SCIENTIFIC REPORT submitted to EFSA

Models for pest's epidemiology: review, documentation and evaluation for Pest Risk Analysis (Mopest)

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Abstract

The main objectives of the Mopest project (acronym of Models for pest's epidemiology: review, documentation, and evaluation for Pest Risk Analysis) were to carry out a review and to produce an inventory of the models describing the establishment, development, and / or spread of plant pests on crops in Europe. This inventory should support the EFSA Panel on Plant Health in providing independent scientific advice on the risk of the spread, establishment, or development of organisms (plant pests) harmful to plants, plant products, or biodiversity; therefore, the inventory considers those models that can be potentially used for accurate and robust quantitative prediction of pest risk through the use of variables related to climate and / or plant growth and development as input factors. A protocol was developed for reviewing literature sources describing models relevant to the Mopest project. This protocol includes: i) a search strategy for retrieving information sources; and ii) a series of descriptors (metadata) that describe each source. The search strategy was developed according to the principles of the "systematic literature review". About 200 metadata were defined for describing each model included in the inventory; international standards and codes were used whenever possible. The protocol was implemented in a user-friendly web-portal. The web-portal was designed to facilitate the on-line entry of new models and the on-line modification or updating of the existing ones. The web-portal also makes it possible to search the models within the inventory by using both basic and advanced search procedures, and to summarize results in a clear and concise way. A database was developed containing models related to wheat pests and quarantine pests for Europe as listed in the EPPO A1 list. About 200 models were entered in the web-based portal.

Summary

The main objectives of the Mopest project were to carry out a review and to produce an inventory of the models describing the establishment, development, and/or spread of plant pests on crops in Europe. This review considers the models that could be potentially used for accurate and robust quantitative prediction of pest risk through the use of climate and / or plant growth and / or development data as input factors. This inventory should support the EFSA Panel on Plant Health in providing independent scientific advice on the risk of the spread, establishment, or development of organisms (plant pests) harmful to plants, plant products, or biodiversity.

A protocol was developed for reviewing sources that describe models of interest for Mopest (i.e., peer-reviewed journals, proceedings, reports from competent authorities/organizations, web-sites, and computer programs) so that the reviews are structured, transparent, and efficient. This protocol includes: i) a search strategy for retrieving information sources; and ii) a series of descriptors (metadata) that describe each source. The search strategy was developed according to the principles of the "systematic literature review". In particular, guidelines for

identifying sources for potential inclusion in the Mopest were defined; these guidelines consist of: i) a clearly stated set of objectives with pre-defined eligibility criteria; ii) a systematic search strategy that attempts to identify all sources that would meet the eligibility criteria. The search strategy was a structured searching based on four successive components: what, where, words, and the working method. “What” refers to phrasing the search assignment correctly so as to focus the search on the needed information. “Where” refers to identifying the bibliographic resources where the search must be performed. “Words” refers to selecting the search-words. “Working method” refers to the method to be adopted for searching and reviewing sources. About 200 descriptors (metadata) were defined for describing each source; international standards and codes were used whenever possible. Some of the metadata are mandatory while others are optional. A metadata was also included to allow the users to include their notes and observations on the proper uses or limitations of the models they have personally used.

The protocol was implemented in a user-friendly, web-based portal. The portal was designed for on-line entry of new models (new to the inventory) and for the on-line modification or updating of models previously entered into the inventory. The web-portal also makes it possible to search the models within the inventory by using both basic and advanced search procedures, and to summarize results in a clear and concise way. Oracle was used as the Database Management System, and Oracle Application Express (Apex) was the programming language. The Mopest web-portal is accessible to authorized users by any computer equipped with a web browser. Two types of users can access the web-portal: standard users and power users, the latter being authorised to perform all the typical actions of a database management administrator. A User’s Manual was developed that describes all the functionalities of the Mopest web-portal.

A database was developed containing models related to 11 pests of wheat and to the quarantine pests for Europe as listed in the EPPO A1 list. About 200 models were entered in the web-based portal. These models were retrieved from the CAB Abstracts database (from 1972 to 2008), which was accessed by means of the Millennium Web Catalogue of the Università Cattolica.

Key words: pest risk assessment, model, quarantine pests, systematic literature review, web-based inventory

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Background

The spread, establishment, or development of organisms harmful to plants, to plant products, or to biodiversity could have great economic or social consequences. The prevention of introduction of plant pests into the European Community is a mayor task of the EC-directive 2000/29/EC, which defined protective measures. Plant models combining climatic data and plant growth and development with the characteristics of plant pathogens or insect pests may also provide valuable information about the potential spread, the establishment, or the development of the harmful organisms. The use of geographical, meteorological, climatic, and / or remote sensing data is a well-established technique for producing risk maps and has already been applied to plant health situations.

Unfortunately, the methods and terminology used for plant pest risk assessment vary widely, and there is an ongoing development of new modelling approaches (EFSA 2008a,b; USDA 2007). Thus, there is a growing need for: i) assessment, documentation, and classification of pest risk models; ii) exploration of possible map representations of pest risks; iii) description of evaluations and uncertainties of the existing models; and iv) requirements on input data and parameters for future applications.

Concerning the first point (i) in the previous paragraph, EFSA called for proposals (CFP/EFSA/AMU/2008/01, “Systematic review of pest risk models using climatic data and plant phenology”) to establish an inventory of quantitative models describing the spread, establishment, or development of plant pest on crops in Europe, with climatic data and / or plant phenology to be included as input factors.

Terms of reference

EFSA sought proposals for establishing an inventory of quantitative models describing the spread, establishment, or development of plant pests on crops in Europe including geographical, climatic data, and / or plant phenology as input factors. According to the call for proposals, the inventory work should focus on model structure, used parameters, and data sets rather than on concrete applications for specific diseases, pests, or crops. To restrict the inventory to the most applicable models for actual predictive measurements, only models including climatic data and / or plant phenology as input factors should be considered.

So that information about different models can be compared and is presented with a clear and transparent structure, the inventory should provide the following information about the models:

- description of outcome variables (qualitative, quantitative, hazard, probability, economic, or social loss) and the objective of the modelling exercise (description, prediction, intervention, identification of influencing factors, sensitivity, etc.);
- description of the scope and application limits of the model (hosts, plants, pests, region, time frame (season, life cycle), regional and temporal aggregation, etc.); definition and justification of assumptions underlying the model;
- description of the assessment method (static, dynamic, mechanistic, or statistical), the concrete model with estimated input parameters and the algorithm to obtain the results, including selection criteria if applicable;
- requirements on possible input variables (including geographical, meteorological, climatic data, microclimate, plant phenology, environment, regional data, area of cultivation, remote sensing data) for forthcoming applications or predictions;
- description of parameters and primary data sets (objective of collection, content, accessibility) and empirical verification (expert judgment, laboratory trials, observations, transfer models, etc.);
- description of the model validation procedure and of the remaining uncertainty concerning the outcome variables (qualitative / quantitative measures).

Similar applications should be compared, classified, and brought together. This work would require the assembly of a structured, electronic inventory of the selected and analyzed models, which could be continuously updated. A precondition of this inventory is a systematic review of relevant published literature on pest risk models that use climatic data and / or plant phenology as input factors. The review should include peer-reviewed articles as well as reports from competent authorities or organizations published before December 2008.

Introduction and Objectives

Pest risk analysis (PRA) is the process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and to determine the strength of any phytosanitary measures to be taken against it (ISPM No. 5). PRA includes: i) initiation of the pest risk analysis; ii) pest risk assessment; and iii) pest risk management (ISPM No. 2).

In the European Food Safety Authority (EFSA), risk assessment is carried out independently from risk management. The EFSA Panel on Plant Health provides independent scientific advice on the risk posed by plant pests that can be considered harmful to plants and plant products or that can affect biodiversity in the EU. The Panel produces scientific opinions and advice to provide a sound foundation for the European decision makers. Currently, by request from the European Commission (EC), the Panel reviews pest risk assessments made by third parties on pests claimed by the original risk assessors to be harmful in the meaning of the Council Directive 2000/29/EC.

This review of risk assessments requires a very large amount of information on the pest itself: the situation in its current area of distribution; its pathways of movement across the world; the factors affecting its establishment, spread, and impacts in the area under threat; and the measures available for its management. The spread, establishment, or development of organisms harmful to plants, to plant products, or to biodiversity might have great economic or social consequences. The prevention of introduction of plant pests into the European Community is a mayor task of the EC-directive 2000/29/EC, which defined protective measures.

Mathematical models combining weather / climatic data and plant development / growth with characteristics of plant pests produce information about the establishment, the spread, or the development of the harmful organisms. Recent developments in botanical epidemiology, modelling techniques, automatic data processing, as well as in the possibility of combining model outputs with geographical information systems or remote sensing data to produce risk maps, make modelling and simulation a very useful approach for estimating risk within the PRA (Rossi, 2008).

Models combining environmental data, plant characteristics, and pest characteristics have been developed since the middle 1900s. The first models were developed following an empirical approach, with simple tools showing relationships between particular stages of the pest and the concomitant weather conditions. Developments in weather monitoring and automatic data processing, as well as an ongoing development of new modelling approaches, increased the number of models and their complexity. To date, several hundred pest models have been developed to identify the factors influencing pest development, describe the pest life cycle, simulate or predict pest outbreaks, or develop decision-making tools for pest control. These models incorporate all information necessary to obtain accurate information; they concern the host (host growth stage, development, or resistance to the disease), the environment (meteorological conditions, soil characteristics, or cultural practices), and the pest (biological, ecological, and epidemiological characteristics). Selection of information to include in the model is crucial: reducing information could reduce accuracy, while increasing information could increase complexity, time, and costs in both model elaboration and use. The goal is to include in the model only that significant and essential information that accounts for the great part of variability in model output. Pest models have also been combined with geographical, meteorological, and / or remote sensing databases to produce risk maps.

A number of these models can be potentially used in PRA. Because approaches, methods, and terminology used in these models vary widely, a clear and transparent review of the published models is needed in order to select the relevant models to be used in PRA. Pest models have been reviewed and classified in several ways. For instance, Campbell and Madden (1990) distinguished models with regard to whether: i) information on host, pest, and environment is used in model development; ii) pre- or post-planting models are developed; iii) empirical or fundamental information is used in developing the model; and iv) specific characteristics of pests (e.g., initial population level and the rate of development) are used as the basis for forecasts. Madden and Ellis (1988) distinguished empirical and fundamental models. Empirical models result from the observation and the analysis of current and historical data on pests and factors affecting pests in the field, whereas fundamental models result from specific experiments carried out in controlled environments or in the field to describe the effect of environment on one or more aspects of the pest. Many empirical models have a fundamental basis, and fundamental models usually have many empirical elements. Although models often combine these approaches, the two main approaches, empirical and fundamental, have been undoubtedly followed in developing pest models. Empirical models can be further differentiated based on the kind of analysis performed on the set of historical data, ranging from no statistical analysis, to parametric, non-parametric, and stochastic analyses. The approach used in developing a model greatly affects model performance, especially with regard to model accuracy under different environmental conditions. Some relevant works published on this topic are listed in the References Section.

