An Ecological Database of the British Flora

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for examination for the degree
Doctor of Philosophy

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October 1992

Abstract

The design and compilation of a database containing ecological information on the British Flora is described. All native and naturalised species of the Gymnospermae and Angiospermae are included. Data on c.130 characteristics concerning habitat, distribution, morphology, physiology, life history and associated organisms, were collected by both literature searching and correspondence with plant ecologists.

The evolutionary history of 25 of the characteristics was investigated by looking at the amount of variance at each taxonomic level. The variation in pollination mechanisms was found at high taxonomic levels suggesting these evolved, and became fixed, early on in the evolution of flowering plants. Chromosome number, annualness, dichogamy and self-fertilization showed most variance at low taxonomic levels, suggesting these characteristics have evolved more recently and may still be subject to change. Most of the characteristics, however, eg. presence of compound leaves, height and propagule length showed variance spread over several taxonomic levels suggesting evolution has occurred at different times in different lineages.

The necessity of accounting for phylogeny when conducting comparative analyses is discussed, and two methods allowing this are outlined. Using these, the questions: 'Why does stomatal distribution differ between species?' and 'Why do different species have different degrees of mycorrhizal infection?' were investigated. Amphistomaty was found to be associated with species of unshaded habitats, those with small leaves and those with hairy leaves, and hypostomaty with woody species, larger leaves and glabrous leaves. Species with arbuscular mycorrhizas occur in more habitat types than non-mycorrhizal species and also in habitats with a greater maximum pH. Annuals and wetland species, however, are typically non-mycorrhizal. Mycorrhizal perennials were also found to have heavier seeds than non-mycorrhizal perennials.

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Acknowledgements

I would like to thank Alastair Fitter for his help and enthusiatic supervision throughout the last three years, and all members of F2, both past and present. Especial mention, however, must be made to: Helen West, for always providing a sympathetic ear; Paula Smith, Mark Coulthard and Kevin Newsham for daring to share a house with me; and Steven Ford, for supplying me with a floor to sleep on whenever I was in London.

This thesis was made possible by NERC and the British Ecological Society who funded the Ecological Flora Project.

Declaration

The research described in this thesis is my own and has not been presented before. The structure of the database, however, is based upon the prototype version designed by Andrea Bullock (Bullock, A.E. 1989. Florabase - a plant ecology database. MSc Thesis, University of York), and the choice of characteristics to include in the database resulted from discussions with members of the Editorial Board (Appendix A, page 165) who are helping to oversee the Ecological Flora Project.

Chapter 1

Introduction

The necessity for a comprehensive account of the ecology of British plants was first stated by Salisbury (1928). In his proposition for the publication of a British Biological Flora containing information on the biology and ecology of British species, he wrote:

> *"Much relevant information is to be found scattered through the multitude of botanical journals but is difficult to access. A great deal is also known to field-naturalists but has never been published, and is likely to be lost with the death of the individuals. It is proposed to incorporate in the Flora all accessible published observations together with the not inconsiderable mass of unpublished data. It is felt that such a compilation will be of great scientific value and at the same time provide the surest means of bringing to the notice of students the many lacunae that require to be filled."*

However, it was not until the 1940's that any progress towards such a flora was made. The 1940 Annual Meeting of the British Ecological Society decided to publish accounts of single species, or small groups of species, in the *Journal of Ecology*, with the aim that eventually a complete account of the biology of all British angiosperms, gymnosperms and pteridophytes would be available. Fifty years later, accounts are available for c. 200 species, approximately 10% of the British Flora. The number appearing each year has fluctuated between a few very productive years (10 in 1955, 12 in 1964) and years when only one flora was published (eg. 1944, 1965, 1989). There does not seem to have been any major changes in the rate of publication of Biological Floras, however, suggesting a complete account of the British Flora will not be available for another 450 years. Writing a Biological Flora is a major task due to the amount and completeness of information that is required. An author must be able to give details on distribution, habitat, substratum, communities, effects of frost and drought, morphology, perennation, reproduction, physiology, biochemistry, phenology, breeding system, seed production, germination characteristics, associated organisms, diseases and history. If such information is not available in the literature then the author has to collect it himself, so the slow rate of production of Biological Floras is not really surprising.

Progress has also been made in other directions. The need for floras to contain ecological information, in addition to descriptive and identification details, was recognised by Clapham *et al.* (1952). Flowering, fruiting and germination times, pollination and seed-dispersal mechanisms, life forms and chromosome numbers were included in their *Flora of the British Isles*. Other than updated editions of this flora, however, no further advances towards an ecological flora of the British Isles were made until 1988 and the publication of *Comparative Plant Ecology* (Grime, Hodgson and Hunt, 1988), the first comprehensive account of a large number of species in a single volume. This book contains standardized autecological accounts of 281 common vascular plants of the British Flora. These accounts resulted from vegetation surveys in the Sheffield region, which recorded characteristics such as pH, altitude, and habitat type, followed by laboratory screening of the common species to determine characteristics such as 2C DNA, germination requirements and relative growth rates. Literature searches for all the species were conducted but no attempt was made to do an exhaustive search. Some of the species included in *Comparative Plant Ecology* also have Biological Flora Accounts, but the two sources combined mean that there are easily accessible reasonably comprehensive ecological accounts available for only c. 22% of the British Flora

An alternative to the autecological approach is to concentrate on a particular subject area, and to collect data on particular characteristics for lots of species, rather than lots of information on individual species. This approach has yielded valuable data in a number of areas, for example: first historical records (Clarke, 1900); pollination mechanisms and breeding systems (Knuth, 1906); seed dispersal mechanisms (Ridley, 1930); altitudinal ranges (Wilson, 1956); hybrids (Stace, 1975); and mycorrhizas (Harley and Harley, 1987) . Much effort has also been put into the recording of plant distribution both in Britain (Perring and Walters, 1962) and Europe (Tutin *et al.*, 1964-1980).

The majority of information on the ecology of British plants, however, is scattered over a wide variety of sources. Salisbury's 'multitude of botanical journals' has now become more of a myriad, with each year seeing the production of more new journals. There are general ecology journals (eg. Oecologia, Oikos), general plant ecology and botanical journals (eg. Annals of Botany, New Phytologist), more specialist plant ecology journals (eg. Aquatic Botany, Weed Research) and journals in other areas which may contain information on plant species (eg. Heredity, Proceedings of the Royal Society of London). There are also many other published sources such as books, conference proceedings and theses. Literature searching has become easier, in some respects, due to the production of large bibliographic databases and the development of computer-based information retrieval systems. However, the effectiveness of these is dependent on the terms used to index documents and it is very difficult to capture the essence of a whole document using a few key words. It is not too difficult to find references for documents on a particular subject area (eg. germination requirements), but much harder to use bibliographic databases to find a reference containing a specific piece of information (eg. the germination requirements or seed weight of particular species). It is therefore very inefficient trying to do an exhaustive literature search for a particular species, making a single literature search for information on all the British Flora extremely valuable.

There is still, therefore, very much a need for the sort of ecological flora of the British Isles envisaged by Salisbury, ie. available biological and ecological information on the British flora, from both published and unpublished sources, concentrated in a single source. This need led to the inception of the Ecological Flora Project in 1989, funded jointly by NERC and the British Ecological Society and supervised by Professor AH Fitter. The aim of the project was first to compile a database containing ecological information on British vascular plants (including habitat details, geographical data, morphology, physiology, life history, phenology, breeding systems, germination characteristics and associated organisms), and subsequently to publish a book containing selected information from the database. This book is to be written by an editorial board of distinguished ecologists (Appendix A, page 165), who have also helped to oversee the whole project. I was employed as a research assistant for three years to compile the database.

All data found from literature searching and from communication with ecologists and botanists have now been entered into the database, which amounts to over 120 000 items of information, from over 1100 sources. Still remaining to be input are data from the Phytophagous Insects Databank owned by the Institute of Terrestrial Ecology and information on geographical distribution of plant species available from the Biological Records Centre. Chapter 2 of this thesis outlines the species included in the database, the type of information collected, the methods of data collection and the structure of the database. This is followed, in chapter 3, by instructions on how to use the database and some sample queries showing the kinds of information that can be retrieved.

Data-sets on large numbers of species are valuable because they allow comparison between species and ecological variables. Hypotheses regarding the evolution of particular structures or life styles in response to a second variable (a trait or environmental factor) can be tested by comparing large numbers of species to see if there is a consistent relationship between the two variables. There are many examples of comparative studies in the plant ecology literature, for example: stomatal density (Salisbury, 1927); seed weight (Salisbury, 1942; Baker, 1972; Mazer, 1989); 2C DNA (Grime and Mowforth, 1982); germination characteristics (Thomson and Grime, 1983); and growth rate (Grime and Hunt, 1975). In all such studies workers have had to collect the data needed to test the hypothesis of interest. The time consuming nature of this task limits the number of relationships that can be tested. The compilation of data-sets containing a wide variety of information for a large number of species, therefore, will help to overcome this problem.

Many comparative studies simply involve comparisons between species, but this practise has recently come under much criticism (eg. Harvey and Pagel, 1991). This is because two species may be similar, not only because they have adapted in an analogous way to the same selection pressures, but also because they share a common ancestor. The degree of relatedness between species needs to be accounted for in comparative analyses, to ensure that significant trends are due to adaptation and not phylogenetic constraints. This problem, and ways of accounting for it, are outlined and discussed in chapter 5.

The degree of relatedness between species, however, can be used productively to investigate the history of evolution in individual characteristics. If a greater proportion of the overall variance occurs at low taxonomic levels in a Linnean hierarchy than at higher levels it suggests the characteristic in question has been evolving recently, whereas if a greater proportion of the variance occurs at high taxonomic levels it suggests the characteristic evolved a long time ago and has since become fixed. In chapter 4, the evolutionary history of 25 plant characteristics is analysed.

The large data-set compiled for the Ecological Flora Project makes possible a wide variety of comparative studies. Two areas of study were chosen for this thesis: stomatal distribution and frequency of mycorrhizal infection. The location of stomata on the leaf surface varies from all stomata on the lower epidermis, some on either epidermis, to all on the upper epidermis. It has been suggested that this variation between species may be linked to a variety of morphological or ecological variables, for example leaf thickness (Parkhurst, 1978), or habitat shade (Mott, 1982). In chapter 6, data on the stomatal distribution of 457 British species is used to test for relationships between stomatal distribution and habitat (shade and water availability), leaf morphology and leaf hairiness. Mycorrhizal infection also differs between species; some are always mycorrhizal, some occasionally mycorrhizal and others never mycorrhizal. Chapter 7 examines various factors (root morphology, life history, habitat and seed weight) which may be related to the frequency of mycorrhizal infection.

An attempt has been made to account for phylogeny in all the comparative analyses included in this thesis. The methods used involve the assumption that a taxonomic hierarchy is a reasonable approximation to a phylogenetic tree. The problems inherent in this assumption are discussed in chapters 4 and 5, and the implications of using this assumption are discussed in chapter 8. Chapter 8 also discusses the current status of the Ecological Flora Database, which reflects, to some extent, the current ecological knowledge of the British Flora. The nomenclature in this thesis follows Stace (1991); authorities for species names have therefore been omitted.

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Chapter 2

The Ecological Flora Database

Introduction

The primary aim of the Ecological Flora Project was to make a comprehensive collection of information about the ecology of the British Flora. It was important early on in the project to decide both which species were to be included and also exactly what type of information was going to be collected. These decisions were made after discussion with the Editorial Board members. The first section in this chapter explains which species were included and why, and the second section the type of information that was collected. This is followed by details of the methods of data collection.

The structure of the database was also designed at the beginning of the project. A structure had to be chosen that would make the database both efficient to use and easy to update. The data are stored in various tables made up of columns of data. The Species table, for example, includes a column containing the species names and the Source table an authors column. Information from several tables can be retrieved by linking tables together using columns that the tables have in common. The final section of this chapter outlines the structure of the database.

The Species

The database contains information on 1777 species, belonging to 118 families and 619 genera. This number includes all British native and naturalised Gymnosperms and Angiosperms. Introduced species are included if they are held to be capable of maintaining a population in the wild without continuous re-introductions. There are approximately 280 naturalised species in the database, although it is not possible to give an exact figure as it is not known whether some species are native or introduced. A list of the species in the database is given in Appendix B (page 166).

Originally all vascular plants were going to be included in the project but it was decided early on to omit the Pteridophyta. This was because many of the categories of information, especially concerning breeding systems and life history (eg. flowering time or pollinator), were not applicable to the Pteridophyta. There were several revisions of the list of species included, principally concerning which introduced species to include. The final one was drawn up after the publication of Stace's new flora (1991).

The Information

The database contains many kinds of ecological information, which fall into six categories: habitat, distribution, morphology, physiology, life history and associated organisms. The actual information recorded was defined very precisely by splitting each category into a number of characteristics and defining the possible alternative values for each characteristic. Some characteristic values were quantitative so only the units of measurement needed to be defined, eg. number of stomata/mm^2 on the lower epidermis. Other characteristics however could not take quantitative values, so in such cases possible alternative values were defined, eg. the characteristic 'woodiness' can take the values: woody/non-woody/woody at base. A slightly different approach was required for associated organisms as the nature of the information recorded was dependent on the type of association. With mycorrhizal associations, for example, the type of mycorrhiza and frequency of infection was recorded, whereas for pathogenic fungi information such as the name of the fungus, alternate hosts and type of disease was recorded. A list of the characteristics, their alternative values and further explanation of the data recorded is given in Appendix C (page 198).

