FYTOTROF – AN EXPERT SYSTEM FOR DIAGNOSIS OF PLANT NUTRIENT DEFICIENCY BASED ON VISUAL SYMPTOMS

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An expert system has been developed to support decision-making for determination of deficiencies in plant nutrition according to visual symptoms. The work with the expert system and the program options are described herein. Expert system FYTOTROF can help farmers in their decisions about fertilizing, but can also be used as a teaching program.

computer program; plant nutrition; deficiencies determination

INTRODUCTION

The current methods for determining mineral plant nutrient deficiency require either the protracted expertise of an experienced agronomist or complete inorganic analysis of plants; the safest way is to use them both. An experienced agronomist can guess about the deficient element in nutrition according to habitual symptoms of the plant or the whole field appearance. A less experienced agronomist can use various illustrated publications but some of them are not very lucid (B e r g m a n n , 1988). For this reason, we have developed a system to support decision-making for determination of deficiencies in plant nutrition according to visual symptoms.

Justification for expert system approach

Visual symptoms of some element deficiencies in plant nutrition are very similar, especially during the early phases of growth. They differ in markers which are not very different at first sight and thus could be overlooked. The use of picture atlases is time consuming during the first step, i.e. in looking for an appropriate page. A lot of theoretical knowledge is needed to obtain

a correct result. However, direct instruction for practical use is often hard to find in many specialized publications.

An expert system can help a lot in this situation, since it asks questions and focus the user's attention on the general appearance of the plant. After answering all the questions, the computer is capable of combining all the answers of the user in a short time, assigning statistical weights and theoretical assumptions, and presenting the user with a qualified conclusion.

MATERIAL AND METHODS

The expert system shell LEQ built by us was used for designing FYTOTROF. LEQ is a MYCIN-like rule-based system (Forsyth), i.e. it processes rules of the form:

„IF assumption THEN conclusion WITH WEIGHT"

where weight is a number characterizing the degree in which one believes that the conclusion holds if it is certain that the assumption holds. If a knowledge base is given, it is possible to execute consultations, i.e. LEQ infers weights of goals from weights of entries (user's answers on questions) using a net of rules constituting the knowledge base. LEQ uses uncertainty processing from EQUANT (Hájek, 1984, 1985).

Inference in LEQ use backward chaining, it means, at first system tries to evaluate goal, in case of absence of information system examines assumption, and in this way it comes back to questions given to user.

The application domain of LEQ is supposed to be described by means of short statements for which we use the term propositions. Conjunction (or disjunction, resp.) of these propositions forms assumption (antecedent) of a rule, a weight of an antecedent is given by the minimum weight of component propositions in case of a conjunction and the maximum one in case of disjunction. At a conclusion (consequent) of a rule stands one proposition only.

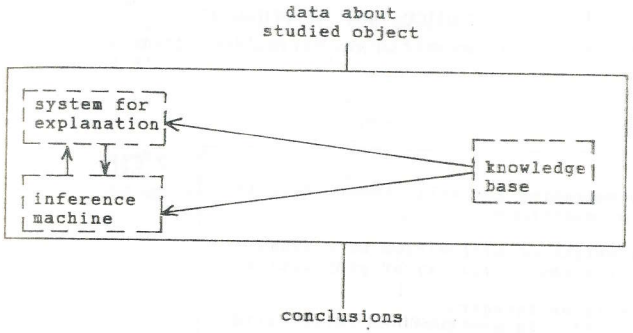
Knowing the weight of a rule and weights of propositions which form an assumption of that rule, LEQ calculates a contribution of the rule to the weight of the proposition at the conclusion. After evaluating all rules having an examined proposition as the consequent it is possible to calculate the (global) weight of the proposition.

Weights are real numbers from an interval [–1, 1] at processing in LEQ but for the purpose of a communication with users there is appointed suitable scale of integer numbers (expressing a conviction of the user in validity of the proposition) which is mapped in [–5, 5].

