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EXPERT SYSTEMS AS A TOOL FOR DECISION SUPPORT IN INTEGRATED PEST MANAGEMENT

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ABSTRACT

An offer of the existing expert systems (ES) for crop production in our country is presented. It was established that the recommendation decision support systems in plant protection are ES-like, since they comprise components typical of ES. The DSS formulate recommendations solving problems concerning justification of protective treatments. Thus such DSS behave similarly to the ES. The availability of the information from the ES in plant protection is still scant in our country. It is necessary to develop new ES for the most important crops. Interpretation of the EU provisions allowed stating the need of presenting the integrated pest management issues in a wider scope of the integrated crop production. The multifaceted scope of these issues calls for a multidisciplinary handling of the ES development: cooperation of agronomists, phytopathologists, plant-protection specialists, meteorologists, economists, agricultural advisers, farmers as well as specialists in databases, software engineering, artificial intelligence, etc.

Introduction

The Common Agricultural Policy (CAP) of the European Union has been executed in Poland since 2004. The main priority of the CAP is providing the EU citizens with food safety and attaining sustainable development of agriculture with particular attention to the environment. In recent years a lot of attention has been paid to limit excessive use of pesticides in agriculture (Duer et al., 2004).

Pursuant to applicable law, crop protection products must be used according to the integrated pest management principles (Wolny, 2012), which requires specialist knowledge on the biology of pests and the host, environment, crop protection products properties, etc. Using all available pest management methods, especially non-chemical ones, is one of the main principles of the integrated pest management (IPM). The non-chemical methods do not completely eliminate the population of pests, but they limit their development and favourably influence the biological balance, which favours natural mechanisms of protection against pests (Wolny, 2012; Zaliwski, 2013a). Another important principle is a rational selection of the crop protection product preceded by a detailed analysis of the crop condition. The analysis should include the variety susceptibility, growth stage of plant and pest, the size of the infection source, atmospheric conditions, properties of the protection product, rotation of products with various action mechanisms, and occurrence of pest forms resistant to particular crop protection products (Nieróbca et al., 2010; Zaliwski 2013a). The need to include so many factors makes the integrated pest management difficult to be used by specialists, especially if several diseases infest the crop simultaneously (Urnańska et al., 2010; Zaliwski, 2013a). In many European countries, including Poland, IT tools are more and more often used for decision support in crop protection (Lipa, 1999; Hosstgaart and Wolny, 2002; Mahaman et al., 2003; Thomson and Willoughby, 2004, Kozlowski et al., 2011). Complex systems in the form of interactive computer programs, which use databases and algorithms, are created. Also, systems for many users which transfer information on the need to perform a treatment directly to a farmer via the Internet and SMS are very popular (Hosstgaart and Wolny, 2002; Nierobca, 2009). Nowadays, dynamically developing neural processing techniques create new analytical opportunities. Artificial neural networks can analyse not only the numerical data collections which come e.g. from experimental research, but also fuzzy sets, which is characteristic of a human brain. The research carried out on the use of neural techniques in agricultural practice shows great possibilities for their use in the integrated pest management (Boniecki, 2007).

The objective of the paper is to describe the offers of expert systems for decision support in integrated pest management and to indicate possible trends of their development.

Legal basis for integrated pest management

Issues concerning the pest management were regulated in detail by Directive 2009/128/EC of the European Parliament and of the Council of 21st October 2009, which sets forth the frames for the community operation for the sustainable use of pesticides, and the Regulation of the European Parliament and of the Council (EC) no. 1107/2009 of 21st October 2009 concerning the placing of plant protection products on the market and repealing Council Directives 779/117/EEC and 91/414/EEC. The Member States of the European Union are obliged to introduce the integrated pest management not later than on the 1st January 2014 (Wolny, 2012). Regulation 1107/2009 EC (art. 1 and 55 and enclosure III) determine general guidelines for using crop protection products, according to the integrated pest management principles.