Based on the these considerations, there is a need to develop an efficient methodology for retrieving models that can be potentially used in PRA and for documenting these models in a clear and transparent manner. In particular, the following information on pest models must be considered: i) scope and application limits of the model: hosts, plants, pests, spatial, and temporal scale; ii) model type: descriptive vs. analytical, empiric vs. mechanistic, static vs. dynamic; iii) relational diagrams and flow charts describing the model theory and structure; iv) input parameters and variables, methods for measurement and/or assessment, geographical and temporal scales; v) assumptions underlying the model: definition and justification; vi) algorithms used for running the model to obtain the output; vii) model output: qualitative, quantitative, hazard, probability, economic or social loss, possible map representation, etc.; viii) intended use of model output: identification of influencing factors, description, simulation, prediction, decision-making, precision farming, etc.; ix) validation and verification of the model output vs. real data: methods for collecting real data, procedures for validation, level of uncertainty; x) sensitivity analysis to determine how parameters and variables influence model output; xi) availability of computerized versions of the model and programming languages used; xii) practical applications of the model at present; and xiii) possibilities for future applications of the model.

The main objective of the Mopest project was to carry out a review and to produce an inventory of the models describing the establishment, development, and / or spread of plant pests on crops in Europe. To meet these objectives, three main activities were planned within the Mopest project. These main activities correspond to three Work Packages (WP1, WP2, and WP3). A fourth activity, WP4, concerns the overall management of the project.

In WP1, two specific tools were developed: i) a protocol for reviewing literature sources, web-sites, and computer programs that describe models of interest for Mopest, and for documenting these models in an efficient, transparent, and comparable manner; ii) a user-friendly web-based portal for storing model information, searching models within the inventory, and extracting and accessing model documentation in a rationale, effective, and rapid manner. In WP2, the two tools developed in WP1 were tested through a feasibility study for wheat pests, while in WP3 an exhaustive review for the pests included in the EPPO A1 list was performed (Fig. 1).

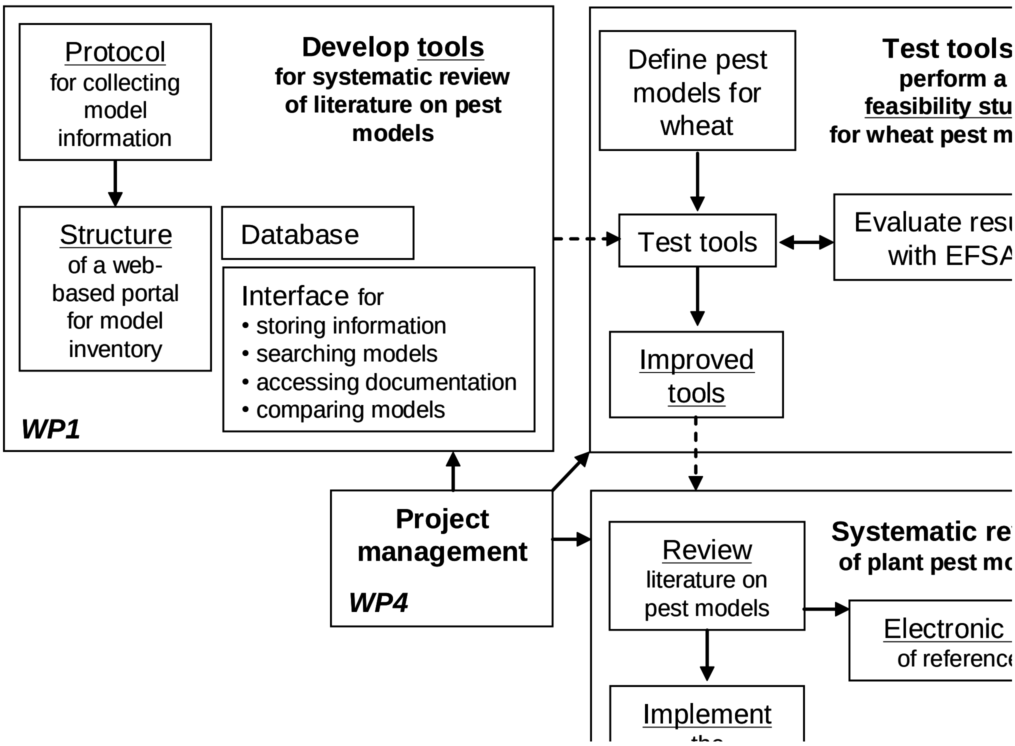


Figure 1. **Pert diagram of the Mopest project**

Project results

The three main results obtained from the Mopest project were: i) a structured, flexible, and transparent protocol for retrieving and reviewing pest models and for documenting these models in an efficient, transparent, and comparable manner (WP1); ii) a user-friendly web-portal for storing, updating, evaluating, and searching the information related to the models present within the inventory via the Internet (WP1); and iii) a database containing the models related to key pests of wheat (WP2) and to the quarantine pests on the EPPO A1 list (WP3).

1. WP1: Tools for systematic literature review

Table 1. **Tasks of the WP1**

Task	Title	Activities
1.1	Develop protocol for systematic literature review	- Define the information needed for characterising the quantitative models that concern establishment, development, and/or spread of plant pest on crops in Europe and that include climate and / or plant growth and development as input factors (see Section 1.1.1 and 1.1.2). - Define the metadata describing this information (see Section 1.2.3). - Prepare a protocol for systematic collection of model information (i.e., reviewing) (see Section 1.1.3 and 1.1.4).
1.2	Develop structure of the web-based portal	-Design and create a database for storing the information from the review of the pest models (see Section 1.1.4). - Develop the structure of the web application (see Section 1.2.2, 1.2.3, and 1.2.4).
1.3	Agree the results with EFSA	-Discuss the results obtained in Tasks 1.1 and 1.2. -Identify possible gaps in provided information for actual applications by EFSA in plant pest predictions / risk assessment. -Modify and improve protocol and structure of the web-based portal accordingly.

1.1 Protocol for literature review

A protocol was developed for reviewing literature sources (i.e., peer-reviewed journals, proceedings, reports from competent authorities/organizations), web-sites, and computer programs that describe models of interest for Mopest. The goal of the protocol was to ensure that reviews were conducted in a structured, transparent, and efficient manner. This protocol includes: i) a search strategy for retrieving information sources based on the principles of "systematic literature review"; and ii) a series of descriptors (metadata) that describe each source.

1.1.1 Principles of systematic literature review

The search strategy of Mopest was developed according to the principles of the "systematic literature review". Initially, a bibliographic search was carried out about the systematic review principles and methods. This was done to clarify how the Mopest inventory should work and to identify a possible road map for building the model review.

Principles of systematic review were developed by The Cochrane Collaboration (www.cochrane.org) to help people make well-informed decisions about health-care interventions. Such principles are needed because a very large amount of information or evidence and a lack of time, skills, and resources make it difficult to find, appraise, and interpret this evidence. The aim is to identify, appraise, and synthesize research-based evidence and present it in an accessible format (Mulrow, 1994). This systematic and explicit approach for making judgements about the quality of evidence and the strength of recommendations reduces errors, facilitates critical appraisal of these judgements, and improves the communication of this information.

A systematic review attempts to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question. It uses explicit, systematic methods that are selected to minimize bias and thus to provide reliable findings from which conclusions can be drawn and decisions made (Antman, 1992; Oxman & Guyatt, 1993). The key processes of a systematic review are cataloguing and analysing. Cataloguing includes: definition of a clearly stated set of objectives with pre-defined eligibility criteria for studies; an explicit, reproducible methodology; and a systematic search that attempts to identify all studies that would meet the eligibility criteria. Analysing includes: an assessment of the validity of the findings of the included studies (for example, an assessment of risk of bias), and a systematic presentation and synthesis of the characteristics and findings of the included studies.

Given the specific theme of the Mopest inventory, the analyses of each pest model must answer two questions: i) Has the model been tested in different environments (locations x years)? and ii) How does the model perform relative to other models for the same pest? The systematic review for answering these questions requires that the same evaluation methods were used in the original research and/or that the original data are available and can be analyzed *ex-novo* using the same evaluation methods. Both of these requirements are difficult to meet because there are only few cases in literature where the same model was evaluated in different environments and because often only one or two models have been developed for the same pest, and in most of these cases, these concern pests of worldwide relevance (which are of minor interest for PRA). A concrete example of the problem in analysing and comparing models is provided by grape downy mildew (a disease of grape caused by *Plasmopara viticola*). This disease has a worldwide distribution, and several epidemiological models have been developed in different countries (10 grape downy mildew models have been documented in literature). These models focus on different stages of the pathogen life cycle: five of them focus on primary infections, three on secondary infection, and two on both primary and secondary infections. Outputs of these models are very different, even among those models focused on the same objective. Thus, they produce different outputs (date of infection vs. date of symptom onset), they use different infection risk indices (percentages vs. empirical numbers), and they use different units for describing epidemic progress (number of lesions vs. an empirical index). In this case, it is impossible to fulfil at least one of the two above-mentioned research questions, i.e., i) the authors have seldom validated their own models in different grape-growing areas, and ii) grape downy mildew models have different outputs that prevent comparison in a systematic review.

Based on these considerations, the search strategy of Mopest was developed according only to the cataloguing principles of the systematic literature review. In particular, protocol guidelines for retrieving sources were defined, so that all searches would be based on:

- a clearly stated set of objectives with pre-defined eligibility criteria for selecting information sources to be included in the inventory (see Section 1.1.2);
- a systematic search strategy that attempts to identify all sources that would meet the eligibility criteria (see Section 1.1.3).

1.1.2 Eligibility criteria

The eligibility criteria for items to be included in the Mopest inventory were directly drawn from the project call CFP/EFSA/AMU/2008/01. These items must:

- concern models describing the establishment, development, and/or spread of plant pests on crops in Europe; in this context, the term “pest” includes any species, strain, or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO, 2008);
- concern models that can be potentially used for accurate and robust quantitative prediction of pest risk through the use of climate and / or plant growth and development as input factors;
- be published in peer-reviewed journals, proceedings, and other publications, as well as in reports from competent authorities/organizations, or be available on web-sites and in computer programs;
- describe or contain a model whose model structure is transparent and reproducible;
- have been published within December 2008.

Based on these eligibility criteria, commercial software solutions that are not supported by peer-reviewed publication and that lack description of the algorithms should not be included in the Mopest inventory.

