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## Eriophyoidea (Acari) on a computer database

### ABSTRACT

Bibliographical information on most eriophyoid mites is scattered in obscure journals and publications, making literature search difficult and discouraging researchers from studying this taxon. Technical difficulties due to slide mounting methods also deter study and cause delays in identification. In the past, some researchers published catalogues or species indexes (NALEPA, 1929; KEIFER, 1952; FARKAS, 1965; DAVIS *et al.*, 1982; AMRINE & STASNY, 1994; BAKER *et al.*, 1996) whose advantages and disadvantages are discussed.

The authors of this paper developed a computerized database for eriophyoids [following the DAVIS *et al.* (1982) format, in part] in which all references are linked to the species, which is useful to help researchers quickly find all available known information on these mites.

The present paper gives a preliminary account on this database, running on Windows and Macintosh systems, and which will be available on CD-ROM. The database is a Filemaker Pro<sup>TM</sup> 3.0 file (©Clarisc Corporation) and contains about 3200 records. Each record is assigned to a single named species and is composed of several fields recording data on the species name, author(s), date, synonymies, host names, symptoms, geographical distribution, references, drawings and so on which are arranged in several appropriate layouts. A search can be made in most fields which can then be sorted alphabetically, studied on the screen and then printed.

Key words: biodiversity, mites, Eriophyoidea, species-reference linkage, Filemaker Pro<sup>TM</sup> 3.0, CD-ROM, Macintosh, Windows, phytophagy, relational database, world fauna, software.

### INTRODUCTION

The Eriophyoids are highly specialized mites adapted to obligate phytophagy on numerous plants (Angiosperms, Gymnosperms and ferns) from all over the world. Most of them occur mainly on a single, or on a few, closely related host plant species, feeding on selected tissues. They feed on all plant parts, except the roots, producing different injuries (galls, erineae, witches' brooms, rolled leaf margins, rust, browning, blisters, etc.).

There is great interest in the Eriophyoids: many of them are pests and cause direct damage to plants; some are able to transmit viruses; quarantine stations need to monitor for many species; some eriophyoids can be successfully applied against weeds; while cecidologists are interested in the gall-making species, etc.

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So, many people need to know at least the name of a particular mite or information on its biology, ecology, pest status and other aspects (i. e., basic information from the literature).

There are several steps in processing the identification of an eriophyoid mite: finding the correct name of the host plant species, determining the host plant deformation or the relationship of the mite to the host plant, collecting and mounting mites on slides, drawing or illustrating main details (according to Keifer's procedure), taking measurements of different parts of the body [according to AMRINE and MANSON (1996)], and comparing this acquired information with that available from the literature.

Unfortunately, research on eriophyoids is very difficult due to their small size, the difficulty in getting good specimens on slides, good drawings and correct morphological descriptions. Also, the bibliographical information which is required for identification (morphometric descriptions, semischematic drawings, scanning electron micrographs, description of plant deformation, etc.) are not always available or easy to find. Generally, searching for this information takes a lot of time, discourages the researcher from studying this taxon and causes delay in identification.

LINDQUIST and AMRINE (1996) and NUZZACI and DE LILLO (1996) suggested collection of eriophyoid bibliographical data into a computerized database containing information on the original description and illustration, geographical distribution, habits, hosts, references, etc.; the archive would be worldwide in scope, easily and quickly available, and become an invaluable aid for researchers.

Since 1988, AMRINE and DE LILLO have been developing their own, individual computerized databases on eriophyoids. They combined them in order to provide a common database [according in part to the format of DAVIS *et al.* (1982) and improvements by AMRINE and STASNY (1996)], in which all pertinent references were linked to each species, to help researchers easily and quickly find all pertinent information on eriophyoids, especially for identification.

Our aim is to illustrate the arrangement of this database which will provide important data on eriophyoid mites and will be made available on CD-ROM and on an Internet web site.

## MATERIALS AND METHODS

A Performa 6320 Macintosh and a Pentium 266 were utilized.

The archive was created and updated using Filemaker Pro™ version 3.0, from ©Clarisc Corporation, loaded on Windows and Macintosh systems.

Data were input by the authors starting from DAVIS *et al.* (1982) catalogue and updated with papers recorded and indexed in the Review of Agricultural Entomology, Zoological Record, Biological Abstracts and Current Contents.

The drawings were scanned by means of an UMAX scanner having an hardware resolution of 600 dots per inch (dpi), by means of Adobe Photoshop 4, utilizing the original publications when available; otherwise, we photocopied or redrew images. The drawings were at first scanned in gray scale at 600 dpi, then checked for gray levels and “dirt”, rearranged for size (10 x 12 cm), maintaining at least 300 dpi as final resolution value, converting to bitmap mode, recorded in TIFF format and then imported into a “container” FileMaker Pro field.