According to the EU documentation, general principles of IPM are as follows:

1. Non-chemical methods are favoured over chemical methods if they ensure a sufficient protection against pests.
2. The non-chemical methods except for biological, physical and mechanical protection treatments include:
   a) the use of crop rotation,
   b) the use of relevant agrotechnology,
   c) the use of resistant or tolerant varieties as well as qualified seeds and planting stock pursuant to the provisions on seed production,
   d) the use of the sustainable fertilization, liming, irrigation and melioration,
   e) the use of substances which prevent introduction of harmful organisms,
   f) creation of conditions which favour beneficial organisms and their protection,

g) preventing the spread of harmful organisms through the use of phytosanitary means, such as regular cleaning of cultivation machines and tools,
h) the use of crop protection products in a way which limits the risk of harmful organisms' resistance.

The above principles show that full implementation of the IPM is not possible without placing it in the context of the integrated crop production management.

The expert system in plant protection

The expert system (ES) is generally a computer information system which uses the expert knowledge for solving complex problems within a narrow field with a result not worse than one reached by a human expert (Mulawka, 1996; Turban et al., 2010). Basic elements of the expert system are as follows (Boniecki, 2007):
1. Knowledge base, which includes knowledge necessary to solve problems.
2. An inference engine (inference means determination of new facts from the knowledge base and the set of initial facts, declared by the expert system user).

Except for those two basic elements in the ES there are auxiliary elements:
1. Permanent and variable database.
2. The system which explains the strategy of the inference leading to a solution.
3. The knowledge base editor.
4. The user interface.

In the early expert systems "if-then" rules were used for storing knowledge. Second generation ESs combine various methods of knowledge representation and inference, e.g. "if-then" rules with fuzzy logic, neural networks or genetic algorithms (Turban et al., 2010).

If the solutions provided by the ES are designed for decision support, then it becomes a decision support system. And reversely, a DSS may integrate the results obtained from many ESs or include only some components of the ES in its architecture. The use of ESs for decision support is limited to specific problems and is preconditioned by the following assumptions (Kisielnicki and Sroka, 2005):
– decision must depend on the well defined set of variables,
– values assumed by these variables must be known,
– the impact of particular variables on the decision must be known,
– the problem must have solutions, which may be defined at the beginning,
– the inference logic is determined in advance,
– the expert is able to articulate the manner of solving the problem.

In the ES for the integrated pest management, the knowledge base includes practical knowledge acquired as a result of long-term experience and the results of the most recent research. It should also include the applicable law. Construction of such a system requires the cooperation of integrated protection experts and of modelling and IT specialists. In the integrated pest management, the ES in a "pruned" form may be used for decision support, where, through the interface, the user usually has an access only to the solutions of the problem provided in the form of recommendations. The system which explains the inference strategy is omitted and only administrators use the knowledge base. The ESs operating in the integrated pest management may be defined as open expert systems: they are supplied with the current weather data processed by the advanced mathematical models and rules, which constitute their knowledge base. In plant protection, mathematical models constitute a very valuable tool for determination of recommendations, since, due to the mathematical description of decision options and their results, the selection of the optimal option is possible from among a great number of choices. That usually exceeds the skills of an expert on account of the time limit. These systems, however, require thorough hand-on experience to get acquainted with the principles of their operation. Therefore, simplicity – easy operation and interpretation of results – is the main principle in designing agricultural ES. The implementation and maintenance of the system and its further development require constant inflow of current data, improvement and development of new models, modernization of software, etc. Success in making the system popular depends on the relevant advertising and training (Skwarcz, 2009; Zaliwski, 2013b).

Deployment of expert systems in practice

The rules of integrated pest management are successfully implemented in horticultural crops and orchards, particularly those under cover. In the nineties, which was the initial period of IPM implementation, human expert knowledge was mainly used. At present, more and more often meteorological DSSs equipped with components typical of expert systems, as well as actual ESs, are used. The system of early signalling in the protection of apple orchards against apple tree scab *Venturia inaequalis* is an example of a meteorological DSS intended for on-farm operation (Doruchowski, 2005). An algorithm which determines the probability of infection and the date of a preventive anti-fungi treatment is based on the criteria of the modified Mill's table. It includes air temperature and humidity, precipitation, and the time of leaf moistening. Another system "SadEkspert" includes almost all fruit tree varieties and enables recognition of approx. 120 of the most important pests. They are presented in the form of pictures, and the database of the program contains over 70 products against pests and diseases (Boniecki, 2007).