1.1.3 Search strategy

Generally speaking, information searching is a sequence of interrelated actions. Every action determines the course of the searching, and thus affects its final result. Because the searcher's reasoning is a key to the success of the searching process, it is essential to adopt structured search strategies based on rational, pre-planned searching procedures and techniques. The search strategy of Mopest is structured based on the principle of planning the search according to four successive components: What, Where, Words, and the Working method (Zins, 1999).

The **What** component refers to the phrasing of the search. Phrasing the search assignment is aimed at focusing the search by specifying the needed information. The process of phrasing compels the searcher to define the needed information in terms of distinct search assignments (Zins, 1999). In Mopest, phrasing comes directly from the Mopest’s scope, i.e., models that simulate the pest in terms of presence/absence, prevalence, incidence, and severity as a function of weather variables and / or variables of the host plant (growth and /or development).

The **Where** component refers to the determination of where to search. Locating potential resources is usually easy for experienced searchers who are familiar with the relevant subject matter. The searcher must first locate relevant resources, using structured search techniques, before he/she can proceed to execute the primary assignment properly (Zins, 1999). For instance, in WP2 and WP3, the bibliographic search was carried out in the CAB Abstracts database (sources from 1972 to 2008), which was accessed by means of the Millennium Web Catalogue of the Università Cattolica between December 2008 and October 2009 (owners of a subscription can also access the database directly at the address: http://www.cabdirect.org). Possible further resources are the AGRIS database and the World Wide Web. These resources are compared in Section 2.2.4.

The **Words** component refers to the selection of search-words. The search-words affect the precision of the results: they should generate adequate results, i.e., results that are not too broad or too narrow. Selecting suitable words requires some basic knowledge and skills. The searcher has to properly characterize the needed information, based on subject-related terminology; he/she should correctly spell the search-words by using printed or computerized references (e.g., dictionaries, spelling checkers, glossaries, and thesauri) (Zins, 1999). In WP2 and WP3, published papers were searched by using combinations of keywords, as follows:

- (Latin name of the pest OR common English name of the pest/disease) AND (model OR simulation OR prediction OR forecast);
- when the name of a pest has recently changed, because of either nomenclature change or new taxonomic classification, the search was carried out for both the most recent and the old version of the name;
- when both the teleomorph and the anamorph participate in causing the disease under consideration, both their Latin names were used in the search;
- common English name of the host plant; if the pest is polyphagous the search should be repeated for each host;
- when the above-mentioned keywords do not produce any results, the search is repeated using Latin names of the higher taxonomic levels (e.g., from *Claviceps purpurea* to *Claviceps*).

An example of how keywords are used is given in Figure 2, which shows the input mask of the CAB Abstracts database. The complete list of the keywords used in WP2 and WP3 is reported in Table 3 and Annex 3.1, respectively.

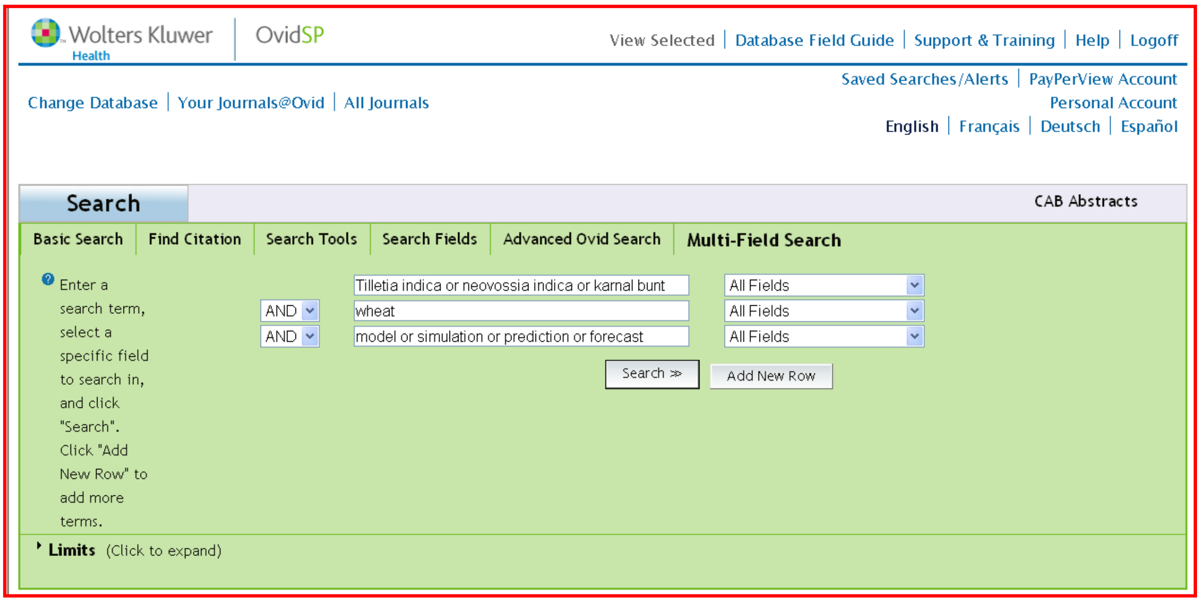


Figure 2: **Input mask of the CAB Abstracts database accessed through the Millennium Web Catalogue. Keywords refer to karnal bunt, a wheat disease considered in WP2.**

The **Working method** refers to how the information is retrieved**.** The working method depends on certain conditions (e.g., the features of the search tools or the resources, the nature of the assignment, the searcher's expertise, etc.). There are two basic methods of information retrieval: browsing and typing a query. Hypertext and hypermedia formats allow two kinds of browsing: ‘occasional’ and ‘structured’. Occasional browsing is based on associative links while structured browsing is usually used in hierarchical lists (Zins, 1999). The following working method was defined for Mopest:

1. perform the literature search in CAB Abstracts database (or any chosen database);
2. review each paper found on the basis of information in the title and abstract: if the paper meets the eligibility criteria, it is considered of potential interest for Mopest; otherwise, it is discarded (note: term ‘potential’ means that the papers could be discarded or used as a related reference of another entry, based on the information drawn from analysing the full text, as described in step 4 below);
3. retrieve the full papers considered of potential interest for Mopest;
4. review the full paper: if the paper meets the eligibility criteria, it is considered of interest for Mopest; otherwise, it is discarded or used as related reference of another entry;
5. select further papers from the “references” section of the papers found; these papers are then managed starting from step 3.

To make the process of selection / rejection of papers as transparent as possible, the criteria for excluding papers from the inventory was codified based on the eligibility criteria. Reasons for excluding papers were codified as follows:

1. the paper does not concern pest modelling;
2. the paper does not concern the kind of models of interest, i.e., weather- or climate-driven models, or models considering plant growth or development;
3. the paper concerns pest modelling, but the model is not described in a transparent manner (e.g., there are no equations), or it refers to pests or plants other than the one of interest, or it shows other mismatches with the eligibility criteria.

1.1.4 Reviewing method

An explicit, reproducible methodology was developed for reviewing the papers retrieved according to the search strategy previously described. For this purpose, a series of descriptors (metadata) that describe each source was defined.

A literature search was preliminarily carried out to analyse how models have been described and reviewed by others. Most of the information found focuses on ecological and crop models rather than on models for specific pests; therefore, only the aspects of interest for Mopest were considered from these sources. The five sources analysed were: i) CAMASE: a Concerted Action for the development and testing of quantitative Methods for research on Agricultural Systems and the Environment. Register of Agro-ecosystems Models (Version June 1996) (http://library.wur.nl/way/bestanden/clc/1763788.pdf); ii) ECOBAS: WWW-Server for Ecological Modelling: web-based information service for modelling and simulation in ecology and environmental sciences (http://ecobas.org/); iii) PestCast: a project to expand the use of computer-based crop disease forecasting with the goal of reducing unnecessary pesticide use. University of California (http://www.ipm.ucdavis.edu/ DISEASE/california_pestcast.html); iv) CREM: EPA's Council for Regulatory Environmental Modeling, U.S Environmental Protection Agency (http://www.epa.gov/crem/ index.html); and v) CSCM (Content Standard for Computational Models). Alexandria Digital Earth Prototype, Metadata for Models Work Group. Content standards for computer model metadata, 2001 (http://ncgia.ucsb.edu /projects/metadata/standard/index.html);

In Mopest, about 200 metadata were defined for describing each model, organised in different sections that contain metadata on specific arguments: Main reference, Related reference, Contact person, Chronology, Model subject, Pests, Plants, Keywords /Descriptors, Abstract, Language, Subject category(ies), Aggregation level, Geographic coverage, Temporal coverage, Technical specifications, Type of model, Scientific model specifications, Input data concerning weather, Input data concerning pest(s), Input data concerning crop(s), Output, Model evaluation, Model application(s), and Notes. Each field present in the sections listed above is described in the "Coding manual" chapter of the Mopest User's Manual. Details on the metadata are available in the Mopest User's Manual (Annex 3.5). A glossary of the terms frequently used in pest modelling was also prepared to facilitate reviewing (see Annex 1.1).

International standards and codes were used whenever possible. Some of the metadata of the protocol must always be filled, whilst others are not mandatory. A metadata was also included to allow authorized users to include their notes and observations on the proper use or limitation of those models they have personally used and applied.

1.2 Web-based portal

This section deals with the technical aspects of the design and development of the web-based portal. The choice of building a web application resulted from a preliminary comparison of the advantages and disadvantages of creating a web application vs. choosing a desktop application. The term "web application" refers to an application hosted on a web server that is accessible by final users through a web browser (so called thin client) and an Internet connection. A "desktop application" is a self-contained (stand-alone) program that runs from a local drive and does not require a network or connectivity to operate. This comparison led to the decision to develop a web application. Advantages and disadvantages of a web application can be summarized as follows.

- Single installation (server side only): no installation is required for each client because only a web browser is needed to access the application; compatibility problems with the client platform are therefore avoided.
- Easy maintenance and upgrading: no need to maintain and upgrade several installations.
- Accessibility: 24 hours per day and 7 days per week; the application is accessible all the time and everywhere an Internet connection is available.
- Connectivity: an Internet connection is required to access the application; nevertheless, most potential users have access to an Internet connection.
- Speed: working online can be slower than working on a local machine. This disadvantage will be taken into account during the entire development cycle with the final goal of improving performance as much as possible.
- Security: working online involves security risks, and the network infrastructure that will host the web application should be properly protected through the adoption of a firewall or an IDS.

The web-based portal was designed with a clear and transparent structure to allow the following functionalities:

- easy and complete storage of the information on the reviewed models;
- fast and effective search of the pest models within the inventory;
- access to the model documentation.

