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A MECHANICAL SEARCH AND RETRIEVAL SYSTEM FOR MYCOTOXINS[1]

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Mycotox is a list of fungi that have been reported to produce toxic metabolites, or metabolites closely related chemically to such toxins. It is intended for use by mycologists and chemists and assumes a working knowledge of mycology and/or natural product chemistry by its users. It has been written onto a computer file and can, therefore, be searched automatically. The data base will be augmented as new information is published.

Introduction

In the last 2 decades, it has become clear that the toxic metabolic products of fungi have wider consequences than occasional cases of *Amanita* poisoning (Weiland & Weiland 1972) or outbreaks of St. Anthony's fire (Gröger 1972). For example, it is now very likely that a group of diseases of sheep and cattle, characterised by photosensitivity, involves a fungal vector (Atherton et al 1974). Similarly, the production of aflatoxins by *Aspergillus flavus* (Detroy et al 1971) is probably a factor in diseases of man and other animals (Gurto et al 1978). There are several other well-documented conditions involving fungi that have been described. The epidemiological characteristic of, for example, contaminated grain, has led the Food and Agricultural Organization of the United Nations to inaugurate laboratories in several parts of the world which will monitor shipments of food-stuffs for mycotoxins (FAO Food Control 1977). Thus, shipments of food-stuffs from Canada will be the object of analyses by these FAO laboratories. For this reason, as well as that of aspiring to export produce of the highest quality, it is prudent for those responsible for quality control of Canadian food-stuffs to have information about mycotoxins readily available. We have been concerned with toxic fungal metabolites for the last 30 years, and have kept a close watch on the literature. We felt that the cumulative results of this reading might be valuable to other workers, and we have written some of this information onto a computer file from which it can easily be retrieved. This paper describes the information written onto the file and the method of search.

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Organization of the File Mycotox

The file consists of 4 columns. The information in each column is: column 1 a list of fungal binomial names; column 2 accession numbers (where applicable) whence the fungi may be obtained; column 3 a list of mycotoxin names; column 4 a list of references. The file is meant to be read horizontally, that is, the name of the fungus, the culture collection from which it is available, the mycotoxin it produces, and one or more references to the original work that describes the occurrence of the mycotoxin. For the purpose of this paper, however, each of the 4 lists will be described in turn.

List of Fungi

Species names are given in full without authorities. Where there exist synonyms for systematic names, the name adopted in the reference given is used. If the same culture of an organism produces 2 or more metabolites, the organism appears 2 or more times in the list. In a few instances, fungi that do not produce toxic metabolites, but which are difficult to differentiate from related species that do, are entered. In particular, such cases are entered where a chemical taxonomic differentiation is possible. A few Actinomycetes are included that produce toxic metabolites closely related to common fungal metabolites.

List of Culture Collections

Where the mycotoxin producing strain of the fungus reported in the reference quoted can be obtained from a public culture collection, either freely or for a fee, the name of the culture collection is given and also the accession number of the isolate. The name of the culture collection is abbreviated, but the search programing allows the enquirer to request a translation of the abbreviation and also the address of the collection. In a few cases a star appears after the accession number. This means that an isolate of this species that produces the particular mycotoxin is in our collection and freely available to Canadian workers.

List of Mycotoxin Names

The choice of mycotoxins in this list was governed by the following criteria:

(a) Each metabolite must be chemically characterised, i.e. enough physical and chemical data must be given in the reference to permit repetition. Thus, all ill defined biological polymers, fleetingly stable biosynthetic intermediates, and metabolites produced by introducing abnormal substrates into fermentations are omitted. However, some artifacts of isolation procedures are admitted.

(b) All the compounds in the list (with the exception of a few Actinomycetes metabolites—see above) are produced by fungi. This restriction results in the omission of several phytoalexins and lichen constituents that may well be of fungal origin.

(c) All listed compounds inhibit growth or some other primary function of a living organism, e.g. respiration. The selection rule has been that if a metabolite is poisonous to one species, e.g. a bacterium, it is likely to be toxic to all. Metabolites that merely affect the catalysis of a particular reaction by an isolated enzyme are not included, but on the other hand metabolites that have not been shown to be toxic but that are related to toxic compounds (whether of fungal origin or not) are included.

