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A COMPUTER–ASSISTED METHOD FOR THE STORAGE, RETRIEVAL AND ANALYSIS OF BIOLOGICAL FIELD DATA

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ABSTRACT

A card for data acquisition was designed and linked to a package of BASIC language computer programs for the input, editing, sorting, storage and retrieval of biological field data. This computer-assisted methodology has been used for the past two years to store and analyse *ca.* 1000 field records of biotic agents collected from *Rumex* species in Europe.

INTRODUCTION

Field data collected by ordinary sampling or experimentation may create a wealth of information that has very little meaning until carefully analysed. The analysis may or may not require statistical techniques. The relatively recent advent of computers has greatly increased the ease with which masses of such data can be stored, sorted, retrieved, analyzed and graphically displayed. This modern technology has set new standards in data management.

The process of data analysis, whether by computer or other means, closely parallels the operation of a computer program. In any research program, there is data acquisition (input), the planning and definition of the analysis (programming), the execution of the analysis (calculation), and the display of the results and summaries (output).

These components define the areas that must be considered when developing a computational capability for data analysis. The provision for effective analysis of field data by biological workers requires some familiarity with recent developments in the area of computing technology.

Each portion of the data analysis is only as good as the previous portion, thus at the foundation of the program is data gathering. The needs for the data must be clarified so that relevant data to fit those needs will be gathered. Often, some data is gathered because its relevance is unknown or the energy expended to collect it along with the relevant data was minimal.

Once a decision is made as to what data is to be collected then the when and how questions must be answered. The question of when the data is to be collected is relevant to the project since timeliness can be critical to the collection of pertinent data. This decision must be made by someone closely associated with the system to be sampled.

The question of how the data is obtained is crucial to the success of the program. The type of analysis to be used on the data must be decided before the sampling or experiment. The method of data collection then is designed so that the resulting data fits the method of analysis.

A computerized data management system was developed for the express purpose of handling the large amounts of field records that are generated in a search for biotic agents for the biological control of a weed species. The same

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general format is also useful when searches are made for biotic agents for insect pest species or when numerous field records are generated in ecological research programs.

A new research program at the Biological Control of Weeds Laboratory-Europe located in Rome, Italy, provided the opportunity to test the computer-assisted data management system. The research program on *Rumex crispus* is described in another paper (Spencer 1981) along with examples of output of the data management system.

METHODS AND MATERIALS

Dr. Gary Buckingham, USDA-SEA-AR, Gainesville, Florida, designed a 20 x 27 cm marginally punched card for field data when he was in charge of the Biological Control of Weeds Laboratory-Europe. His original design was tested for use with a computer input program.

The computer program requires a format that provides for all possible responses to a question; i.e., all possible members of the set of valid responses must be predetermined. The responses must be coded when entered into the computer. Several generations of this card were designed to increase the compatibility of the card with the data management system without loss of information.

The present generation of the field data card contains the computer codes which facilitates data entry, decreases input time and has greatly increased accuracy. Utilizing this card has also resulted in comparable data when taken at different times and/or different sites.

Once entered, the data is rigorously edited for validity and internal consistency. This edited record then becomes part of the random access data base.

The data base can be queried through the use of a package of programs that provide for searching, sorting, decoding and printing. Additional simple programs and procedures can be written for specific purposes such as the entry of the data into standardized formats and routines and the recovery of specific portions of records. Information from the data base can be retrieved for data analysis and plotting through the use of another package of statistical programs.

Many of the codes are flexible and code lists are maintained as separate files so that changes, deletions or additions can be made without changing the program package extensively. Additional plants and/or biotic agents can be added to the data base simply by increasing the code list.

Our extended language BASIC is on a dual floppy disk Olivetti[4] Computer with a 32K memory. A 10 megabyte fixed disk provides the storage for both the program libraries and the data base. Floppy disks contain copies of all programs and data for back-up purposes. A flatbed digital plotter is connected to the computer and is used extensively for graphs, charts, and tables, and was also used to layout the field data card as seen in Figure 1.

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[4] Mention of a proprietory product in this paper does not constitute an endorsement of that product by the USDA.

PROJECT ..... DATE ..... CARD ..... OF .....

COLL. # ..... COLLECTOR'S INITIALS ..... NAME .....

COUNTRY ..... REGION .....

CITY ..... SITE .....

PLANT, GENUS-SPECIES-AUTHOR ..... ( )VERIFIED

( )HERBARIUM ( )SEEDS # OF PLANTS EXAMINED ..... TIME .....