1.2.1 Portal architecture

The EFSA's standards for on-line procedures were adopted in designing the web-portal architecture. Oracle was used as the DBMS (Database Management System), and the Oracle Application Express (also called Oracle Apex) was the software. With Apex, which is a free software development environment based on the Oracle database, complex web-based applications can be created relatively rapidly. In this application, Apex runs in every web server thanks to an embedded PL/SQL gateway. The embedded PL/SQL gateway runs in the XML DB HTTP server in the Oracle database and includes the core features of mod_plsql. Figure 3 shows the Oracle Application Express architecture using the Embedded PL/SQL Gateway. No client software is required to develop, deploy, or run Application Express applications. On the final user side, the Mopest application is accessible by any computer equipped with a web browser.

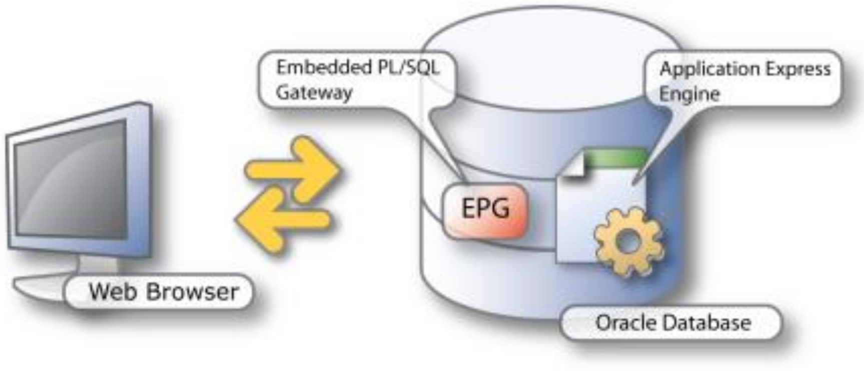


Figure 3. **Oracle Application Express architecture**

1.2.2 Database structure

The Oracle database required to run the web-portal was created starting from the metadata identified in Task 1.1. The main tables of this database are presented in Annex 1.2 (Mopest_database_structure). Several other tables have been created to manage the content of some dropdown menus (e.g., cities, languages, etc.), which are accessible through the database administration interface. The SQL dump of the Oracle database and the Apex application are also provided in Annex 1.3 and 1.4, respectively.

1.2.3 Portal design and functionalities

The web-based portal was designed to offer the typical functionalities of a database management tool: authorized users can enter, update, and delete information about sources, and can search within the inventory by keywords (either through a basic or an advanced search feature). Two kinds of user profiles have been defined: i) Standard Users are allowed to view the database content and search within it; ii) Power Users can view the database content, perform a basic or advanced search, and perform all the typical actions of a database administrator (enter, update, and delete the database entries). All the features of the Mopest web-based portal are described in the Mopest Manual.

Some screenshots of the web-portal are presented in Figures 4, 5, and 6. As shown in these figures, the application was organized in different “folders” accessible through the labels on the upper-right corner of the screen. This presentation format was selected to avoid the need for long scrolling on a single page and to guarantee that each page is loaded quickly.

The folder called MOPEST contains the following information:

- Bibliographic information of the main and the related references: in this section, reference details must be inserted following the CAB Abstracts standards, for both the main published paper on the model (i.e., the most relevant work describing the model or the last version of the model itself) and the related references (i.e., works related to the main reference, such as previous versions and validations, made either by the original researcher or another researcher).
- Contact information of the model's author: this part contains the full address of the person to be contacted for any need about the model (i.e., corresponding author, modeller, responsible party for the model, etc.); address details are drawn following WMO Core Metadata Profile and ISO11180.
- Record chronology: profile creation and modification dates are automatically generated by the system.
- Model subject: basic information about the model: acronym, name, and version.
- Identification of pests and hosts: pests and host plants on which the model is focused are defined by selecting the correspondent EPPO codes from a menu.

The folder called MOPEST 2 is structured as follows:

- Keywords: list of keywords drawn from the paper, as well as additional keywords, that clearly identify the model.
- Abstracts: original abstract from the published paper, as well as from additional sources, when available.
- Language(s): the language(s) of the published paper, following the standard ISO639-2.
- Subject categories: the broad subject class (e.g., crop science, soil science, environmental science, etc.) in which the model falls can be selected from a menu.
- Aggregation level: the aggregation level (e.g., organism, population, meta-population) in which the model falls can be selected from a menu.
- Temporal and geographical coverage: geographic and temporal coverage of the model can be selected, specifying whether the model is limited to a specific geographic location or has a specific temporal range.
- Technical specifications: specifications that refer to the computerized version of the model can be indicated; examples of these specifications are: computer hardware required to store and operate the model, operating system requirements to run the model, other software requirements, computer language in which the modelling software was written, whether source code is available, existence of any access or use constraints or conditions.
- Type of model: the type of model can be selected from a menu (e.g., descriptive, analytical empiric, mechanistic, etc.).
- Scientific specifications: information about scientific aspects of the model can be indicated, including: flow diagram, mathematic details (steps or equations used by

the model to transform and / or manipulate the model inputs to the output), assumptions made by the author(s) for abstracting the model from reality, model uncertainty (i.e., the imperfect knowledge regarding the system to be modelled or concerning the model formulation that can trigger uncertainty of model output).

The folder called MOPEST 3 contains the following information:

- Inputs concerning weather, pest, and crop: described here are the data sets required for processing the model, in terms of: measured variables (with the proper measurement time step, measurement methods, and instruments, etc.), calculated variables (i.e., how the input variables are calculated from measured variables; e.g., degree-days, vapour pressure deficit, etc.), input time step (i.e., the time step at which the variable is both measured and included in the model).
- Output: output produced by the model can be defined by describing the output details, specifying the time step at which the output is produced, and specifying any temporal extent.
- Model evaluation: information can be inserted about the procedures used for model evaluation, in terms of validation (i.e., the ability of the model to reproduce the behaviour of the real world), verification (i.e., inspection of the internal consistency of the model), sensitivity analysis (i.e., the study of model properties through changes in the input variables and the analysis of consequent effects on model outputs), uncertainty (i.e., imperfect knowledge regarding parameters, constants, input data, and assumptions of the model), and calibration (i.e., the procedures used to adjust some model parameters such that model behaviour matches the set of real-world data considered).

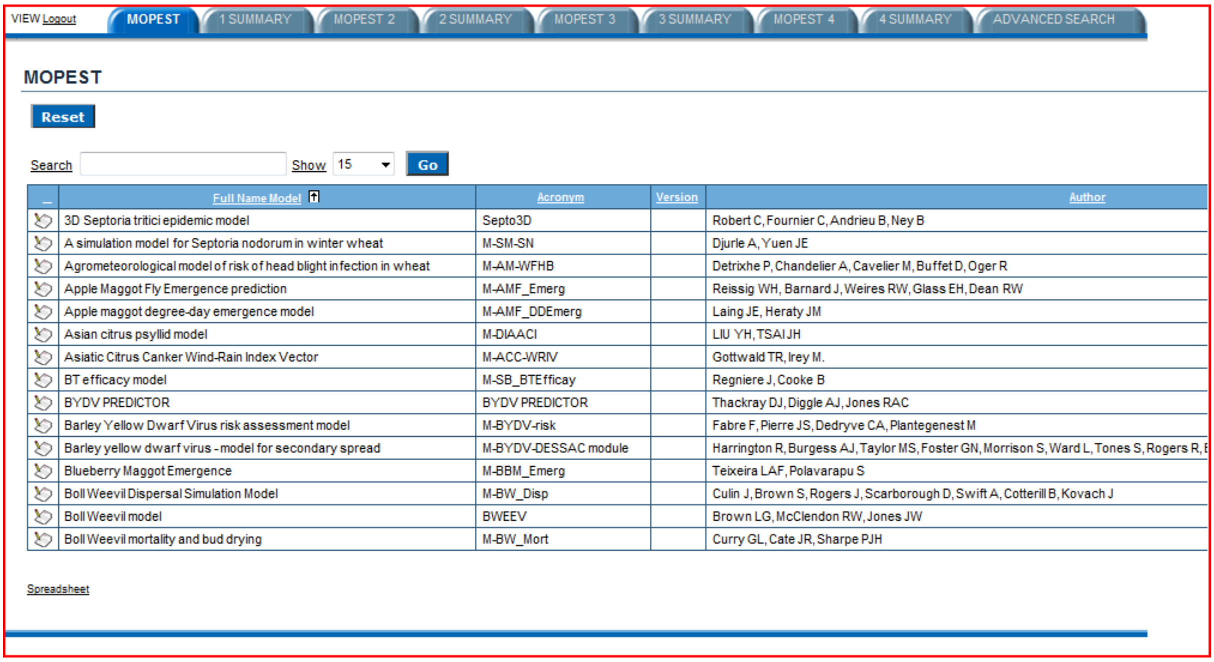
The folder called MOPEST 4 contains the following information:

- Model application(s): information can be inserted about the practical application, current limitations, and perspectives of the model, in terms of field(s) of application (i.e., the main purpose for which the model was developed and its current field of application), current limitation(s) (i.e., drawbacks to parts of the model based on the developer's observations or on published literature about the model), future direction(s) (i.e., the potential future direction of work on the model based on the developer's observations), and suggestion for proper use(s).
- Notes: comments and observations can be inserted concerning the proper use or limitation of the model.

A printable summary page of the selected model can be generated by both standard and power users from the folders called SUMMARY (Fig. 7).

The folder called ADVANCHED SEARCH makes it possible to perform an advanced search of models within the inventory. The user can enter several keywords by specifying the fields to be searched for each term. The main advantage of this feature is that it enables the user to combine different search criteria in a single search. Some key metadata were selected to be used as search parameters for the advanced search (Fig. 8). These metadata include, for instance, the full name of the model, keywords, author(s), year of publication, the pest's Latin or common name, the plant's Latin or common name, kind of input variables, etc.

Other folders (called MODEL TYPES, OP SYSTEMS, PROG LANGS, CALC VARS WEATHER, HOST VARS, MEAS VARS WEATHER, METHOD USED, PEST VARIABLES, SENSOR LOCATIONS, PUBLICATION TYPES, PESTS OUTPUTS, LOSSES OUTPUTS, MEASURED PARAMETER PEST, and MEASURED PARAMETER CROP) make it possible to add new descriptors when the existing ones are not suitable for describing a new model to be inserted.



