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THE EXPERT SYSTEM SUPPORTING DECISION-MAKING IN THE PROCESS OF VEGETABLE PESTS EXTERMINATION DURING VEGETATION PERIOD

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ABSTRACT

The paper presents a computer system supporting the identification of vegetable pests during the vegetation period and the way in which it works on the example of red beet. The objective was to develop an ex-

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pest identification,
red beet,
mechanical engineering

pert system to facilitate the identification of pests and suggest an appropriate method of controlling them. Filling the database with the knowledge applying to one narrow area of knowledge turns the expert system framework into an expert system in this area of knowledge. The system consists of the expert system and the database in the form of text files, which contain additional explanations. The user of the expert system - "DSS – pest control" needs to answer the following questions: in the first stage the user selects the diagnosed vegetable, in the second stage, the user selects the symptom or symptoms on the above-ground vegetable part, in the third stage, the user selects the symptom or symptoms on the below-ground vegetable part. The designed decision support system ("DSS – pest control") may be used by individual vegetable growers. It may also serve as an educational program, e.g. for students who want to find out more about the specific areas of knowledge as well as for scientists and researchers.

Introduction

The issue of pest control is especially important in agricultural plant production where the goal is to obtain the highest possible yield using the smallest possible number of pesticides in relevant time. The expert system facilitating the identification of pests and suggesting the appropriate method of control may be a valuable tool supporting the food producers' decisions. Early identification of the pest allows for selection of a suitable method of control. The paper presents a model of such a system as well as the process of pest identification carried out by the system on the example of red beet.

Red beet is used for production of dried material, juice and pickles. Due to a high content of fiber, it belongs to dietetic vegetables (Sojak, 1995). In Poland, this root vegetable, available all-year-round, has the second highest consumption. The harvest reaches 450-590 thousand tons and the yield is between 20-30 $t \cdot ha^{-1}$. Due to a high demand for this vegetable, the quality is very important.

The problem of (red) beet pest control in many European countries is presented i.a. in the report No. 14 (Hermann, 2006). This report lists 40 pests, 13 of which can be found in more than 11 countries (a table with selected pests - Table 1).

Table 1.
Main (red) beet pests

Latin equivalent	Pest	Number of countries	ENDANGERED AREA IN A GIVEN COUNTRY, (%)																
			A	B	CH	CZ	D	E-n	E-s	F	FIN	GR	I	IRL	NL	PL	RO	S	TR
Agriotes lineatus	Lined click beetle	14	29	5	10	10	0	3	5	10	0	30	30	1	2		12		1
Aphis fabae	Black bean aphid	15	70	100	10	10	x	25	32	10		12	30	5	10	x	60	30	1
Atomaria linearis	Pygmy mangel beetle	11	27	100	3	7	3			3			10	1	40	x		50	
Chaetocnema concina	Mangold flea beetle	14	35	5	80	6		50	5	80	70	12	30	3	5	x	42		7
Heterodera schachtii	Beet cyst nematode	13	30	50	1	25	1	3	25	1	20		40		50	x		30	6

Pegomyja hyosciami P.	Mangold fly	14	34	50	1	3	10	1	1	1	2	3	2	10	x	14	20

The expert system "DSS – pest control" that was created contains information about identification and control methods of the most serious pests of red beet.

Expert systems (ES) are used in many fields of knowledge such as medicine, chemistry, mathematics, or computer science. They are also used in education e.g. programs which support learning and teaching. Expert systems were used to prove a lot of mathematical theorems, which no mathematician was able to prove for 60 years. Another source of knowledge on expert systems may be the free decision support systems glossary (Power, 2014).

In the production engineering, decision support systems were used to diagnose the condition of grain as well as the storage and drying methods (Mann et al., 1997; Weres et al., 1999) and to control the work of tomato stores (Morimoto et al., 1997). Such systems were also used to analyze the processes vegetables undergo during storage and drying (Trajer et al., 1999) and to identify storage diseases (Kaleta et al., 2005). The expert system for swine manure management was created by Karmakar et. al., (2010). Seidel et. al., (2003) compared diagnoses from expert systems and human experts. The decision support system (DSS) 'Coptimizer' was created to help growers optimize copper-based treatments against downy mildew on grapevine (Kuflik et al., 2009). The DSS, created by Kuo, Merklem, and Liu (2000), supports irrigation project planning. Cohen et al., (2008) created the spatial decision support system for Medfly control in citrus.

