Expert system application: the smart tools for citrus pest and disease management

S Wuryantini1*, Harwanto1, O Endarto1 and R C Wicaksono1

1 Indonesian Citrus and Subtropical Fruits Research Institute Jl. Raya Tlekung No. 1 Jl. Raya Tlekung No. 1 Junrejo, Batu, Jawa Timur 65301, Indonesia

*Email: susi_wur@yahoo.com

Abstract. Expert system technology of the citrus pest and diseases was created by Indonesian Citrus and Subtropical Fruits Research Institute (ICSFRI). This technology was developed to overcome problem with delayed disease monitoring. If the pest attack was not immediately resolved, it would cause more serious damages to the plant and would cause decreasing in the quantity and quality of the citrus yield. In order to anticipate the delay in control, an observation or monitoring carried out during the critical period of the plant was necessary to be done. This technology was in the form of a web-based or android-based program or software application system that was used to monitor citrus pest and disease. The use of this expert system application had been validated in several citrus center areas in Indonesia, i.e. Jember and Banyuwangi, East Java; Sambas - West Kalimantan; Barito Kuala - South Kalimantan and Bangli - Bali. Observation using this application, the data of pest and diseases status at a certain time and location were automatically be recorded in the system and immediately would be known whether or not the control was needed. Thus, the use of this technology as a tool for monitoring citrus pests and disease can be used as a reference for Early Warning System on citrus pest and disease control.

1. Introduction
Agricultural sector plays an important role in the development of economic sector in Indonesia. Therefore, crop productivity must be maintained to be stable or even increased in agribusiness. In the development of technology and facing the industrial era 4.0, the agriculture sector must also follow it with technological innovations in solving problems that arise. One area that is often an obstacle in agribusiness is the presence of pests and diseases. Citrus become the national flagship commodity in Indonesia, however, high consumption has not been supported with sufficient product, so there are still many imported products. Researcher [1] reported that citrus farming is economically profitable for farmers after 2 fruiting periods, therefore certain areas show a very striking addition of planting area. Consequently, increasing the existing area is expected to be a production leverage to reduce imports. In addition, optimal plant maintenance in order to control pests and diseases is very important, because the main factor of low citrus productivity in Indonesia was caused by pests and diseases. The causes high frequency of citrus pests and diseases in Indonesia include the using of unlabelled seeds as free of disease, poor plant maintenance, late monitoring and so on. It is known that there are at least 12 kinds of major pests and 17 kinds of...
diseases that attack citrus plants in Indonesia, starting from seedling to harvest period [2]. Monitoring or observation of citrus pests and diseases is the first step to find out the presence of pest and disease attacks, hence, this is important to do as an effort to prevention and control. New innovation for monitoring citrus pest and diseases is by using the expert system application. The design and establishment of the expert system application was made on a web-based.

In general, the technology components are grouped into 2 categories, namely conventional technology and information technology (computer science). The computer-based information technology that was used to solve certain problems is usually referred to as expert system technology [3]. The development of computer-based information technology seems to have a very broad spectrum, one of which is in agriculture. One effort to overcome pest problems is the use of expert system technology to monitor pest population level in the field [4].

As an illustration, expert system technology has been widely used in agriculture, for example, it is used for irrigation, plant simulation, and crop management [5, 6]. Specific expert system technology for pests and diseases on crops other than citrus plants have been used, such as on vegetable crops (shallots), estate crops (coffee), rice, patchouli, and soybean [7-14].

The expert system application for monitoring citrus pest and diseases was made to provide information on pests and diseases of citrus plant in the form of symptoms descriptively or visually based on images. Then, this information was used as the main content of the application used for monitoring. Applications that were made also provided solutions to pest problems found in the field based on observations made. Thus, the application was expected to be able to assist farmers in monitoring plants and addressing existing citrus pest problems, so that the risk of crop damage and lost yield can be anticipated.

This application was made based on the web, so that it can be easily accessed by users, such as farmers, officers, or citrus agribusiness practitioners. The application was made by using the inference method, which was the forward chaining. The design of this expert system application was created by using PHP and the Mysql database, which were easily accessible and lightweight methods.

2. Methods
The design of an expert system application for monitoring citrus pest and disease was compiled by combining several fields of science, i.e. information, computer and plant pest and diseases. The process started by making a concept about the group of information that would be displayed in the application. A database which came from several references and images was then compiled based on the grouping system. In general, the design process of the expert system can be explained as follows.