VIEW Logout | MOPEST | 1 SUMMARY | MOPEST 2 | 2 SUMMARY | MOPEST 3 | 3 SUMMARY | MOPEST 4 | 4 SUMMARY | ADVANCED SEARCH

MOPEST

Reset

Search Show 15 Go

_	Full Name Model	Acronym	Version	Author
	3D Septoria tritici epidemic model	Septo3D		Robert C, Fournier C, Andrieu B, Ney B
	A simulation model for Septoria nodorum in winter wheat	M-SM-SN		Djurle A, Yuen JE
	Agrometeorological model of risk of head blight infection in wheat	M-AM-WFHB		Detrixhe P, Chandelier A, Cavelier M, Buffet D, Oger R
	Apple Maggot Fly Emergence prediction	M-AMF_Emerg		Reissig WH, Barnard J, Weires RW, Glass EH, Dean RW
	Apple maggot degree-day emergence model	M-AMF_DDEmerg		Laing JE, Heraty JM
	Asian citrus psyllid model	M-DIAACI		LIU YH, TSAI JH
	Asiatic Citrus Canker Wind-Rain Index Vector	M-ACC-WRIV		Gottwald TR, Irey M.
	BT efficacy model	M-SB_BTEfficay		Regniere J, Cooke B
	BYDV PREDICTOR	BYDV PREDICTOR		Thackray DJ, Diggle AJ, Jones RAC
	Barley Yellow Dwarf Virus risk assessment model	M-BYDV-risk		Fabre F, Pierre JS, Dedryve CA, Plantegenest M
	Barley yellow dwarf virus - model for secondary spread	M-BYDV-DESSAC module		Harrington R, Burgess AJ, Taylor MS, Foster GN, Morrison S, Ward L, Tones S, Rogers R,
	Blueberry Maggot Emergence	M-BBM_Emerg		Teixeira LAF, Polavarapu S
	Boll Weevil Dispersal Simulation Model	M-BW_Disp		Culin J, Brown S, Rogers J, Scarborough D, Swift A, Cotterill B, Kovach J
	Boll Weevil model	BWEEV		Brown LG, McClendon RW, Jones JW
	Boll Weevil mortality and bud drying	M-BW_Mort		Curry GL, Cate JR, Sharpe PJH

Spreadsheet

Figure 4. **Part of the main form of the Mopest web-portal**

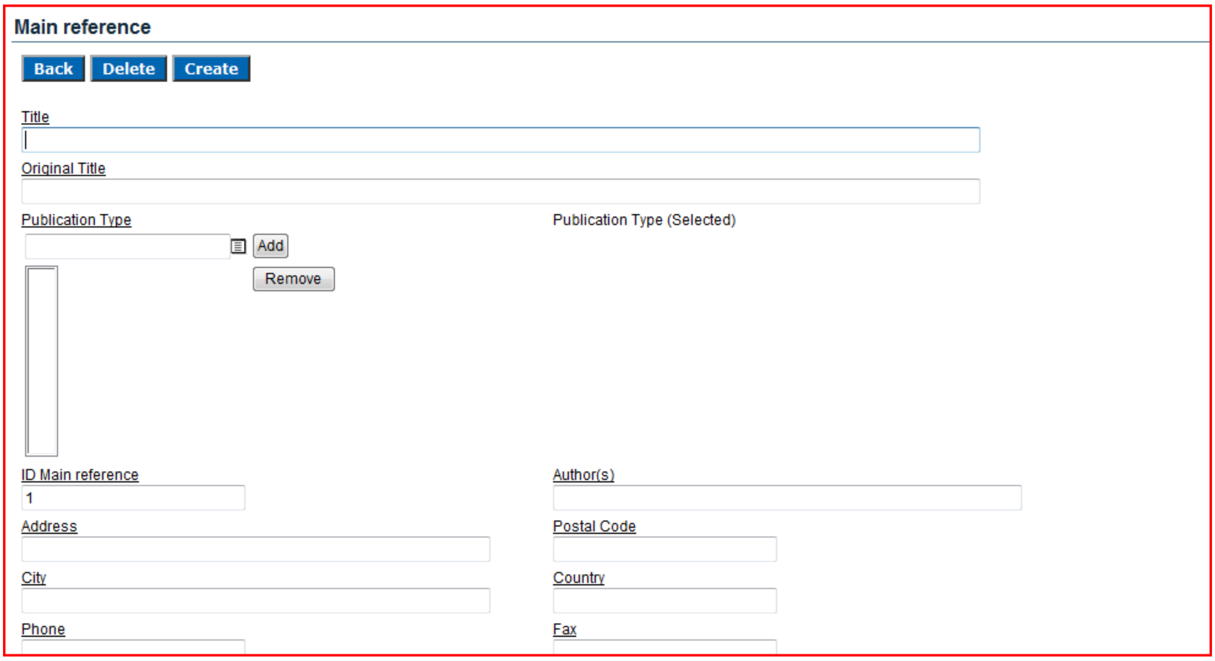
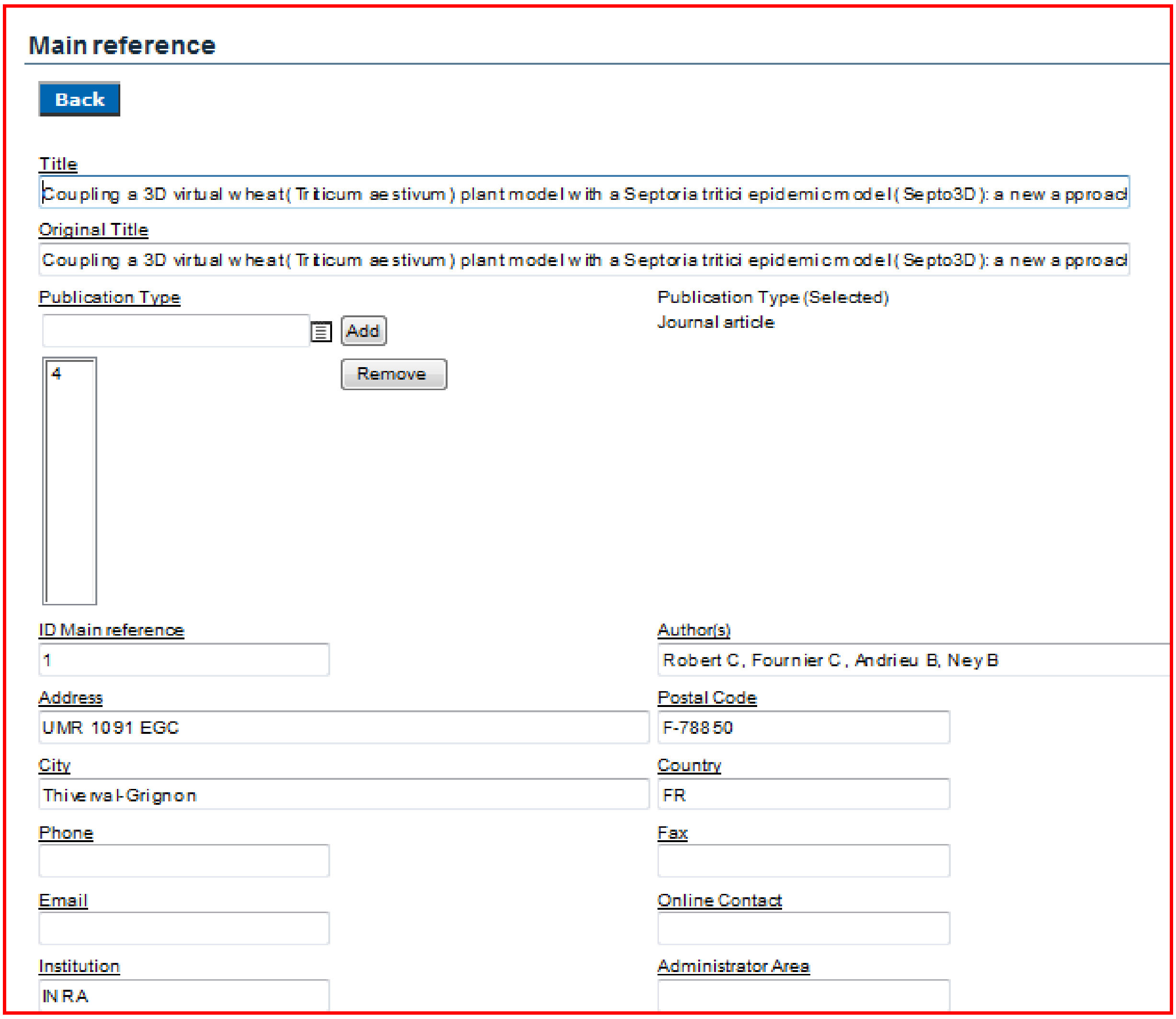


Figure 5. **Part of the input mask**



Main reference

Back

Title

Coupling a 3D virtual wheat (Triticum aestivum) plant model with a Septoria tritici epidemic model (Septo3D): a new approach

Original Title

Coupling a 3D virtual wheat (Triticum aestivum) plant model with a Septoria tritici epidemic model (Septo3D): a new approach

Publication Type

Add

4

Remove

Publication Type (Selected)

Journal article

ID Main reference

1

Author(s)