A decision support system is an intelligent program, which uses reasoning procedures to solve problems, which are too difficult to solve without experts' opinion. While traditional programs use mathematical models, decision support systems operate on 'non-formalized knowledge'. The knowledge that is necessary to provide a reliable opinion and the reasoning procedures may be considered as a knowledge model, which the best specialists in a given area possess (Duch, 1997; Woźniak and Kosecka, 2022; Francik and Pudło, 2016).

The role of the expert system is to solve problems like a human expert would solve them (Mulawka, 1996). The level of knowledge offered by a given expert system depends largely on the size and quality of the database a given system has. The quality depends on the accuracy of the process of knowledge acquisition and the method used to represent it in the database.

Expert systems have a lot of advantages (Górnicki and Sojak, 1999; Sojak and Trajer, 1999), namely, provide experts' opinions, which are cheaper than the opinions provided by specialists. They are also faster than specialists, improve the quality of the opinion using logical reasoning, make smaller number of mistakes and reduce the length of breaks (may work in real-time mode). They also store opinions that are difficult to access, which is useful when the number of experts is insufficient. Moreover, they increase the work safety as they may be used in-stead of experts in harmful conditions. Furthermore, opinions are available in many computers all the time. The systems provide thorough analysis, and a few different solutions may be obtained. They also combine the knowledge possessed by a few human experts. In consequence, such systems may work better than an expert. Expert systems 'work unlike human experts' work is not influenced by stress factor and it makes no difference to the system whether it works 'under pressure'. Finally, the database may easily be expanded as new experience is gained, and the systems are able to explain the solutions suggested by them (see Fig. 6).

Expert systems may be designed using two different kinds of tools. The first includes programming language (Duch, 1997; Mulawka, 1996), and the second one, expert system frameworks. In the second case, the role of the system's designer is to obtain and formalize expert knowledge, which is sometimes a difficult task. In this case, 'filling' the database with the knowledge applying to one narrow area of knowledge turns the expert system framework into an expert system in this area of knowledge (Białko, 1996). This paper uses the second method.

Material and methods

SPHINX (Michalik, 1998) with an empty knowledge base was used as an expert system platform supporting the selection of the red beet pest control method. Knowledge representation is in the form of rules and facts. Knowledge in the form of images, sounds and video sequences was also used in the process of user-system interaction. The system uses backward reasoning (based on Modus Tollens rule: goal - rules - facts) and is able to use knowledge contained in external modules directly.

Figure 1 presents the structure of expert system.

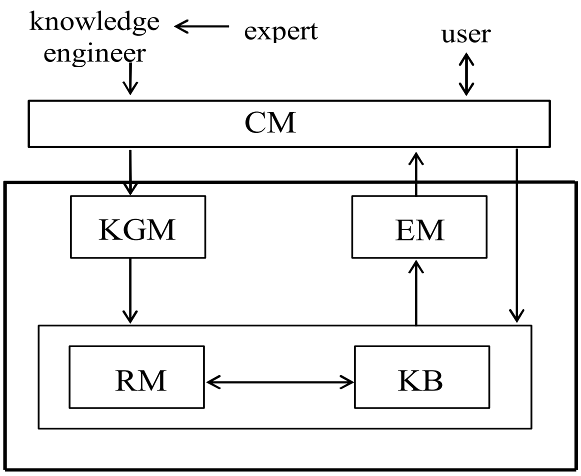


Figure 1. The structure of expert system (Sojak and Głowacki, 2005)

The modules presented in figure 1 have the following functions:

– gathering module (KGM) allows to obtain reasoning rules from an expert in a given area.
– Communication module (CM), i.e. the interface) allows to have an 'intelligent conversation' with the user both in the process of obtaining knowledge (knowledge engineer) as well as during the presentation and explanation of the method of solving the problem (user).

Communication module (interface) and the explanation module allow the user to communicate with the system, input data and understand the reasoning process. Facts and statements made by the user when the problem is solved may contain probabilistic uncertainty or may indicate the lack of knowledge. The expert system may provide multi-variant solutions (Sojak and Trajer, 1999).

The system of authorization prevents unauthorized users from changing the application source code. The following user categories can be distinguished by the system:

- system administrator: authorized to make changes in the source code of the application created based on the SPHINX shell system, modify the knowledge base, add / delete users and change data about the users.
- knowledge engineer: authorized to modify the source code the application created based on the SPHINX shell system, in particular, to extend or change the structure of the knowledge base,
- user of the developed application: can run the application, is not authorized to modify the source code or the knowledge base.