2.1. Design analysis.
This was to design an expert system software used to monitor populations and incidence of citrus pests and diseases in the field. The expert system component that was designed consisted of several parts, including:

- **User interface.** This is a guidance to direct the users to the problem search flow until solution found. The problem referred to the development of the target pest population of citrus plants in the field.
- **Inference engine (forward and backward chaining).** This part of an expert system is used for forward and backward reasoning towards information or data coming in with a rule-based list. Monitoring results that were entered into the system included: plant parts that are attacked, types of target pests and diseases, symptoms occurred, descriptions of the affected plants accompanied by pictures, methods of controlling and so on.
- **Knowledge database.** Knowledge representation from an expert in the form of a rule-based system composed of facts, objects, and information. All information held by an expert must be contained in the system. The more complete the information compiled in the system, the more precise the execution results to be obtained. The knowledge of the target pests on citrus plants used for the study was included as thoroughly as possible as input data on the system to be implemented (Fig 1)
2.2. Initiation of system implementation

A system that was designed with several parts of the system cannot work well if a preliminary test has not been carried out by simply implementing some of the information inputted on the system. There were at least 3 parts of the system to be implemented, namely master data input (main pest types / target pests, symptoms of attacks, rules, experts, identification, consultation), database systems (used to store and retrieve data), expert systems (calculation systems with Naive Bayes), the process of

**Figure 1.** Flowchart of design analysis.

**Figure 2.** Flowchart of implementing system.
calculating input data and system output (type of pest, number, number of samples, economic threshold, and technical control (Fig. 2).

2.3. Testing system.
To find out the accuracy of the system designed in the expert system by implementing the real conditions in the field, a test was necessary to be conducted. The approach of expert system testing was by 2 methods, namely the results of calculations with input data obtained from the field which were tested manually/expertly, and the results of calculations of input data calculation method by Naive Bayes. The results of the 2 methods of testing were then observed for the level of accuracy. Furthermore, the results of the data collection were obtained. Based on the test results, a conclusion or decision related to the target pest would be obtained (Fig. 3).

![Flowchart of testing system](image)

**Figure 3.** Flowchart of testing system.

2.4. Technical implementation in the field
The technical implementation of the research was conducted by the use of a map or the spread of citrus plants. Data collection methods used sampling techniques or systematically adjusted to the existing land conditions. Decisions on target pest and diseases control were based on economic thresholds that have been included in the expert system. The data obtained were tabulated, observed for the frequency of occurrence, and then calculated on average.

3. Results and discussion
Based on the design that have been made, the application of citrus pest and diseases expert system was arranged with the composition of the homepage, guidelines, pest and diseases, expert system, expert results and the drafting team.

The component of web-based expert system for main citrus pest and disease consisted of 6 parts, namely the homepage, system usage guidelines, system rule of the main pest, expert system, expert results, and the drafting team. Each part had a specific function. In detail, each part was shown in Figs. 4 to 8.

The home page (Fig. 4) was part of the front page of an expert system program in citrus pest and disease. This part contained short information about the arrangement of the menu and a brief description of the application, and displayed the contact address of the expert system developer. In the initial stages, the design of this expert system used web-based applications, then along with the times and information technology (IT), an Android-based program can be used. Expectedly, this would facilitate users (stake holders) to use it while in the field.
The system guide menu (system tutorial) (Fig. 4b) contained a complete information on how the program was run. Without understanding how the program run, the user could experience difficulties during implementation in the field. Therefore, this system guide must be socialized to users at the initial stage. To enable the users to use this application, they must register by completing data in the column provided (Fig. 5). Furthermore, for observations, there were several forms that must be completed, i.e. monitoring location, varieties of citrus, age of citrus plant, number of monitoring samples, the execution of observations, observation results, and leaving the system. Those points were an illustration of the importance of understanding the system guidelines. The system guide was also made in the form of videos in the hope of making it easier for users to operate.

In order to know that the expert system compiled can be used or can be implemented, there must be pest and disease object data used as a model included in the system rules. The types of pests selected as the expert system model were made up of ten types, these were citrus psyllid, citrus aphids, scale...
insects (3 types), mites (3 types), thrips, fruit flies, citrus leaf miner, fruit borer, citrus pock caterpillar, and citrus mealybug, and 6 types of diseases, namely Huanglongbing, Diplodia, shooty mold, powdery mildew, citrus cancer and citrus scab (Fig. 6).

This pest and disease section contained detailed information related to the symptoms of the attack, the plant part that was attacked, the economic threshold of each type of pest, and how to control. Symptoms of attacks of each type of pest or disease were described descriptively and were equipped with pictures of symptoms at different severity. Expert database input included in the application design system was used as material for grouping in accordance to the rules in the program created. Each content created based on the rules could be opened by pressing the button as per the information needed.

The observation or monitoring form section was able to be opened by pressing the expert system button. This section was the core of the expert system application made. From this section, all information were processed according to the data entered. The data that must be filled in included: location, position / place - then the latitude and longitude were automatically informed, elevation, the varieties of citrus, plant age, and number of observations. All information inputted would provide the appropriate data at the time of the observation or the data was real time (Fig. 7).