In LEQ there is an explanation modul helping user to understand the way the system gets results.

The problem domain of FYTOTROF is formed by visual symptoms induced by a nutrient deficiency, so mentioned propositions are statements describing possible conditions of the plant (or the field) examined, and goals are assertions about concrete deficiencies. Rules of FYTOTROF represent a collection of knowledge concentrated in the expert system which is applicable for decision-making on individual deficiencies.

The operation of expert system FYTOTROF can be described in lines of the following scheme (Fig. 1).



1. Scheme of the expert system function

The rules represent a collection of knowledge concentrated in the expert system and used for decision-making concerning individual deficiencies. We have used some generally known information from the literature (Bergmann, 1988; Brandenburg, 1961), and also our own experience (Černohorská, 1985; Černohorská et al., 1989; Dvořák, 1960; Dvořák, Černohorská, 1969, 1972, 1981, 1984; Dvořák et al., 1991; Nátr, 1970).

It is almost impossible to specify such rules with a 100% certainty, as some symptoms observable on the plant lead only to suspicion of certain deficiencies in plant nutrition. Similarly, it is often not easy to decide unequivocally whether a symptom in the plant does exist. Therefore, the expert system accounts for these uncertainties and a measure of validity for individual propositions is expressed in terms of statistical weights.

The weights are integers ranging from –5 to +5. The proposition has a weight of –5 if it is absolutely false. The weight +5 is assigned to a proposition which is fully valid. The weight 0 means that nothing can be said about truthfulness of a proposition, either because there is no information available, or the question asked does not apply to the plant examined (for example, a question concerning fruit of plants which have not yet bloomed). Zero can

also express a situation, where the symptom asked for by the expert system is very vague and we are unable to decide whether to consider or reject it. With numbers between –5 and 0 or 0 to +5 it is possible to express an increasing measure of truthfulness of presented proposition. For example, the proposition „the leaves are yellow" will not be considered as fully true in a situation when the plants have only a few yellow leaves, or if yellow leaves can only be found on some plants in the field.

Operation of FYTOTROF

In its introduction, the program offers basic information:

1. It characterizes the concept of weight of answer and its degree of certainty (Fig. 2).

```
During the  consultation you will  insert weights
of individual propositions

Understand the weight of proposition as a measure
of your conviction about validity of proposition

Insert the weights as integers,
maximum  weight (+5)  is assigned  to fully valid
proposition,
minimum weight (-5) is  assigned to fully invalid
proposition

weight 0  is assigned to  a proposition you  know
nothing about.
```

2. Capture of the opening screen

2. It offers a commentary to the concept used. Here the system assumes that the users know the healthy appearance of the plant, both the upper part and the roots. When in doubt, the user can call up the commentary any time.

Consultation itself with the system follows – the expert system asks the user questions to find in what aspects and to what degree the followed plant(s) differs from healthy ones. We have to keep in mind the necessity of both positive and negative answers, because the system derives its conclusions from negative answers as well.

Some questions are clustered by the system, so the user can evaluate possibilities of a certain symptom and decide about his/her answers.

In the menu offered, where all the answers are originally set to zero, it is possible to answer the questions in any order that a user wishes and user can change the answers. If all the proposition weights agree with the situation described, the user progresses to the next menu.

The offered menus:

„Habitual disorders" – see screen capture in Fig. 3.

```
                Habit disturbances
  2 slower development of plants.....................0
  4 shorter internodia ..............................0
  5 turgor-less plants, collapse.....................0
160 perishing  of whole plants.......................0
  6 un-even field....................................0
  7 apical part of the plant disturbance.............0
  8 basal part of the plant disturbance..............0
  9 the disturbances are incidentally placed
    on the plant.....................................0
 10 atypically opened leave rosettes.................0
 90 reproducible organs development disturbance...0
Insert weights of individual propositions
(Weight have to lay between values -5 and +5)
Individual weights changes confirm by pressing ENTER
Insertion of the weights in a given menu finish by ESC
 Press F1 for help
```

3. An example of a group menu offered. The numbers of propositions presented on the left can be used during later check or correction of propositions

The questions stem from the appearance of the whole plant, the whole habitus. Here it is necessary to decide which part of the plant is disturbed; for example, if the disorder affects apex or base.