For crops under cover, where environment may be controlled much better, special guidelines for the integrated pest management were developed. They allow efficient reduction of pests with simultaneous sustainable use of pesticides. The guidelines may be easily implemented due to such expert systems as ES "Integrated cultivation of tomato under cover", which was developed at the Institute of Horticulture (Adamicki et al., 2013). This system, among few others in Poland, was made available on the Internet for free-of-charge use. It enables the determination of the causes of the observed disorders with regard to the growth and development of the tomato plant caused by non-infectious agents, as well as the causes of damages to plants by fungi, bacteria, virus diseases and pests. The user session starts with a selection of the key, which enables determination of the above-mentioned agents. Using the key comes down to answering either "Yes" or "No". After the agent has been recognized, the user can read a description and look at the pictures of particular disorders or damages in order to confirm the diagnosis and recommendations for prevention and control of the observed irregularities.

Another ES is designed for recognizing beetroot pests in the vegetation period and enables the user to determine a suitable method of their control. Decision assumptions were developed here in the form of rules and facts and a photographic knowledge was made available in the multimedia form: pictures, sounds and film sequences. The user carries out a dialogue with the system. The system may connect with external modules to extend its repertoire of the presented information. For groups specializing in vegetable growing, the Internet is an important source of obtaining and transferring agricultural information (Cupiał, 2010).

For large area crops an advisory system "Rzepinfo" was developed. It enables complex protection of the winter rapeseed plantation (Kozłowski and Weres, 2007). Rzepinfo may provide information on the varieties of winter rapeseed, seed dressing, pests and diseases, which cause the greatest damage, crop protection products, etc. It supports identification of pests based on their morphological structure and diseases based on characteristic damages to plants, enables selection of varieties, crop protection products and supports planning of protection treatments. For Rzepinfo system, fast identification methods with regard to pest and diseases of winter rapeseed were developed, using decision trees. They do not require specialist knowledge.

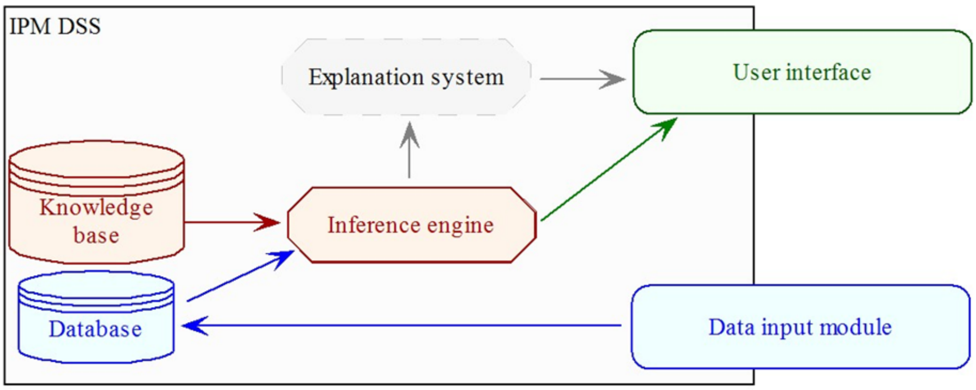


Figure 1. Architecture of the Internet integrated pest management decision support system (IPM DSS)