## DATABASE ORGANIZATION

### WHY FILEMAKER PRO 3.0?

Many applications are available for creating and utilizing databases. Some are very powerful but complicated (4th Dimension, Fox Base Pro, Omnis 7, Access) and require considerable experience by the user. Others are not true database applications, but are electronic spreadsheets (Quattro Pro, Excel, Lotus). FileMaker Pro, in its release 3.0 and beta versions, offers several advantages in respect to the above software. Listed below are the major attributes of FileMaker Pro 3.0, which we consider important in software selection:

a) FileMaker Pro is available for Macintosh, Windows 3.1 and other systems. You can open and utilize the same files in both systems (Mac and Windows) without any translation. Whilst the Windows release identifies the file produced by FileMaker Pro with the extension ‘.FP3’, Macintosh handles files without an extension. To use a Macintosh file in the Windows system, you need only type ‘.FP3’ after the document name.

b) It is more user-friendly compared to classical databases and allows management of information easily and effectively. Beginning users only need a little training to become comfortable with the commands which are often intuitive. The pop-up menus and onscreen help simplify the work considerably.

c) FileMaker Pro 3.0 permits passing from a *flat-file* database (composed of one file) to a *relational* database (composed of many inter-related files). Employing a *relational* database means that you can create more specialized files containing data on particular topics (database system). Each occurrence of data is stored in only one file at a time, but you can access and work with

those data from any file. You can show data in a field of the current file pasted which was from another file (*lookup* option) or displayed from another file without pasting (*relational* option). In this last case each data modification in the related field will be always displayed in the current field.

d) You can arrange the field in the layout mode, establishing its position and size. Each field can contain data for 64,000 alfa-numerical characters in a “text” field and 255 alphanumeric characters in a “number” field. Thus, you can store data up to these limits, but not up to graphical size limits, in the browse mode. You can click on the field to show all hidden information. You can also utilize “container” fields which can contain graphics.

e) It contains SCRIPTMAKER® from Claris Corporation that allows you to create and perform automatic tasks (macros).

f) It can open up to 50 files simultaneously, depending on available RAM.

g) The maximum size of a single file is 2 Gigabytes.

h) It is very flexible and allows arrangement of layouts appropriate for your own use. In fact, you can create fields for letters, numbers, images, and related fields from different databases.

i) It automatically saves modifications made on a single record when you change the record.

A database file created by FileMaker Pro contains one or more records and each record is composed of one or several fields (single or repeating -”multiple”) that can store the data you have entered. The field values utilized in the database files are text, numbers, pictures, date or summary. The fields can be sized and located in the layout mode to best utilize a particular-sized screen in the browse mode.

For more details on the properties and functions of FileMaker Pro 3.0, consult the manual.

## FILES

Our database system is composed of 4 files, called (names for Windows users are in parentheses):

- DRAWINGS (DRAWINGS.FP3),
- GENERA (GENERA.FP3),
- PAPERS (PAPERS.FP3),
- SPECIES (SPECIES.FP3).

SPECIES is the main file; it is the first to be opened and utilizes the information recorded in the other files which are related to the main file (fig. 1).

SPECIES and DRAWINGS contain as many records as named species; each record corresponds to one species.

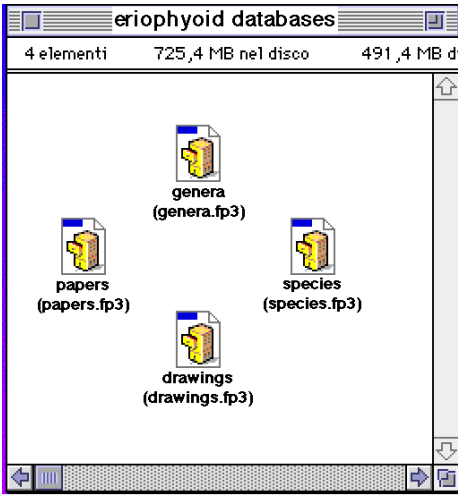


Fig. 1 - Screen picture of the icons for the database files.

GENERA contains as many records as named genera; each record corresponds to one genus.

PAPERS contains as many records as linked references; each record corresponds to one contribution or publication.

