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Expert system for identification of economically important insect pests in commercial teak plantations

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A B S T R A C T

Homogeneous teak plantations in Brazil occupy large areas with genetically close plants, which may favor insect pests. The insect pests can reduce the quantity and quality of wood produced. The identification of insects at early stages is important to prevent its spread. The objective of this study was to develop an expert system to identify, with mobile smartphones as inference engine, economically important insects attacking commercial teak plantations. The expert system developed (ENTOTECA) proved to be an appropriate technology to identify 23 insects of economic importance at the species level, through a practical and easy interface, usable by any common man. The use of ENTOTECA is aligned with the forest certification that requires the identification of insects before the control decision-making process.

1. Introduction

Commercial teak plantations (*Tectona grandis* L.f.) are established in 88,270 ha in Brazil during 2013 and are expanding because of the high commercial value of teak timber and also due to the favorable climatic conditions for its development (ABRAF, 2013). Homogeneous and extensive forest plantations favor insect pests such as leaf-cutting ants and defoliating Lepidoptera (Zanuncio et al., 1998, 2002). Pest outbreaks in these crops are mainly due to increasing area planted and climate changes that alter the importance of insects as pests (Guedes et al., 2000; Medeiros et al., 2003).

Insects, including *Hyblaea puera* (Cramer, 1777) (Lepidoptera: Hyblaeidae) which is one of the main pests, caused losses of up to 44.1% in volume in teak plantations in India (Nair and Mohandas, 1996). Leaf cutting ants, especially the genus *Atta*, defoliate many plants (Zanetti et al., 2003) and can cause damage to forest plantations in Brazil (Zanetti et al., 2014).

Expert systems are like intelligent computer programs that use knowledge and inference procedures (a process by which new facts are derived from known ones), to solve problems in a particular area (Waterman, 1986) that requires human expertise for their solution (Harmon and King, 1988). These programs are composed of a knowledge base and an inference machine or processor that produce conclusions or decisions (Genaro, 1986).

The design of an expert system involves the steps of evaluating the problem, knowledge acquisition, design, testing, documentation, and maintenance (Durkin, 1994). The most sensitive part to develop and use an expert system is the acquisition of knowledge (Bittencourt, 1998) from an expert. In this process, the engineer helps the expert to articulate their experience for decide the best way to structure this knowledge (Genaro, 1986). Expert systems broaden the horizons and maximize the solution of academic problems and tasks that can be developed (Liao, 2005).

Expert systems are intended to assist in the diagnosis of diseases and locating mineral deposits, among other applications. The Pest Expert System (PEST), a basic prototype system of expert knowledge, was developed in the 1980s to identify insect pests and recommend its control in annual crops in Australia (Clocksin and Mellish, 1984). An expert system can quickly identify insect pests, and combined with control recommendations, reduce losses by insects in agricultural production (McKinion and Lemmon, 1985).

The identification of insects at early stages is important because forest managers have limited actions for their management and if their populations expand, the environmental impact of chemical

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Table 1
Order, family, species, and place of insects occurring on teak plants included in the knowledge base (SE) ENTOTECA.

Order	Family	Species	Place
Isoptera	Termitidae	*Syntermes molestus*	Nursery and field
Isoptera	Rhinotermitidae	*Heterotermes* sp.	Field
Isoptera	Kalotermitidae	*Coptotermes testaceus*	Field
Coleoptera	Lagriidae	*Lagria villosa*	Nursery
Coleoptera	Curculionidae	*Naupactus fatuus*	Field
Coleoptera	Curculionidae	*Pantomorus* sp.	Field
Coleoptera	Curculionidae	*Parapantomorus fluctuosus*	Field
Coleoptera	Curculionidae	*Teratopactus nodicolis*	Field
Hemiptera	Aphidae	*Aphis spiraecola*	Field
Hemiptera	Pentatomidae	*Nezara viridula*	Field
Hemiptera	Pseudococcidae	*Maconellicoccus hirsutus*	Nursery and field
Hemiptera	Pentatomidae	*Piezodorus guildinii*	Field
Hemiptera	Pentatomidae	*Edessa meditabunda*	Field
Lepidoptera	Saturniidae	*Dirphia rosacordis*	Field
Lepidoptera	Eucleidae	*Miresa clarissa*	Field
Lepidoptera	Psychidae	*Oiketicus geyieri*	Field
Lepidoptera	Noctuidae	*Spodoptera cosmioides*	Field
Lepidoptera	Noctuidae	*Spodoptera eridania*	Field
Lepidoptera	Noctuidae	*Agrotis repleta*	Nursery
Orthoptera	Gryllidae	*Gryllus assimilis*	Nursery
Hymenoptera	Formicidae	*Atta sexdens*	Nursery and field
Hymenoptera	Formicidae	*Atta laevigata*	Nursery and field
Hymenoptera	Formicidae	*Acromyrmex subterraneus subterraneus*	Nursery and field

Table 2
Questionnaire and performance criteria applied to perform the sensory analysis of SE.

Questions	Answers	Evaluator
Teak growing area	Nursery or field	Research
Time for damage diagnosis	Time (min)	
Plant injury characterization	Injury description	
Insect pest identification time	Time (min)	
Correct identification of the causal insect name	Common and scientific name	
Is the ES is easy to use?	Yes or not	Interviewee
Did the screen size made it difficult to identify insect and damage?	Yes or not	
Did the images and texts help to find the damage and to identify the insect correctly?	Yes or not	
If you could make improvements in the ES what would change?	Image quality, arrangement and size of the tabs, text content and color	
What do you think of the ES interface?	Better, Good and Bad	
What note would you give to the ES?	Scale of zero to 10	

control over large areas may be unacceptable (Kaloudis et al., 2005).

Entomologists must feed the expert system with information, photos, and situations to identify with a high degree of confidence, the causative organism of damage to forest plantations and help managers in decision making. The expert system should be simple to use and easy to handle by professionals with different education levels. Smartphones with a storage capacity and processing similar to personal computers (Gutierrez et al., 2011) can be used in experts systems in field such as forest plantations.

The objective of this study was to develop an expert system named ENTOTECA for using in mobile handheld devices with Android operating systems to identify insects of economic importance in teak commercial plantations in Brazil. This system is an auxiliary tool in the integrated management of forest pests for extension workers and forest teak farmers and as a complementary learning for forestry students.

Fig. 1. (a) Device developed to validate the sensory analysis; (b) insects view to be identified; (c) magnifier.

2. Materials and methods

2.1. Expert system

The expert system (SE) ENTOTECA was developed for Android operating system (version 2.3 or higher) on smartphones facilitating mobility and accessibility. This system was developed in personal computer processor Intel Celeron CPU 560–2.13 GHz, 2 GB of RAM, and Windows® 7 operating system in the municipality of Cáceres, Mato Grosso, Brazil. SE was created in HTML environment 5 (Hyper Text Markup Language) using the Sublime Text 2.0 software (used to write the app), jQuery 1.9® (JavaScript Library), and PhoneGap (creating mobile applications).