"The Internet integrated pest management decision support system" (IPM DSS) is an example of the DSS which uses almost all components of the expert system except for the explanation system (fig. 1). Work on the system development has been initialized at IUNG in Puławy in 2001 in cooperation with the Danish Institute of Agricultural Sciences, which provided prototypes of disease models (Hosstgaart and Wolny, 2002). Moreover, the following institutes participated in the project: IOR [Institute of Plant Protection] in Poznań as well as IHAR [Plant Breeding and Acclimatization Institute] in Radzików and Bonin, and it was supported by PIORiN [State Inspection of Plant Protection and Seed Science] in Warsaw, LODR [Lublin Agricultural Advisory Centre] in Końskowola and IMGW [Institute of Meteorology and Water Management] in Poznań. The cooperation resulted in the development of the Polish version of the system (components concerning cereals and potato protection) and its verification in Polish conditions (Wolny et al., 2003; Horoszkiewicz-Janka et al., 2005). The main assumption of the IPM DSS (2013) is a precise use of economic thresholds in the models of diseases in order to generate recommendations concerning the need to carry out a treatment. Economic thresholds were verified in field experiments in various environmental conditions for various diseases (Horoszkiewicz-Janka et al., 2005; Wolny et al., 2005). Moreover, the system enables an interactive access to information on varieties and crop protection products, included in the databases. Figure 2 presents the sequence of analyses in the system.

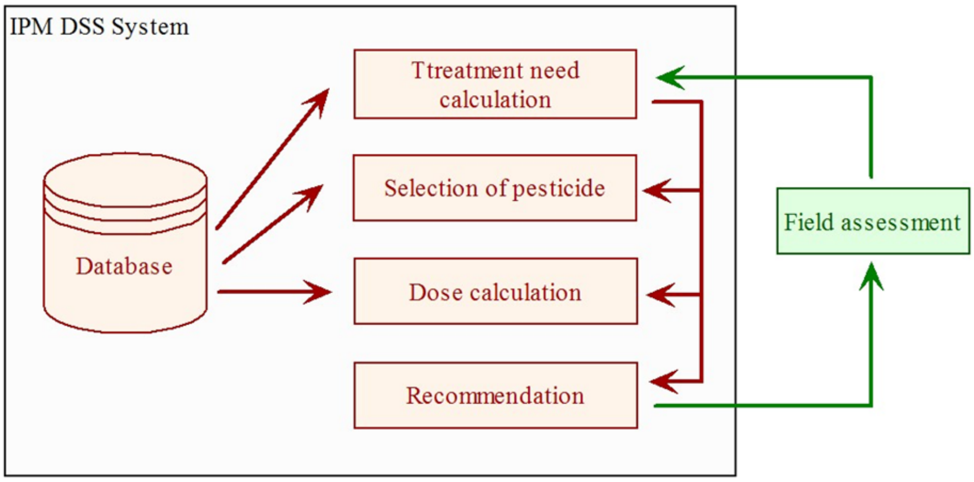


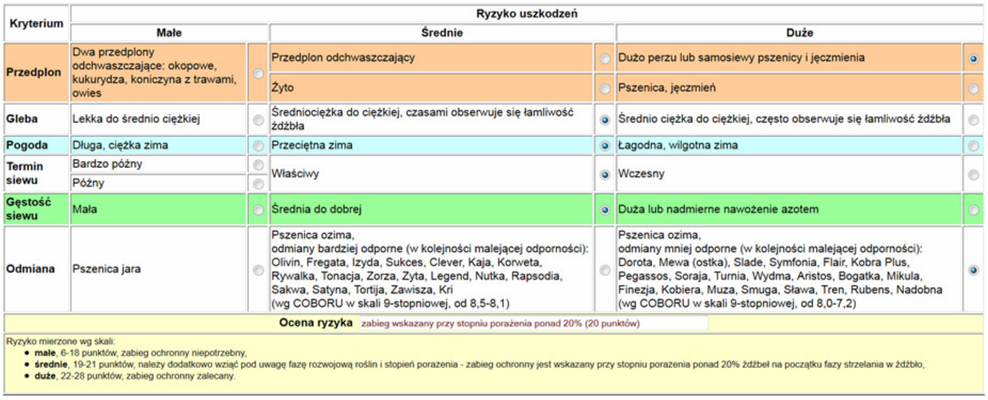
Figure 2. The sequence of operations performed in the Internet Pest Management Decision Support System

The most important elements included in the IPM DSS are:

- growth stage of cereals (acc. to Zadok),
- infection degree (number of plants with symptoms of infection expressed in %),
- variety resistance to disease,
- weather conditions,
- effectiveness of pesticides.

