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DISTRIBUTION MAPPING AT THE NATIONAL LEVEL FOR THE EUROPEAN PLANT-PARASITIC NEMATODE SURVEY

by

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It may appear incongruous that the European Plant-Parasitic Nematode Survey (EPPNS) was formally recognised in April 1980 by the European Science Foundation (ESF) as an Additional Activity in Taxonomy. To quote from the ESF report (Anon, 1980) the survey is a « research programme on the border line between pure science and those [sic] of agricultural interest... The aim of the survey is to establish collaboration among European national centres engaged in research in plant-parasitic nematodes with a view to producing computer-based maps of the distribution of individual nematode species ». The reasons for viewing an exercise in establishing distributions and producing computer maps in a wider biological context will be examined later.

Even before the establishment of this research project the Scottish Horticultural Research Institute [1] had a programme of survey work to establish the distribution of nematode species within the British Isles (Alphey and Boag, 1976; Taylor and Brown, 1976). This earlier work was supported by computerised data processing (Topham *et al.*, 1975; Brown *et al.*, 1978) followed by the use of computer mapping techniques (Taylor *et al.*, 1980). The initial surveys were closely co-ordinated with those of the Biological Records Centre, Institute of Terrestial Ecology, Monkswood and culminated in the

[1] Now incorporated in the Scottish Crop Research Institute.

production of an atlas of the nematodes of the British Isles (Heath *et al.*, 1977).

At a NATO Advanced Study Institute held near Bari, Italy, 1974 it was suggested that a European nematode survey be undertaken using the expertise and facilities developed at SCRI during the previous UK nematode surveys. Representatives from several European countries agreed that it would be useful to record the distribution of virus-vector nematodes for the whole of Europe. Close contact between workers at SCRI and European nematologists existed and in 1978 workers from thirteen European countries expressed interest in a European Survey and SCRI agreed to co-ordinate the survey, to establish the most suitable programmes for map production and manipulation of data banks, and to advise and assist participants in collecting and presenting their data.

In 1979 a Workshop on the Taxonomy of Longidorid and Trichodorid Nematodes and Survey Techniques was held under the auspices of the ESF. At this workshop 32 scientists representing 15 countries discussed the problems associated with the taxonomy, morphology and identification of longidoroid and trichodorid nematodes in Europe and also computer techniques used in data handling and mapping (Alphey *et al.*, 1979).

In April 1980 the European Plant-Parasitic Nematode Survey was confirmed as an Additional Activity of the European Science Foundation by the European Science Research Councils and the necessary funds to finance the project were secured. This official recognition of the EPPNS can assist participants in submitting proposals for funding and can justify them in devoting some of their resources to making a worthy contribution on behalf of their country. Several European countries including France, Italy, Spain, the Netherlands and West Germany had already accumulated data on the distribution of vector nematode species from various national surveys. Others (Belgium, Poland and Switzerland) initiated projects which included the collection of survey data. Among the first countries to respond was Spain and as the result of collaboration between Spanish and British workers an atlas of Spanish nematode distributions has been published (Alphey, 1979).

Survey management

The provision of what is essentially a service to the participating scientists in relation to computer mapping presents both organisational and cartographic problems which must be solved before the EPPNS can fulfil its purpose of biogeographical investigation.

The organisational problems largely concern the co-ordination of the survey. Nematologists are few in any country and their time must often be devoted to scientific investigations other than geographical surveys. Amateur nematologists are unknown, whereas the study of the distribution of Lepidoptera and the flowering plants for example has been much advanced by the assistance of enthusiastic and knowledgeable amateurs contributing to Network Projects (see for example Peterken, 1975). The time which many participants can devote to the project is thus often limited. The records which they are able to contribute may not have been collected deliberately for the EPPNS or even for a national survey, although, as we have already noted, there are exceptions (De Waele, 1980).

Cartographic problems largely follow from the adoption of the UTM (Universal Tranverse Mercator) co-ordinate system as an International standard. This system is used for military purposes, and is perhaps the closest to a universal system to reference distribution data. The use of geographical co-ordinates is even more basic but the UTM grid lends itself to arbitrary sub-division into equal areas which smooth out some of the irregularities of both distribution and recording and give a broader view of species occurrence. Different size grids have been chosen by individual countries for their own national surveys, the most frequent being 10 km, but for the European map 50 km has been selected.