The list of characteristics also underwent many revisions with new characteristics being added and some characteristics being omitted. Additions were made when, after some of the literature searching, the existing characteristics seemed inadequate, or else a characteristic not previously considered was thought of. Omission of characteristics generally occurred if there was difficulty in interpreting the literature to fit the possible characteristic values (although the alternative values were revised whenever possible), or if no data were available for that characteristic. Appendix D (page 212) lists some of the characteristics that were omitted.

Methods of Data Collection

Four methods were used to collate information: use of existing data-sets; literature searching; species questionnaires; and experimental determination of new data by volunteers and assistants.

1. Existing Data-sets

Information from the Flora Europaea (Tutin *et al.*,1964-1980) was available in machine-readable form from BIOSIS, U.K. in York. The European countries that species occur in and chromosome numbers were obtained directly from this source. Geographical information on the regions in Britain that species occur in is to be obtained from the Biological Records Centre, Monkswood Experimental Centre, Huntingdon. In the future it is hoped that information on plant-insect associations can be retrieved from the phytophagous insects databank held by the Institute of Terrestrial Ecology.

2. Literature Searching

Literature searching was conducting using both primary (journals, books etc.) and secondary (abstracts, indexes and other bibliographic tools) sources of information. It was important to collect as much of the available relevant information as possible without the search becoming uneconomical because it was taking too long to find anything new. To achieve this the following methods were used.

i. Recent floras were scanned for relevant information, mainly for morphological, and distribution data, but also some ecological information such as flowering times.

ii. Journals which were likely to contain many relevant papers (ie. the major UK and north-western European ecological journals) were comprehensively scanned from the first issue to the latest. These journals were:-

Acta Botanica Neerlandica
Annals of Botany
B.S.B.I. News
Heredity
Journal of Applied Ecology
Journal of Ecology
Oecologia
Oikos
New Phytologist
Watsonia
Weed Research

iii. '*BSBI Abstracts*' published by the Botanical Society of the British Isles, which abstracts literature relating to the vascular plants of the British Isles was used to identify relevant papers occurring in other journals.

iv. The CABS publication '*Current Advances in Ecological & Environmental Sciences*' was scanned for recent relevant papers.

v. Books were identified by using library subject indexes and by looking through the review sections of journals such as '*Journal of Ecology*' and '*Watsonia*'.

vi. The plant ecology section of ASLIB's '*Index to Theses*' was scanned.

vii. The reference lists of any items containing useful information were scanned for items of possible relevance.

All the material noted to be of possible relevance was read and any useful information extracted. This was generally done by noting anything of relevance on to a card index ordered by species and subsequently adding the records to the database.

Priority was given to information regarding British populations of plant species, but information recorded from foreign populations was extracted if no information on that characteristic concerning British populations was found. All records in the database referring to non-British data are marked to that effect. Very little attempt was made to extract data from papers written in languages other than English due to the time-consuming task of translation. Only items likely to hold a lot of useful information were translated, such as several volumes of Hegi's Flora von MittelEuropa.

Further use of secondary sources was not made because it was decided early on in the project that this was not a profitable method. '*Biological Abstracts*' and its online equivalent BIOSIS are only useful when it is possible to do a search which eliminates most of the irrelevant references. In this case it was not possible to limit a search to retrieve a manageable number of references because information over a broad range of subjects, but only for British plant species was required. In certain subject areas, however, use was made of a CD-ROM version of Biological Abstracts as this method has all the advantages of an online rather than a hard copy search but does not involve the high costs of online searching.

3. Species Questionnaires

It was thought likely that a lot of details about the ecology of individual plant species were not readily available in the literature but were known by botanists and ecologists (professional and amateur) with a special interest in particular species. An attempt to identify these 'species experts' was made as follows.

- i. Asking members of the editorial board for suggestions.
- ii. Advertising the search for experts in the BES Bulletin.
- iii. Writing to ecologists in biology/ecology departments of British universities and polytechnics asking for suggestions.
- iv. Using the database to pick out authors who had published a lot on particular species or who had written biological floras.
- v. Getting a list of people who have in the past proposed to write a biological flora - courtesy of Professor AJ Willis, University of Sheffield.

Almost 300 'experts' were identified with expertise on over 600 species altogether. A listing of the information held in the database was printed for each of these species.

Each list, together with a questionnaire to fill in about the species, was sent to the relevant expert. The questionnaire comprised of a list of the database characteristics, omitting those which had already been entered from a standard source (eg life form and woodiness), with, where relevant, their alternative values. Experts were asked either to tick the appropriate alternative or to fill in a value if known. This method also allowed the experts to act as error checkers as they were able to identify information in the database that they felt was wrong.

4. Collection of New Data

A request was made in several publications (BES Bulletin, BSBI News, The Biologist) for volunteers able to collect data. These volunteers were sent a list of protocols which outlined what data we wanted collecting and how to collect it. The protocols included some characteristics that were easy to measure with limited amounts of equipment and others that were unlikely to occur much in the literature. A list of the protocols is given in Appendix E (page 214).

Further data were collected at York by students. This was restricted to characteristics of particular interest, mainly stomatal location and density and root diameters.

Structure of the Database

A prototype version of the Ecological Flora Database was drawn up by Bullock (1989). The extant structure retains many of the features of the prototype, although most of the table structures are slightly different, some of the original tables are missing and several additional tables now exist.

The Ecological Flora database contains 13 tables (Figure 2.1):-

1. Species
2. Synonyms
3. Source
4. Characteristic
5. Alternatives
6. Plant_characteristic
7. Distribution
8. Country
9. Hybrid
10. Mycorrhiza
11. Fungus
12. Habitat
13. Habitat_class

The tables consist of a number of columns which have a specified width (the numbers of characters the column can contain in any one row) and type (whether the data in the column are numerical or textual). Columns in a table may be obligatory, meaning that there is always a value for that column in any row of data - eg. plant_no in the plant_characteristic table (this column indicates which species an item of information refers to), while other columns are voluntary and may be empty in some rows of data - eg. char_qual column in the plant_characteristic table (this column allows additional information to be added to a record, eg. it is used to indicate that a piece of information refers to a non-British population).

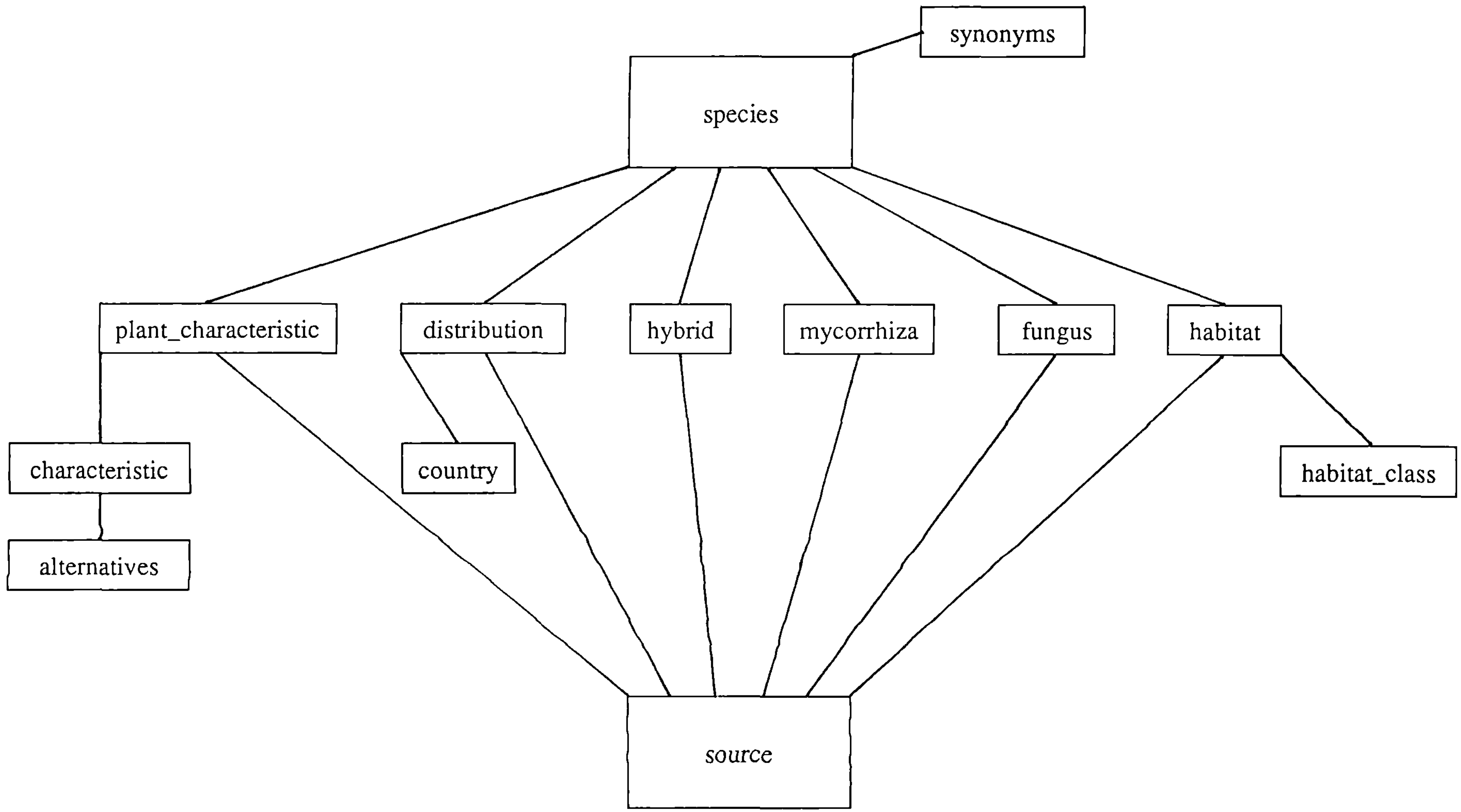

Figure 2.1 - A diagram of the structure of the database. Table names are given in boxes and the lines indicate links between tables.

The tables are relational, each row of a particular table is unique and repetition of information has been minimised where it is efficient to do so. This is achieved by using code numbers to refer to pieces of information that may come up several times in one table and having a second table which contains the code numbers and information once only. For example, the characteristic descriptions are held in the characteristic table, along with a code number referring to each description. The code numbers are used to refer to characteristics in other tables (eg. plant_characteristic, distribution), so only the code numbers, which take up little storage space, are repeated many times, rather than the much longer descriptions. The benefit of this type of database structure is that if information needs to be changed, for some reason, only one table has to be updated.

The columns in tables can be indexed to speed up information retrieval. Indexes aid retrieval because normally information is not stored in the databases in an ordered format; inserted rows of data are simply added on to the bottom of a table. This means that in order to find a particular row of information the whole table has to be scanned. An index, however, comprises of an ordered list of all items in the indexed column. Each item is followed by the address of the row in the table that the item refers to. Because the index is ordered the correct entry in it can be found quickly, and this leads directly to the relevant row in the table being queried.

Each item of information in the database is referenced to a source. This allows users to refer back to the original literature/author if further information is required or the data are questionable in some way. Errors may occur in the database for several reasons; due to mistakes in the original literature, the interpretation of the data or the typing in of the data. Attempts have been made to minimise errors, especially the third kind. Various error checking queries were run regularly to ensure there were no unexpected values in the tables, such as a source_no in one table that does not reference an actual source in the source table, or a value in the plant_characteristic table that is not one of the possible alternative values for that particular characteristic.

A species may have several values for a particular characteristic. It may, for example, live in some habitats with a permanently high water table and other habitats with a periodically high water table, or have seeds dispersed by both birds and mammals. In such cases all relevant alternatives are entered in the database. This does, however, lead to problems in analysing data as multiple values have to be taken account of. This will be discussed further in later chapters.

The Database Tables

1. Species

This table contains information on the species in the database - recording the name, authority, family, genus and when available a common name. The nomenclature in the table follows Stace (1991). Each species has been allocated a number which is used to link the species name with ecological information held in other tables. This number was taken from the *Flora Europaea* (Tutin *et al.* 1964-1980), in which the first 2/3 digits refer to the family, the second three to the genus and the final three to the species. A final digit was added to distinguish between species which are subspecies in *Flora Europaea* but are classed as species in Stace (1991). The family and genus columns allow queries concerning particular families or genera to be formulated easily.

2. Synonyms

This table lists all the names for the species in the database that have been used in recent floras and links them to the relevant plant_no. It includes all species names and synonyms in Stace (1991), plus a few other synonyms that have been used in recent literature. The status column is empty if the name is the one used in Stace (1991), or else contains 'S', if the name is a synonym. This table should contain any species name that a user is likely to use.

There is repetition between information in this table and the species table, which is not ideal because if there are changes in nomenclature both tables will need to be updated. However, the repetition makes the database easier to use. If a user requires information about a particular species, the synonyms table can be queried to find the relevant plant_no with which to query other tables. By querying the synonyms table it is unlikely that the user will input a species name that the database does not recognise. If, on the other hand, a user requires a list of species from the database, for example species which are hemi-parasitic, the relevant plant_nos are retrieved by querying the plant_characteristic table and used to retrieve the species names from the species table. By querying the species table only one name for each species is retrieved rather than all synonyms of the name.