Generally speaking, names given to mycotoxins by their discoverers are quoted. When no name is given but the systematic (I.U.P.A.C.) nomenclature used, this is given if the name is less than 35 characters long. Sometimes the systematic name is slightly abbreviated, where the stem can be used to abstract all of one group of toxins from the list. If the systematic name is longer than 35 characters, the

molecular formula is given and the elements are quoted in accordance with *Chemical Abstracts* usage. To some extent family names, e.g. trichothecene, are also given in addition to the name used by authors. This is to help in the abstraction of all members of a group. This device is also used when the chemical structure of the metabolite is unknown, but sufficient of its chemistry is known to allow it to be classified in a well-known group.

List of References

References have been chosen with the following order of priority in mind. Review references are quoted if they exist. In the absence of a review, the original full report of the production of a mycotoxin is given. Preliminary reports have been avoided as far as possible as these sometimes refer to fictitious work. We have tried to quote papers that give full experimental details, but workers should not fail to write for fuller information to the authors (we wish them luck!!). Most of the references contain toxicological data, but not necessarily those of the most important studies on this aspect of the subject. No author's names are given, the names of journals are drastically abbreviated and years of publication are usually (where there is a volume number) omitted as superfluous. The numbers after the journal abbreviation are always the volume number and the first page of the paper. Most users of the file will be able to guess the meaning of the abbreviations, but if they are in doubt the system has been designed to allow enquirers to ask for a translation. Usually only one reference is given, because we wish to leave room on the line for other important references that may occur in the future. In several cases we have a large number of references to a mycotoxin(s) that has not been the subject of a review article. In such cases we are willing to supply a list to colleagues in the field.

Method of Searching the Mycotox File

Before any use of the file can be made, it is necessary to obtain a user number from the Computer Center, Dalhousie University, Halifax, Nova Scotia, B3H 4J3. Write to this address and ask for a user number for searching the mycotox file. Having a number, one can then find a computer terminal, e.g. a telex machine with an acoustic coupler and a telephone. If the terminal is set to 300 baud one then dials the number 902-424-8800 (if 110 baud, 902-424-6480) and when a high pitched buzz is heard in the telephone the receiver is placed (the right way round) on the acoustic coupler. The carriage return key is pressed and the computer responds:

YEAR/MONTH/DAY. HOUR, MINUTE, SECOND.
DALHOUSIE UNIVERSITY NOS 1.2-446 (K) NOS 1.2-446
USER NUMBER:

The user number given by the computer center is now typed in followed by a comma, a space, and a carriage return, after which the computer responds:

TERMINAL: X, TTY
RECOVER/SYSTEM

In the vast majority of cases the user now types **mycotox**. If however there has been a fault in the telephone transmission which resulted in the connection being broken (for 5 min or less) one can type **Recover, X, TTY** where X is the integer given on the original connection after the word TERMINAL in most cases the computer responds:

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FUNGAL TOXIN REFERENCES

TYPE HELP OR ENTER A COMMAND
C?

It is now possible to start the search and retrieval procedure, and for the majority of enquiries an entry **List** followed by the name of a fungus or a mycotoxin and a carriage return will print all the entries on the file in which the name of the fungus or mycotoxin occurs. Lifting the telephone off the acoustic coupler then terminates the session.

It is possible, however, to use the system to acquire further information, and to obtain a more polished printed record of the search. The means of doing these tasks are discussed in the next sections.

Format of the Printed Record

There are 4 commands that are used to control the format of the printed output. These are: Narrow, Wide, Limit and Relist.

The commands **Narrow** and **Wide** govern the width (i.e. the number of characters) on a printed line. The one to use depends on the computer terminal in use. The **Wide** command permits the user to print the information available on the file pertaining to 1 fungus or 1 mycotoxin on 1 line of print. Such a terminal must have a platten at least 126 characters wide. The **Narrow** command prints the same information on 2 lines and must be used when the teminal prints lines of 72 or fewer characters wide. The system normally assumes that the terminal in use is less than 72 characters wide. If on searching the file in response to the **List** command more than 5 entries are found, the first 5 lines will be printed and then the user will be asked if the information they require has been printed or whether they wish the remaining information to be divulged. The purpose of this format is to reduce to a minimum telephone line charges. However, if all the data found in the search are needed, the printed results of the search become fragmented. Thus, the limit of 5 lines can be overcome by the use of the **Limit** command in the form **Limit X** where X is an integer. If X is chosen as the total number of lines found in the search, the record can now be printed out continously, without using further computer time, by entering the **Relist** command (see Table I). The **Relist** command can be used any number of times, to e.g. obtain copies of the search record, or to obtain a copy of the sorted file if a recovery operation has been successfully completed.

