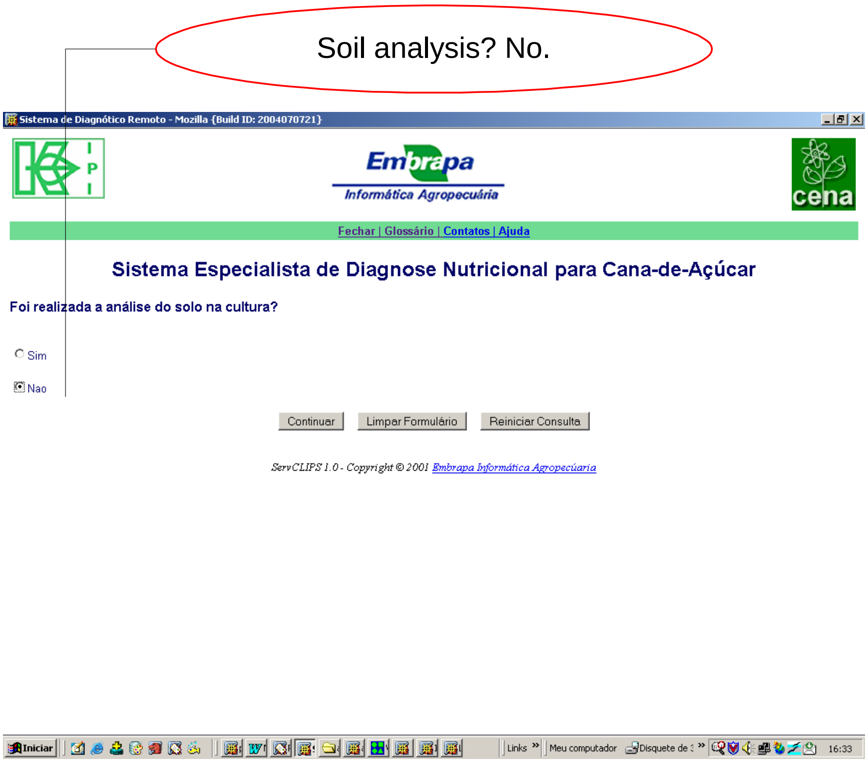


Figure 4: An example of diagnosis.

Figure 5: An example of diagnosis result.