PLANT STAGE
( ) SEEDLINGS
( ) ROSETTE
( ) VEGETATION
( ) BUDDING
( ) BOLTING
( ) FLOWERING
( ) FRUITING
( ) SEEDING
( ) SENESCENT

HABITAT
1 FIELD
2 PASTURE
3 HIGHWAY
4 FOREST
5 AQUATIC
6 WINDROW
7 RIVER BED
8 SEASHORE
9 OTHER

1 CULTIVATED
2 UNCULTIVATED
3 ABANDONED
- NOT APPLICABLE
0 OTHER

SOIL TYPE
1 SILTY LOAM
2 LOAM
3 SANDY LOAM
4 SILT
5 CLAY
6 SAND
7 GRAVEL (STONY)
8 PEAT
9 OTHER

1 DRY RED
2 HUMID RED
3 DRY BROWN
4 HUMID BROWN
5 WET BROWN
6 DRY GREY
7 WET GREY
8 WHITE
9 OTHER

WIND
1 NONE
2 GENTLE
3 MEDIUM
4 STRONG

SKY
1 SUNNY
2 CLOUDY
3 OVERCAST
4 RAINING
0 OTHER

TEMPERATURE °C
AIR ..... SOIL .....

DENSITY
1 FEW SCATTERED
2 FEW CLUMPED
3 COMMON BUT SCATTERED
4 COMMON IN CLUMPS
5 DENSE STAND

.....

.....

.....

.....

SPECIMEN # ..... ORDER ..... FAMILY ..... * * * *

TRIBE ..... GENUS-SPECIES-AUTHOR .....

COLL.
( )IN
( )ON
( ) ROOT
( ) CROWN
( ) STEM
( ) LEAF
( ) FLOWER
( ) DETRITUS
( ) PETIOLE
( ) FRUIT
( ) SEED
( ) SOIL
( ) AIR
( ) INSECT

STAGE
( ) EGG
( ) LARVA
( ) NYMPH
( ) PUPA
( ) ADULT

DAMAGE
1 NONE
2 LIGHT
3 MEDIUM
4 HEAVY
5 DEATH

FEEDING
( ) ENDOPHAGOUS
( ) ECTOPHAGOUS
( ) NOT FEEDING

METHOD
1 VISUAL
2 SWEEPING
3 D'VAC
4 BEATING
5 TRAPPING
6 DISSECTING
0 OTHER

PLTS INFESTED .....
OF BIOTIC AGENTS FOUND ..... COLL. .....

REARING
1 NOT REARED
2 FED, SURVIVED OR DIED
3 FED, DIED ON DIET
4 NO FEEDING, SURVIVED
5 NO FEEDING, DIED
6 DIED IN HANDLING
7 FED, PARASITE-DISEASE
8 NO FEEDING, PARASITE-DISEASE
9 OTHER

DETERMINATION
1 DETERMINED
2 TENTATIVE ID.
3 NO ID.
4 DISEASED
5 PARASITIZED
6 NO SPECIMEN
7 INVALID ID.
8 OTHER

1 BY SPECIALIST
2 ??? - ID.
3 BY LAB STAFF
4 NOT YET DET.
5 SENT OUT
7 MORE ID. REQUIR.
8 NOT DETERMINABLE
9 OTHER

DET. BY .....
SPEC. LOCATED .....
DATE SENT ..... RETURNED .....
IDENT. NOS .....
SENT TO .....

.....

.....

.....

SPECIMEN # ..... ORDER ..... FAMILY ..... * * * *

TRIBE ..... GENUS-SPECIES-AUTHOR .....

COLL.
( )IN
( )ON
( ) ROOT
( ) CROWN
( ) STEM
( ) LEAF
( ) FLOWER
( ) DETRITUS
( ) PETIOLE
( ) FRUIT
( ) SEED
( ) SOIL
( ) AIR
( ) INSECT

STAGE
( ) EGG
( ) LARVA
( ) NYMPH
( ) PUPA
( ) ADULT

DAMAGE
1 NONE
2 LIGHT
3 MEDIUM
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FEEDING
( ) ENDOPHAGOUS
( ) ECTOPHAGOUS
( ) NOT FEEDING

METHOD
1 VISUAL
2 SWEEPING
3 D'VAC
4 BEATING
5 TRAPPING
6 DISSECTING
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PLTS INFESTED .....
OF BIOTIC AGENTS FOUND ..... COLL. .....