For determination of the date of performing the first treatment against potato late blight, the IPM DSS includes the internet application which implements the "Negative prognosis" model. The system generates daily and accumulated risk values, compiled in a table from the day of potato emergence to the day of simulation. Operation of the application consists in the selection of two parameters: the date of potato emergence and the locality of the meteorological station closest to the potato field.

The webpages of the IUNG-PIB [Institute of Soil Science and Plant Cultivation – State Research Institute] include also models for determination of the need to carry out a protective treatment against eyespot and septoria of winter wheat (Zaliwski and Nieróbca, 2007; Zaliwski and Nieróbca, 2010). Recommendations concerning the protection treatment depend on the calculated risk of crop damage, representing a resultant impact of various factors (fig. 3). The risk of damage is measured against the scale of three values: small, average and high. In these models and in all models of the IPM DSS, representation of knowledge with the use of rules "if-then" was used.



Kryterium	Ryzyko uszkodzeń: Małe	Średnie	Duże
Przedplon	Dwa przedplony odchwaszczające: okopowe, kukurydza, koniczyna z trawami, owies	Przedplon odchwaszczający	Dużo perzu lub samosiewy pszenicy i jęczmienia
		Żyto	Pszenica, jęczmień
Gleba	Lekka do średnio ciężkiej	Średniociężka do ciężkiej, czasami obserwuje się łamliwość źdźbła	Średnio ciężka do ciężkiej, często obserwuje się łamliwość źdźbła
Pogoda	Długa, ciężka zima	Przeciętna zima	Łagodna, wilgotna zima
Termin siewu	Bardzo późny Późny	Właściwy	Wczesny
Gęstość siewu	Mała	Średnia do dobrej	Duża lub nadmierne nawożenie azotem
Odmiana	Pszenica jara	Pszenica ozima, odmiany bardziej odporne (w kolejności malejącej odporności): Olivin, Fregata, Izyda, Sukces, Clever, Kaja, Korweta, Rywalka, Tonacja, Zorza, Zyta, Legend, Nutka, Rapsodia, Sakwa, Satyna, Tortija, Zawisza, Kri (wg COBORU w skali 9-stopniowej, od 8,5-8,1)	Pszenica ozima, odmiany mniej odporne (w kolejności malejącej odporności): Dorota, Mewa (ostka), Slade, Symfonia, Flair, Kobra Plus, Pegassos, Soraja, Turnia, Wydma, Aristos, Bogatka, Mikula, Finezja, Kobiera, Muza, Smuga, Sława, Tren, Rubens, Nadobna (wg COBORU w skali 9-stopniowej, od 8,0-7,2)
Ocena ryzyka	zabieg wskazany przy stopniu porażenia ponad 20% (20 punktów)		

Ryzyko mierzone wg skali:
- **małe**, 6-18 punktów, zabieg ochronny niepotrzebny,
- **średnie**, 19-21 punktów, należy dodatkowo wziąć pod uwagę fazę rozwojową roślin i stopień porażenia - zabieg ochronny jest wskazany przy stopniu porażenia ponad 20% źdźbeł na początku fazy strzelania w źdźbło,
- **duże**, 22-28 punktów, zabieg ochronny zalecany.

Figure 3. Interactive application to assess the risk of Pseudocercosporella herpotrichoides infection (www.dss.iung.pulawy.pl/Documents/ior/pseudocercosporella.html)

Conclusion

The Polish agriculture is presently at the stage of implementation of the integrated pest management principles. The use of the IPM cannot be effective without the use of innovative solutions, such as expert systems, which allow exhaustive analysis of a decision situation based on the local data. Currently, the offer of expert systems with regard to the integrated pest management is still quite poor in our country. Of the few ESs offered most are available as one-user systems, but there are also ESs for many users available on-line. The existing DSSs in the integrated pest management use components of expert systems. It results from the fact that obtaining information for formulating a recommendation requires solving a problem on the treatment justification. Solving such problems lies within the field of expert systems application.