Results

Figure 2 presents a diagram of a system facilitating the identification of vegetable pests and supporting decision concerning the appropriate method of pest control during the vegetation period. The system consists of the expert system, which recognizes the pests, and analyzes and selects appropriate control methods as well as the database in the form of text files which contain additional explanations (Fig. 3). The paper describes how the system works on the example of red beet. The database of the expert system -"DSS – pest control" contains i.a. the information about the pesticides used to control red beet pests, the application method and the recommended dosage. The database may be further extended by adding other than chemical methods of pest control.

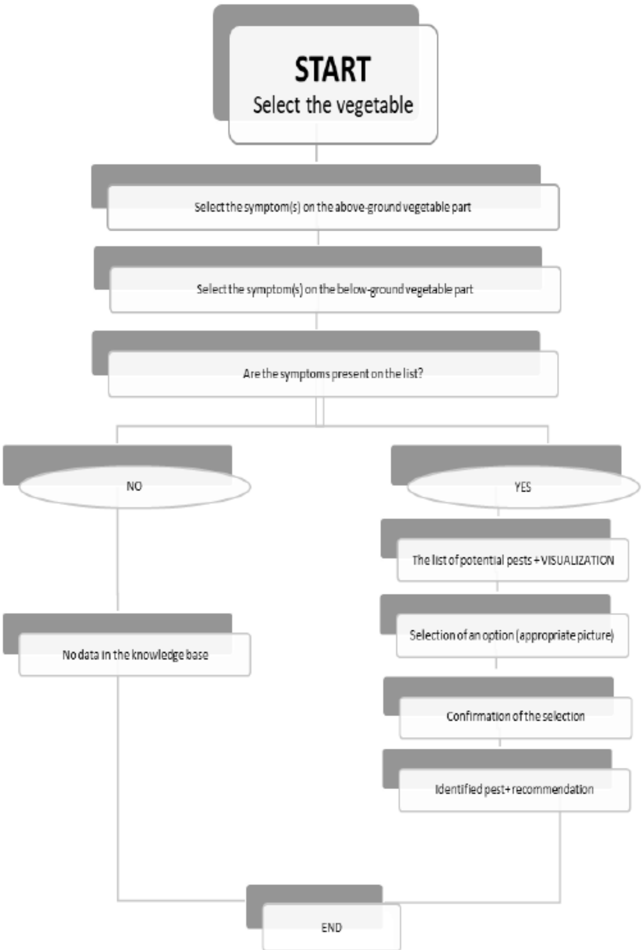


Figure 2. A diagram of the expert system - "DSS – pest control" recognizing pests

The user of the expert system - "DSS – pest control" needs to answer the following questions: in the first stage the user selects the diagnosed vegetable, in the second stage, the user selects the symptom or symptoms on the above-ground vegetable part, in the third stage, the user selects the symptom or symptoms on the below-ground vegetable part.

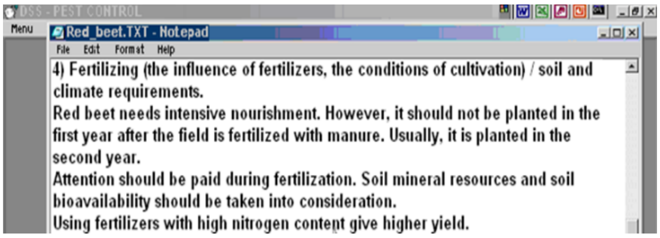


Figure 3. Knowledge databases - text files with additional explanations in "DSS – pest control"

If the pest kind can be identified based on the symptoms (identification is unequivocal), a window containing the name of the pest and its picture appears (Listing 1). Obtaining the same diagnosis is also possible if the user enters incomplete data during the dialogue with the application "DSS – pest control" (e.g. when the user of the application inputs the following data: vegetable: "red beet"; symptoms_on_beet_leaves: "no"; symptoms_on_beet_roots: "eaten-out holes". Then, the developed application connects "matching" symptoms (selected by the user) in the appropriate reasoning rule and the solution for the symptoms selected in this way is the appearance of the window with the pest responsible for the damage. In the discussed case it is the rule for the turnip moth (Agrotis segetum). Such property of the developed application is obtained by means of implementation of the appropriately con-structed rules.

```
Element:  rule
Rule no:  2015
Definition:
  identification = "turnip moth (Agrotis segetum)" if
     vegetable = "red beet"
     and symptoms_on_beet_leaves = "no"
     and ( symptoms_on_beet_roots = "eaten-out holes"
     or  symptoms_on_beet_roots = "drying out of roots" );
```