REARING
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9 OTHER

DETERMINATION
1 DETERMINED
2 TENTATIVE ID.
3 NO ID.
4 DISEASED
5 PARASITIZED
6 NO SPECIMEN
7 INVALID ID.
8 OTHER

1 BY SPECIALIST
2 ??? - ID.
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4 NOT YET DET.
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7 MORE ID. REQUIR.
8 NOT DETERMINABLE
9 OTHER

DET. BY .....
SPEC. LOCATED .....
DATE SENT ..... RETURNED .....
IDENT. NOS .....
SENT TO .....

.....

.....

.....

Figure 1. Field data card — Front.

SPECIMEN # .... ORDER .... FAMILY .... * * * *

TRIBE .... GENUS-SPECIES-AUTHOR ....

COLL.	STAGE	FEEDING	# PLTS INFESTED	DETERMINATION	
( ) IN	( ) EGG	( ) ENDOPHAGOUS	# OF BIOTIC AGENTS	1 DETERMINED	1 BY SPECIALIST
( ) ON	( ) LARVA	( ) ECTOPHAGOUS	FOUND .... COLL.	2 TENTATIVE ID.	2 777 - ID.
( ) ROOT	( ) NYMPH	( ) NOT FEEDING		3 NO ID.	3 BY LAB STAFF
( ) CROWN	( ) PUPA			4 DISEASED	4 NOT YET DET.
( ) STEM	( ) ADULT		REARING	5 PARASITIZED	5 SENT OUT
( ) LEAF		METHOD	1 NOT REARED	6 NO SPECIMEN	7 MORE ID. REQUIR.
( ) FLOWER			2 FED, SURVIVIED ON DIED	7 INVALID ID.	8 NOT DETERMINABLE
( ) DETRITUS	DAMAGE	1 VISUAL	3 FED, DIED ON DIET	0 OTHER	0 OTHER
( ) PETIOLE	1 NONE	2 SWEEPING	4 NO FEEDING, SURVIVED	DET. BY	
( ) FRUIT	2 LIGHT	3 D'VAC	5 NO FEEDING, DIED	SPEC. LOCATED	
( ) SEED	3 MEDIUM	4 BEATING	6 DIED IN HANDLING	DATE SENT .... RETURNED	
( ) SOIL	4 HEAVY	5 TRAPPING	7 FED, PARASITE-DISEASE	IDENT. NOS	
( ) AIR	5 DEATH	6 DISSECTING	8 NO FEEDING, PARASITE-DISEASE	SENT TO	
( ) INSECT		0 OTHER	0 OTHER		

SPECIMEN # .... ORDER .... FAMILY .... * * * *

TRIBE .... GENUS-SPECIES-AUTHOR ....

COLL.	STAGE	FEEDING	# PLTS INFESTED	DETERMINATION	
( ) IN	( ) EGG	( ) ENDOPHAGOUS	# OF BIOTIC AGENTS	1 DETERMINED	1 BY SPECIALIST
( ) ON	( ) LARVA	( ) ECTOPHAGOUS	FOUND .... COLL.	2 TENTATIVE ID.	2 777 - ID.
( ) ROOT	( ) NYMPH	( ) NOT FEEDING		3 NO ID.	3 BY LAB STAFF
( ) CROWN	( ) PUPA			4 DISEASED	4 NOT YET DET.
( ) STEM	( ) ADULT		REARING	5 PARASITIZED	5 SENT OUT
( ) LEAF		METHOD	1 NOT REARED	6 NO SPECIMEN	7 MORE ID. REQUIR.
( ) FLOWER			2 FED, SURVIVIED ON DIED	7 INVALID ID.	8 NOT DETERMINABLE
( ) DETRITUS	DAMAGE	1 VISUAL	3 FED, DIED ON DIET	0 OTHER	0 OTHER
( ) PETIOLE	1 NONE	2 SWEEPING	4 NO FEEDING, SURVIVED	DET. BY	
( ) FRUIT	2 LIGHT	3 D'VAC	5 NO FEEDING, DIED	SPEC. LOCATED	
( ) SEED	3 MEDIUM	4 BEATING	6 DIED IN HANDLING	DATE SENT .... RETURNED	
( ) SOIL	4 HEAVY	5 TRAPPING	7 FED, PARASITE-DISEASE	IDENT. NOS	
( ) AIR	5 DEATH	6 DISSECTING	8 NO FEEDING, PARASITE-DISEASE	SENT TO	
( ) INSECT		0 OTHER	0 OTHER		

SPECIMEN # .... ORDER .... FAMILY .... * * * *

TRIBE .... GENUS-SPECIES-AUTHOR ....