#### LAYOUTS

The database system is composed of the following layouts in the main file (fig. 2): *data catalog*, *references*, *drawings*, and *genus*. A layout determines the appearance of data selectively displayed from fields. In fact

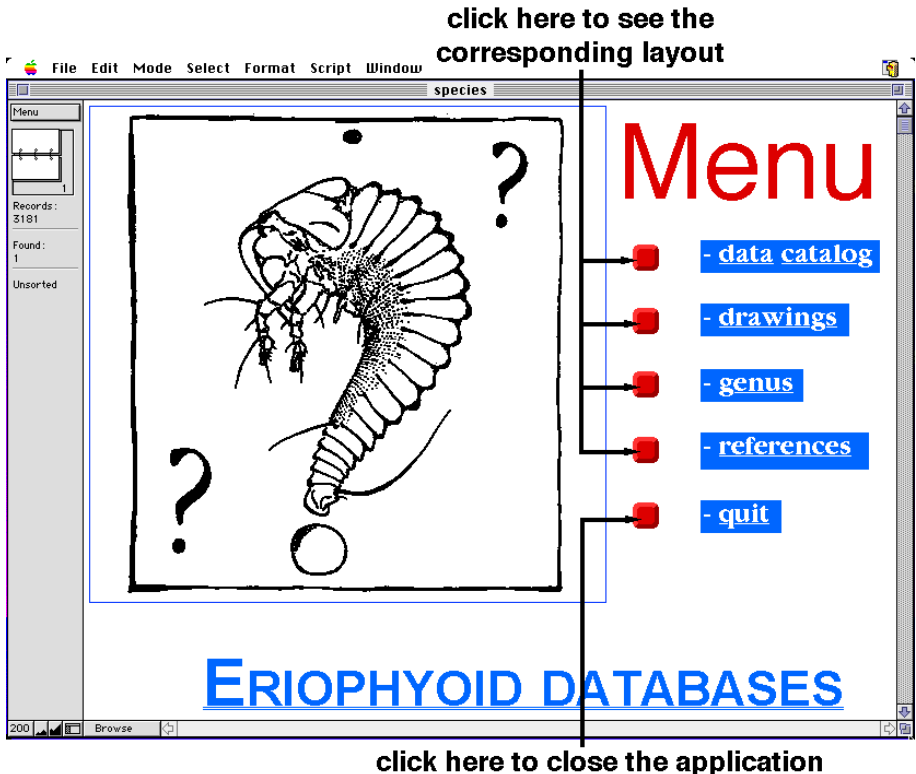


Fig. 2 - Screen picture of the Browse mode of menu in the SPECIES file.

you can add, arrange and format fields and graphics and you can specify how to print records. Switches, in the form of buttons, allow you to pass from one layout to another and viceversa or to print the selected records in that layout.

### FIELDS AND FIELD DEFINITIONS

SPECIES file contains several fields which are arranged in the following layouts.