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Postal Code

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City

Thiverval-Grignon

Country

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Phone

Fax

Email

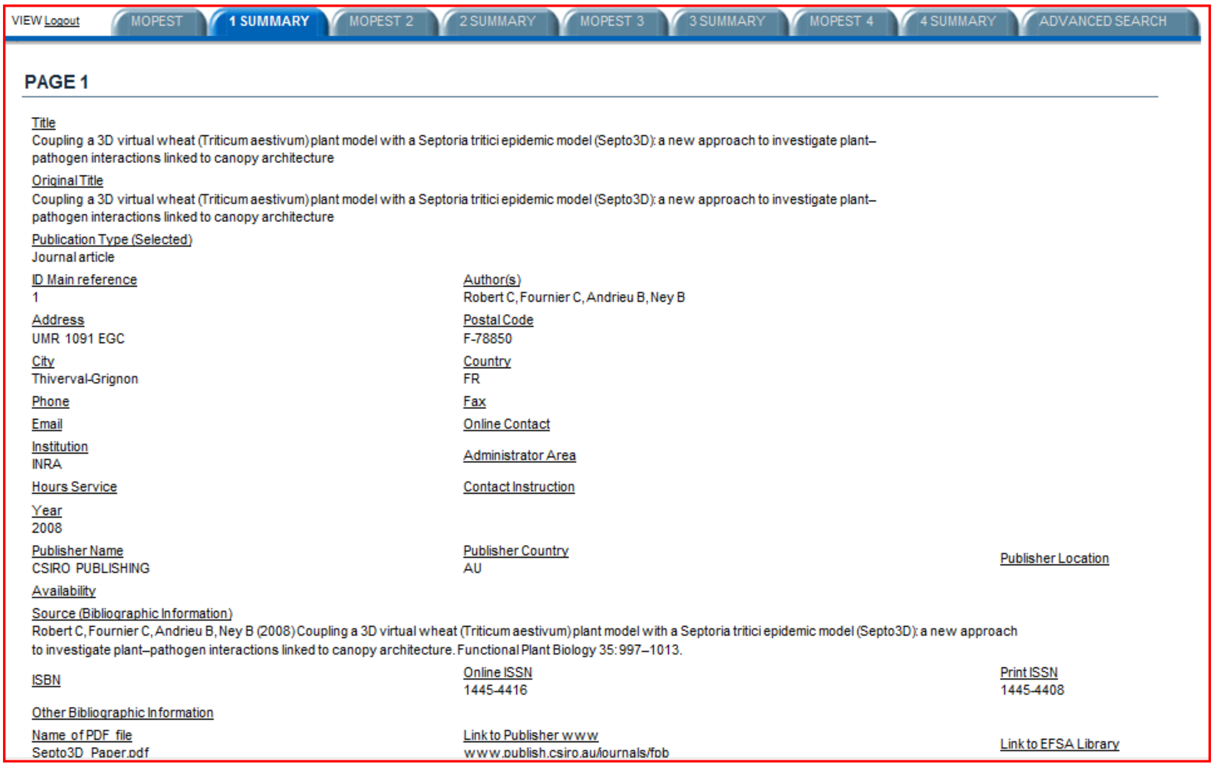
Online Contact

Institution

INRA

Administrator Area

Figure 6. **Part of the model details form**


VIEW Logout | MOPEST | 1 SUMMARY | MOPEST 2 | 2 SUMMARY | MOPEST 3 | 3 SUMMARY | MOPEST 4 | 4 SUMMARY | ADVANCED SEARCH

PAGE 1

Title
Coupling a 3D virtual wheat (Triticum aestivum) plant model with a Septoria tritici epidemic model (Septo3D): a new approach to investigate plant–pathogen interactions linked to canopy architecture
Original Title
Coupling a 3D virtual wheat (Triticum aestivum) plant model with a Septoria tritici epidemic model (Septo3D): a new approach to investigate plant–pathogen interactions linked to canopy architecture
Publication Type (Selected)
Journal article
ID Main reference
1
Author(s)
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Email
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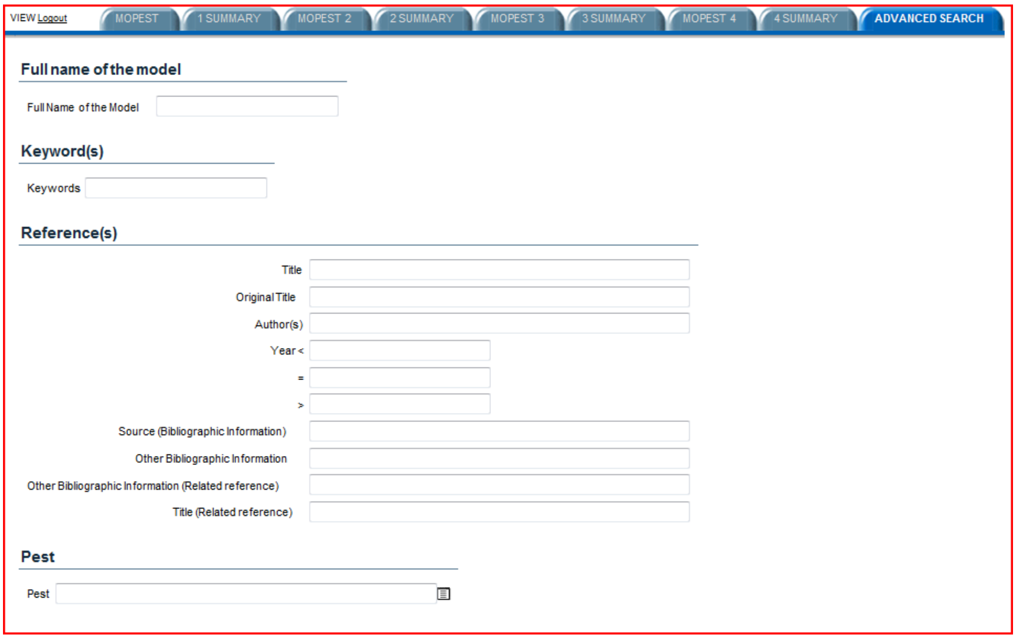
Institution
INRA
Administrator Area
Hours Service
Contact Instruction
Year
2008
Publisher Name
CSIRO PUBLISHING
Publisher Country
AU
Publisher Location
Availability
Source (Bibliographic Information)
Robert C, Fournier C, Andrieu B, Ney B (2008) Coupling a 3D virtual wheat (Triticum aestivum) plant model with a Septoria tritici epidemic model (Septo3D): a new approach to investigate plant–pathogen interactions linked to canopy architecture. Functional Plant Biology 35: 997–1013.
ISBN
Online ISSN
1445-4416
Print ISSN
1445-4408
Other Bibliographic Information
Name of PDF file
Septo3D_Paper.pdf
Link to Publisher www
www.publish.csiro.au/journals/fpb
Link to EFSA Library

Figure 7. **Part of the printable summary form**


VIEW Logout | MOPEST | 1 SUMMARY | MOPEST 2 | 2 SUMMARY | MOPEST 3 | 3 SUMMARY | MOPEST 4 | 4 SUMMARY | ADVANCED SEARCH

Full name of the model
Full Name of the Model
Keyword(s)
Keywords
Reference(s)
Title
Original Title
Author(s)
Year <
=
>
Source (Bibliographic Information)
Other Bibliographic Information
Other Bibliographic Information (Related reference)
Title (Related reference)
Pest
Pest

Figure **8. Part of the advanced search form**

2. WP2: Feasibility study for wheat pest models

Table 2. **Tasks of the WP2**

Task	Title	Activities
2.1	Define pest models for wheat	-Define the pest to be included in the study (see Section 2.1).
2.2	Test tools on wheat pest models	-Use the protocol for filling the web-based portal for the pests included in the study (see Section 2.2).
2.3	Agree the results with EFSA	-Discuss the results obtained in Tasks 2.1 and 2.2 with EFSA. -Identify gaps in the protocol for the systematic literature review and / or documentation. -Modify and improve tools accordingly.

2.1 Pest models for wheat

The choice of wheat pests to be considered for the feasibility study was based on their relevance and on their presence in the EPPO A1 and A2 lists or in other quarantine lists (specifically: CAN, Comunidad andina; OIRSA: Organismo internacional regional de sanidad agropecuaria; CPPC: Caribbean Plant Protection Organisation). Eleven pests were included in this list:

1. karnal bunt (*Tilletia* = *Neovossia indica*)
2. ergot (*Claviceps purpurea*)
3. leaf rust (*Puccinia recondita*)
4. powdery mildew (*Blumeria graminis*)
5. leaf and glume blotch (*Septoria tritici* and *Stagonospora nodorum*)
6. Fusarium head blight and related mycotoxins (*Fusarium* spp.)
7. bacterial leaf streak (*Xanthomonas translucens* pv. *translucens*)
8. barley yellow dwarf virus
9. *Agriotes* spp.
10. Russian wheat aphid (*Diuraphis noxia*)
11. cereal leaf beetle (*Oulema melanopus*)

2.2 Inventorying the wheat pest models

2.2.1 Search strategy

The search strategy developed in WP1 was tested in WP2 for the selected wheat pests. The searching was structured according to the four components described in paragraph 1.1.3

What: models that simulate wheat pests in terms of presence/absence, prevalence, incidence, severity, as a function of weather variables and / or phenological variables of the host crop.

Where: searches were performed in the CAB Abstracts database (from 1972 to 2008), which was accessed by means of the Millennium Web Catalogue of the Università Cattolica between December 2008 and October 2009. For the first eight diseases listed above, the search was performed also in AGRIS database and the World Wide Web using Google as a search engine to verify the appropriateness of using the CAB Abstracts database for locating items to be inventoried in Mopest (see Section 2.2.4).

Words: the keywords used for each pest considered are shown in Table 3.

Woking method: as described in Section 1.1.3.

Table 3: **Keywords used to perform the literature search for wheat pest models in the CAB Abstracts database.**

Pest	Key Words
Karnal bunt	(tilletia indica OR neovossia indica OR karnal bunt) AND wheat AND (model OR simulation OR prediction OR forecast)
Ergot	(claviceps OR claviceps purpurea OR ergot OR sphacelia segetum OR sclerotium clavus OR sphaeria purpurea) AND wheat AND (model OR simulation OR prediction OR forecast)
Leaf rust	(brown rust OR puccinia recondita) AND wheat AND (model OR simulation OR prediction OR forecast)
Powdery mildew	(blumeria graminis OR erysiphe graminis OR powdery mildew) AND wheat AND (model OR simulation OR prediction OR forecast)
Leaf and glume blotch	(septoria tritici OR mycosphaerella graminicola OR septoria nodorum OR stagonospora nodorum OR leaf blotch OR glume blotch) AND wheat AND (model OR simulation OR prediction OR forecast)
Fusarium head blight	(gibberella zeae OR fusarium graminearum OR fusarium head blight OR wheat scab) AND wheat AND (model OR simulation OR prediction OR forecast)
Fusarium spp. and related mycotoxins	mycotoxin AND wheat AND (fusarium OR gibberella) AND (model OR simulation OR prediction OR forecast)

Bacterial leaf streak	(xanthomonas translucens OR bacterial leaf streak) AND wheat AND (model OR simulation OR prediction OR forecast)
Barley yellow dwarf virus	barley yellow dwarf virus AND wheat AND (model OR simulation OR prediction OR forecast)
Agriotes spp	(agriotes OR wireworm*) AND wheat AND (model OR simulation OR prediction OR forecast)
Russian wheat aphid	(diuraphis noxia OR russian wheat aphid) AND wheat AND (model OR simulation OR prediction OR forecast)
Cereal leaf beetle	(oulema melanopus OR cereal leaf beetle) AND wheat AND (model OR simulation OR prediction OR forecast)

2.2.2 Search results

In total, 576 papers on wheat pests were found in the CAB Abstracts database. The abstracts of these papers were carefully analyzed, and 218 of them were considered for potential inclusion in the Mopest inventory; 358 papers were rejected because they did not meet the eligibility criteria. The papers of potential interest were retrieved for further analysis; of the papers of potential interest, however, 24 were not retrieved because they were either not found anywhere or they were not received from the libraries or contacted authors (these papers are listed in Annex 3.4 Not_retrieved_papers). Only 78 of the papers considered to be of potential interest were subsequently added to the Mopest inventory (see Annex 3.3: List of the reviewed literature) (Table 4). Reasons for excluding papers are discussed in Section 2.2.3.