„Plant apex disorder" –

By his/her decision the user influences the further course of the consultation. If the user denies the apex disorder, the system does not ask further questions dealing with the apex (see the example in Fig. 3).

„Leaves disorders" –

The possibilities offered:

„Specification of leaves deformation" –

drying, collapses, deformations, etc. If the user does not confirm the given disorder, that is, he/she gives a negative answer or 0, the system stops questioning in this direction.

„Leaves color changes" –

It is possible to choose from several positive answers, if it is impossible to express an opinion on color changes unequivocally, or if the leaves of the plants in the field are of various colors.

„Localization of color changes of leaves and leaflets"

„Color of spots"

„Specification of leaves/leaflets necrosis"

„Specification of leaf/leaflets collaps" –

In all these menus, the system takes all the answers into account, therefore, the result of the consultation depends on combinations of individual propositions. The following parts are first of all distinguished on the leaf: apex, base, periphery, whole leaf.

„Condition of stalk" –

If it is impossible to observe the stalk, the answer to all questions is 0.

„Developmental disorders"

„Spots on fruit" –

The user answers the questions of this menu only if he/she gave a positive answer to the question about disorders of reproductive organ formation previously. In early stages of development, these questions would not be relevant.

„Roots conditions" –

This last menu appears only when the user tells the system that the roots are observable.

In the next phase of the consultation, the system asks individual questions which do not fit into the groups of question discussed previously.

After the user is asked a question, it is possible to request an explanation from the system for why this question has been asked. The system progresses to the next question only after the user states the weight of the proposition contained in the the question. Our system makes it also possible to attribute a weight to any proposition, outside the order of the propositions. This mode can be used not only for attributing weights to propositions which have not yet been asked, but also for correcting earlier weights.

Information on the weights of some important propositions out of the schedule can be useful, e.g., in a situation where the user would like to finish the session prematurely. The system then evaluates the consultation only with the facts available. The results are understandably „worse", because not all the information available has been used.

Output from the expert system

The result is attribution of weights to individual element deficiencies, listed in a scale from –5 to +5 with the same meaning as used for the questions. The weight can be considered as the „measure of the reasons" supporting the diagnosis. At the same time, a numerical expression of the weights is less decisive than the order of the individual deficiencies – the system works with far finer discrimination than that in the input scale. The proposition

about that element deficiency which has the highest output weight is, therefore, most strongly supported by the symptoms provided.