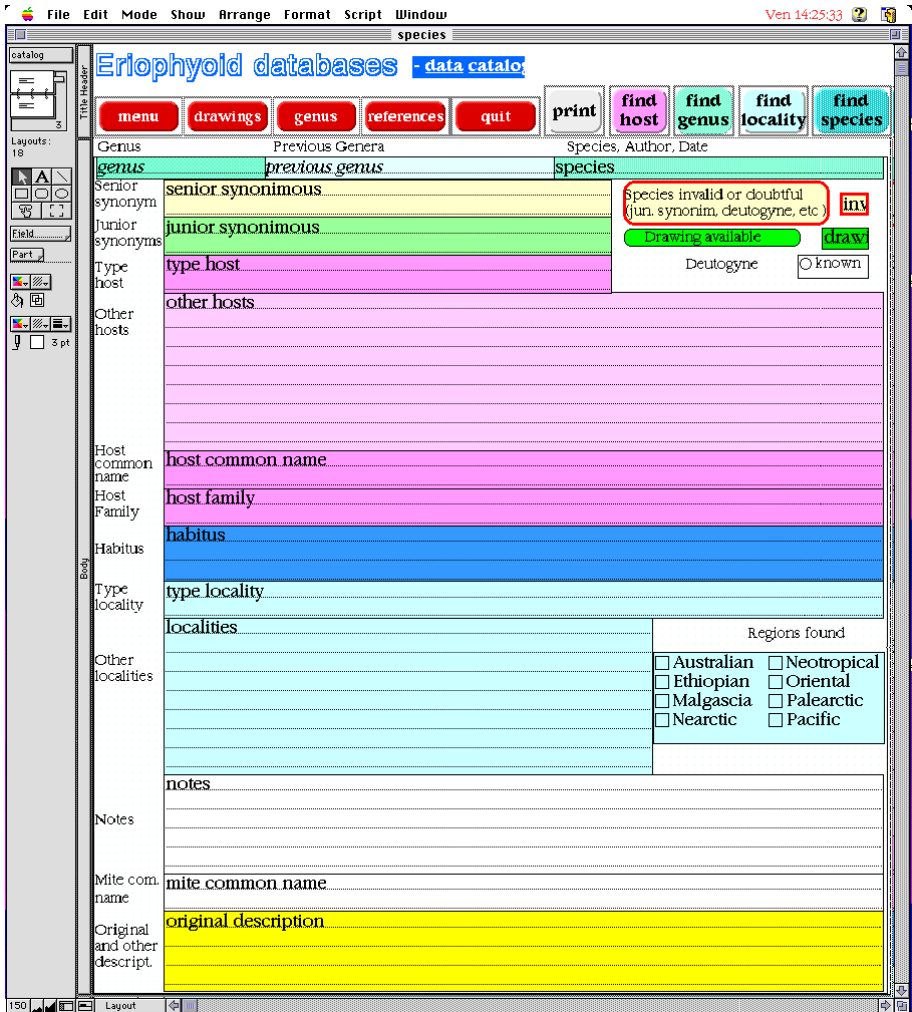


Fig. 3 - Screen picture of the data catalog layout in the SPECIES file with the field arrangements.

Genus	Previous Genera	Species, Author, Date
<b>Aceria</b>		<b>baccharices Keifer, 1945.</b>
Senior synonym		Species invalid or doubtful (jun. synonym, deutogyne, etc.) <input type="checkbox"/>
Junior synonym		Drawing available <input checked="" type="checkbox"/>
Type host	<i>Baccharis satifolia</i> (Ruiz. & Pavon) Pers., originally listed as <i>B. viminea</i> DC.	
Other hosts	<i>Baccharis glutinosa</i> Pers.	
Host common name	Mule-fat, seep-willow, water wally, Sticky Baccharis.	
Host Family	Asteraceae	
Habitus	Irregular, lower surface, leaf bead galls.	
Type locality	California, USA.	
Other localities	(California) USA;	Regions found <input type="checkbox"/> Australian <input type="checkbox"/> Neotropical <input type="checkbox"/> Ethiopian <input type="checkbox"/> Oriental <input type="checkbox"/> Malgascia <input type="checkbox"/> Palearctic <input checked="" type="checkbox"/> Nearctic <input type="checkbox"/> Pacific
Notes		
Mite com. name	Mango leaf-coating mite	
Original and other descript.	Keifer 1945, E. S. 15, Bull. Cal. Dept. Agric. 34: 139, pl. 195; Keifer 1952, Er. M. Cal.: 24, 9-37.	

Fig. 4 - Screen picture of the data from the enlarged central portion of data catalog layout in SPECIES file.

*Data catalog* is the main layout and contains 19 fields (figs 3-4): genus name, previous genus name, species name-author-date, senior synonymy, junior and other synonymies, type host, other hosts, host common name, host family name, mite habitus, type locality, other localities, notes, mite common name, the reference of the original description and other descriptions, validity or doubt regarding the species name, drawings available from the literature, known deutogynes, and distribution by zoogeographical regions. In this layout, 5 buttons indicate macros (short procedures or a sequence of com-

mands) created to find data on the basis of the host plant, genus name, geographical distribution, species name and to print (see 1.6. *Find request and other functions*).

More expert researchers can arrange different and more complex find

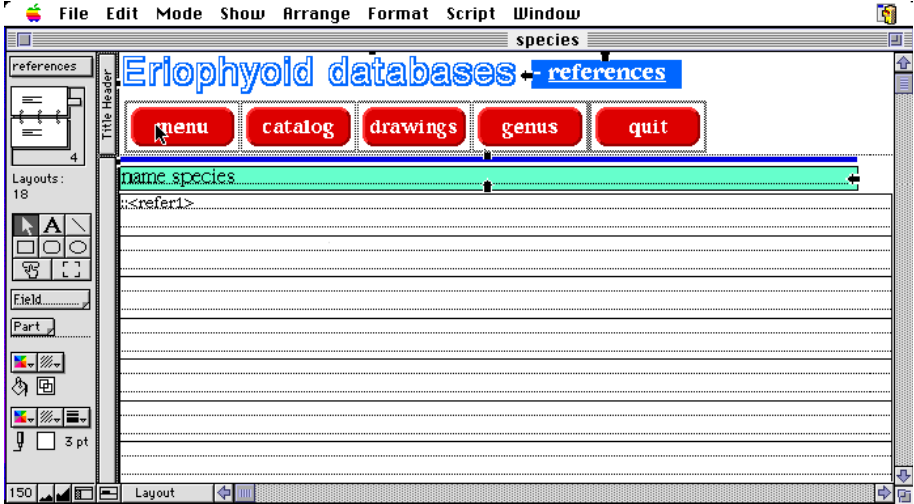


Fig. 5 - Screen picture of the references layout in the SPECIES file with the field arrangements.