Searching Mycotox for Information

Four commands are used for this purpose. By far the most important is **List.** An example of the use of this command in its simplest form has been given, and a typical response by the computer is shown in Table 1. It should be noted that a space is required between the word **List** and the word, or part of a word, for which a search is done. It is possible, however, to use the list command, to search the file in greater or lesser degrees of discrimination. For example, the Command **List Aspergillus** will result in the selection of all the genus *Aspergillus* that are known to produce toxic metabolites. Similarly the command **List Aspergillus flavus** will result in a list of all the mycotoxins known to be produced by *A. flavus.* Finally the **List** command can be used in the form **List Aspergillus flavus . . .afla** and this will now reduce the printed record to only those isolates of *Aspergillus flavus* that produce a mycotoxin having the sequence of letters **afla** in its name, i.e. it prints (among other things) all entries on the file that record the production of aflatoxin by *A. flavus.* It follows that complete words are not required by the **List** command, and this is a useful attribute in a chemical sense. Obviously **List acid** will result in the selection of all the acids on the file where the word acid appears in the name. Thus, polyporic acid will be selected but penicillin will not. However, the command can be used in a more sophisticated sense chemically, e.g. **List ol** resulting in the selection (among other things) of

Table I. Typical enquiry session illustrating format and reformat of the search results.

```
                    ***NRC ATLANTIC REGIONAL LABORATORY***
                        FUNGAL TOXIN REFERENCES

      TYPE 'HELP' OR ENTER A COMMAND
C? LIST HELMINTHOSPOR
   COCHLIOBOLUS SATIVUS                  IMI 125851
     9-HYDROXYPREHELMINTHOSPOROL                    J 1970 686
   COCHLIOBOLUS SATIVUS                  IMI 125851
     PREHELMINTHOSPOROL                             J 1970 686
   HELMINTHOSPORIUM DEMATIOIDEUM         O
     CYTOCHALASINS                                  J 1969 923
   HELMINTHOSPORIUM DEMATIOIDEUM         O
     CYTOCHALASIN F                                 J (U) 1972 148
   HELMINTHOSPORIUM DEMATIOIDEUM         IMI74812
     C29H35N05                                      CH 66 9972E        CR
MORE LINES TO COME; TYPE 'END' TO STOP HERE?
   HELMINTHOSPORIUM HEVEAE               IMI 80137
     HEVEADRIDE                                     J 1973 194
   HELMINTHOSPORIUM LEERSII              O
     LUTEOLEERSIN                                   BJ 32 449
   HELMINTHOSPORIUM LEERSII              O
     ALBOLEERSIN                                    BJ 32 449
   HELMINTHOSPORIUM MONOCERAS            IMI 125855
     MONOCERIN                                      J 1970 2598
   HELMINTHOSPORIUM SACCHARI             O
     HELMINTHOSPOROSIDE                             JBC 246 4350:
                                                    PH 61 691:66 423
   HELMINTHOSPORIUM SATIVUM              O
     HELMINTHSPOROL                                 CH 65 19273A
   MORE LINES TO COME; TYPE 'END' TO STOP  HERE? END                    CR
C? LIMIT 20                                                             CR
C? RELIST                                                               CR
   COCHLIOBULUS SATIVUS                  IMI 125851
     9-HYDROXYPREHELMINTHOSPOROL                    J 1970 686
   COCHLIOBOLUS SATIVUS                  IMI 125851
     PREHELMINTHOSPOROL                             J 1970 686
   HELMINTHOSPORIUM DEMATIOIDEUM         O
     CYTOCHALASIN S                                 J 1969 923
   HELMINTHOSPORIUM DEMATIOIDEUM         O
     CYTOCHALASIN F                                 J (U) 1972 148
   HELMINTHOSPORIUM DEMATIOIDEUM         IMI74812
     C29H35NO5                                      CA 66 9972E
   HELMINTHOSPORIUM HEVEAE               IMI 80137
     HEVEADRIDE                                     J 1973 194
   HELMINTHOSPORIUM LEERSII              O
     LUTEOLEERSIN                                   BJ 32 449
   HELMINTHOSPORIUM LEERSII              O
     ALBOLEERSIN                                    BJ 32 449
   HELMINTHOSPORIUM MONDCERAS            IMI 125855
     MONOCERIN                                      J 1970 2598
   HELMINTHOSPORIUM SACCHARI             O
     HELMINTHOSPOROSIDE                             JBC 246 4350:PH 61
                                                    691:66 423
MORE LINES TO COME; TYPE 'END' TO STOP HERE? END                        CR
   C?
```

alcohols and phenols. The most useful form of this facility is in selection on the basis of the stem of a systematic name, e.g. **List trichothec** will select from the file all the T2 type mycotoxins.