Table 4: **Number of papers for the wheat pest models inserted into the Mopest inventory.**

Pest	Number of papers
karnal bunt (*Tilletia* = *Neovossia indica*)	5
ergot (*Claviceps purpurea*)	0
leaf rust (*Puccinia recondita*)	21
powdery mildew (*Blumeria graminis*)	5
leaf and glume blotch (*Septoria tritici* and *Stagonospora nodorum*)	22
Fusarium head blight and related mycotoxins (*Fusarium* spp.)	16
bacterial leaf streak (*Xanthomonas translucens* pv. *translucens*)	1
barley yellow dwarf virus	5
Agriotes spp.	0
Russian wheat aphid (*Diuraphis noxia*)	3
cereal leaf beetle (*Oulema melanopus*)	6

Although Table 4 indicates a total of 84 papers, the total number of models inserted into the inventory was only 78, because some of the papers describe models that dealt with more than one pest, e.g., the model simulates at the same time two or three of the following diseases: brown rust, leaf and glume blotch, and powdery mildew. Brown rust, leaf and glume blotch, and Fusarium head blight had the highest numbers of models because they are economically important diseases worldwide. Karnal bunt, whose causal agent is a quarantine pest for Europe, had fewer papers: of the five models for karnal bunt, three were developed in India and two in the US. For *Claviceps purpurea*, the causal agent of ergot, only two papers were found in the first stage of the search and both were considered unsuitable in the next stage. A further attempt was made to find relevant papers on ergot / *Claviceps purpurea* by repeating the search using the Latin name of the genus *Claviceps* (i.e., the higher taxonomic level) as a keyword, but no results matched the eligibility criteria. Thirty-three papers were found for the Russian wheat aphid and eleven for the cereal leaf beetle; none of the three papers initially found for *Agriotes* spp. was considered suitable because they focused on modelling the spatial distribution of the insect in soil but did not consider climate or plant data.

2.2.3 Reasons for excluding papers

Codified reasons for excluding papers from the inventory were tested during the selection procedure for the wheat eight pest models listed from 1 to 8 in Section 2.1. A summary of the proportion of papers discarded for various reasons is shown in Table 5, while a record-by-record list is provided in Annexes 2.1 to 2.8 (one list for each pest considered).

The most common reasons for rejecting papers were that the papers did not concern modelling or, if they did concern modelling, they did not use meteorological variables or plant (growth or development) data as input data (Table 5).

Table 5: **Codified reasons for excluding papers from the Mopest inventory, and percentage of the wheat pest models discharged (pests 1 to 8 of the list in Section 2.1).**

Reason for exclusion	Percentage of papers excluded
1. The paper does not concern pest modelling	52
2. The paper does not concern the kind of models of interest, i.e., weather- or climate-driven models, or models considering plant growth or development	29
3. The paper concerns pest modelling, but the model is not described in a transparent manner (e.g., there are no equations), or it refers to pests or plants other than the one of interest, or it shows other mismatches with the eligibility criteria.	19

2.2.4 Comparison of literature sources

The completeness of the search performed in the CAB Abstracts database was evaluated by comparing the results obtained with the CAB database (shown in Section 2.2.1) with the results obtained with the AGRIS database (available at: http://www.fao.org/agris/search /search.do) and with the Internet (using Google as the search engine). Completeness was evaluated as the possibility of missing relevant papers by using only the CAB Abstracts database.

For searching in AGRIS, the same keywords adopted for searching in the CAB Abstracts database were used, modified as required to meet the specific syntax rules of AGRIS (see Table 6). The two searches differed in two main aspects: i) the CAB Abstracts database provides literature sources from 1972 to date, while AGRIS provides literature sources from 1975 to date; ii) information provided by CAB Abstracts includes abstract, title (in English), original title, broad terms, and heading words, while AGRIS provides the text as a default field (an option for selecting many fields at the same time is not available). These two differences were not considered as a constraint for a comparison between the two databases because i) three years of difference during the first half of the 1970s should not cause a significant difference in the amount of the literature sources found (in the results from the CAB Abstracts database, only 5 out of 520 records were dated before 1975); and ii) information provided by the two databases is comparable.

AGRIS provided results only for leaf rust, leaf and glume blotch, Fusarium head blight and related mycotoxins, barley yellow dwarf virus, and karnal bunt (Table 6). The complete lists of literature sources, obtained from the AGRIS database, are enclosed as single files (Annexes 2.9 to 2.14, one list for each pest considered). CAB Abstracts provided results for all the considered diseases. CAB was also far superior to AGRIS in terms of numbers of records found (e.g., 130 records for leaf and glume blotch were found in CAB and only 11 in AGRIS) (see Annex 2.15). Only a few records were found in AGRIS but not in CAB Abstracts. For instance, 19 records for leaf rust were found in AGRIS but not in CAB; nine of the 19 were considered of potential interest for Mopest, and six of the nine are Conference papers. It was considered that works presented at conferences are frequently only preliminary or partial results of complex research, which will be or had already been published in scientific journals. This consideration was confirmed in two of these cases.

Table 6. **Numbers of records found by searching in CAB vs. AGRIS databases. Keywords are listed according to the AGRIS syntax.**

Disease	Key Words	CAB	AGRIS	AGRIS only
Bacterial leaf streak	(“xanthomonas translucens” OR “bacterial leaf streak”) AND wheat AND (model OR simulation OR prediction OR forecast)	2	0	0
Powdery mildew	(“blumeria graminis” OR “erysiphe graminis” OR “powdery mildew”) AND wheat AND (model OR simulation OR prediction OR forecast)	118	0	0
Leaf rust	("brown rust" OR "puccinia recondita") AND wheat AND (model OR simulation OR prediction OR forecast)	137	40	19
Leaf and glume blotch	(“septoria tritici” OR “mycosphaerella graminicola” OR “septoria nodorum” OR “stagonospora nodorum” OR “leaf blotch” OR “glume blotch”) AND wheat AND (model OR simulation OR prediction OR forecast)	130	11	4
Karnal bunt	(“tilletia indica” OR “neovossia indica” OR “karnal bunt”) AND wheat AND (model OR simulation OR prediction OR forecast)	21	1	1
Fusarium head blight	(“gibberella zeae” OR “fusarium graminearum” OR “fusarium head blight” OR “wheat scab”) AND wheat AND (model OR simulation OR prediction OR forecast)	83	1	1
Fusarium spp. and mycotoxins	mycotoxin AND wheat AND (fusarium OR gibberella) AND (model OR simulation OR prediction OR forecast)	19	1	1
Ergot	(claviceps OR “claviceps purpurea” OR ergot OR “sphacelia segetum” OR “sclerotium clavus” OR “sphaeria purpurea”) AND wheat AND (model OR simulation OR prediction OR forecast)	2	0	0
Barley yellow dwarf virus	“barley yellow dwarf virus” AND wheat AND (model OR simulation OR prediction OR forecast)	17	1	0

In the search made with Google, it was not possible to use the same set of keywords used in the previous two bibliographic searches because the searching system of Google does not allow the use of multiple groups of keywords connected by means of the Boolean operator “OR”. In CAB and AGRIS searches, two sets of multiple keywords were used: one for selecting based on Latin names of the pathogen and the common name of the disease, and the other for selecting for the terms model, simulation, forecast, and prediction. Only the latter set of multiple keywords was used in Google, while the first set was substituted by the common name of the disease. The search was carried out both in Google web (http://www.google.it/)

and in Google Scholar (http://scholar.google.it/). Because too many records were found, an advanced search on Google web was performed by searching only files in the pdf format, which is usually the electronic format of journal articles, conference proceedings, etc. With the aim of searching for additional information possibly not available in CAB Abstract, a specific search on "simulation software" was performed in Google web. For this search, two different combinations of keywords were used (the notation respects Google syntax): i) "disease common name" wheat software "model | simulation | prediction | forecast"; ii) "disease common name" wheat software.

Results of these Goggle searches were compared with results of searches in the CAB Abstracts database, as shown in Table 7 (and Annex 2.16). Because of the huge quantity of records found and the difficulties of handling them, a qualitative comparison between the results from Google and those from CAB Abstracts was not performed.

Table 7. **Numbers of records found by searching in CAB Abstracts and by using Google. Keywords are listed according to Google syntax.**

Disease	Key Words	CAB	Google	Google (pdf files)	Scholar Google	Google (software)	Google (*)
Bacterial leaf streak	"bacterial leaf streak" wheat "model | simulation | prediction | forecast"	2	1290	228	129	210	670
Powdery mildew	"powdery mildew" wheat "model | simulation | prediction | forecast"	118	117000	8400	5900	29700	18900
Leaf rust	"brown rust" wheat "model | simulation | prediction | forecast"	137	23300	1040	719	512	2250
Leaf and glume blotch	"leaf blotch" wheat "model | simulation | prediction | forecast"	130	5330	1510	1010	1570	3430
Karnal bunt	"karnal bunt" wheat "model | simulation | prediction | forecast"	21	13500	1540	554	1890	4120
Fusarium head blight	"fusarium head blight" wheat "model | simulation | prediction | forecast"	83	12900	3500	1970	4260	10400
Fusarium spp. and mycotoxins	mycotoxin wheat fusarium "model | simulation | prediction | forecast"	19	70000	6710	3830	8120	13100
Ergot	ergot wheat "model | simulation | prediction | forecast"	2	13100	2940	1820	7710	8650

Barley yellow dwarf virus	"barley yellow dwarf virus" wheat "model | simulation | prediction | forecast"	17	5980	1670	1440	2250	5000

*disease name + wheat+ software

2.2.5 Considerations on testing the Mopest tools

WP2 made it possible to evaluate both the protocol for retrieving, reviewing, and documenting pest models, and the web-portal in a practical search focused on 11 pests of wheat. To obtain a reliable test, WP2 was carried out by two persons (one skilled in plant pathology and one in entomology) who did not participate in WP1. Therefore, these operators approached the protocol and the web-portal for the first time.

The results were satisfactory. The two operators required only a short time to become confident with both the protocol and the web-portal. They judged the protocol clear, rationale, flexible, and easy to use for finding papers, evaluating their relevance in relation to the eligibility criteria, and extracting the relevant metadata. Similarly, they reported that the web-portal was easy- and fast-to-use. Based on their comments, however, some minor changes were made to make it easier to compile some fields of the web-portal and to reduce the possibility of errors.

The number of papers on wheat pest models retrieved using the Mopest search strategy was high. Apart from those pests for which papers of potential interest were not retrieved in full form (i.e., some models on rust, powdery mildew, and Septoria blotch, and one model for karnal bunt and the Russian wheat aphid), the inventory of models for wheat pests may be considered complete. Comparison between the results obtained by using CAB Abstracts and AGRIS databases and Google for searching in the World Wide Web showed that the CAB Abstracts database may be considered the primary source of literature for the Mopest inventory, and that no relevant papers may be missed using this resource.

3. WP3: Systematic review of plant-pest models

Table 8. **Tasks of the WP3**

Task	Title	Activities
3.1	Review literature on pest models	- Review the significant pest models identified in literature using the protocol tested in WP2 (see Section 3.1).
3.2	Produce an electronic list of references	- Produce an electronic list with complete citation and abstracts of the references identified (see Section 3.1).
3.3	Implement the web-based inventory	- Implement the inventory in the web-based portal tested in WP2, with the review literature from Task 3.1 (see Section 3.31).