Aceria baccharis Keifer, 1945.
KEIFER H.H., 1945 - Eriophyid Studies XV. <i>Bull. Calif. Dept. Agr.</i> , 34: 137-140.
HISLOP R., JEPSON L.R., 1976 - Morphology of the mouthparts of several species of phytophagous mites. <i>Ann. Entomol. Soc. Am.</i> , 69(6): 1125-1135.
KEIFER H.H., 1952 - The Eriophyid mites of California (Acarina, Eriophyidae). <i>Bull. Calif. Insect Survey</i> , 2(1): 1-123.
OLDFIELD G.N., 1973 - Sperm storage in female Eriophyoidea (Acarina). <i>Ann. Entomol. Soc. Amer.</i> , 66(5): 1089-1092.
AMRINE J.W.JR., STASNY T.A., 1994 - Catalog of the Eriophyoidea (Acarina: Prostigmata) of the world. Indira Publish. House, West Bloomfield, Michigan, USA: 804 pp.
NUZZACI G., DE LILLO E., 1996 - Perspectives on Eriophyid mite research. <i>Entomologica</i> , Bari, 30: 73-91.
BAKER E.W., KONO T., AMRINE J.W.JR., DELFINADO-BAKER M., STASNY T.A., 1996 - Eriophyid mites of the United States. Indira Publishing House, W Bloomfield, MI. 394 pp. + i-viii.
DAVIS R., FLECHTMANN C.H.W., BOCZER J.H., BARKS H.E., 1992 - Catalogue of Eriophyid mites (Acari: Eriophyoidea). Warsaw Agricultural University Press, Warsaw, Poland: 1-254.
BOLDT P.E., ROBBINS T.O., 1990 - Phytophagous and flower-visiting insect fauna of <i>Baccharis salicifolia</i> (Asteraceae) in the southwestern USA and northern Mexico. <i>Environ. Entomol.</i> , 19(3): 515-523.

Fig. 6 - Screen picture of the data from the References layout in SPECIES file.

requests.

The *References* layout is composed of 2 fields (figs 5-6): species name and references.

The *Drawings* layout is composed of 2 fields (figs 7-8): species name and drawings.

The *Genus* layout is composed of 7 fields (figs 9-10): genus name, syn-



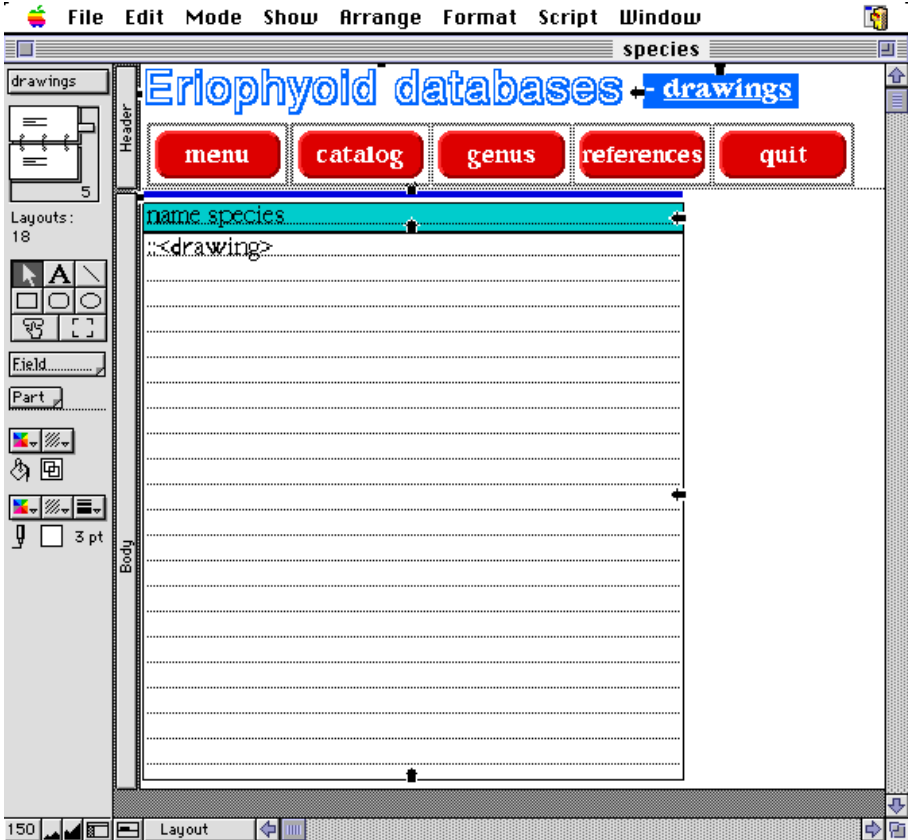


Fig. 7 - Screen picture of the drawings layout in the SPECIES file with the field arrangements.

onymies, type species, eriophyoid family, eriophyoid subfamily, eriophyoid tribe and validity of species.