COLL.	STAGE	FEEDING	# PLTS INFESTED	DETERMINATION	
( ) IN	( ) EGG	( ) ENDOPHAGOUS	# OF BIOTIC AGENTS	1 DETERMINED	1 BY SPECIALIST
( ) ON	( ) LARVA	( ) ECTOPHAGOUS	FOUND .... COLL.	2 TENTATIVE ID.	2 777 - ID.
( ) ROOT	( ) NYMPH	( ) NOT FEEDING		3 NO ID.	3 BY LAB STAFF
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( ) STEM	( ) ADULT		REARING	5 PARASITIZED	5 SENT OUT
( ) LEAF		METHOD	1 NOT REARED	6 NO SPECIMEN	7 MORE ID. REQUIR.
( ) FLOWER			2 FED, SURVIVIED ON DIED	7 INVALID ID.	8 NOT DETERMINABLE
( ) DETRITUS	DAMAGE	1 VISUAL	3 FED, DIED ON DIET	0 OTHER	0 OTHER
( ) PETIOLE	1 NONE	2 SWEEPING	4 NO FEEDING, SURVIVED	DET. BY	
( ) FRUIT	2 LIGHT	3 D'VAC	5 NO FEEDING, DIED	SPEC. LOCATED	
( ) SEED	3 MEDIUM	4 BEATING	6 DIED IN HANDLING	DATE SENT .... RETURNED	
( ) SOIL	4 HEAVY	5 TRAPPING	7 FED, PARASITE-DISEASE	IDENT. NOS	
( ) AIR	5 DEATH	6 DISSECTING	8 NO FEEDING, PARASITE-DISEASE	SENT TO	
( ) INSECT		0 OTHER	0 OTHER		

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Figure 2. Field data card – Back.

RESULTS

The field data card designed for use with the computerized data management system is shown in Figures 1 and 2. The first section on the front side of the card (Figure 1) is for collector, site and plant (host) data. The next five sections; two sections in Figure 1 and three on the back of the card (Figure 2) are for biotic agents associated with the host described on the top of the card in Figure 1. If more than five species are found within several hours at one site on the same host then other cards are used and given the same collection number.

The collection number we use has two spaces available for the plant code, two spaces for the collector's initials, two spaces for the year, four spaces for the card number and two spaces for the specimen numbers; i e., RC-NS-80-0099.03 (*Rumex crispus*-Neal Spencer-1980-Card 99 and specimen #3).

Our program package creates and maintains the data base 'Insect'. This program package consists of the following programs:

1) IENTER – To enter new records
2) IEDIT – Data editing
   (see also IERROR (18) to only print error list)
3) IPRINT – Print record in standard format
   (use SPRINT (16) to print only selected fields)
4) IFIX – Change data or delete records
5) ISERCH – Query the data base
   (use SSERCH for a sequential input file like SBUGS)
6) ISORT – Sorts insect file (3 levels)
7) SORT – Sorts code lists (sequential file input)
8) IRESQ – Remove deleted records, re-addresses records
9) PTAB – Prints code lists
10) IADDON – Adds records from work file to master file
11) PREC – Prints record format
12) IMERGE – Merges two files that have already been sorted
13) IOUT – Print coded records from the insect file
14) NEWTAB – Creates a new code list
15) ADDTAB – Add an item to an existing code list
16) SPRINT – Print record by selected fields
17) CODEBK – Format pages for code book
18) IERROR – Print error list for IEDIT

Figure 3 shows an example of a coded record as it is held in a file on disk and below it the same two records in our standard print format.

Formatting of printouts can easily be varied to suit the needs of the user. Table 1 shows the type of information that may be obtained from the system. The number of identified insects causing light, medium, or heavy damage found in the data base were sorted, counted, and decoded along with the location of where they were found on the *Rumex* species.

CONCLUSION

The development of a computer-assisted method for handling large amounts of field data has simplified record keeping, increased the speed and accuracy of data handling and provided the researcher with expanded capabilities for data analysis.