Structure of the Species Table

COLUMN	PLANT_NO	PLANT_NAME	AUTHORITY	FAMILY	GENUS	VERNACULAR NAME
TYPE	number	character	character	character	character	character
WIDTH		40	50	20	20	50
MANDATORY?	yes	yes	no	yes	yes	no
INDEXED?	yes	yes	no	no	no	no
TABLES LINKED	synonyms plant_characteristic distribution hybrid habitat fungus mycorrhiza					
EXAMPLE	470020180	POLYGONUM ARENASTRUM	BOREAU	POLYGONACEAE	POLYGONUM	
EXAMPLE	1690890010	TUSSILAGO FARFARA	L.	ASTERACEAE	TUSSILAGO	Coltsfoot

Structure of the Synonyms Table

COLUMN	PLANT_NO	PLANT_NAME	AUTHORITY	STATUS
TYPE	number	character	character	character
WIDTH		40	50	1
INDEXED?	yes	yes	no	no
MANDATORY?	yes	yes	yes	no
TABLES LINKED	species plant_characteristic distribution hybrid habitat fungus mycorrhiza			
EXAMPLE	1960020069	LEMNA MINUSCULA	HERTER	S
EXAMPLE	1960020069	LEMNA MINUTA	KUNTH	

3. Source

This table contains the source of each item of information in the database. The author and publication details are included, but for journal articles the title has been omitted both to save space in the database and the time it would have taken to type them in. The title field is used for books where the title, edition, publisher and place of publication is given, and also to indicate unpublished sources such as personal communications. Columns title_2 and title_3 were added to improve the output of source details on the computer screen as the screen is only 80 characters wide. Title_2 contains a continuation of the source details if the title field reaches 80 characters in length, Title_3 is a further 'overflow field' if title_2 reaches its maximum of 80 characters in length. A source_no column links the source details with the information extracted from each source which is stored in different tables. The benefits of a relational database can be seen here as the source table means that bibliographic details need only be stored once. Even if a single source refers to several items in another table, only the source_no field is repeated.

Structure of the Source Table

COLUMNS	SOURCE_NO	AUTHORS	JOURNAL	YEAR	VOLUME	PAGE	TITLE	TITLE_2	TITLE_3
TYPE	number	character	character	number	character	character	character	character	character
WIDTH		80	60		5	12	240	80	80
MANDATORY?	yes	no	no	no	no	no	no	no	no
INDEXED?	yes	yes	no	no	no	no	no	no	no
TABLES LINKED	plant_characteristic distribution hybrid habitat fungus mycorrhiza								
EXAMPLE	11	Hubbard JCE	Journal of Ecology	1970	55	329-334			
EXAMPLE	55	Ridley HN		1930			The Dispersal of Plants Throughout the World, L Reeve and Co Ltd,	Ashford, Kent	

4. Characteristic

The characteristic table holds the title of each category of information that data have been collected on, together with a code number for each title. This code links the name of the characteristic with the information contained within tables such as plant_characteristic, or distribution. The codes are in the form of a digit followed by 2 decimal places and sometimes a letter. The first digit refers to the type of information:- 1=habitat, 2=distribution, 3=morphology, 4=physiology, 5=life history, 6=responses to other organisms. An A is added to the code if a category is relevant only to aquatic plants.

Structure of the Characteristic Table

COLUMNS	CHAR_NO	CHAR_NAME
TYPE	character	character
WIDTH	6	80
MANDATORY?	yes	yes
INDEXED?	yes	no
TABLES LINKED	plant_characteristic distribution alternatives	
EXAMPLE	1.05	Salinity
EXAMPLE	5.08	Flowering time: 2. latest month

5. Alternatives

This table lists the values that qualitative characteristics can take. A numerical column, alt_order, was added to the table to aid output when listing alternative values. Oracle can only order lists alphabetically or numerically, but the alt_order field provides a numerical conversion and allows the alternatives to be ordered sensibly. For example the codes for soil fertility (1 = very infertile, 2 = infertile, 3 = fertile, 4 = very fertile) give a listing for soil fertility of 'very infertile/infertile/fertile/very fertile' which is much more sensible than the alphabetic listing 'fertile/infertile/very fertile/very infertile. The main purpose of this table was for inputting data. A form was set up so that when a characteristic number was entered a list of the possible characteristic values was displayed. It is also of use, however, as a quick reference table to the possible alternatives for a given characteristic.

Structure of the Alternatives Table

COLUMNS	CHAR_NO	ALTERNATIVE	ALT_ORDER
TYPE	character	character	number
WIDTH	8	50	
MANDATORY?	yes	yes	no
INDEXED?	yes	no	no
TABLES LINKED	characteristic plant_characteristic distribution		
EXAMPLE	3.19	both	1
EXAMPLE	3.19	lower	2

6. Plant_characteristic

This table contains the majority of the data. The char_value column contains items of information, with the plant_no, char_no, and source_no codes linking the information to the relevant species, type of information, and source of the information. The values the char_value field can take are usually either particular alternatives or else numerical values (see Appendix C, page 198). The char_qual column is a notes column. It is used when information needs qualifying in some way, or when further information can be given. For example stomatal location may differ on aquatic and terrestrial plants of a single species; the location for both can be given, with the char_qual column indicating which type of plant the data refer to. The subspecies column is used if an item of information applies to a named subspecies.

Structure of the Plant_characteristic Table

COLUMNS	PLANT_NO	CHAR_NO	CHAR_VALUE	SOURCE_NO	CHAR_QUAL	SUBSPECIES
TYPE	number	character	character	number	character	character
WIDTH		8	50		100	15
MANDATORY?	yes	yes	yes	yes	no	no
INDEXED?	yes	yes	no	no	no	no
TABLES LINKED	species synonyms distribution hybrid habitat fungus mycorrhiza	characteristic alternatives		source		
EXAMPLE	570220010	3.20	aestival	37		
EXAMPLE	1291080080	5.03	6-12 weeks	674	annual plants	carota

Structure of the Distribution Table

COLUMNS	PLANT_NO	CHAR_NO	CHAR_VALUE	SOURCE_NO	NOTES	SUBSPECIES
TYPE	number	character	character	number	character	character
WIDTH		6	50		100	30
MANDATORY?	yes	yes	yes	yes	no	no
INDEXED?	yes	no	no	no	no	no
TABLES LINKED	species synonyms plant_characteristic hybrid habitat fungus mycorrhiza	characteristic alternatives		source		
EXAMPLE	680740020	2.12	Br	38		
EXAMPLE	1691780430	2.11	Bu	41		

7. Distribution

This table is basically the same as the plant_characteristic table. It contains the European countries that each species is native or naturalised in. These data were put into a separate table due to the large amount of information. Species can occur in up to 34 European countries, so the table has c. 30 000 rows - almost half as many as in the plant_characteristic table. Inclusion of the data in the plant_characteristic table would have a substantial effect on its size and slow down the execution of many queries.

8. Country

The data in the distribution table gives countries of occurrence using 2 letter codes. This table links these codes to the country name.

Structure of the Country Table

COLUMNS	COUNTRY_CODE	COUNTRY
TYPE	char	char
WIDTH	2	25
MANDATORY?	yes	yes
INDEXED?	no	no
TABLES LINKED	distribution	
EXAMPLE	Ga	France
EXAMPLE	He	Switzerland

9. Hybrid

This table contains information derived from both Stace (1975) and Stace (1991). As well as the plant number for each parent and the hybrid name, the distribution column gives, where possible, an indication of how frequent the hybrid is with respect to its parents.

Structure of the Hybrid Table

COLUMNS	PARENT_NO_1	PARENT_NO_2	HYBRID_NAME	DISTRIBUTION	SOURCE_NO
TYPE	number	number	character	character	number
WIDTH			50	70	
MANDATORY?	yes	yes	no	no	yes
INDEXED?	yes	yes	no	no	no
TABLES LINKED	species synonyms plant_characteristic distribution habitat fungus mycorrhiza	species synonyms plant_characteristic distribution habitat fungus mycorrhiza			source
EXAMPLE	810280090	810280080	Lupinus x pseudopolyphyllus	occasional where parents occur	1041
EXAMPLE	1930870220	1930870020		rare	1041

10. Mycorrhiza

The bulk of the information has been extracted from Harley and Harley (1987). This table gives the types of mycorrhiza that have been found, if any, and also information on the frequency of infection - whether normally, occasionally, rarely or never infected. The frequency of infection was determined by AH Fitter depending on the number of records of mycorrhizal studies given in Harley and Harley (1987).

Structure of the Mycorrhiza Table

COLUMNS	PLANT_NO	MYCORRHIZA	FREQUENCY	SOURCE_NO
TYPE	number	character	character	number
WIDTH		15	30	
MANDATORY?	yes	yes	no	yes
INDEXED?	yes	no	no	no
TABLES LINKED	species synonyms plant_characteristic distribution hybrid habitat fungus			source
EXAMPLE	310010390	VA	occasionally mycorrhizal	940
EXAMPLE	340010010	ecto	normally mycorrhizal	940

11. Fungus

The table contains information extracted from Ellis and Ellis (1985). This table contains information on the fungi - the part of the plant the fungus infects, any alternate hosts of the fungus, the number of different species that are infected, the abundance of the fungus on a particular species, and the type of the disease - rust, mildew etc.

Structure of the Fungus Table

COLUMNS	PLANT_NO	FUNGUS	PLANT_PART	ALTERNATE_ HOSTS	NO_HOSTS	STATUS	DISEASE	TYPE_ ATTACK	SOURCE_ NO
TYPE	number	character	character	character	character	character	character	character	number
WIDTH		50	40	50	12	11	30	50	
MANDATORY?	yes	yes	no	no	no	no	no	no	yes
INDEXED?	yes	no	no	no	no	no	no	no	no
TABLES LINKED	species synonyms plant_characteristic distribution hybrid habitat mycorrhiza								source
EXAMPLE	1850040010	Botrytis galanthina	leaves,stems		monophagous	frequent		spots	1145
EXAMPLE	2030190040	Puccinia sessilis	leaves	Phalaris arundinacea	oligophagous	frequent	-	rust	1145

12. Habitat

This table contains information on the habitats in which a species occurs. The habitat classification used is that found in the CORINE biotopes manual (Moss, 1991). Much of the information in this table was extracted using the Tablefit program (Hill, 1989). This program was devised to match up a sampled area with its most similar vegetation type as defined by the National Vegetation Classification (Rodwell 1991a,b and in press) but it also cross-references NVC codes with their corresponding CORINE codes. Tablefit was used to extract a list of the species which occur in each habitat type. The following table, habitat_class, lists the CORINE codes that are included with a brief description of the habitat. Only around half of the British species have been classified by the NVC, so other sources of information had to be sought for the rest of the British flora.

Structure of the Habitat Table

COLUMNS	PLANT_NO	HABITAT_CODE	SOURCE_NO	SUBSPECIES
TYPE	number	character	number	character
WIDTH		6		30
MANDATORY?	yes	yes	yes	no
INDEXED?	yes	yes	no	no
TABLES LINKED	species synonyms plant_characteristic distribution hybrid fungus mycorrhiza	habitat_class	source	
EXAMPLE	1930041030	C16.24	658	
EXAMPLE	1690890010	C37.7	658	

13. Habitat_class

This table gives a brief description of the habitat each code number refers to. For fuller details see The CORINE Biotopes Manual (Moss, 1991).

Structure of the Habitat_class Table

COLUMNS	HABITAT_CODE	HABITAT_TYPE
TYPE	character	character
WIDTH	6	60
MANDATORY?	yes	yes
INDEXED?	no	no
TABLES LINKED	habitat	
EXAMPLE	C31.21	Submontane Vaccinium Heaths
EXAMPLE	C41.3	Ash Forests

The database structure is independent of the software used. The next chapter, therefore, describes both the relational database software used, how to use this software, and also gives some examples of the type of information that can be extracted from the database.

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Chapter 3

Using the Ecological Flora Database

This chapter has been taken from a user-guide that was written to accompany the database.

The Database Software:-

The database has been constructed using version 5.1B of Oracle software on a 386 personal computer with MS-DOS operating system. It is a relational database management system which uses a version of structured query language (SQL) to create, update and query databases within it. There are three different items of software which can be used to retrieve data from the database - SQL*ReportWriter, SQL*Forms, and SQL*Plus. These differ in the amount of familiarity the user needs with Oracle and SQL, the kind of information that can be retrieved and the device information can be output to. A brief description of each is given below followed by detailed instructions on how to use each one (pages 40-63).

SQL*ReportWriter

SQL*ReportWriter uses queries that have been set up in advance to generate output in a preset format. This means that complex output can be produced without requiring each user to write complicated queries. Several reports for use with the Ecological Flora Database have been set up; these are described in 'Using SQL*ReportWriter' on page 40. Output from the report writer can be written onto the screen, to a file or straight to a printer.

SQL*Forms

SQL*Forms'main purpose is to make data input straightforward, but it also ideal for simple queries. As in SQL*ReportWriter its use is limited by how it has been set up by the original programmer. Refer to 'Using SQL*Forms' on page 50 for instructions on how to use it. At present only two forms have been set up, one which retrieves information on a particular species and the second on a particular characteristic. The forms are easy to use, but output is limited to viewing on the screen (it is possible to print out information shown on the screen, but the output is not very well formatted).

SQL*Plus

This is the most versatile of the three pieces of software and therefore the most complex to use. SQL*Plus allows the user to use structured query language (SQL) to write queries that will retrieve what the user requires. A knowledge of both SQL and the additions to SQL provided by Oracle are needed. The advantages over the above two pieces of software are that the user can link exactly which tables and rows he wants and also choose the format of the final output. Output is written to the screen or to a file which can be subsequently edited/printed. Refer to page 52 for more details about SQL*Plus and some sample queries.

Getting Started:-

1. Switch on the computer and wait for the c:\> prompt.
2. Type eco_flora (this command loads Oracle).
3. Choose which piece of software to use and type the relevant command - see Table 3.1.

	SQL*ReportWriter	SQL*Forms	SQL*Plus
Access Command	runrep report name.rep username/password	runform form name username/password	sqlplus username/password
Input	Specific codes, words or phrases in reply to screen prompts	Function keys and typed input prompted by screen help line	Typed query, either straight onto the screen, or into a text editor
Flexibility	None	A limited amount as it is possible to qualify queries	Much
Ease of Use	Very simple to use	Slightly more complicated than SQL*ReportWriter, but plenty of help is given	Knowledge of SQL and Oracle required
Output device	Screen, file or printer	Screen	Screen or file

Table 3.1 - a summary of the three types of software giving details on how to access each one, input commands, and output devices.