The disadvantages of the UTM system are of various types. The commonly available maps in many countries do not carry this grid — for instance, British Ordnance Survey maps have only geographic and National Grid lines. Furthermore, very full grid references are required to prevent loss of accuracy in converting by algorithms from one system to another. Although the use of an equal area grid referencing system lends itself well to automatic map production for small areas (Fig. 1), with small scale maps of larger areas the curvature of the earth becomes important, and the UTM zones of compensation at every 6° longitude must be taken into account (Fig. 2a). The manner in which the latter problem is tackled will often depend upon the equipment available. For example when mapping Spain, at the SCRI, the two zones of compensation which occur in the Iberian peninsula were initially « opened out » to permit the use of square symbols on a matrix plotter during map production (Fig. 2a).

Fig. 1 - CAMAP showing the cosmopolitan distribution of *Trichodorus primitivus* (■) throughout Britain and the localised distribution of *T. hooperi* (⊞) in the south-west of the country (cf. Alphey and Boag, 1976).
(Like 2a and 4b, this map is produced directly from matrix plotter output, without retouching. Apparent variation is line thickness at the edges could be eliminated by a different choice of symbols).

Equipment which produces square symbols is commonly available and cheap — a daisywheel typewriter may cost just over £ 1000, whereas vector pen plotters, especially of cartographic quality, are expensive devices. Variable spacing is available on daisywheel typewriters but the resulting map is device-dependant and loses the advantage of subdividing the region mapped into equal-area quadrats. However, Rey (per. com.) using a Hewlett Packard microcomputer has closed the zones on the outline map of Spain having transformed the co-ordinates of the lateral zones to the same co-ordinate system as the central zone (Fig. 2b).

Thus, for national or local maps the EPPNS has a requirement for a general purpose computer mapping program providing base maps and subroutines to convert UTM co-ordinates of distribution data to the base-map co-ordinates; and this need has been met by writing a new program IMENS. Mapping on a European scale, using a flatbed pen plotter of cartographic quality to reproduce the Flora Europaea base map, is also being developed in co-operation with the Department of Geography, University of Dundee.

Mapping program IMENS for national data

The previously produced national atlases (Heath *et al.*, 1977; Alphey, 1979) had relied substantially on two centres external to SCRI — the Biological Records Centre (BRC) and the Edinburgh Regional Computing Centre (ERCC) — for map production. The ERCC program used was « CAMGRID », which had several limitations for our purposes eg the input for mapping had to be run through a separate program to make it compatible; the maximum size of maps produced was restricted to 120 × 120 grid squares; and the command structure was clumsy and involved writing a separate command file. To overcome these problems it was decided to design and write our own program. Although such grid-mapping programs are well understood they are not always available to our collaborators whose university computing centres often lack extensive applications software and skilled advisers. We therefore present enough technical detail to enable a biologist with limited computing experience to assess its potential in conjunction with a technical adviser. This program not only processes the data of currently participating countries but is also flexible enough to be updated readily to accommodate data