3.4	Produce a manual to continue the inventory by EFSA	- Produce a clear and complete manual to be used by EFSA for continuing the inventory (see Section 3.2).

3.1 Review of models for the EU quarantine pests

WP3 focused on the 175 pests listed in the EPPO A1 list (available at: http://www.eppo.org/QUARANTINE/listA1.htm). The literature search was performed by using the CAB Abstracts database and the same methods used in WP2. The keywords used were taken from the specific data sheet for each pest available on the EPPO website; names of the host plants were not included as keywords because the search focused on pests and not on particular hosts. Keywords used for the 175 pests are listed in Annex 3.1.

Results of this activity were summarised in Table 9 by grouping pests in macro-categories (bacteria and phytoplasmas; fungi; viruses and virus-like organisms; insects and mites; nematodes); details are provided in Annex 3.1 (Bibliographic search_EPPO_A1).

Table 9. **Number of papers found for the pests listed in the EPPO A1 list**

		No. of records found					
Pest group	No. of pests in A1 list	0	1-5	6-10	11-20	21-30	>30
Bacteria and phytoplasmas	11	4*	3	1	0	2	1
Fungi	37	15	14	3	2	2	1
Viruses and virus-like organisms	24	7	14	3	0	0	0
Insects and mites	100	26	38	11	10	4	11
Nematodes	4	0	2	0	1	1	0

* number of pests (in this case, four of the 11 pests in this group 4 were represented by 0 records).

The search provided 1,739 records. Out of a total of 176 pests, almost one-third (52 pests) did not have any records; this occurred especially for insects and mites (26 pests) and fungi (15 pests), while all the nematodes had at least one record. Only 244 (14%) of the 1,739 records were considered of potential interest for Mopest: 57 were related to diseases caused by phytoplasmas, bacteria, fungi, viruses, and virus-like organisms; and 187 were related to insects, mites, and nematodes (see Annex 3.2, Selected_References_ EPPO_A1, for details). At this stage, the most common reasons for rejecting papers were: “2. the paper does not concern the kind of models of interest, i.e., weather- or climate-driven models, or models considering plant growth or development”, or “3. the paper concerns pest modelling, but the model is not described in a transparent manner (e.g., there are no equations), or it refers to pests or plants other than the one of interest, or it shows other mismatches with the eligibility criteria".

The 244 papers considered of potential interest were acquired from the library system of the Università Cattolica, directly from the author, or from Italian and international libraries. Unfortunately, 71 papers were not retrieved from the libraries or authors; the complete list of these papers is in Annex 3.4. Thirteen of the papers of potential interest were translated from the original language (Chinese, German, Italian, Japanese, Persian) to English. The analysis of the entire papers led to the rejection of some, and some papers were used as related references for other papers rather than as an entry on their own. The list of these records is provided in Annex 3.3 (List of the reviewed literature) as full bibliographic reference, related reference(s), acronym, and abstract.

The inventory of models for the pests listed in the A1 EPPO list may be considered almost complete. In fact, there are pests for which papers of potential interest were not retrieved in full form; some of these papers could contain models of interest for Mopest, and they should then be added to the inventory. Moreover, it is possible that a few papers not reviewed in the CAB Abstracts database contain models that meet the eligibility criteria for inclusion in the inventory. Based on the results from WP2, however, the probability of this is considered low.

3.2 Production of the User's Manual

The manual to continue the inventory by EFSA was produced and enclosed in the Annex 3.5 (Mopest_Manual). The Manual provides guidance for the use of the Mopest inventory. Instructions are given to those users (Standard Users) who need to consult the inventory for retrieving models on pests and to those users (Power Users) who instead intend to improve the inventory by adding new entries and / or modifying those previously inserted. Examples are also provided in the Annex.

Conclusions and Recommendations

CONCLUSIONS

The Mopest project produced tools that make it possible to: i) perform a structured and systematic search of the literature concerning the models that describe the establishment, development, and/or spread of plant pests and that have been published in peer-reviewed journals, proceedings, and reports, or are available on web-sites and in computer programs; ii) review the retrieved literature, extracting the relevant information and documenting each model in a structured, transparent, and efficient manner through a series of descriptors (metadata); iii) insert the information into the inventory through a user-friendly web-based portal that allows the on-line entry of new models and modification or updating of the existing ones; iv) search the models within the inventory by using both basic and advanced search procedures of the web-portal, and to then document and summarize the results in a clear and concise way.

At the end of the Mopest project, the inventory contains about 200 models related to 11 pests of wheat and to the quarantine pests for Europe as listed in the EPPO A1 list. For these pests, the literature retrieved using the search strategy developed within the project may be considered complete. It is still possible that a few papers not reviewed in the CAB Abstracts database used for the search contain models that meet the eligibility criteria for inclusion in the inventory; based on the project results, however, the probability of this event may be considered low. Unfortunately, the inventory needs to be completed, because there are papers that have been considered of potential interest that were not retrieved in full form before the project ended. When these papers become available in the future, the information they contain should be added to the inventory if the information meets the Mopest eligibility criteria.

RECOMMENDATIONS

The Mopest web-portal is a useful tool for the searching of pest models important to the EFSA Panel on Plant Health. The web-portal will therefore support the EFSA Panel on Plant Health in providing independent scientific advice on the risk of the spread, establishment, or development of organisms (plant pests) harmful to plants, to plant products, or to biodiversity. Nevertheless, the inventory needs to be enlarged and regularly updated. In awareness of this need, the web-portal was designed so that information about new models could be included and information about included models could be modified.

These functionalities are “ready-to-use”: the web-portal is accessible via the Internet by any browser through a user name and a password; with the assistance of the manual and the online help, any person with a minimum of experience with web applications can use the web-portal. However, caution must be exercised in defining people who can access the web-portal as power users. Both the insertion of new information and the modification of existing information require a wide knowledge about pest modelling. All the processes that lead to the insertion of new pest models into the inventory require expertise, from searching the specific literature that meets the eligibility criteria to analysing the papers and extracting the relevant metadata. Misinterpretations of what the author(s) said in the original paper and / or errors in implementing information are difficult to check by a standard user and can lead to a misuse of the information.

Notwithstanding the efforts made for rendering the inventory clear and transparent, standard users will need a basic expertise in pest modelling to understand the information contained in the inventory. In addition, it must be emphasized that the web-portal is designed to search for models within the inventory and to extract relevant information for documenting and comparing models; users who require a complete understanding of a model or who intend to apply a model will need to access the original paper.

Finally, the web-portal will require maintenance and probably periodic revision for meeting new needs or adding new functionalities. Such maintenance and revision could be performed by the EFSA staff, using the EFSA IT standards for developing databases and software.

References

Antman EM, Lau J, Kupelnick B, Mosteller F, Chalmers TC, 1992. A comparison of results of meta-analyses of randomized control trials and recommendations of clinical experts. Treatments for myocardial infarction. JAMA 268, 240-248.

Campbell CL, Madden LV, 1990. Introduction to plant disease epidemiology. John Wiley and Sons Inc., New York.

EFSA, 2008a. Pest Risk Assessment - Science in support of phytosanitary decision-making in the European Community, summary report (draft version) of the 10th EFSA Scientific Colloquium held on December 06-07, 2007 in Parma. Parma: EFSA, 2008.

EFSA, 2008b. Data constraints and the choice of qualitative versus quantitative methodology for phytosanitary risk assessment: Perspective of the European Food Safety Authority. Presentation on the 2nd World Congress on Risk, Guadalajara, 8-11. June 2008.

FAO, 2008. Glossary of phytosanitary terms, International Standards for Phytosanitary Measures ISPM no. 5.

Glass GV, 1976. Primary, secondary and meta-analysis of research. Educational Researcher 5, 3-8.

Hau B, Eisensmith SP Kranz J, 1985. Construction of temporal models: II. Simulation of aerial epidemics. Adv. Plant Patho. 3, 11-28.

Kranz J, 1984. Epidemics of Plant Disease: Mathematical Analysis and Modelling. Springer-Verlag, New York, pp. 7-54.

Leffellar PA, 1993. On Systems analysis and simulation of ecological processes. Kluiwer Academic Publishers, London.

Madden LV, Ellis MA, 1988. How to develop plant disease forecasters, in J. Kranz, J. Rotem, (Eds.), Experimental Techniques in Plant Disease Epidemiology. Springer-Verlag, Berlin, pp. 191-208.

Mulrow CD, 1995. Rationale for systematic reviews. In: Chalmers I, Altman DG, (Eds.) Systematic Reviews. BMJ Publishing Group, London.

Mulrow CD, 1994. Systematic Reviews: Rationale for systematic reviews. BMJ 309, 597-599.

Oxman AD, Guyatt GH, 1993. The science of reviewing research. Ann. N. Y. Acad. Sci. 703, 125-133.

Rossi V, 2003. Ruolo dei modelli epifitologici nella difesa delle piante dalle malattie. Giornata di studio su "Proprietà ottiche e stato sanitario delle piante: potenziali applicazioni nella difesa delle malattie", Firenze, Italia, 2003. In: Atti dell'accademia dei Georgofili, VII serie, L, 275-298.

Rossi V, 2008. Analisi del rischio di introduzione di organismi nocivi per le piante. Giornata di studio su “Globalizzazione e difesa delle colture”, Firenze, Italia, 2008. In: Atti dell'Accademia dei Georgofili, 23-57.

Rossi V, Racca P, Giosuè S, Battilani P, 1997. Decision support systems in crop protection: from analysis of the pathosystems to the computerized model, Proc. 1st Workshop on Successful application of information and communication technologies in plant protection (Roma, Italy, 1996) in Petria, 7 (suppl. 1), pp. 7-26.

Shaw M, 1996. Simulating dispersal of fungal spores by wind, and the resulting patterns. Asp. Appl. Biol. 46, 165-172.

USDA 2007. US Department for Agriculture - Center for Plant Health Science and Technology: Report on the APHIS-PPQ-CPHST Workshop on Pest Risk Mapping held on June 5-7, 2007 in Fort Collins, Colorado. Releigh, NC: USDA - CPHST, 2007. Published in the internet: www.nappfast.org, downloaded May 23rd, 2008.

Vanderplank J. P., 1963. Plant diseases: epidemics and control. Academic Press, New York.

Wainwright J, Mulligan M, 2004. Environmental modelling: finding Simplicity in Complexity. John Wiley and Sons, London.

Xu XM, Ridout M, 1996. Analysis of disease incidence data using a stochastic spatial-temporal simulation model. Asp. Appl. Biol., 155-158.

Zadoks JC, 1984. A quarter century of disease warning, 1958-1983. Plant Dis. 68, 352-355.

Zins C, 1999. Success - structured search strategy: information retrieval in the age of global information systems. 65th IFLA Council and General Conference, Bangkok, Thailand, 20 – 28 August, 1999.

Appendices

Annexes are provided as separate documents.