Using SQL*ReportWriter

1. Type *runrep report_name.rep name/password*. For a list of report names see the table on page 41.

2. Choose the kind of output you want - type Screen, File or Printer in the 'destination type' field.

3. If the output is being written into a file, give this file a name in the 'file name/spool device' field.

4. Alter the 'printer description file' field and the 'number of copies' field if necessary; if the output is not being written straight to a printer then just leave this field as it is.

5. The other fields on the form are specific to each report and are therefore explained in the descriptions of each report, but in general a value is typed into these fields in response to the prompted question.

6. Press *Enter* when all the relevant fields are filled in. This automatically activates the query set up by the report and the output is sent to the requested device.

7. If the output is being viewed on screen use the page up/down keys to move to different pages of the report. A page may be larger than the screen so to scroll through the records on a page you need to go into window mode. To do this press *CTL-F2*, and then use the up and down arrows to view the records. To exit the window mode, which is necessary in order to go to another page or to return to the DOS prompt press *F10*. When you have finish viewing the output press *F10* to get back to DOS.

Report Descriptions

Six reports have been set up to retrieve information from the database; their names and functions are summarised (Table 3.2) followed by a detailed description of how to use each one together with an example.

Report Name	Information Retrieved
1. SPECIES_QUERY	all information held on a particular species
2. CHAR_QRY_TEX	a list of species and their values for a given characteristic
3. CHAR_QRY_NUM	a list of species and their values for a given range of a numerical characteristic
4. CHAR_VAL_QRY	a list of species which have a given value of a characteristic
5. LINK1_COUNT	a table showing the combinations of possible values of 2 given characteristics and the number of species which are recorded as having each combination of values
6. LINK2_MEAN	a table giving a list of the alternative values of one given characteristic, and the mean value, standard deviation and number of species for which there is information on a second given numerical characteristic

Table 3.2 - a list of the reports that have been set up for use with the Ecological Flora Database.

1. SPECIES_QUERY

Output:- A list of all the information contained within the database for a given species, and the sources of these data.

Input:- Type in a species name in the final field of the parameter form. See Appendix B (page 166) for a full list of species in the database.

Sample Input:- Anacamptis pyramidalis

Sample Output:-

ANACAMPTIS PYRAMIDALIS		Reference
1.10	Shade none	53
1.10	Shade mid	53
1.10	Shade light	53
1.12	Altitude: 1. maximum recorded (m) 320	43
1.13	Altitude: 2. minimum recorded (m) 0	43
1.14	Altitude: 4. typical minimum (m) 0	43
2.01	Status native	1
2.04	First historical record: 1. date 1660	36
2.05	First historical record: 2. site Cambridgeshire	36
2.11	Range: 3. continents where native Europe	1
2.11	Range: 3. continents where native Asia	2
2.11	Range: 3. continents where native Africa	2
3.01	Stems: 1. woodiness non-woody	2
3.02	Stems: 2. support self-supporting	2

3.03	Height: 1. extreme maximum (cm) 75	2
3.05	Height: 3. typical maximum (cm) 50	2
3.06	Height: 4. typical minimum (cm) 20	2
3.22	Leaf longevity: 1. type aestival	37
5.01	Life-form geophyte	2
5.03	Age at first flowering 5-20 yrs	61
5.04	Mono/poly-carpic monocarpic	31
5.05	Vegetative reproduction/persistence: 1. method tubers	53
5.07	Flowering time: 1. earliest month 6	2
5.08	Flowering time: 2. latest month 8	2
5.15	Pollen vector insect	2
5.16	Dicliny hermaphrodite	2
5.19	Fertilization normally cross	27
5.25	Chromosome number(s): 1. number 36	1
5.36	Seed production: 2. typical range (/flower) >1000	61
5.37	Seed production: 3. typical range (/plant) >10000	31
5.38	Dispersal agent wind	298

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2. CHAR_QRY_TEX

Output:- A list of all the species within the database which have a value for a given characteristic. The output is ordered alphabetically according to the value of the characteristic.

Input:- Type in a characteristic number in the final field of the parameter form. See Appendix C (page 198) for a full list of characteristic numbers and the characteristic each number refers to. This report form is best used only for characteristics which are textual, or take particular ranges of numerical values (eg leaf area or longevity of stems) because it orders the characteristic values alphabetically and numerical values do not get ordered properly. Use the CHAR_NO_QRY report for numerical characteristics. The output list will be very long if a characteristic for which most species have a value is chosen.

Sample Input:- 4.06

Sample Output:-

```
A list of species and their database values for characteristic:
4.06 - Carnivory

   ARUM MACULATUM                    kills insects but not carnivorous
   CAPSELLA BURSA-PASTORIS           kills insects but not carnivorous
   DIPSACUS FULLONUM                 kills insects but not carnivorous
   PICRIS ECHIOIDES                  kills insects but not carnivorous
   SILENE NUTANS                     kills insects but not carnivorous
   DROSERA ANGLICA                   leaves
   DROSERA INTERMEDIA                leaves
   DROSERA ROTUNDIFOLIA              leaves
   PINGUICULA GRANDIFLORA            leaves
   PINGUICULA LUSITANICA             leaves
   PINGUICULA VULGARIS               leaves
   SARRACENIA PURPUREA               traps
   UTRICULARIA AUSTRALIS             traps
   UTRICULARIA INTERMEDIA            traps
   UTRICULARIA MINOR                 traps
   UTRICULARIA VULGARIS              traps
```

3. CHAR_QRY_NUM

Output:- A list of species which have characteristic values between a given range, together with the actual values of characteristic. Species are ordered numerically.

Input:- Type in a characteristic number where prompted on the parameter form. See Appendix C (page 198) for a full list of characteristic numbers and the characteristic each number refers to. Then type in the range of values of the characteristic you are interested in, lowest value followed by the highest value (output will include species which have both of these values as well as all values in between). If you want to list the values of all species there is information for then put in 0 and a very high number such as 99999 in as the range. This report can only be used for characteristics which have numerical values (ie for 1.06-1.09, 1.12-1.14, 2.04, 3.03-3.06, 3.20, 3.21, 4.01, 5.07-5.09, 5.11, 5.13, 5.21, 5.23, 5.24, 5.26, 5.30-5.35, 5.41-5.44). An error will occur if an attempt is made to use the form for any other characteristic numbers.

Sample Input:- 5.26, 0.9, 1.1

Sample Output:-

```
Species with 2C DNA content (pg) between 0.9 and 1.1

  SALIX CINEREA                      0.9
  TRIFOLIUM CAMPESTRE                0.9
  SINAPIS ALBA                       1.0
  ANTHYLLIS VULNERARIA               1.0
  BRACHYPODIUM SYLVATICUM            1.0
  ERIOPHORUM VAGINATUM               1.0
  ALNUS GLUTINOSA                    1.1
  FUMARIA MURALIS                    1.1
  SANGUISORBA MINOR                  1.1
  APHANES ARVENSIS                   1.1
  LOTUS TENUIS                       1.1
  LOTUS ULIGINOSUS                   1.1
  JUNCUS SQUARROSUS                  1.1
  SPARGANIUM ERECTUM                 1.1
  CAREX NIGRA                        1.1
```

4. CHAR_VAL_QRY

Output:- A list of all the species within the database which have a given value for a given characteristic.

Input:- Type in a characteristic number and the characteristic value in the final fields of the parameter form. See Appendix C (page 198) for a full list of characteristic numbers, names and alternative states.

Sample Input:- 4.02, C4

Sample Output

```
Species with Photosynthetic pathway value: C4

  ATRIPLEX LACINIATA
  ATRIPLEX PROSTRATA
  SALSOLA KALI
  PORTULACA OLERACEA
  CYNODON DACTYLON
  SPARTINA ANGLICA
  SPARTINA ALTERNIFLORA
  ZEA MAYS
  CYPERUS LONGUS
```

5. LINK1_COUNT

Output:- A list of alternative values for two characteristics and the number of species which have this combination of values.

Input:- Type in two characteristic numbers in the final fields of the parameter form. See Appendix C (page 198) for a full list of characteristic numbers and their associated characteristics. It must be remembered, however, that if both characteristics have a lot of alternative values the output list could be very long.

Sample Input:- 2.03,2.01

Sample Output

```
Dynamics          Status          No species

declining         native          152
declining         naturalised     2
increasing        native          53
increasing        naturalised     8
stable            native          15
```

6. LINK2_MEAN

Output:- A list of values for a given characteristic with the mean, standard deviation and a count of all species which have the listed value of the first characteristic and also a value for the second given characteristic.

Input:- Type in two characteristic numbers in the final fields of the parameter form. The first should refer to a characteristic which has stated alternative values, and the second to one which has a numerical value (refer to the list above on page 46 in the CHAR_QRY_NUM documentation). See Appendix C (page 198) for a full list of characteristic numbers and their associated characteristics. If the second characteristic number does not refer to a numerical characteristic value an error will result when the report is executed.

Sample Input:- 5.01,4.01

Sample Output

	Seedling growth rate - maximum (/d)		
Life-form	Mean	St dev	no. spp
chamaephyte	.14	.08	17
geophyte	.35	0	1
helophyte	.16	.03	7
hemicryptophyte	.17	.07	86
hydrophyte	.23	.1	3
phanerophyte	.08	.04	11
therophyte	.23	.07	22

Using SQL*Forms

Two forms have been set up to retrieve information using SQL*Forms.

1. SPS_QUERY - retrieves information about a given species.
2. CHAR_QRY - retrieves information about a given characteristic.

Both allow you to restrict the amount of information retrieved. The sps_query form can be used to find the value, if present, of a particular characteristic for a particular species, and char_qry can be used to retrieve those species which have a given value for a stated characteristic.

To use SQL*Forms:-

Type *runform form_name name/password.*

The SPS_QUERY form

Function:-

To retrieve information about a particular species. This form is ideally used if information about a particular species is required - for example 'does species x need light for germination?'. The form retrieves the information if present in the database, the source and any notes that are appended to the information.

Instructions:-

1. Type in the name of the species (the letter case is unimportant) and press *enter.*

2a. If all known information about the species is required, press *F8.* Use the up and down arrow keys to scroll through the records.

2b. If a particular item of information is required, press *F7*, type in the relevant characteristic number, press *F8.* To retrieve details of the source, press the *Page Down* key.

3. To start again with a new species, press *Esc*, which brings up a blank form, continue from number 1.

4. To exit from the form press *Esc* once or twice until the DOS prompt is reached.

5. For help press *F2* which will bring up a form giving help specific to your position. Press *Esc* to exit help.

6. For a list of characteristic numbers and their associated characteristics, press *F4* from any point on the form. Press *Esc* to return to your original place.

The CHAR_QRY form

Function:-

To retrieve information about a particular characteristic.

Instructions:-

1. Press *F7*, type in the number of the characteristic you are interested in.

2. If you only want to retrieve a list of species which have a particular value for that characteristic then press *Enter* and then type in the relevant value, otherwise go straight to step 3.

3. Press *F8*.

4. For a list of characteristics and their numbers press *F4* (if you have already pressed *F7*, then press *Esc* followed by *F4* and then proceed from step 1) or refer to Appendix C (page 198).

5. For help press *F2*.

6. To get information on a new characteristic start again from step 1, and to exit press *Esc* several times until the DOS prompt is reached.

Using SQL*Plus

To enter SQL*Plus type *SQLPLUS name/password.* The SQL> prompt will appear.

Information can now be retrieved from the database using structured query language (SQL) and the additional commands provided by SQL*Plus. This user guide does not include detailed instructions on how to use SQL, or a comprehensive list of SQL*Plus commands. Some sample queries are included which show a wide range of the commands in use, but more detailed documentation can be found elsewhere, for example:- the Oracle manuals; Hursch JL and Hursch CJ, 1987, Working with Oracle,Tab Professional and Reference Books, Blue Ridge Summit, Pa; and for SQL - Lans RF van der, 1988, Introduction to SQL, Addison Wesley, Wokingham.

Once in SQL*Plus a query can be typed in using SQL and ended with a semi-colon. The semi-colon indicates that the query is complete and causes it to be executed.

Buffers

The most recently executed SQL and SQL*Plus commands are stored in a buffer. This means firstly, that the most recently executed query can be edited without the need to re-type it, especially useful if there is a syntax error in it or only a small modification is required, and secondly, that any SQL*Plus commands (eg format or pagelength commands - see example queries) remain in force for all executed queries until they are reset.

Commands can be cleared from the buffer by typing the command 'clear buffer', which resets all SQL*Plus commands to their default values, and empties the buffer of any SQL commands.

It is also possible to use more than one buffer, which is useful if in one session several queries are being run, each requiring different SQL*Plus commands. To do this use the command 'set buffer <buffer_name>' (the buffer name can be any text up to 30 characters long), and then enter the relevant SQL*Plus commands and the query. Once this query has been executed the default buffer is returned to, so use the command 'set buffer' prior to running the query each time. Use a different buffer name for each query and its associated SQL*Plus commands.

Editing Queries

SQL*Plus does include some editing commands but editing is made much easier if a text editor is used. To do this enter the SQL*Plus command 'define _editor = '<text editor>', where <text editor> is the command which calls up the required editor. Subsequently whenever the edit command is used the SQL query in the buffer will be transferred into the text editor. When editing is complete save the query and exit from the editor. The new query is now in the current buffer; type 'run' to execute it.

Storing and Retrieving Queries

An SQL query can by saved using the command 'save <filename>'. It can be retrieved using 'get <filename>' which puts it into the current buffer where it can be executed by typing 'run'.