Listing 1. The code introducing the rule for the pest called the turnip moth (Agrotis segetum)

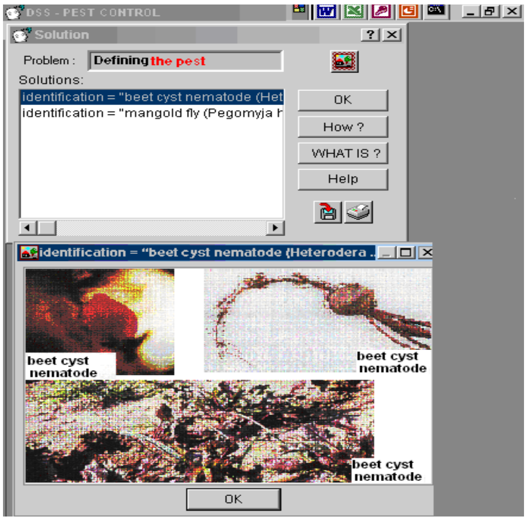


Figure 4. The visualization of the suggested solution for the beet cyst nematode

If it is not possible to unequivocally identify the pest (the second case), a window with the list of several pests potentially responsible for the damage appears together with their illustrations (Fig. 4 and listing 2) and the program goes to stage 4 - the selection of the appropriate picture. If the combination of symptoms is not listed in the knowledge base, the window containing the information 'no data in the knowledge base' appears (Fig. 5) (e.g. when the user of the application inputs the following data: vegetable: "red beet"; symptoms_on_beet_leaves: "no"; symptoms_on_beet_roots: " no ").

Element: rule
Rule no: 2017
Definition:
identification = "mangold fly (Pegomyja hyosciami Panz.)" if
vegetable = "red beet"
and (symptoms_on_beet_leaves = "leaves yellowing"
or symptoms_on_beet_leaves = "irregular spots "
or symptoms_on_beet_leaves = "dying-out"
and (symptoms_on_beet_roots = "no"
or symptoms_on_beet_roots = "I don’t know");
Element: rule
Rule no: 2018
Definition:
identification = "beet cyst nematode (Heterodera schachtii)" if
vegetable = "red beet"
and (symptoms_on_beet_leaves = "leaves yellowing"
or symptoms_on_beet_leaves = "dying-out")

and (symptoms_on_beet_roots = "beard-like roots (small, numerous roots in the thickened area)"
or symptoms_on_beet_roots = "I don’t know");

Listing 2. Code introducing the rules for the pests called the mangold fly (Pegomyja hyosciami Panz.) and beet cyst nem-atode (Heterodera schachtii)

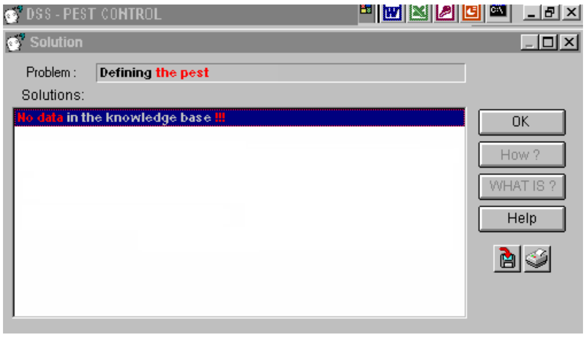


Figure 5. Dialogue window containing the information 'no data in the knowledge base'

Visualization allows to make the final selection. Having obtained the solution it is possible to get the detailed description of the pest (what is it?), and, more importantly, the suggestions concerning pest prevention and control using the method recommended by the system (extended explanation - a metaphor) (Fig. 6). Some data contained in the metaphors were presented in section 4 in the form of tables.

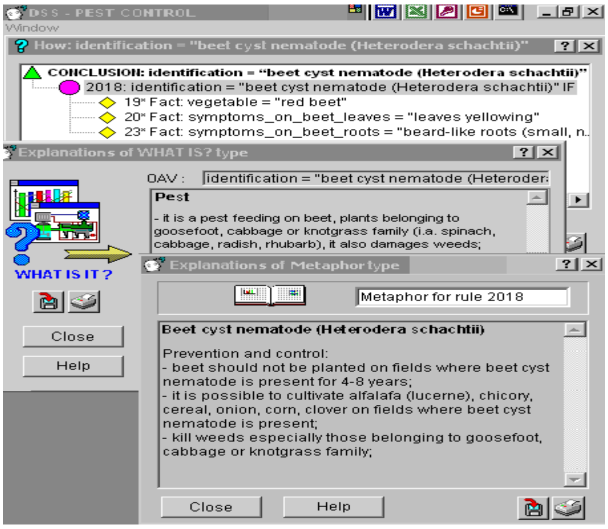


Figure 6. The description of the suggested method of the identified pest control

For each of the pest, the rule contains the identified results of its feeding in the form of the description of the damage made to the leaves and roots. Different pests may cause different symptoms but there are also many symptoms that are typical of many different pests. In these cases, it is difficult to identify the pest (the second case that was described).