The results can be summarized either according to the numbers of propositions dealing with the individual element deficiencies or according to the weights of the propositions. This mode allows fast identification of the particular element deficiency; or the user's attention is first turned to the most serious deficiencies, while deficiencies with the same weight are sorted according to a finer evaluation system. In both cases the user can have all the propositions displayed, or only those propositions which have attained certain minimal positive or negative weights determined by the user (an example of screen capture is given in Fig. 4).

```
Weight of the proposition 110: Manganese deficiency is 3

Weight of the proposition 106: Nitrogen deficiency is - 3

Weight of the proposition 108: Iron deficiency is - 3

                        ATTENTION ! ! !

The symptoms of Manganese deficiency coincide with the symptoms
of manganese over-fertilization!
If the need is to decide between both of these possibilities,
find how deep are tissues disturbed by spots - for
over-fertilization the spots affect the epidermis only.
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4. An example of a shortened output of the consultation – minimal weight entered = ±3.

After the consultation ends, the user can ask for explanation of the weights assigned to all the propositions. The system then lists all the rules affecting the final weight of the proposition, together with information about a weight of the rule. All the weights are, in this case, presented on a finer scale, from –100 to +100 with the same sense of both the extreme values and zero value as above.

The program can save the whole consultation. It is possible to save only the results of the consultation, or, in addition, the answers to the individual questions asked. The user can determine the names of the file, to which arbitrarily long information can be written (Fig. 5). The saved input information can be of a great advantage for repeated consultations with the system. The utility of repeated consultations with the system is twofold:

- it is possible to perform a trial of sensitivity analysis in which weights of certain propositions are varied between successive consultations,
- it is possible to finish a consultation interrupted prematurely.

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Now you can add any notes to the record of
consultation



finish every line by "Enter",
finish the notes by "Esc".
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5. Screen capture from the saving process

DISCUSSION

Decision-making concerning insufficiency in mineral nutrition of plants according to visual symptoms has some limitations. For example, the same disturbances in the plant habitus can exhibit deficiency in one element and toxicity of the second, or the effect can be phytopathological. In such cases, the system gives a warning. Together with warning, the system further offers detailed characters for discrimination of potentially confusing situations.

We have found during our work on the expert system that expressions of deficiencies at individual groups of plants have different significant characteristics. Besides the basic general system FYTOTROF, specific versions have been developed, for special groups of plants, like grain crops, rape (*Brassica napus*) and potato. Outputs from these species-specific systems are more focussed and consultation are shorter.

The system has been designed so that it is completely self-explanatory when following the instructions and questions, without any additional instruction for use. We have checked with users and found out that they could be easily understood and follow the program.

CONCLUSIONS

„Fytotrof" has been developed as a decision-support system for determination of deficiencies in plant nutrition according to the visual symptoms. Fytotrof is intended for help in agriculture management – as a part of large crop management systems. In our country complete transformation of agriculture is going on and with it also application of computers in all of its activities. Even now there is a demand for suitable software.

Because of Fytotrof's explanatory ability, the expert system offers much more than advice about nutrition deficiency. It is also possible to use the system as a teaching program to help in learning the basic symptoms of mineral nutrition deficiencies.

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Received for publication April 24, 1995

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Expertní systém FYTOTROF podporující diagnostiku deficitu ve výživě rostlin podle vizuálních symptomů.

Scientia Agric. Bohem., *26*, 1995 (3): 199–208.

Určit deficience v minerální výživě rostlin podle vizuálních příznaků může agronom s dlouholetou zkušeností. Méně zkušený má k dispozici různé obrazové publikace, nebo se může orientovat podle anorganických rozborů rostlin. Nevýhodou je jejich vysoká cena a nutnost znalosti vhodných poměrů mezi obsahem prvků, aby bylo možné příslušný relativní deficit (ve vztahu k dalším živinám) vyhodnotit. Správně se rozhodnout znamená disponovat velkým množstvím znalostí a umět je správně zkombinovat s praktickou zkušeností. Počítačový program provede ohromné množství kombinací během několika vteřin a poskytne tu nejlepší radu.

Expertní systém je tvořen předně souborem krátkých tvrzení, která popisují možné stavy sledované rostliny či porostu – výroků. Dále pak soustavou pravidel, jež představují souhrn znalostí soustředěných v expertním systému. Váhy jsou pak celá čísla v intervalu (1 až 5) nebo (–1 až –5), určující pravděpodobnost platnosti určitého výroku. Práce uživatele spočívá v konzultaci s expertním systémem. Jejím výsledkem je výrok o deficienci jednotlivých prvků podle toho, jaké váhy uživatel jednotlivým symptomům přiřadil. Pracovní operace expertního systému Fytotrof popisuje obr. 1; na obr. 2 až 5 jsou ukázky jednotlivých částí konzultace a výstupu. Program nabízí další možnosti, např. ukládání jednotlivých konzultací a jejich zpětnou analýzu.

počítačový program; výživa rostlin; určení deficiencí

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