It is also possible to store the SQL*Plus commands associated with a query. The best way to do this is to enter the SQL*Plus commands and the associated query into the text editor and to save the file. Enter SQL*Plus and then run the query by typing 'start <filename>'. This file can be edited from within SQL*Plus by typing 'edit <filename>'. It is a good idea to start such a file with the 'clear buffer' command so old SQL*Plus commands do not affect the output.

Saving and Printing Output

The output from a query can be read into a file by using the command 'spool <filename>' before typing in the query or using the run or start commands. Once the output is finished type 'spool off' to stop subsequent keystrokes/output being read into the file. To send the output straight to a printer, type 'spool out' instead of 'spool off'.

Setting Default SQL*Plus Commands

Any SQL*Plus commands that are stored in a file called 'login.sql' are immediately operative on logging in to SQL*Plus. It is useful to have page length, line length and define _editor commands in such a file, as well as any commonly used column format commands.

Sample Queries

The line numbers next to each query have been added solely to refer to the notes below each one, they are not a part of the actual query. The queries contain both SQL*Plus commands and SQL language commands. The SQL*Plus commands occur at the beginning of the query and are responsible for defining the format of the output (titles, page lengths, column widths etc.). The 'select' command marks the beginning of the SQL commands which actually retrieve information from the database. I have tried in these queries to use a variety of Oracle's features and commands and to explain their usage. They are not however by any means comprehensive.

Any of these queries can be run by entering SQL*Plus and typing *start query_name*. Text which is underlined is dependent on which species or characteristic the user wants to retrieve data on and so should be altered before running the query.

1. SPECIES.QRY

Outputs a list of information in the database about a particular species.

```
1.1   clear buffer
1.2   set pages 5000
1.3   set underline off
1.4   column char_name format a60
1.5   column char_no heading ' '
1.6   column char_name heading ' '
1.7   column char_value heading ' '
1.8   column char_value newline
1.9   ttitle left 'POLYGONATUM MULTIFLORUM'
1.10  select characteristic.char_no,char_name,'        ' || char_value
1.11  from characteristic,plant_characteristic
1.12  where characteristic.char_no = plant_characteristic.char_no
1.13  and plant_no = 1830460040
1.14  order by characteristic.char_no
1.15  /
```

Notes:-

SQL*Plus commands

1.1 This command clears all previous SQL commands that might affect the query.

1.2 Sets the page length to 5000 lines, which means that no page breaks will appear in the output. The page length can be set to 0 to suppress all page breaks, headings and titles if required.

1.3 This switches off the underline character normally displayed under the column headings. It is not required here because the column headings have been set to a blank character.

1.4 Sets the width of the char_name column to 60 characters.

1.5-1.7 Set the column headings to a blank character to suppress the printing of any headings.

1.8 Prints the char_value column on a new line.

1.9 Prints a title at the top of the output on the left hand side of the screen/page. The title needs to be input by the user.

SQL commands

1.10 Tells the database which columns to retrieve data from. If columns in more than one table have the same name, then the column name must be prefixed with the table name followed by a full stop. The '||' symbol joins output from more than one column or output from a column and text together. So in this case, for example, seven spaces are printed before the value of the char_value column is output.

1.11 Tells the database which tables the requested columns are to be found in.

1.12 The 'where' and following 'and' commands qualify the select statement. This line links together the char_no column of the characteristic and plant_characteristic table, so a char_no extracted from the plant_characteristic table can be used to retrieve the relevant row in the char_name column from the characteristic table.

1.13 This line tells the database which plant_no to look for in the plant_characteristic table. This number needs to be input by the user before running the query.

1.14 The 'order by' command dictates which column or columns the data is to be ordered by. So in this case the output will be ordered according to the char_no column.

1.15 The slash indicates the end of the query.

The Output:-

```
POLYGONATUM MULTIFLORUM

1.12    Altitude: 1. maximum recorded (m)
        243

2.04    First historical record: 1. date
        1562

2.11    Range: 3. continents where native
        Europe

2.11    Range: 3. continents where native
        Asia

etc...
```

2. SOURCE_QRY

Outputs a list of sources that information on a particular characteristic was extracted from.

```
2.1    clear buffer
2.2    set pages 0
2.3    column source_details word_wrapped
2.4    select authors || ', ' || year, title || title_2 || title_3 || journal || ' ' || volume || ' '
       || page source_details
2.5    from source
2.6    where source_no in
2.7    (select distinct source_no from plant_characteristic
2.8    where char_no = '2.04')
2.9    order by authors, year desc
2.10   /
```

Notes:-

2.2 Suppresses all column titles and headings.

2.3 Causes output which is longer than one line to wrap round onto the next line, the 'word_wrapped' command means that the line break will only occur between words.

2.4 Text can be put into the select statement by surrounding it with single quotes. This text appears in each row of output. Columns can be given alias headings by leaving a space after the column title in the select statement followed by the alias name. In this query the amalgamation of columns has been given the much shorter name source_details. It is this name which is used where necessary in SQL*Plus commands - see line 2.3.

2.6 The 'in' clause is an alternative way of joining two tables together. Here only the rows in source which have a source_no which is also retrieved by the sub-query which follows 'in' will be retrieved.

2.7-2.8 The brackets indicate a sub-query, the results from this query have an effect on the data retrieved by the main query. The 'distinct' command deletes any duplicate rows that a query retrieves - a source_no may occur several times in the plant_characteristic table, but each number is only retrieved once by the query.

2.9 This orders the output by two columns, firstly by authors, then if more than one row has the same author, secondly by the year. By default columns are sorted in ascending order so 'desc' overrides the default and means the years will be ordered with the most recent first.

The Output:-

```
Barry R, Wade PM, 1986
Journal of Ecology 74 289-294

Beddows AR, 1973
Journal of Ecology 61 587-600

Burdon JJ, 1983
Journal of Ecology 71 307-330

Cavers PB, Harper JL, 1964
Journal of Ecology 52 737-766

Clapham AR, Tutin TG, Moore DM, 1987
Flora of the British Isles, 3rd ed, Cambridge University Press,Cambridge

Clarke WA, 1900
First Records of British Flowering Plants, 2nd ed., West, Newman &
Co.,London

Clement EJ, 1985
BSBI News 41 20

Coker PD, Coker AM, 1973
Journal of Ecology 61 901-913

Coombe DE, 1956
Journal of Ecology 44 701-713

Cross JR, 1975
Journal of Ecology 63 345-364

etc...
```

3. FAM_MEAN.QRY

Calculates the average value of a numerical characteristic according to family.

3.1 clear buffer

3.2 set pages 5000

3.3 col family format a16

3.4 col mean format 999.99

3.5 select family, round(avg(char_value),2) mean, count(char_value) no_species

3.6 from plant,plant_characteristic

3.7 where plant.plant_no = plant_characteristic.plant_no

3.8 and char_no = '5.34'

3.9 group by family

3.10 /

Notes:-

3.4 This command specifies the lay out of numerical data. It states that in the column entitled mean the data can have up to 3 figures before the decimal point and will always have 2 figures after the point. Other formats are available.

3.5 'Round(avg(char_value),2) mean' calculates the average of char_value, rounds the answer to 2 decimal places and outputs it in a column entitled mean. 'Count(char_value)' totals the number of species used for each mean calculation.

3.9 The 'group by' command files the data by its value of the specified column, in this case family. The data for each family are then dealt with separately, giving the mean value of char_no '5.34' - average seed weight, for each family.

The Output:-

```
FAMILY                 MEAN NO_SPECIES
---------------- ------- ----------
ACERACEAE         103.80          3
ADOXACEAE            .71          1
ALISMATACEAE         .27          1
AMARYLLIDACEAE     50.00          1
APIACEAE            5.11         29
AQUIFOLIACEAE      40.00          1
ARACEAE            31.60          4
ARALIACEAE         33.11          3
BALSAMINACEAE      10.58          4
BERBERIDACEAE      14.85          2
BETULACEAE           .57          3
BORAGINACEAE        8.53         13
BRASSICACEAE        2.04         37
etc...
```

4. RANGE.QRY

Produces a list of species and their associated characteristic values for a given numerical characteristic between two stated values.

4.1 clear buffer

4.2 col plant_name format a33

4.3 col to_number(char_value) format 99.99

4.4 select plant_name,to_number(char_value)

4.5 from species,plant_characteristic

4.6 where species.plant_no = plant_characteristic.plant_no

4.7 and char_no = '3.20'

4.8 and to_number(char_value) between 170 and 175

4.9 order by to_number(char_value),plant_name

4.10 /

Notes:-

4.4 The 'to_number( )' command converts character values into numerical ones. In this query it is useful because char_value is a column of type char even though some of its values are numerical. The 'order by' command and the 'between...and...' commands, among others do not treat numerical values properly if they are of type char as they are treated according to their ASCII codes

4.8 The 'between... and...' command retrieves rows of data if the value in the selected column is of either of the stated values, or of any value in between. In the example species with stomatal densities greater than or equal to 170/mm^2 and less than or equal to 175/mm^2 are retrieved.

The Output:-

```
PLANT_NAME                         TO_NUMBER(CHAR_VALUE)
---------------------------------- ---------------------
LITHOSPERMUM PURPUROCAERULEA                      170.00
SERRATULA TINCTORIA                               170.00
POTENTILLA STERILIS                               171.00
POLYGONUM VIVIPARUM                               172.00
DIPSACUS PILOSUS                                  175.00
GEUM URBANUM                                      175.00
LAMIASTRUM GALEOBDOLON                            175.00
```

5. NO_INFO.QRY

Generates a list of species for which the database holds no information for a given characteristic.

```
5.1   clear buffer
5.2   break on family skip 1
5.3   col family format a16
5.4   col plant_name format a33
5.5   select family,plant_name
5.6   from species
5.7   where plant_no in
5.8   (select plant_no from species
5.9   minus
5.10  select distinct plant_no
5.11  from plant_characteristic
5.12  where char_no = '5.25')
5.13  group by family,plant_name
5.14  /
```

Notes:-

5.2 The 'break on' command is generally used with the 'group by' command. It organises rows of output into groups, so in this case each family is only printed once at the top of the output for each species in that family. The 'skip' command defines how many lines are left between each group (one line between each family in this case).

5.9 The 'minus' operator is used to select rows that are retrieved by the preceding query but not by the following query. So in this example plant_nos that are in the species table but not in the plant_characteristic table associated with a char_no of 5.25 are retrieved. Two other operators 'intersect' and 'union' can be used in a similar manner and they work in the way suggested by their names. Intersect returns only rows that both queries select, and union all the rows that each query selects.

The Output:-

```
FAMILY            PLANT_NAME
---------------   ----------------------------------
APIACEAE          PHYSOSPERMUM CORNUBIENSE
                  SISON AMOMUM

ARACEAE           LYSICHITON AMERICANUS

BORAGINACEAE      SYMPHYTUM IBIRICUM
                  SYMPHYTUM ORIENTALE

CAMPANULACEAE     WAHLENBERGIA HEDERACEA

CAPRIFOLIACEAE    LEYCESTERIA FORMOSA

CARYOPHYLLACEAE   ARENARIA BALEARICA
                  SAGINA X NORMANIANA
                  SILENE ALBA
                  SILENE LATIFOLIA

CHENOPODIACEAE    ATRIPLEX PRAECOX
                  CHENOPODIUM BOTRYODES
                  SALICORNIA LUTESCENS

COMPOSITAE        ARCTIUM PUBENS
                  ASTER NOVI-BELGII
                  BIDENS CONNATA
                  CICERBITA MACROPHYLLA
                  CONYZA SUMATRENSIS
                  HIERACIUM ARGENTEUM
                  HIERACIUM DEWARII
                  HIERACIUM DIAPHANOIDES
                  HIERACIUM FLAGELLARE
                  HIERACIUM HOLOSERICEUM
                  HIERACIUM IRICUM
                  HIERACIUM LASIOPHYLLUM
                  HIERACIUM OISTOPHYLLUM
                  HIERACIUM ORCADENSE
                  HIERACIUM PELLUCIDUM
                  HIERACIUM PRAEALTUM
                  HIERACIUM RETICULATUM
                  HIERACIUM SENESCENS
                  HIERACIUM SPARSIFOLIUM
                  SENECIO SMITHII
                  TARAXACUM OFFICINALE AGG.

etc...
```

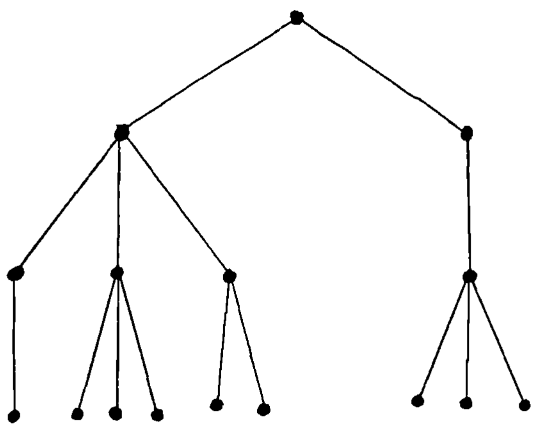
Chapter 4

An Investigation into the Antiquity of Ecological Characteristics in Angiosperms

Introduction

Some angiosperm characteristics are known from fossil evidences to have become established early on in the evolution of angiosperms. Such characters are predominantly morphological eg woodiness, presence of stipules, actinomorphy (Sporne, 1973). In many cases due to the paucity of the fossil record or the nature of the characteristic (eg. self/cross pollination or annual/perenniality) the fossil record cannot offer the necessary data. The distribution of characteristics in living species, however, can be used to investigate their evolutionary history.