When the user of the application selects the theoretically contradictory symptoms e.g.: vegetable: "red beet"; symptoms_on_beet_leaves: "no", "irregular spots"; symptoms on beet roots: "no", "drying out of roots" the developed application connects "matching" symptoms (selected by the user) in appropriate reasoning rules and the solution for the symptoms selected in this way is the appearance of the window with the list of pests potentially responsible for the damage. In the discussed case these are rules selected for the turnip moth (Agrotis segetum) and mangold fly (Pegomyja hyosciami Panz.).

It is possible that both in the described case (the second case) where symptoms typical of many pests appear, as well as in the case of contradictory symptoms (the above case) the developed system, “DSS – pest control”, will return a few pests potentially responsible for the damage and these will all (100%) be the pests that infested the crop at the same time.

The information "spots appear on leaves" is much 'poorer' than the images showing these spots and their shape, size and color. Information contained in the multimedia - image is much more effective than the description. Therefore, the “DSS – pest control” expert system was equipped with images of pests as well as damage they are responsible for.

Eleven reasoning rules were implemented in the developed expert system for pest identification.

The attributes symptoms_on_beet_leaves and symptoms_on_beet_roots were implemented in the control block. The code is presented in listing 3. Val someof – means that the user of the application may choose from a few values; ask yes - a question asked by the “DSS – pest control” system during the dialogue with the user.

```
Element:  attribute
Attribute name:  symptoms_on_beet_roots
Type:  symbolic
Definition:
  symptoms_on_beet_roots :
    ask     yes
    query   "Choose [B symptom[b(s)_on_beet_roots"
    val someof
    {
      "eaten out holes",
      "drying out of roots",
      "scabby,dark brown,  cork-like cracks in the skin",
      ……………………………………………………….,
      "no",
      "I don’t know",
      "beard-like roots (small, numerous roots in the thickened area)"
    };
Element:  attribute
```

```
Attribute name:  symptoms_on_beet_leaves
Type:  symbolic
Definition:
  symptoms_on_beet_leaves :
    ask     yes
    query   "Choose [Bsymptom[b(s)_on_beet_leaves"
    val someof
    {
      "no",
      "round spots",
      "dark brown spots",
      "necrotic spots",
      "spots with silvery-grey centre",
      "spots with red-dark brown edge",
      "spots with the inside crumbling away",
      ……………………………………….,
      "leaves yellowing",
      "dying out",
      "irregular, light spots"
    };
```

Listing 3. The code introducing symptoms_on_beet_leaves and symptoms_on_beet_roots in the developed system

The individual elements denote: [B – attribute of the font - bold, [b – cancellation of bold font.

Pest identification was based on the list by Nieć (1989) and Robak (1998).

```
begin
setSysText(problem,"Defining [B[1the pest");
setSysText(notConfirmed,"[B[1No data [b[0in the knowledge base [B[1!!!");
solutionWin(yes);
solve( diagnosis,"identification=X");
delNewFacts;
end;
```

Listing 4. Code that starts the process of diagnosis in the developed system

The individual elements denote: [B – attribute of the font - bold, [b – cancellation of bold font, [1 - font colour - red, [0 - font colour - white.

Part of the control block of the developed application concerning red beet pests - “DSS – pest control” was presented in listing 4.

The designed expert system has the protection preventing the formation of contradictions. After entering a new search criterion (which is used to recognize red beet pest) the value (X) selected for a given criterion is deleted from the list (delNewFacts;) and a new list of available values is made (listing 4).

The expert system "DSS – pest control" facilitating the identification of red beet pests helps to identify eleven most common pests based on the symptoms (on the leaves and on the root) as well as on the basis of the pictures of pests. Table 2 presents the list of these pests and their Latin equivalents.