The program package is available to any interested researcher on standard

2 coded records.

```
--6152,NH,78,012,----5.05,I--,13,10,RO,0,4,001000000000,23,29,3,005,11,4,------;
,100000,1000,0100000000000000,1,6,001,001,001,1,04-,10-,01-,01-,4,CAR----------

--6193,NH,78,012,----5.06,I--,13,10,RO,0,4,001000000000,23,29,3,005,13,2,------;
,001000,0100,0100000000000000,1,6,005,004,999,3,04-,10-,01-,01-,4,CAR----------
```

decoded in standard print format.

```
--6152                          RO -NH -78 -5.05
ITALY---------- ABRUZZI---------------- L'AQUILA----------------     12/I/78
RUMEX OBTUSIFOLIUS (?)  STAGE:ROSETTE  NO HERBARIUM SAMPLE-NO SEEDS
HABITAT:ABANDONED PASTURE          SOIL:LOAM , UNKNOWN
DENSITY:COMMON BUT SCATTERED   >1/10 sq.m.      NO. OF PLANTS EXAMINED=005
NO.OF PLANTS INFESTED=001  NO.OF INSECTS COLLECTED=001  NO.OF INSECTS FOUND=001
LEPIDOPTERA--------------       SESIIDAE-----------------
   PYROPTERON--------------         CHRYSIDIFORME-----------                    ****
STATUS:DETERMINED              - BY SPECIALIST
/   ?   COLLECTED  IN    ROOT
METHOD:DISSECTING           DAMAGE ESTIMATE:NONE          NO FEEDING-SURVIVED

--6193                          RO -NH -78 -5.06
ITALY---------- ABRUZZI---------------- L'AQUILA----------------     12/I/78
RUMEX OBTUSIFOLIUS (?)  STAGE:ROSETTE  NO HERBARIUM SAMPLE-NO SEEDS
HABITAT:ABANDONED PASTURE          SOIL:LOAM , UNKNOWN
DENSITY:COMMON BUT SCATTERED   >1/10 sq.m.      NO. OF PLANTS EXAMINED=005
NO.OF PLANTS INFESTED=005  NO.OF INSECTS COLLECTED=004  NO.OF INSECTS FOUND= ?
LEPIDOPTERA--------------       SESIIDAE-----------------
   PYROPTERON--------------         CHRYSIDIFORME-----------                    ****
STATUS:DETERMINED              - BY LABORATORY STAFF
ENTOPHAGOUS   LARVA   COLLECTED  IN    ROOT
METHOD:DISSECTING           DAMAGE ESTIMATE:MEDIUM          FED-SURVIVED ON DIET
```

Figure 3. Coded and decoded records from collection #5 made in 1978 on *Rumex* by Niklaus Hostettler.

Table 1. An example of information resulting from the sorting and counting of computer records.

Insects on *Rumex* spp.	Light Damage		Medium Damage		Heavy Damage	
	No. of records	Location on plant	No. of records	Location on plant	No. of records	Location on plant
LEPIDOPTERA						
Noctuidae						
Mithimna unipuncta	1	crown				
Hoplodrina ambigua	4	crown				
Phlogophora meticulosa	1	leaves				
Peridroma saucia			1	leaves		
Autographa gamma			1	leaves	1	leaves
Geometridae						
Eupithecia centaureata	1	leaves				
Pyralidae						
Udea ferrugalis	1	leaves				
Sesiidae						
Pyropteron chrysidiforme	5	stem, root	24	root, stem	18	root, stem
Tortricidae						
Olethrutes lacunana	1	leaves				
COLEPTERA						
Curculionidae						
Hypera philantha	14	leaves, crown	1	leaves		
Apion sp.	2	stem				
Apion (Perapion)	12	stem, petiole, leaves	3	stem, petiole		
Apion (Erythrapion)	3	stem, leaves	4	stem, leaves, root		
Lixomorphus ocularis	1	root	1	root		
Rhinoncus pericarpius	2	root	1	root		
Buprestidae						
Capnodis tenebricosa			8	root, stem	10	root
DIPTERA						
Anthomyiidae						
Pegomya bicolor	1	leaves	3	petiole, leaves		

8-inch Floppy disks. The USDA-SEA-AR Biological Control of Weeds Laboratory-Europe, APO NY 09794 will copy the program on two disks if requested by an interested laboratory. The request should be accompanied by two blank 8-inch Floppy disks. Some modification will be necessary to fit the programs to the user's system.

REFERENCE

Spencer, N.R. (1981). Exploration for biotic agents for the control of *Rumex crispus* Proc. V Int. Symp. Biol. Contr. Weeds, Brisbane, Australia, 1980 (In Press.)