A species may have a particular characteristic for two reasons. Firstly, because it has evolved, either in response to natural selection or non-selective causes such as genetic drift, or alternatively, because its ancestors also had that particular characteristic. If the characteristic value is determined solely by evolution, species more closely related to one another will not be more likely to have a similar value for the characteristic than species less closely related unless they share a more similar way of life. The converse is true, however, if the characteristic value depends to some extent on the characteristic value present in an ancestor. If it is assumed that taxonomy represents phylogeny, then species belonging to the same taxon will be more closely related to one another than species of different taxa. This means that the amount of variance in a characteristic at a particular degree of relatedness between taxa indicates how much evolutionary change in the characteristic has occurred at the chosen taxonomic level. Therefore, the evolutionary history of a characteristic can be investigated by calculating the percentage of variance in the characteristic at each taxonomic level (see Figure 4.A). If the majority of variance is found at high taxonomic levels it suggests the characteristic values evolved a long time ago and have since become fixed, either due to phylogenetic constraints, or because there is no selection pressure for alternative values of the characteristic. If, on the other hand, much of the variance is found at low taxonomic levels it suggests the characteristic has been evolving much more recently and may still be responding to selection pressures.



taxonomic level	estimated mean square
order	$\sigma^2_{sp(g)} + c\sigma^2_{g(f)} + q\sigma^2_{f(o)} + z\sigma^2_{o}$
family	$\sigma^2_{sp(g)} + b\sigma^2_{g(f)} + p\sigma^2_{f(o)}$
genus	$\sigma^2_{sp(g)} + a\sigma^2_{g(f)}$
species	$\sigma^2_{sp(g)}$

Figure 4.A - a diagram showing the total amount of variance for each taxonomic level in a hierarchical tree. The values of the variance components are found by calculating the expected mean square values using a nested analysis of variance and estimating the coefficients (*a,b,c,p,q,*and *z*) of the variance components. These have to be estimated as taxonomic trees are not balanced (ie. do not have equal numbers of species within each genus, or equal numbers of genera within families etc.).

Bell (1989), for example, calculated the variance in body mass of eutherian mammals at seven taxonomic levels. The majority of the variance was found at the ordinal (44.2%) and supraordinal (18.8%) levels. He suggests that diversification in body mass mainly occurred during the radiation of the eutherian mammals shortly after their appearance in the upper Cretaceous. When chromosome number was analysed, however, there was a higher proportion of the variance at the species and genus levels, which may mean a change in chromosome number is more frequently associated with speciation than is a change in body mass.

The Ecological Flora Database contains information on a large number of ecological variables, such as habitat, distribution, morphology, life history and breeding system variables, in British flowering plant species. It was therefore possible to use these data to investigate the amount of variance at different taxonomic levels for a wide range of ecological characteristics in angiosperms.

Method

A nested analysis of variance was used to estimate the percentage of the overall variance contributed by each taxonomic level. This partitions the overall variance in a characteristic into the amount of variance found between species within genera, between genera with families, between families within orders etc.

$$\sigma^2_{tot} = \sigma^2_{sp(g)} + \sigma^2_{g(f)} + \sigma^2_{f(o)} + \sigma^2_{o(sc)} + \sigma^2_{sc(c)} + \sigma^2_{c}$$

σ^2_{tot} represents the total variance and $\sigma^2_{sp(g)}$, for example, represents the variance of species within genera (tot = total, sp = species, g = genus, f = family, o = order, sc = subclass, c = class). The variance components are converted into percentages by multiplying each component by $100/\sigma^2_{tot}$.

The nested analysis of variance calculates the amount of variance at the lowest level in the analysis and uses this result to calculate the extra variance contributed by the level above, and this in turn for the next level up, and so on. This means that if the total variance at one level is less than that at a lower level then the variance component for the higher level will be negative. In such cases, since no further variance is added by the higher level the variance component is set to zero.

The computation of the variance components is complicated due to the nature of taxonomy. Taxonomic groups do not all have the same number of species in them, a family, for example, may contain only one species (eg. Adoxaceae) or may contain several hundred, or even thousand, species (eg. Poaceae, Asteraceae). The unbalanced nature of the data, therefore, means the coefficients of the variance components have to be calculated in order to estimate the values of the variance components; the method used was that of Steel and Torrie (1980) page 163.

Example of the computation of variance components

Data were available on the proportion of stomata on the lower epidermis for 455 British angiosperms.

Coefficients of Expected Mean Squares

These were estimated using the method in Steel and Torrie (1980) page 163.

Source	Class	Subclass	Order	Family	Genus	Species
Class	170.87	73.20	35.67	22.55	6.89	1.00
Subclass		37.93	12.61	9.63	2.47	1.00
Order			8.44	6.38	2.41	1.00
Family				3.22	1.75	1.00
Genus					1.49	1.00
Species						1.00

Nested Analysis of Variance

	df	Sum of Squares	Mean Square
Class	1	7.86	7.86
Subclass	8	8.96	1.12
Order	35	31.24	0.89
Family	36	16.68	0.46
Genus	186	21.74	0.12
Species	188	22.03	0.12
Total	454	108.50	0.24

$\sigma^2_{sp(g)} = 0.12$

$\sigma^2_{sp(g)} + a\sigma^2_{g(f)} = 0.12$ $\therefore \sigma^2_{g(f)} = (0.12 - 0.12)/1.49 = 0$

$\sigma^2_{sp(g)} + b\sigma^2_{g(f)} + p\sigma^2_{f(o)} = 0.46$ $\therefore \sigma^2_{f(o)} = (0.46 - 0.12 - 1.75*0)/3.22 = 0.11$

similarly:

$\sigma^2_{o(sc)} =$ 0.01

$\sigma^2_{sc(c)} =$ 0.00

$\sigma^2_{c} =$ 0.03

$\sigma^2_{tot} =$ 0.27

The variance components can then be used to calculate the percentage of variance contributed by each taxonomic level.

	variance component	% variance
Class	0.03	12
Subclass	0.00	0
Order	0.01	4
Family	0.11	40
Genus	0.00	0
Species	0.12	44

Nested analyses of variance were conducted on 25 ecological characteristics of British plant species representing a wide variety of ecological information including distribution, morphology, reproductive behaviour and life history. The species were classified into class, subclass, order, family and genus using the classification in Stace (1991) which follows Cronquist (1981). Data were analysed using the 'nested' procedure in SAS version 6.

14 quantitative characteristics were chosen (Table 4.1) for analysis. This list includes all quantitative characteristics in the Ecological Flora database for which data were available for at least 250 species. In a few cases a species may have more than one

value for a characteristic due to conflicting values having been found in the literature. These species were omitted from the analysis. It would have been possible to include them by calculating within species variance, but this variance would have been too high because the database only includes multiple values for a characteristic if very different measurements are recorded; several records of similar values are not noted. There is however one exception to this - within species variance was calculated for the characteristic 'chromosome number' as in this case a reasonably comprehensive list of the possible chromosome numbers for each species was available.

Four of the quantitative characteristics - 'maximum altitude', 'first historical record', 'proportion of European countries a species is native in' and 'number of database categories filled', were included as control characteristics. The data values for these characteristics are unlikely to be affected by taxonomy so it can be predicted that the majority of the variance will occur at the within genus level.

Characteristic	Transformation	No. spp
Number of database characteristics filled		1772
Percentage of European countries species is native in	arcsin square root	1677
First historical record		1273
Maximum altitude		929
Pollen diameter	natural logarithm	357
Maximum number of seeds produced/flower	natural logarithm	400
Proportion of stomata on the abaxial epidermis of the leaf	arcsin square root	455
Propagule length	natural logarithm	850
Dispersule length	natural logarithm	716
Maximum height	natural logarithm	1549
Minimum height	natural logarithm	1239
Seed weight	natural logarithm	584
2C DNA	natural logarithm	290
Chromosome number	natural logarithm	1540

Table 4.1 - A list of the quantitative characteristics analysed, showing what transformations, if any, were used and the number of species data were available for.

Many of the characteristics in the database are categorical and so can not be analysed in the same way as quantitative characteristics. Some qualitative characteristics, however, take one of two values (Table 4.2) and the variation in these characteristics was analysed using the proportion of species in a genus which had a particular value of a characteristic. The data were transformed using the Freeman-Tukey transformation (Mosteller and Youtz, 1961).

$$0.5\left(\arcsin\sqrt{\frac{x}{n+1}} + \arcsin\sqrt{\frac{x+1}{n+1}}\right)$$

where:

x = number of species/genus with chosen value for the characteristic

n = number of species/genus

This transformation takes into account not only the proportion of species in a genus with a particular value of the characteristic but also the number of species for which data were available to calculate that proportion.

Species that are:
wind pollinated
insect pollinated
commonly self-fertilized
dioecious
hermaphrodite
dichogamous
woody
compound leaved
annual
normally mycorrhizal
normally arbuscular mycorrhizal

Table 4.2 - A list of the qualitative characteristics analysed using the proportion of species in a genus with the given characteristic value.

Results

The four control characteristics: no. of database characteristics filled, % European countries a species is native in, first historical record and maximum altitude, each had over 70% of variance at the between species within genus level (Figures 4.1-4.4). None of the other quantitative characteristics had such a high percentage of the variance at any one taxonomic level. Pollen diameter and number of seeds/flower have most of the variance at the between family within order level (Figures 4.5 and 4.6) and proportion of stomata on the lower epidermis varies mainly at two taxonomic levels: between families within order and between species within genus (Figure 4.7). The rest of the quantitative characteristics have the variance spread over several taxonomic levels. The majority of the variance, however, occurs at the between genera within family level for propagule and dispersule length (Figures 4.8 and 4.9). The variance of maximum height is spread chiefly over the species, genus and family level (Figure 4.10) as is the variance of minimum height although in this case there is a higher proportion of variance at the between species within genus level (Figure 4.11). Seed weight has most of the variance at the genus and family level (Figure 4.12) and 2C DNA at the family level although the subclass, genus and species level each contribute to over 15% of the variance (Figure 4.13). Most of the variance in chromosome number occurs at the within species level (Figure 4.14).

The qualitative characteristics also have variances spread over several taxonomic levels. Wind and insect pollination have much variance at the class and subclass level although insect pollination also has over 20% of the variance at the within genus level (Figures 4.15 and 4.16). Woodiness has almost all the variance at the between families within orders and between genera within family levels with the majority at the between family level (Figure 4.17). The results for species that are normally mycorrhizal and normally arbuscular mycorrhizal are very similar with most of the variance at the family and genus levels (Figures 4.18 and 4.19). The variance in species/genus that are dioecious is spread over order, family and genus levels (Figure 4.20), as is the variance in species/genus that are hermaphrodite although in this case the majority of the variance is at the genus level (Figure 4.21). The variance in the occurrence of compound leaves is also mainly at the between genera within family level, but some variance is present at all taxonomic levels (Figure 4.22). The remaining qualitative characteristics: annualness, dichogamy and self fertilization each have over 70% of the variance at the between genera within family level (Figures 4.23-4.25).

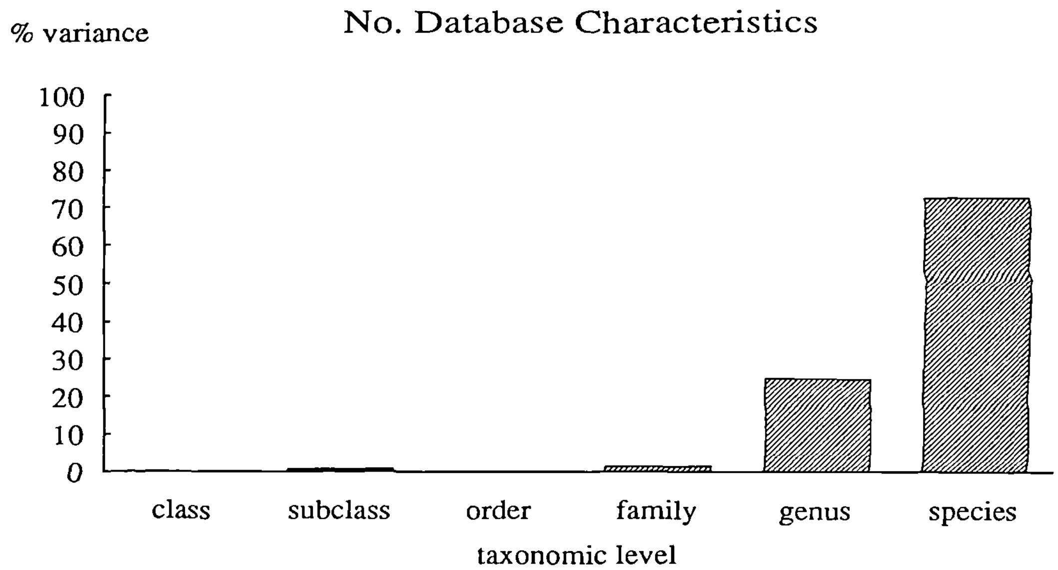


Figure 4.1 - The percentage variance at each taxonomic level in the number of database categories filled for 1772 British angiosperms.