Table2.
The list of pests contained in the Knowledge Base of the designed expert system

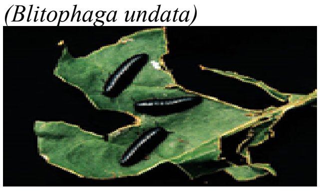
Pest	Latin equivalent
Turnip moth	*Agrotis segetum*
Black bean aphid	*Aphis fabae*
Pygmy mangel beetle	*Atomaria linearis*
Beet carrion beetle	*Blitophaga undata*
Beet root weevil	*Bothynoderes punctiventris*
Beet tortoise, tortoise beetle	*Cassida nebulosa*
Mangold flea beetle	*Chaetocnema concina*
Click beetle	*Elateridae*
Beet cyst nematode	*Heterodera schachtii*
Mangold fly	*Pegomyja hyosciami Panz.*
Beet leaf bug	*Piesma quadrata*

Table 3 contains sample information about four pests, their pictures, descriptions of symptoms caused by the pests and the method of prevention and control.

Table 3.
Pests, description, symptoms, control

Pest	Latin equivalent
Turnip moth (*Agrotis segetum)* 	***Description*** *Large, 30-60 mm long and about 5 mm thick caterpillar of a moth, grey, brownish and grey or olive green in color. They curl up into a ball when touched.* ***Symptoms*** *They damage the above-ground and the below-ground part of the vegetable by destroying young plants, which have 2-3 leaves, in the spring. They may eat the whole plants and destroy a large area. In older plants cutworms of turnip moth make holes in beet roots, which destroys them. When the roots are bigger, later in the summer, they eat out big holes in beet roots. The damage may result in the roots being infected by microorganisms causing diseases, which leads to additional loses during storage due to decay.* ***Control*** *The most important method of controlling and reducing the number of turnip moths is skimming, performed just after the harvest and deep ploughing in the fall. Ploughing waste places and idle lands decreases considerably the population of this pest. If the pest occurs, use the pesticides listed in table 3.*

Beet carrion beetle
(Blitophaga undata)



Description
The beetles are dull black and have coarse wings with visible ribs. Larvae are black and as big as grown-up beetles. They overwinter in dry grasses, under dry plant residue, in forest duff and in moss.
Symptoms
It damages the above-ground part of the plant. Both beetle and larvae can damage plants by making big, irregular-shaped holes in leaves. It may lead to complete skeletonizing of leaves.
Control
Make sure that the red beet growth is fast, vigorous, and undisturbed. Kill weeds. Remove carefully the remaining red beets from the field after harvest. Use registered pesticides, e.g. Decistab TB.

Beet tortoise, tortoise beetle
(Cassida nebulosa)

Description
It has a flat, shield-shaped body. The beetle length is up to 7 mm. It is olive-green or light brown from above with black irregularly shaped spots.
Symptoms
It damages the above-ground part of the plant. Both larvae and grown-up beetles damage leaves. First, they eat out small 'windows' in the underside of the leaves. Then, they eat out holes in leaves. Huge number of pests may completely skeletonize leaves leaving only veins.
Control
Killing weeds belonging to the goosefoot family is a very important method of prevention. If large numbers of the pests appear, spray the field with the appropriate pesticide.

Mangold fly
(Pegomyja hyosciami Panz.)

Description
The adult mangold flies are up to 7 mm long with greyish or grey-greenish bodies. They lay small white elongated eggs, approximately 1 mm long. Eggs are laid in clusters, attached to the undersides of leaves. The larvae are legless, cream-colored, and up to 8 mm long.
Symptoms
They attack the above-ground part of the plant.
Larvae burrow into the leaves and live between the upper and lower surfaces, eating out large, irregular-shaped spots in the leaves.
Control
Early sowing or planting, appropriate method allowing for the steady growth of plants, spraying the field with Bioczos 2 or 3 times (at seven-day intervals) at sprouting of plants (vegetables), keeping the plantation free of flowering weeds and those belonging to the goosefoot family reduces the damage to a large extent. When beets have 2-3 appropriate leaves, pesticides from table 3 should be used.

After the identification of the pest, the user may obtain additional information included in the Explanations called Metaphors that are gathered in the Base of Metaphors. The Base of Metaphors contains the knowledge about prevention against as well as control of the pest identified by the system. Table 4 contains selected data on the basis of which the Base of Metaphors was built.