#### RELATIONSHIPS

The relationship between the species and other files is made by means of an exposed or hidden field according to the following scheme:

related file	match fields	data displayed in SPECIES	type of relationship
PAPERS	ref1 - ref10	references	lookup
GENERA	genus	all fields of the genus layout	relational database
DRAWINGS	index number	drawings	relational database

These relationships allow a reduced size for the main database and pro-

Aceria baccharices Keifer, 1945.

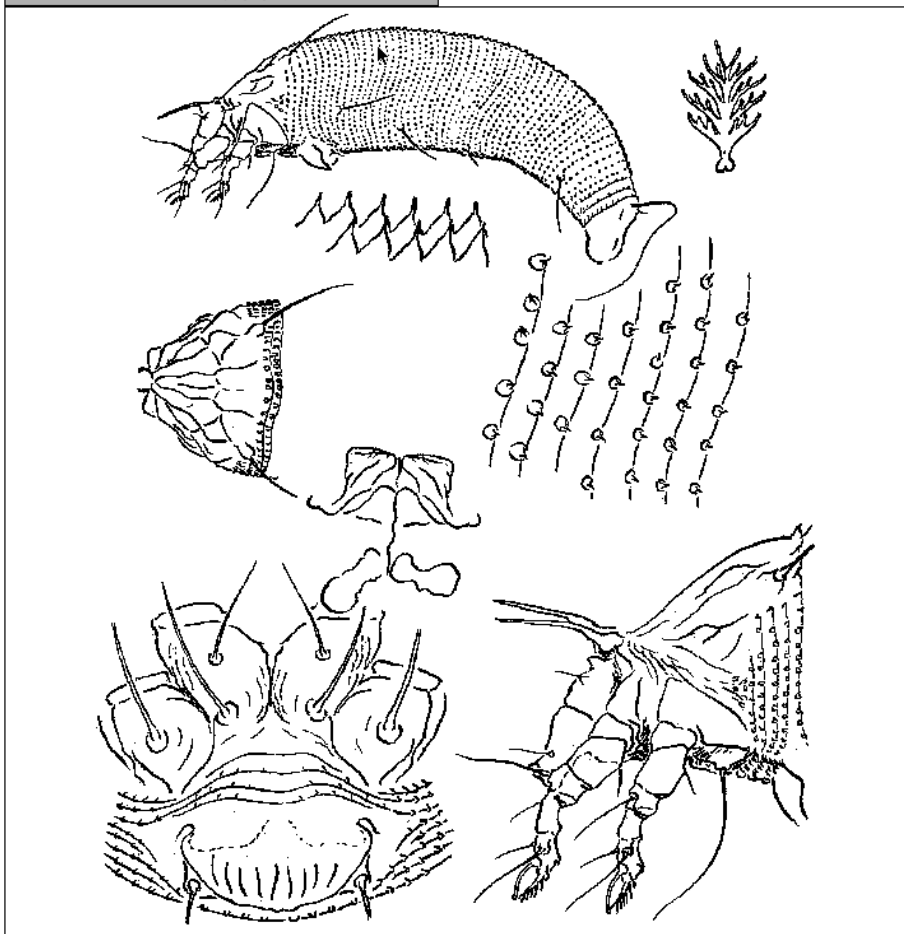


Fig. 8 - Screen picture of the data from the Drawings layout in SPECIES file.

vides faster find requests.

#### FIND REQUEST AND OTHER FUNCTIONS:

In the data catalog layout are 5 buttons corresponding to the most common operations performed by the researcher:

- *find genus*,
- *find host*,
- *find locality*,
- *find species*,

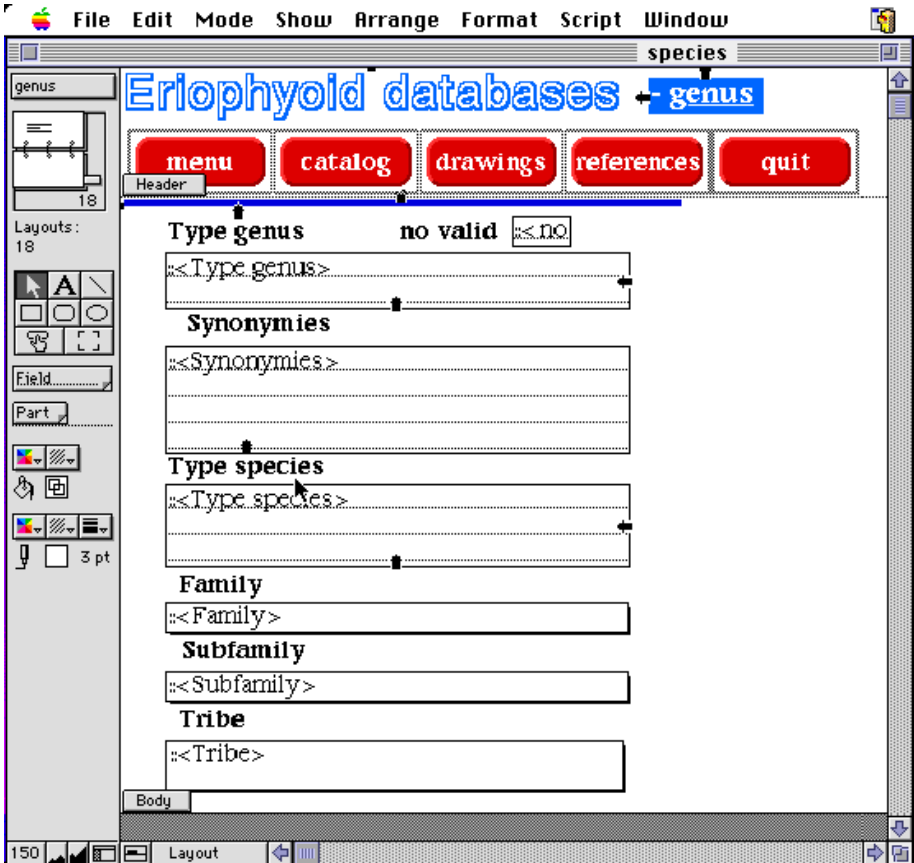


Fig. 9 - Screen picture of the genus layout in SPECIES file with the field arrangements.

- print.

When you click *find genus*, a dialog box appears with the cursor blinking in the field *Genus*. You have to type in the genus name to be found (i.e. all species belonging to that genus) and then press return or Find. The script finds records containing this name in the Genus field, sorts the records alphabetically on the basis of the species name and shows the results of the Find.

When you click *find host*, a dialog box appears with the cursor blinking in the field *Type host*. You have to type in the scientific name of the host plant species to be found and then press return or Find. The script finds records containing this name in both host plant fields (*Type host* and *Other hosts*), sorts the record alphabetically on the basis of the genus name, and then the species

**Type genus**

Aceria Keifer, 1938.

**Synonymous**

Artacris Keifer, 1970; Trichostigma Gerber, 1901; Eriophyes von Siebold, 1851 sensu Newkirk & Keifer, 1971.

**Type species**

A. tulipæ (Keifer), 1938.

**Family**

Eriophyidae Nalepa, 1898.

**Subfamily**

Eriophyinae Nalepa, 1898.

**Tribe**

Acerini Amrine & Stasny, 1994

Fig. 10 - Screen picture of the data from the Genus layout in SPECIES file.

name, and shows the results of the Find.

When you click *find locality*, a dialog box appears with the cursor blinking in the field *Type locality*. You type the name of the country to be found and then press return or Find. The script finds records containing this name in both locality fields (*Type locality* and *Other localities*), sorts the record alphabetically on the basis of the genus name, and then the species name and shows the results of the Find.

When you click *find species*, a dialog box appears with the cursor blinking in the field *Species*. You type in the species name to be found

and then press return or Find. The script finds records containing this name in *Species* field, sorts the records alphabetically on the basis of the genus name and shows the results of the Find.

In the above Find requests you can find one or more records: the current record is the one you are reviewing and you can move from one record to another using the 'book' in the status area or by pressing control key and up or down arrow simultaneously (fig. 3). Below the 'open book', the number of found records is reported.

When you click on the *print* button you select the command for printing the results of the Find.

## DISCUSSION AND CONCLUSION

In the past, some researchers tried to arrange catalogues of eriophyoid mites. NALEPA (1929) listed each plant species with the associated eriophyoids and symptoms.

KEIFER (1952) published a catalogue of the Eriophyoid mites of the

California with drawings for each species, and a list of associated host plants and symptoms.

FARKAS (1965) arranged a key for species of the Eriophyoids of Europe, reporting a brief description and several drawings.

DAVIS *et al.* (1982) published a catalogue of Eriophyoid world fauna which was composed of several sections: eriophyoid species (about 1700), plant species, and references (about 800). These were connected together by means of index numbers. It did not include the trinomial and quaternomial species reported by Nalepa (these were neglected) and the generic names were frequently wrong, but it linked a relevant number of papers to the species.