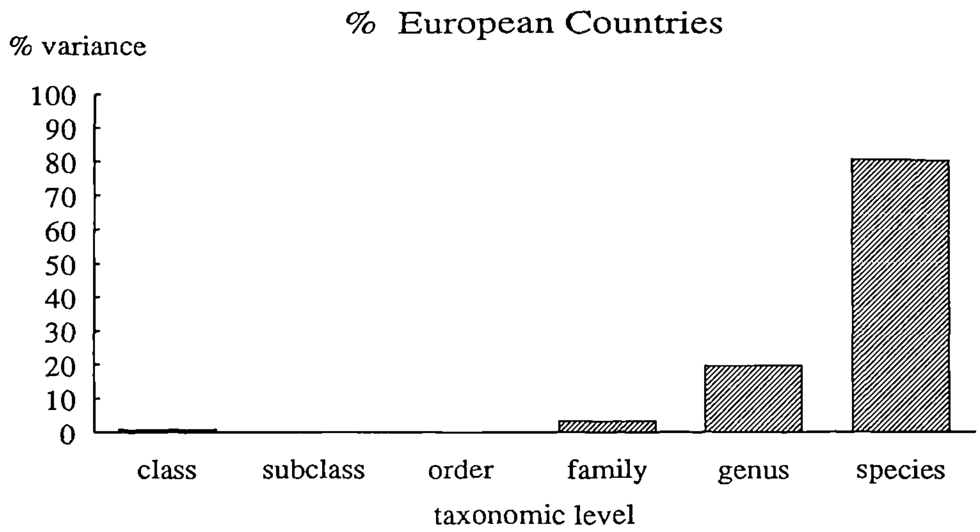


Figure 4.2 - The percentage variance at each taxonomic level in the percentage of European countries a species is native in for 1677 British angiosperms.

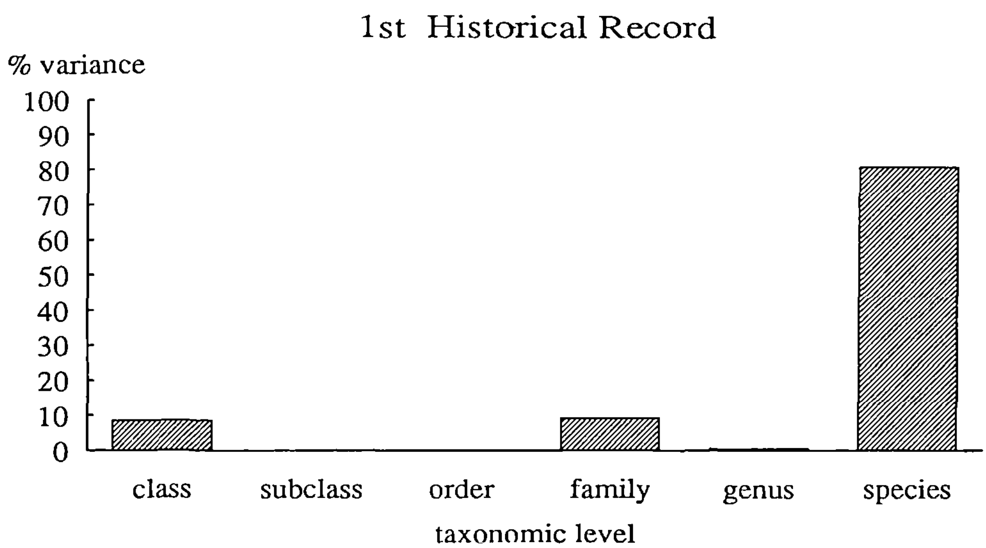


Figure 4.3 - The percentage variance at each taxonomic level in the first historical record of 1273 British angiosperms.

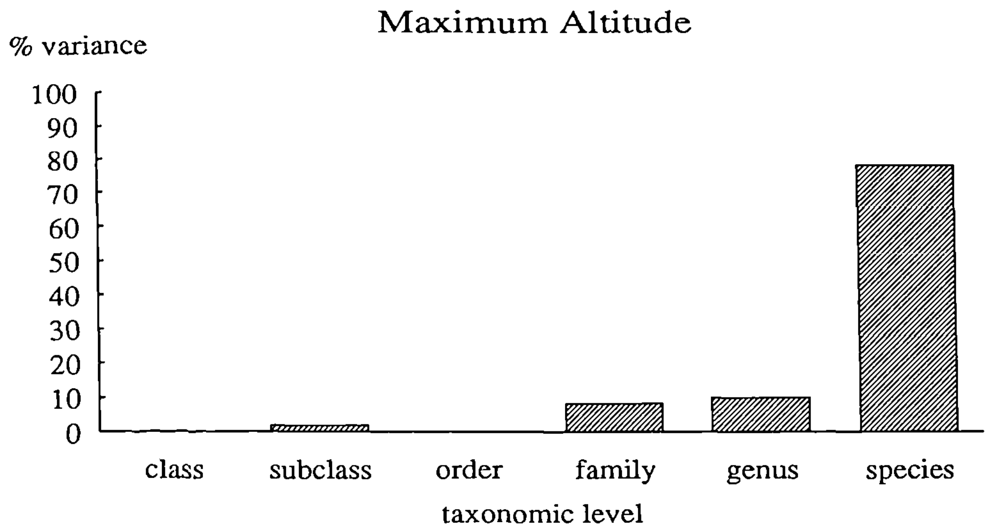


Figure 4.4 - The percentage variance at each taxonomic level in the maximum altitude of 929 British angiosperms.

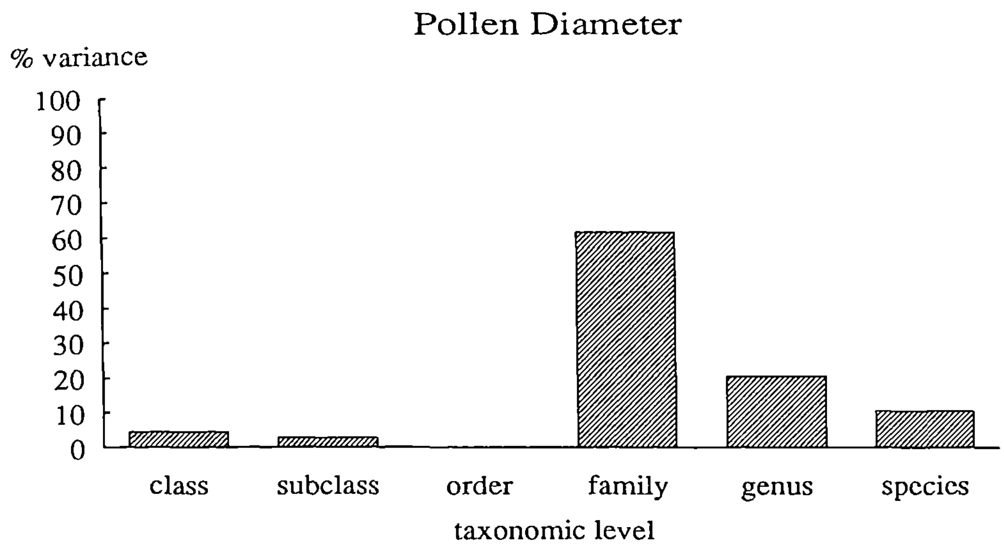


Figure 4.5 - The percentage variance at each taxonomic level in the pollen diameter of 357 British angiosperms.

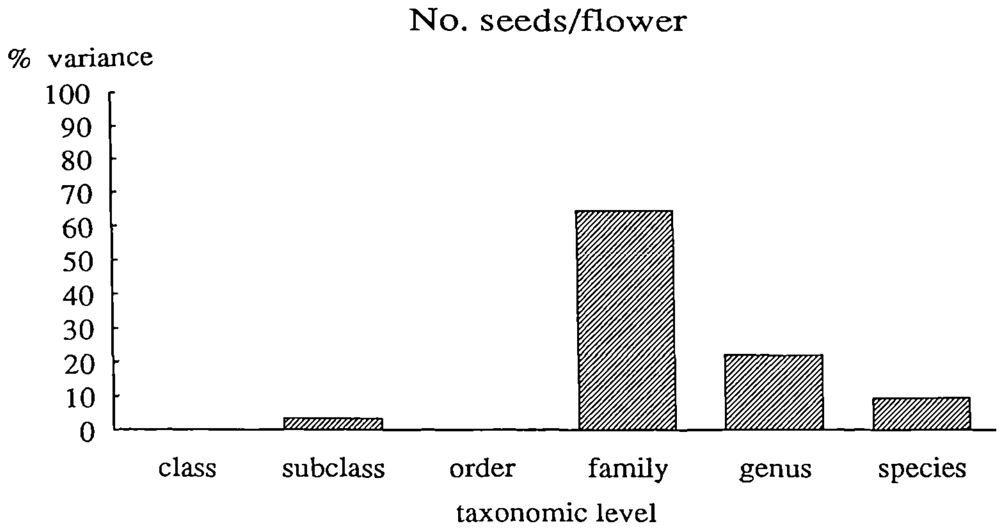


Figure 4.6 - The percentage variance at each taxonomic level in the maximum number of seeds/flower of 400 British angiosperms.

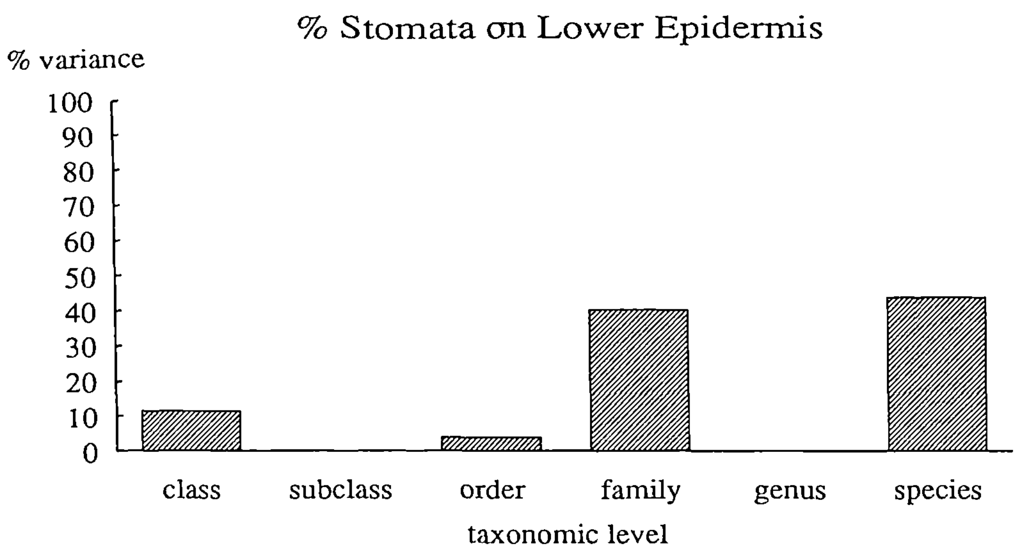


Figure 4.7 - The percentage variance at each taxonomic level in the percentage of stomata on the lower epidermis of the leaf for 455 British angiosperms.

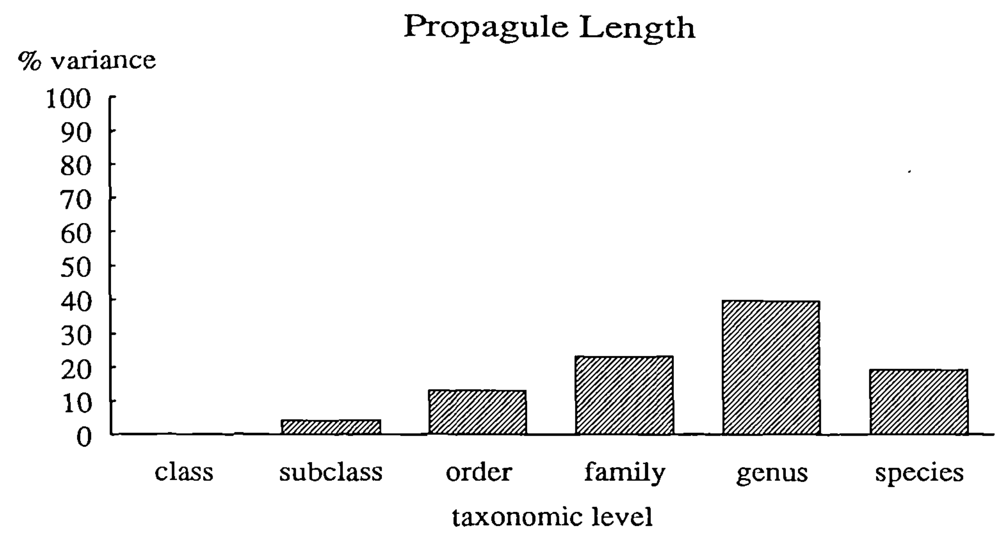


Figure 4.8 - The percentage variance at each taxonomic level in the propagule length of 850 British angiosperms.

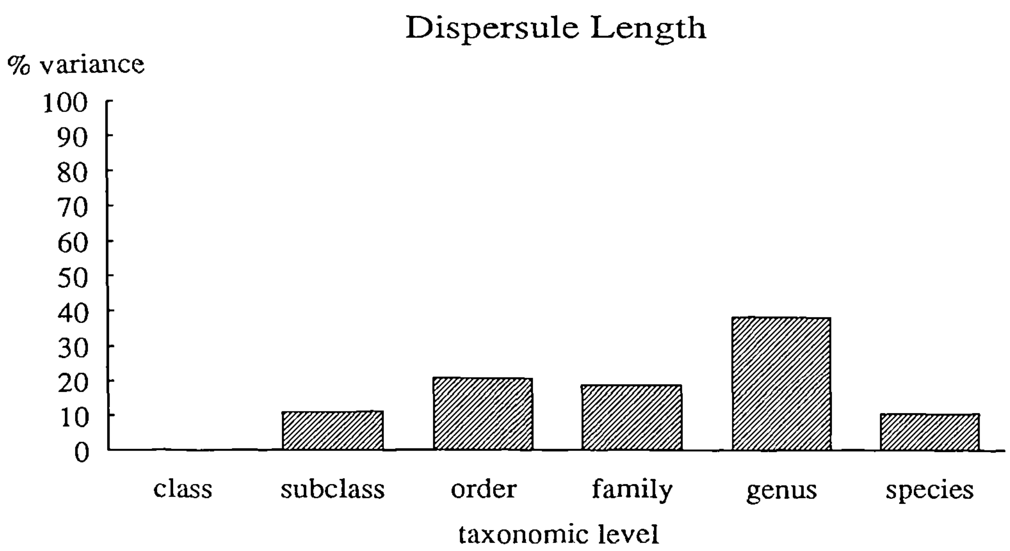


Figure 4.9 - The percentage variance at each taxonomic level in the dispersule length of 716 British angiosperms.