The expert system results section was the information that had been processed in the expert system application. The data inputted on the form of number of observations were captured or processed into status information of each type of pest and diseases found at the time of monitoring. The results of the observations made was the status of the attack of citrus pests and diseases at a certain location at a certain time. In the observation results, there were instructions for making a decision whether the pest population conditions in the field required a controlling action or not. The status of pests was clearly seen by considering the economic threshold of each kind of pest and diseases. When the results indicated status that the pest needed to be controlled, then proceed with pressing the control method button, and the pest control instructions would appear in accordance to the results obtained (Fig. 8).
The design team of the expert system came from various disciplines, including: plant protection, information technology, programmers, information networks, and field technicians. Each team had tasks and functions according to their knowledge. Those in plant disease discipline were in charge for preparing a rule system related to the types of pests and diseases used as models, symptoms of diseases, economic threshold, and controlling techniques.

This expert system application program had been validated in several regions of Indonesian citrus production centers (East Java, Bali, West Kalimantan and South Kalimantan) for application
evaluation involving officers and farmers. From the validation process, there were a lot of feedbacks obtained from the users. The feedback was used as material for evaluation and improvement in the design and development of citrus pest and diseases expert system applications.

This expert system application technology had several advantages, such as easy to apply, and direct monitoring tool (real time) on condition of citrus pest and diseases status in the production center. The results of the observations that contained pest attack status from specific locations and time periods could be used as an Early Warning System in managing citrus pests and diseases. If the results obtained indicated that the pest disease status was above the control threshold, control instructions can be seen by pressing the control method button. By immediately taking control measures, further crop damage resulting in economically losses yield could be avoided.

4. Conclusion
Citrus pest and disease expert system was an application for monitoring citrus pest and disease in the field that was easy to use. Observation results by this application showed the status of citrus pests and disease in certain locations in real time. The results of monitoring that indicated the status of the pests and disease was above the economic threshold could be immediately anticipated by exercising control contained in the application, so as to reduce crop damage and yield loss.

References
[1] Zaman L, Harwanto and Utomo J S 2013 Analisis Outcome Benih Jeruk Bebas Penyakit (Malang: Balitjestro)
[2] Dwiasutti M E, Triwiratno A Endarto O, Wuryantini S and Yunimar 2011 Pengenalan dan Pengendalian Hama dan Penyakit Tanaman Jeruk. Balai Penelitian Tanaman Jeruk dan Buah Subtropika (Jakarta: Badan Litbang Pertanian)
[3] Kusrini 2006 Sistem Pakar Teori dan Aplikasi (Yogyakarta: Andi Offset)
[4] Rahmawati Y 2009 Online Expert System for Pest Indentification at Orange Plants (Surabaya: STIKOM)
[5] Rafea A 1995 Integrating Agricultural Expert Systems with Data Bases and Multimedia Central (Egypt: Laboratory for Agricultural Expert System)
[6] Pinter Jr PJ, Hatfield J L, Schepers J S, Barnes E M and Moran M S 2003 Remote Sensing for Crop Management (Nebraska: USDA Agricultural Research Service – Lincoln – Nebraska University of Nebraska – Lincoln)
[7] Ginanjar, Sasmito W, Bayu, Surarso, Aris and Sugiharto 2011 Aplikasi Sistem Pakar Untuk Simulasi Diagnosa Hama dan Penyakit Tanaman Bawang Merah dan Cabai Menggunakan Forward Chaining dan pendekatan Berbasis Aturan (Semarang: Diponegoro University)
[8] Angkie A 2008 Aplikasi Sistem Pakar Untuk Mendiagnosis Penyakit Pada Tanaman Kopi Dengan Metode Forward Chaining (Surabaya: STIKOM)
[9] Honggowibowo A S 2009 Telkomnika 7(3) 187-194
[10] Sofa R, Destiani D and Susanto A 2012 Pembangunan Aplikasi Sistem Pakar Untuk Diagnosis Penyakit Tanaman Padi Algoritma (Garut: Sekolah Tinggi Teknologi Garut)
[11] Sembiring A S 2013 Sistem Pakar Diagnosa Penyakit dan Hama Tanaman Padi (Medan: STMIK Budi Darma Medan)
[12] Nurhidayati U 2010 Sistem Pakar Untuk Diagnosa penanggulangan Penyakit dan Hama Pada Tanaman Nilan (Yogyakarta: AMIKOM)
[13] Sain H, Kamal R and Sharma A N 2012 International Journal of Information Technology 8(1)
[14] Roja A 2012 Design and Implementation of Expert System Application Program for Soybean Plant Major Pests Diagnosis Informatika Pertanian 21