Table 4.
Pesticides and treatments recommended for the red beet protection against pests - selected information included in the Base of Metaphors

Pest	**Method/date of treatment**	**Pesticide/dose/waiting period (days)**	
Turnip moth, Click beetle	apply directly to soil after harvest, before sowing or planting	Alfamor 050 SC / (0.3 l / ha) / 7 Alfazot 050 EC / (3 l / ha) / 7 Ammo 250 EC / (0.12 l / ha) / 14 Basudin 25 EC / (1.0 l / ha) / 9 Basudin 600 EW / (0.4 l / ha) / 9 Basudin 10 GR / (40-60 kg/ha) / 60 Decis 2.5 EC / (0.3 l / ha) / 7 Decistab TB / * / 7	Diazol 250 EC / (1.0 l / ha) / 9 Owadofos Extra 480 EC / (2.5 l/ha) / 30 Patriot 2.5 EC / (0.3 l / ha) / 7 Pyrinex Extra 480 EC / (2.5 l / ha) / 30 Ripcord Super 050 EC / (0.3 l /ha) /7 Sherpa 100 EC / (0.3 l /ha) / 14 Diazinon 10 GR / (40-60 kg/ha) / 60
Black bean aphid	spray plants after first aphid colonies are noticed	Basudin 25 EC / (0.9 l/ha) / 9 Basudin 600 EW / (0.35 l/ha) / 9 Bioczos BR / ** / 0 Diazol 250 EC / (0.9 l/ha) / 9 Fyfanon 500 EC / (1.2 l/ha) / 7	Pirimor 500 WG / (0.35 kg/ha) / 7 Sumithion 500 EC / (0.9 l/ha) / 14 Sumithion 1000 EC / (0.45 l/ha) / 14 Zolone 350 EC / (0.9 l/ha) / 15
Beet carrion beetle	spray plants when first beetles appear or when damage is noticed	Basudin 25 EC / (0.9 l/ha) / 9 Basudin 600 EW / (0.35 l/ha) / 9 Decis 2.5 EC / (0.3 l / ha) / 7	Decistab TB / * / 7 Diazol 250 EC / (0.9 l/ha) / 9
Beet tortoise, tortoise beetle	apply directly to soil, after harvest, before sowing or planting	Diafuran 5 GR / (15 kg/ha) / 30 Furadan 5 GR / (15 kg/ha) / 30	Owadofos Extra 480 EC / (2.5 l/ha) / 30

Pest	Method/date of treatment	Pesticide/dose/waiting period (days)	
Mangold fly	spray plants when most eggs are laid and at the beginning of the larvae hatching period	Basudin 25 EC / (0.9 l/ha) / 9 Basudin 600 EW / (0.35 l/ha) / 9 Diazol 250 EC / (0.9 l/ha) / 9 Fyfanon 500 EC / (1.2 l/ha) / 7	Owadofos 480 EC / (0.9 l/ha) / 14 Sumithion 500 EC / (2.5 l/ha) / 30 Sumithion 1000 EC / (0.45 l/ha) / 14 Zolone 350 EC / (0.9 l/ha) / 15

* - (12 – 16 tablets / ha), **- (2-4 cubes/1 liter of water/ 10 running meters row)

It should be remembered that pesticides (including insecticides) ought to be used according to the instructions on the label of each product as inappropriate use may have serious consequences for the people's health , animals and for the environment.

The Base of Metaphors also contains information about insecticides used to control the above-mentioned soil pests. They may be divided into five groups depending on the form of the formulation (Table 5).

Table 5.
The list of insecticide types - selected information included in the Base of Metaphors

Group	Use	Insecticide
Seed dressings	Use just before sowing	Gaucho, Cruiser, Montur, Diafuran, Furadan
Concentrates for making water emulsion	Spray the entire field or parts 3 days before sowing	Durban, Pyrinex
Granular formulation	Spray the entire field prior to sowing/planting or spray the rows during sowing or planting	Basudin, Diazinon
Soluble concentrates	Spray when beets have 1-2 appropriate leaves	Vydate
Concentrated or granular formulations (for making water solution)	Spray the field, used to control turnip moth in the early stages of the pest development	Alfamor, Alfazot, Alphaguard, Afphatop, Ammo, Basudin, Decis, Decistab, Diazinon, Diazol, Fastach, Karate, Patriot, Ripcord, Sherpa

Evaluation

As mentioned in section 2 (Toolls - SHINX), the system uses backward reasoning (on the basis of Modus Tollens - Latin modus tollendo tollens - rule: goal - rules - facts). Thus, the rules on which the reasoning process is based, belong to so called reliable reasoning rules. Therefore, rules used in the reasoning process are tautologies. A tautology is a statement that is always true, which results from its form (it is a statement that is true in any non-void domain (Wolniewicz, 1997). Thus, some authors of decision support systems (Molina-Martinez and Ruiz-Canalez, 2009) only perform verification instead of validation.