AMRINE and STASNY (1994) published a catalogue containing a list of mite species, plant species with the associated mites, and several references. It reported almost all described species and revised the genus and species names but it linked only the most important papers for systematics.

Finally, BAKER *et al.* (1996) published a catalogue of the eriophyoids of the United States, giving the morphological description, the infested plants, the drawings and related information.

All of these catalogues were printed on paper; they were often expensive, they did not offer a complete linkage between references and mite species and the descriptions and drawings were almost always lacking.

The large expansion of micro computers in research laboratories and offices has completely changed methods for working on the writing-desk. Researchers have become familiar with a lot of software and can save a lot of time in typing letters, scientific reports, in elaborating statistical data, in drawing graphics, and in creating databases.

Systematic works require a large amount of data (and space in the book-case) and a simplified arrangement of them is needed to find the stored information easily and quickly. At present, there are about 3200 eriophyoid named species and 5000 related papers regarding different aspects (systematics, faunistics, biology, ethology, control, natural enemies, and so on). A researcher can find it very difficult to put all these data together on paper and he or she can waste a lot of time trying to find the information stored on paper when you need to identify a species quickly.

Generally, the protocol utilized to identify an eriophyoid species on a host plant requires a check of the suspect species on the basis of the morphometric details of the eriophyoids known on that host plant, then on mites on plant species of the same genus of the host and then on mites on plants belonging to the same family. Just in case there is no morphometric similarity

of the suspect species with the selected ones, you need to check it with all eriophyoids reported in the same genus.

In the case where there is no morphometric similarity in species found, then the suspect species should be described as a new species.

Following this protocol a researcher needs to look for a species list at least once and at most four times. Those who work with systematics know how much time a bibliographical search takes on a printed catalog and from publications. In addition, when a researcher needs to know extra or helpful information about a species he has to search again the publications or contributions on that species. A lot of time is required for a thorough search!

On the basis of these facts we developed this computer database system which is a complex of files in which there is a collection of information that you can organize, update, sort, search through, and print as needed. We put in it all information that we collected during our past years of work and we arranged several layouts to find and print the required information. Of course, updating the data and getting information from reviews and abstracts takes a lot of time but which systematic researcher doesn't update his archive and spend time to do this?

The novelty is the way in which the researcher creates his archive, considering that computerized databases are already utilized for other taxa. There is no more need for paper records but reliance instead on an informational support that can be printed when needed. It saves space, it is easy to carry and move, it is easy to update, it saves paper, and it saves time in finding stored data.

## AKNOWLEDGEMENTS

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## RIASSUNTO

### ERIOPHYOIDEA (ACARI) IN UN DATABASE COMPUTERIZZATO

Le informazioni bibliografiche sulla maggiorparte degli eriofioidei e distribuita in riviste e pubblicazioni di non facile reperibilità, rendendo la ricerca bibliografica difficile e scoraggiando i ricercatori che si avvicinano a questo gruppo. Le difficoltà tecniche nell'allestimento di preparati microscopici sono anch'esse causa deterrente nello studio del gruppo e ritardano le identificazioni. I vantaggi e svantaggi dei cataloghi e degli indici delle specie già pubblicati sono evidenziati (NALEPA, 1929; KEIFER, 1952; FARKAS, 1965; DAVIS *et al.*, 1982; AMRINE & STASNY, 1994; BAKER *et al.*, 1996).

Gli autori del presente lavoro hanno sviluppato un database informatico sugli eriofioidei partendo dallo schema adottato da DAVIS *et al.* (1982); in questo database si è avuto cura di asso-

ciare tutti i riferimenti bibliografici disponibili al nome di specie.

Il presente lavoro illustra il database disponibile per Windows e per i sistemi Macintosh e che potrà essere disponibile in versione CD-rom. Utilizza l'applicativo Filemaker Pro™ 3.0 (©Claris Corporation) e contiene circa 3200 records. Ogni record identifica un nome di specie e contiene numerosi campi relativi al nome di genere, specie, autore(i), anno, sinonimie, nome dell'ospite tipo e di quelli alternativi, sintomi, distribuzione geografica, riferimenti bibliografici, disegni e altro. Questi campi sono organizzati in appropriate schede; è possibile eseguire una ricerca per ogni campo singolarmente o combinati fra loro, ordinare alfabeticamente i dati, vederli a video e stamparli.

Parole chiave: biodiversità, acari, correlazione tra specie e riferimenti bibliografici, Filemaker Pro™ 3.0, CD-Rom, Macintosh, Windows, fitofagia, database relazionale, fauna mondiale, applicativi.

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