The second command to obtain information is the **Help** command. By the use of this command, most of the information given in this paper can be acquired. Its use for this purpose is likely to be expensive in telephone line charges from any but a local (i.e. Halifax) terminal. Rather, the command is designed as an amenity for a user who needs to prompt their memory while engaged in a search for information. The form of the command is **Help XXX** where XXX is another command, or if it is the name of a command that has been forgotten **Help index** which results in all the topics on which help is available to be printed.

The third command that provides information is the **Changes** command. It is intended to update the file on about a monthly basis. The information added will be that, we have culled from the literature as part of our normal reading, and also information that other users have found to be in error or omitted. By entering the command **Help changes,** the user will find out the last date that new information was entered on the file and also any other change in the amenities provided by the Computer Center to aid future searches.

Lastly the command **Abbrev**, in the form **Abbrev X** where X is an abbreviation used in the file, will result in the printing of a full translation of the abbreviation. Typical examples are given in Table 2. When the abbreviation is a journal name, the full title of the journal is printed; when it refers to a culture collection, the full name of the collection and its postal address is printed.

Disconnection from the System

As mentioned above, when an enquirer has finished a search of the file, the session can be terminated merely by replacing the telephone on its cradle. A better method is to respond to the system prompt C? by typing **End.** This is an improvement because the computer will disconnect the telephone and in addition it will provide useful information i.e. the cost of the computer session, for which the user will be charged by the Computer Center, and the length in hours of the session. This latter information is useful for checking telephone charges (Table 2).

Discussion

This search and retrieval system is essentially a "do it yourself" utility for the use of mycologists and natural product chemists. The user needs to know how to use a remote computer terminal, which amounts to an acquaintance with the use of a acoustic coupler for a telephone with a typewriter keyboard, and with the necessity of sending each line of typed information to the computer by means of the carriage return key. Beyond this the user needs to become acquainted with the commands described in this paper, and we have found that colleagues who have consented to act as guinea pigs have learned these quickly. Recently the system has been demonstrated publicly in Montreal and Winnipeg, and has performed faultlessly. It seems reasonable to extrapolate this result and to assume that a similar success will attend its use anywhere in Canada. About 200 searches of the file have been done so far, and the average cost of a single search is about $0.30. Using a terminal operating at 300 baud, the time of searches of about 10 lines output, is less than 1 minute. This assumes that no other enquires about abbreviations, or reformatting the output have been made. Thus, the total cost of an enquiry from Vancouver at the period of maximum telephone charges would be about $1.50. Such charges compare very favorably with all other mechanical search and retrieval systems, and we hope that this economy will make the system popular. As indicated in the description of the **Changes** command, it is possible for a user to contribute to the informa-

Table II. Illustration of the use of the "Abbrev" command to translate journal abbreviations or names and addresses of culture collections.

```
ABBREV N
C? N
      NATURE, LONDON
C? ABBREV IMI
  IMI
      Commonwealth Mycological Institute, Ferry Lane, Kew, England
C? END
NRGE001    LOG OFF          14.04.55.
NRGE001    SRU              3.981 UNITS.
CONNECTED        0.116 HOURS,
SESSION COST     0.560 DOLLARS.
```

tion in the file. At the moment, this must be done by mail. It is suggested that when a user finds an error or omission in the file, they send details (preferably on a postcard commonly used for reprint requests) to one of the authors at the Atlantic Regional Laboratory. The information will then be checked, and if it meets criteria stated in the first part of this paper, it will be incorporated in the following update of the file. If it does not meet these criteria, the reasons for its omission will be sent to the user.

Some minor additions to the information on each line are possible and we welcome suggestions. A little more chemical information could be given, e.g. molecular formulae and perhaps toxicological references. Correspondence on these matters should be addressed to the authors at the Atlantic Regional Laboratory. Readers interested in the computational devices used should send their enquiries to Mr. Evans at the Computer Center.

We regard the system not only as a useful tool to the busy practising mycologist who urgently needs to know if a fungus isolated from a toxic feed sample is a known producer of mycotoxins, but also as an experiment in a literature awareness facility, controlled and operated by research workers for their own benefit.

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