Assumptions used to design the rules of the expert system “DSS – pest control”:

(i) facilitating the reasoning - allowing the facts and statements input by end-users contain probabilistic uncertainties or they may lack knowledge,

(ii) reasoning rules must consist of the smallest possible number of facts - the emphasis on fast diagnosis of the pest.

These assumptions (i, ii) demand that uncertainty be introduced in some rules such as (e.g. "I don't know", "I think so") and that the number of facts, on which the expert opinion was based, be decreased. Therefore, it was decided to repeat the verification of the rules prior to including them in the system. The system was verified by five experienced researchers from the Department of Plant Genetics, Breeding, and Biotechnology, Warsaw University of Life Sciences (SGGW). Correctness of reasoning rules was equal 100%.

Moreover, the system verification was achieved by systematic testing of the functionality of all its components during the implementation phase (Kaloudis et al., 2010). Having finished the implementation of all the rules and other components of the expert system, it was evaluated. The evaluation was conducted by:

– ten other researchers from the Department of Plant Genetics, Breeding, and Biotechnology, Warsaw University of Life Sciences (SGGW),
– thirty students of the above-mentioned Department (last-year students),
– three experts in expert systems,
– by a group of fifteen farmers.

The following criteria were evaluated: effectiveness, usefulness, understanding of questions and user friendliness, and the outcome were presented as a percentage, from 0 to 100%.

Table 6.
The average results of “DSS – pest control” system evaluation (%)

Group	Effectiveness	Usefulness	Understanding	Friendliness
Researchers	95	97	100	99
Students	100	99	100	98
Experts of ES	Not relevant	Not relevant	Not relevant	100
Farmers	98	100	97	100

Similar evaluations of decision support systems were performed by Mahaman (2002, 2003), Gonza-lez-Andujar (2006), Kaloudis (2010).

To sum up the results, the designed expert system received very good marks (table 6). The obtained results, especially among students and farmers indicate high demand for such applications. This paper presents the use of expert systems in a new area of red beet crop protection against pests.

Conclusions

The designed decision support system “DSS – pest control” may be used by individual vegetable growers. It may also serve as an educational program, e.g. for students who want to find out more about the specific areas of knowledge as well as for scientists and researchers.

The system allows to obtain opinion in the process of communication with the system, visualizes the solutions and provides support during each stage in the form of extended explanation module. The "DSS – pest control" expert system may be further extended e.g. by adding new pest control methods by the users: system administrator and knowledge engineer of the application "DSS – pest control". In addition, versions in other languages may be created.

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SYSTEM EKSPERTOWY WSPOMAGAJĄCY PODEJMOWANIE DECYZJI W PROCESIE ZWALCZANIA SZKODNIKÓW WARZYW W OKRESIE WEGETACJI

Streszczenie. Artykuł przedstawia system komputerowy wspomagający identyfikację szkodników warzyw podczas procesu wegetacji, a także sposób jego działania na przykładzie buraka czerwonego. Celem było opracowanie systemu ekspertowego ułatwiającego identyfikację szkodników oraz zaproponowanie odpowiedniej metody ich zwalczania. Wypełnienie bazy wiedzy informacjami odnoszącymi się do wąskiego obszaru wiedzy zamienia system ekspertowy w system w danej dziedzinie wiedzy. System składa się z systemu ekspertowego oraz bazy danych w postaci plików tekstowych, które zawierają dodatkowe wyjaśnienia. Użytkownik systemu ekspertowego - "DSS – zwalczanie szkodników" musi odpowiedzieć na następujące pytania: w pierwszym etapie użytkownik wybiera diagnozowane warzywo, w drugim etapie użytkownik wybiera objaw lub objawy na nadziemnej części warzywa, w trzecim etapie użytkownik wybiera objaw lub objawy na podziemnej części warzywa. Zaprojektowany system wspomagania decyzji ("DSS – zwalczanie szkodników") może być stosowany przez indywidualnych plantatorów warzyw. Może również służyć jako program edukacyjny, np. dla studentów, którzy chcą pogłębić swoją wiedzę, może być także pomocny dla naukowców i badaczy.

Słowa kluczowe: wspomaganie decyzji, system ekspertowy, identyfikacja szkodników, burak czerwony, inżynieria mechaniczna