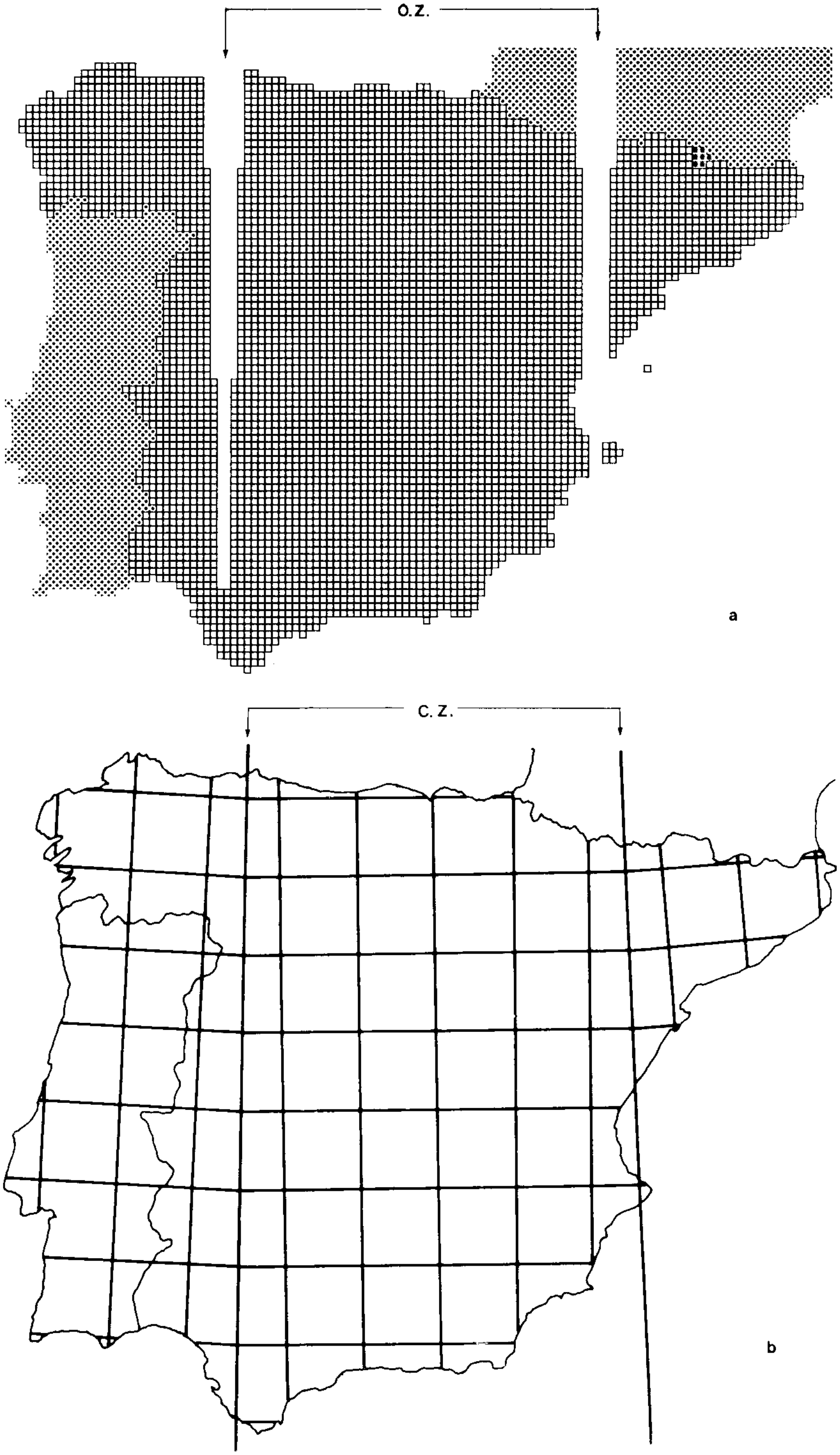

Fig. 2 - (a) CAMAP of the Iberian peninsula showing 'open' zones-of-compensation (O.Z.), as used by Alphey (1979). (b) Iberian peninsula with lateral zones transformed to 'close' zones-of-compensation (C.Z.), reproduced with permission of Dr. J. M. Rey.