In order to meet the requirements of the EU, there is a great need to carry out work on the expert systems in the integrated pest management for the most important crops in the country. They must take into account the context wider than the plant protection, including issues of the integrated crop production. Multi-faceted nature of these issues requires a multi-disciplinary approach at the development of knowledge bases – cooperation of agronomists, phytopathologists, plant protection specialists, meteorologists, economists, etc. as well as practicioners: agricultural advisers and agricultural producers. Ensuring high technological standard in this field requires the cooperation of computer specialists: database developers, software engineers, specialists in artificial intelligence, etc.

References

Adamicki, F., Kropczyńska-Linkiewicz, D., Nawrocka, B., Owczarek, M., Ślusarski, Cz., Viscardi, T. (2013). *Integrowana uprawa pomidora pod osłonami.* Obtained from: http://www.inhort.pl

Boniecki, P. (2007). System ekspertowy wspomagający procesy decyzyjne w produkcji roślinnej. *Technika Rolnicza Ogrodnicza Leśna*, *5*, 22-24.

Cupiał, M. (2010). Wykorzystanie źródeł informacji w gospodarstwach rolniczych małopolski o różnym kierunku produkcji. *Inżynieria Rolnicza*, *4*(122), 37-42.

Doruchowski, G. (2005). Elementy rolnictwa precyzyjnego w ochronie roślin. *Inżynieria Rolnicza*, *6*(66), 131-138.

Duer, I., Fotyma, M., Madej, A. (2004). *Kodeks Dobrej Praktyki Rolniczej*. Wyd. Min. Rolnictwa i Rozwoju Wsi, Min. Środowiska, Warszawa, ISBN: 83-88010-58-1.

Dyrektywa 2009/128/WE. Dziennik Urzędowy Unii Europejskiej, L 309/71-85. (2009). Obtained from: http://eur-lex.europa.eu/.

Horoszkiewicz-Janka, J., Nieróbca, A., Czembor, J.H., Sikora, H. (2005). Porażenie pszenicy ozimej przez grzyby chorobotwórcze w zależności od zastosowanej strategii ochrony. *Postępy w Ochronie Roślin*, *2*(45), 708-711.

Hosstgaart, M. B., Wolny, S. (2002). Założenia duńskiego sytemu w ochronie roślin i możliwość jego wdrożenia w Polsce. *Postępy w Ochronie Roślin*, *1*(42), 283-290.

Kisielnicki, J., Sroka, H. (2005). *Systemy informacyjne biznesu.* Warszawa, Wydawnictwo Placet, ISBN 83-85428-94-1.

Kozłowski, R.J., Weres, J., Rudowicz-Nawrocka, J. (2011). *Komputerowe systemy wspomagania decyzji w zarządzaniu gospodarstwem rolniczym*. Ekspertyza. UP w Poznaniu, Poznań. Obtained from: http://www.agengpol.pl/

Lipa, J.J. (1999). Nowoczesna ochrona zbóż. *Pamiętnik Puławski*, *1*(114), 241-259.

Mahaman, B.D., Passam, H.C., Sideridis, A.B., Yialouris, C.P. (2003). DIARES-IPM: a diagnostic advisory rule-based expert system for integrated pest management in Solanaceous crop systems. *Agricultural Systems*, 76, 1119-1135.

Model *Pseudocercosporella Herpotrichoides*. (2007). Puławy, IUNG-PIB,. Obtained from: http://www.dss.iung.pulawy.pl.

Mulawka, J. (1996). *Systemy ekspertowe*. Warszawa, WNT, ISBN-8320418909.

Nieróbca, A. (2009). Systemy wspomagania decyzji w ochronie roślin jako element Integrowanej produkcji. *Studia i Raporty IUNG-PIB*, *16*, 31-44.

Skwarcz, J. (2009). Założenia systemu eksperckiego do sterowania procesem produkcji zbóż. *Inżynieria Rolnicza*, *9*(118), 235-240.

System IPM DSS. (2013). Puławy, IUNG-PIB. Obtained from: http://www.ipm. iung.pulawy.pl.