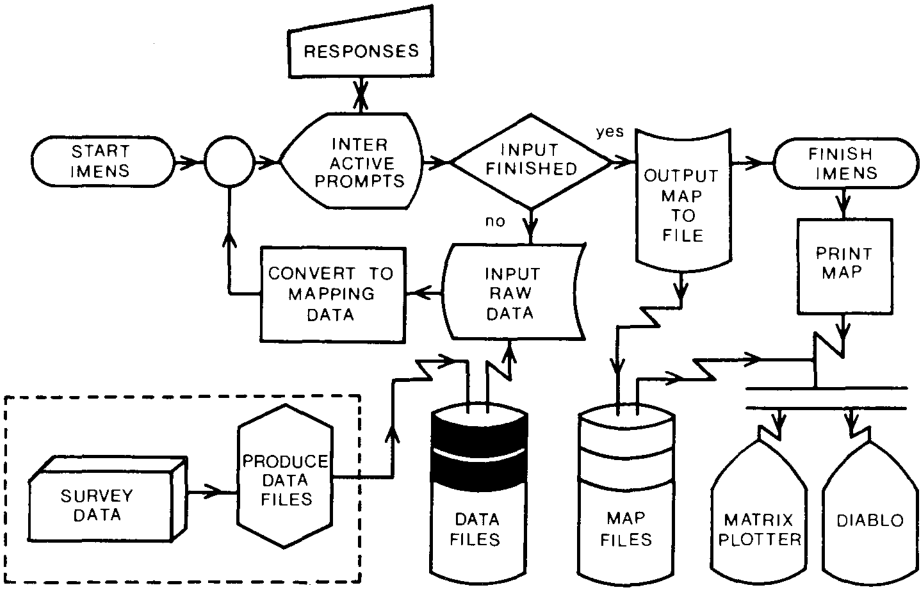

Fig. 3 - Flow-chart of IMENS mapping program.

from additional countries as they become available. The program creates a map output which is suitable for printing on either of the two output devices available to us, a Diablo Teletype 1650 KSR at the SCRI or a matrix-plotter at the ERCC (Fig. 3).

This program IMENS [Interactive Mapping for the European (Plant-Parasitic) Nematode Survey] permits the size of the output map to be 128 grid squares wide (the width of the matrix-plotter) and as long as required. It is used interactively with a simple set of prompts requesting the information required to run the program (Fig. 4a). Internal error checks are included. The output file produced is suitable for either the matrix-plotter or the Diablo.

FORTRAN77 was selected because it is the new standard FORTRAN, widely available on mainframes. Compilers also exist for microcomputers and a machine-independant program permitting the use of a relatively cheap standard output device may find wide applications and it is also a very suitable language for this type of program. FORTRAN77 permits the use of OPEN and CLOSE and INQUIRE statements. The OPEN and CLOSE statements allow the program to open and close data files from within the program eliminating the need to define stream numbers and files before running the program. The INQUIRE statement is used when an error occurs when calling an input file, it checks whether the input file name corresponds to an existing file, and whether the input file is a valid data file or not. This checking is supplemented by a second checking process which takes place whilst the data is being read-in. If an error occurs at this point the input is aborted but the program allows the user to continue and input another set of data. When data has been input correctly a subprogram, unique to each country, converts the map references to the corresponding position on the output mapping grid and inserts a preselected mapping symbol. When input is complete the program directs the final map into an output file. At this stage the program prompts for further information required on the output map, eg title, labels (Fig. 4a). As well as these file manipulation capabilities in the program which help inexperienced computer users, additional advantages of FORTRAN77 for us include its extensive character handling facilities; as a result this program requires less storage space, and the enhanced ability to make literal comparisons has made the addition of subprograms for further countries a simple process. The insertion of a single new line of program accepts a new key word to call the respective new subprograms. The countries for which subroutines have been written include Great Britain, Spain, Belgium, Italy, Germany and the Netherlands. Workers studying the distribution of other organisms on the 10 km, or similar, scale may find the program useful. Copies are available on request from the authors.

Biological importance of distribution data

The last 30 years have seen a widespread interest in establishing distribution atlases for many groups of organisms (Cartan, 1978). However, the field of nematology is relatively new and our knowledge of the biology of these animals is still very limited. Most species have been described in the last 50 years and much work remains to be done to establish the geographical ranges of many species. Without a broad geographical approach the taxonomy of nematodes will be difficult. To date taxonomists in nematology rely almost entirely on morphology and describe morphospecies. Workers studying morphological variation in a small geographical area may accept too