Thomsona, A.J., Willoughby, I. (2004). A web-based expert system for advising on herbicide use in Great Britain. *Computers and Electronics in Agriculture*. *42*, 43-49.

Turban, E., Sharda, R., Delen, D. (2010). *Decision Support and Business Intelligence Systems*. Pearson/Prentice Hall, 9th ed., ISBN 978-0-13-610729-3.

Urbańska, M., Gierszal, H., Nowacki, M. (2010). System wsparcia decyzji w ochronie roślin uprawnych. *Inżynieria Rolnicza*, *7*(125), 223-228.

Wolny, S. (2012). Integrowana ochrona roślin a integrowana produkcja roślinna – nowe regulacje prawne oraz program krajowego planu działania 2013-2018. *Wybrane problemy integrowanej ochrony kukurydzy oraz zbóż w warunkach północno-wschodnich regionu Polski.* Program Wieloletni Instytutu Ochrony Roślin – PIB 2011–2015. Obtained from: http://www.ior.poznan.pl.

Wolny, S., Horoszkiewicz-Janka J., Sikora, H., Kapsa, J., Zaliwski, A., Nieróbca, A., Kozyra, J., Domaradzki, K. (2005). Wyniki prac badawczych i adaptacyjnych nad polskim internetowym systemem wspomagania decyzji w ochronie roślin w 2003 roku. *Postępy w Ochronie Roślin*, *1*(44), 513-522.

Zaliwski, A., Nieróbca, A. (2007). Internetowy system wspomagania decyzji do oceny ryzyka występowania *Pseudocercosporella herpotrichoides*. *Postępy w Ochronie Roślin*, 2(47), 358-390.

Zaliwski, A.S. (2013a). *Integrowana ochrona roślin. System doradztwa w zakresie zrównoważonej produkcji roślinnej*. IUNG-PIB Puławy. Obtained from: http://www.dss.iung.pulawy.pl /Documents/manual/doc/ior/integ.o.r.htm.

Zaliwski, A.S. (2013b). *System wspomagania decyzji jako źródło informacji. System doradztwa w zakresie zrównoważonej produkcji roślinnej*. IUNG-PIB Puławy. Obtained from: http://www.dss.iung.pulawy.pl/Documents/ipr/DSSasInfoSource.html.

Zaliwski, A.S., Nieróbca, A. (2010). Przedstawienie systemu wspomagania decyzji do określania potrzeby zabiegu przeciw septoriozie plew pszenicy (*Septoria nodorum*). *Postępy w Ochronie Roślin, 4*(50), 1837-1840.

SYSTEMY EKSPERTOWE JAKO NARZĘDZIA WSPIERAJĄCE DECYZJE W INTEGROWANEJ OCHRONIE ROŚLIN

Streszczenie. Przedstawiono istniejącą w kraju ofertę systemów ekspertowych (SE) dla produkcji roślinnej. Stwierdzono, że rekomendacyjne systemy wspomagania decyzji (SWD) w ochronie roślin są SE-podobne, ponieważ wykorzystują komponenty właściwe systemom ekspertowym. SWD formułują zalecenia rozwiązując problemy dotyczące zasadności wykonania zabiegu ochronnego, zachowują się więc podobnie jak SE. Dostępność informacji pochodzącej z SE w zakresie integrowanej ochrony roślin jest jeszcze w naszym kraju niewielka. Konieczne jest opracowanie nowych SE dla najważniejszych upraw. Interpretacja przepisów UE pozwoliła stwierdzić potrzebę ujęcia zagadnień integrowanej ochrony roślin w szerszym kontekście integrowanej produkcji roślinnej. Wieloaspektowość zagadnień integrowanej produkcji roślinnej wymagać będzie multidyscyplinarnego podejścia do budowy SE: współpracy agronomów, fitopatologów, specjalistów od ochrony roślin, meteorologów, ekonomistów, doradców rolniczych, producentów rolnych, a także specjalistów od baz danych, inżynierii oprogramowania, sztucznej inteligencji, itd.

Słowa kluczowe: system ekspertowy, system wspomagania decyzji, integrowana ochrona roślin, integrowana produkcja roślinna