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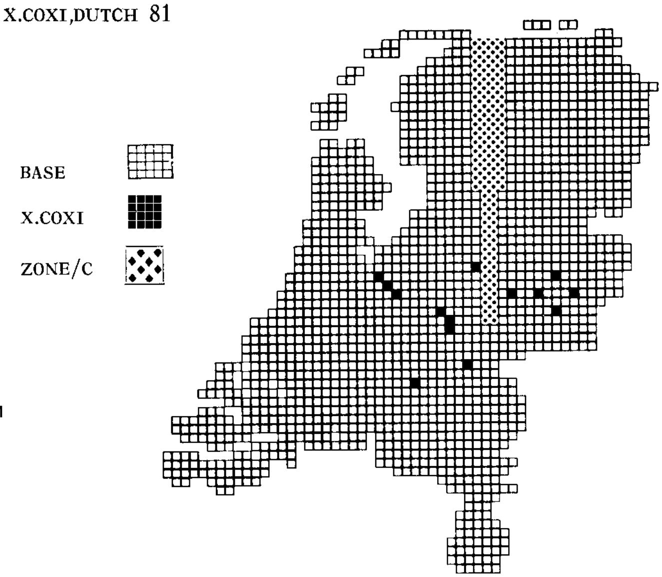
IMENS PROGRAM

NO OF SYMBOLS: 3
SYMBOL: □
SYMBOL: ■
SYMBOL: ⁘
MAP/DATA: BASE
SYMBOL NO: 1
FILE NAME: NLBASE
MAP/DATA: BASE
SYMBOL NO: 3
FILENAME: ZONE/C
MAP/DATA: HOLLAND
SYMBOL NO: 2
FILE NAME: NLDATA<COXI
MAP/DATA: FINISH

INPUT FINISHED
OUTPUT FILE: COXIMAP
TITLE: X.COXI,DUTCH DATA 81
BORDERS: NO
KEY: YES
LABELS: YES
LABEL(6CHAR): BASE
LABEL(6CHAR): X.COXI
LABEL(6CHAR): ZONE/C

END OF PROGRAM
```

a



b

Fig. 4 - (a) Typical computer print-out of mapping job and (b) its output an IMENS map of the Netherlands.

narrow a species concept. Further information such as distribution and habitat could be used to describe a species more comprehensively, approximating to the biospecies concept. Within nematology a sound taxonomic foundation must be established on which biologists and ecologists can work. Because of this need the EPPNS has been identified as an Additional Activity in Taxonomy by the ESF.

Within the EPPNS, correct identification of a species is essential and so the survey has highlighted the need for proficient taxonomistis in plant nematology. Apart from routine identification the taxonomists must also identify and describe new species which occur in survey samples and check and confirm identifications for species records which appear to be geographically isolated from the main area of their distribution. Conversely the primary patterns of distribution can be used as a taxonomic aid in nematode identification.

« The distribution of a species coincides with the broad geographic limits inside which the species may be found more or less permanently established » (Andrewartha and Birch, 1964). The difficulties encountered in the interpretation of geographical distribution of plant-parasitic nematodes have been discussed by Norton (1978). However, such studies can yield interesting results if it is assumed that each distribution is a reflection of the ecological needs of the particular species. A study of national distribution patterns may show that a species has a wide-ranging or a localised distribution (Fig. 1). This information, if used in conjunction with other ecological data, also held on computer file, may indicate which factors affect the distribution (Alphey and Boag, 1976; Alphey *et al.*, 1977; Boag and Orton Williams, 1976; Taylor and Brown, 1976). Comparison of distributions of a single species in countries with different climates, topography, vegetation etc make even more obvious which factors are important and may also suggest historical origins on either the geological or the human scale for the observed patterns. Biogeography supplies essential background to our understanding of these plant-parasitic nematodes in a context wider than that of agronomic control.

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SUMMARY

The history of the international co-operative project, the European Plant-Parasitic Nematode Survey, is outlined. Organisational, cartographic and biological problems are discussed. A mapping program (IMENS) written in FORTRAN 77 and suitable for mapping distribution data at the 10 km scale is described. Subroutines exist for six European countries; subroutines for additional areas may be added very simply. The paper concludes that establishing distribution patterns for this little understood group of animals will further our understanding of the biology, taxonomy and speciation and the ecology both in relation to other nematode species and to crop plants.

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