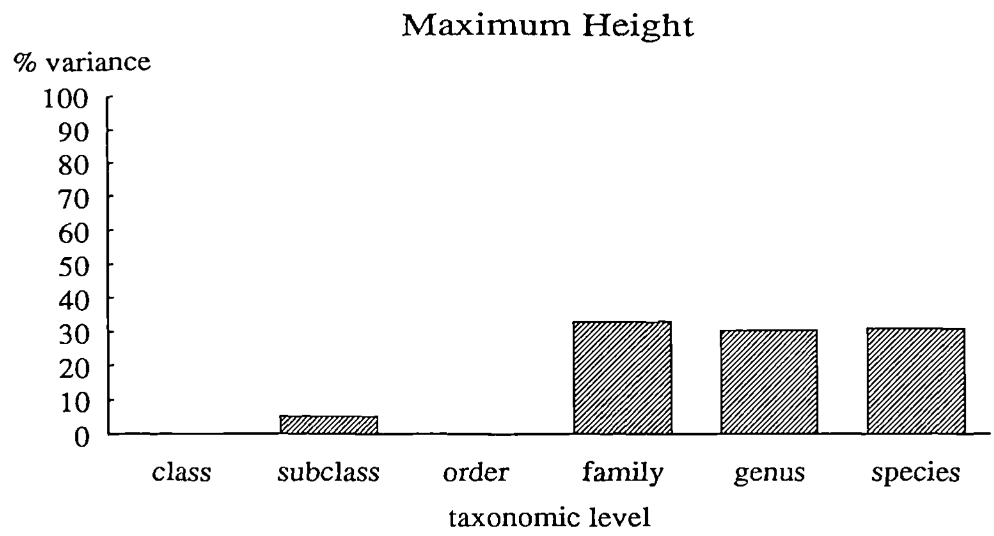


Figure 4.10 - The percentage variance at each taxonomic level in the maximum height of 1549 British angiosperms.

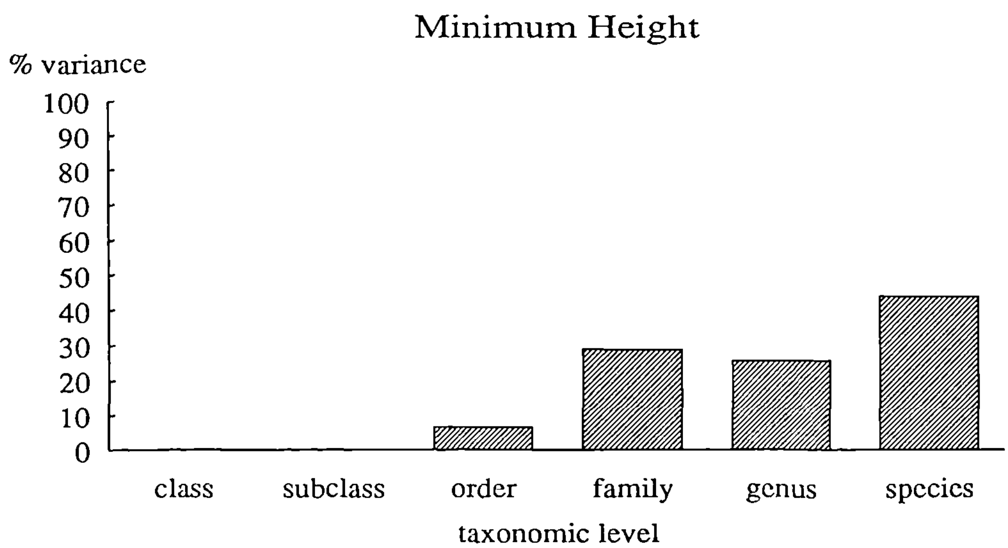


Figure 4.11 - The percentage variance at each taxonomic level in the minimum height of 1239 British angiosperms.

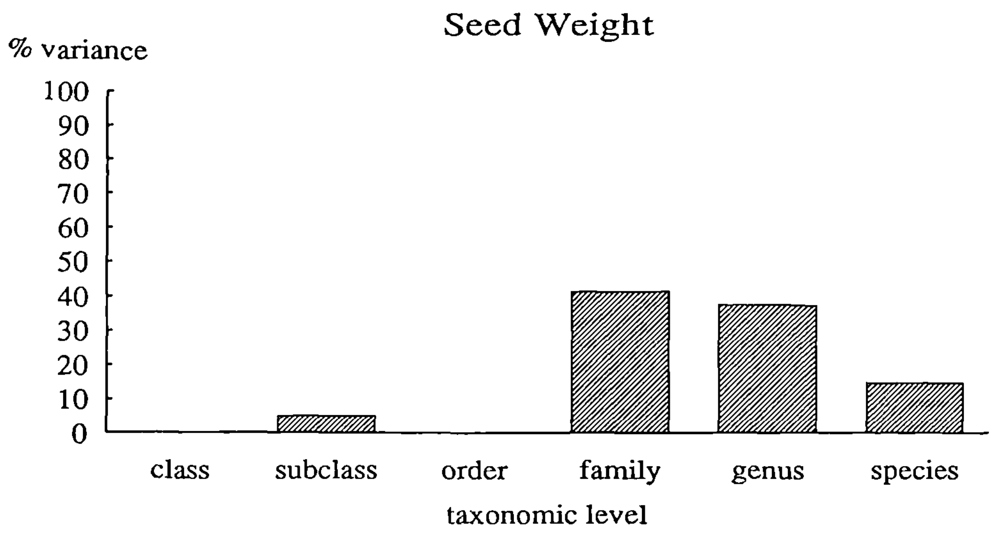


Figure 4.12 - The percentage variance at each taxonomic level in the mean seed weight of 584 British angiosperms.

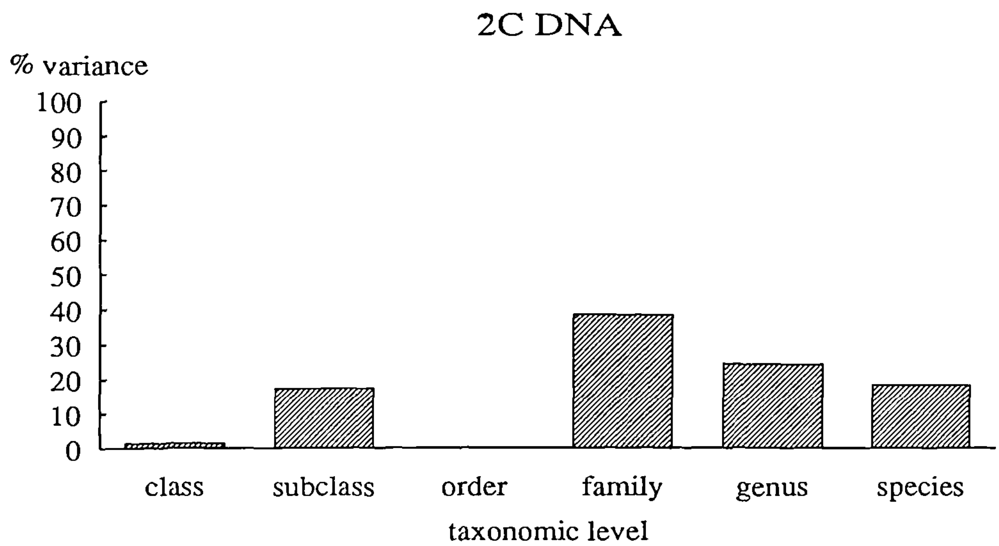


Figure 4.13 - The percentage variance at each taxonomic level in the 2C DNA of 290 British angiosperms.

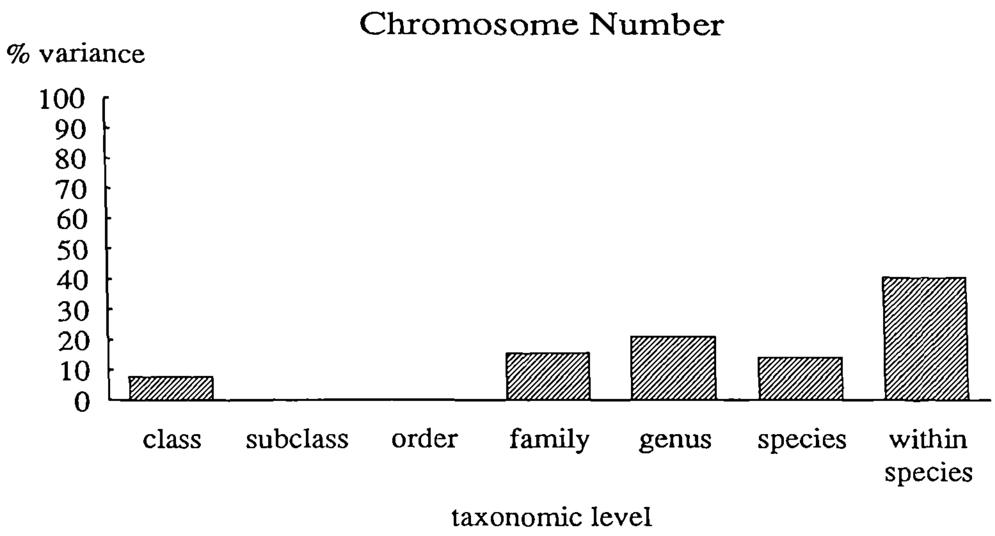


Figure 4.14 - The percentage variance at each taxonomic level in the chromosome number of 1540 British angiosperms.

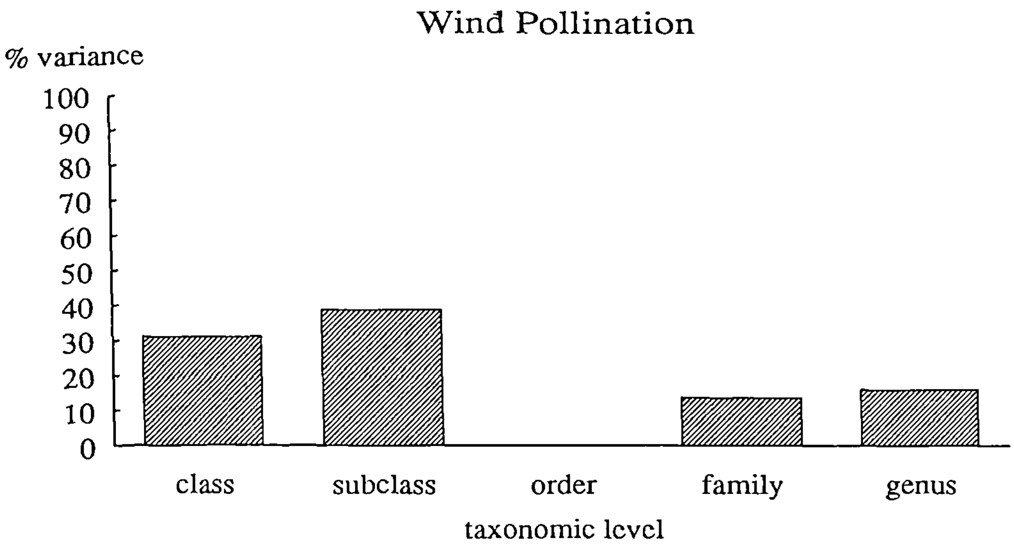


Figure 4.15 - The percentage variance at each taxonomic level in the proportion of species/genus that are wind pollinated.

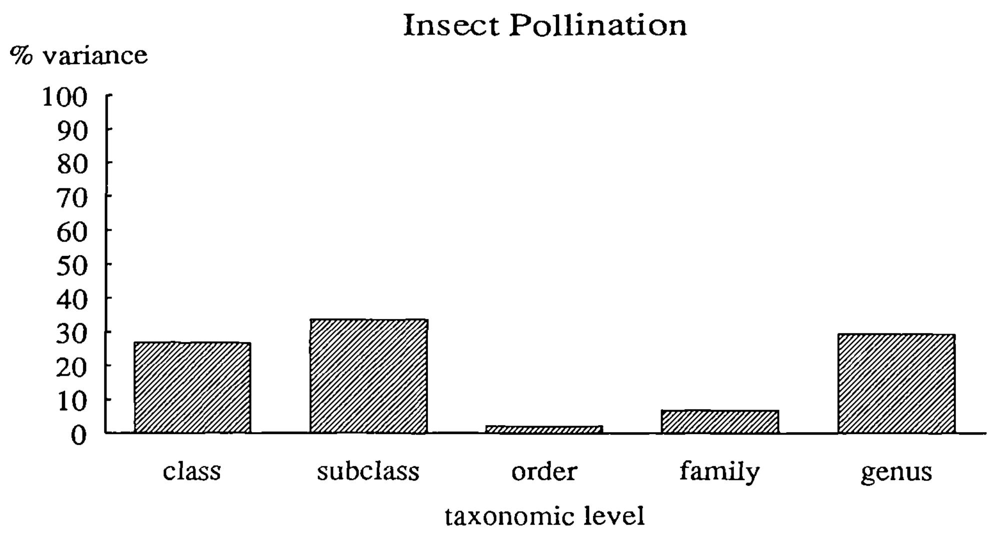


Figure 4.16 - The percentage variance at each taxonomic level in the proportion of species/genus that are insect pollinated.

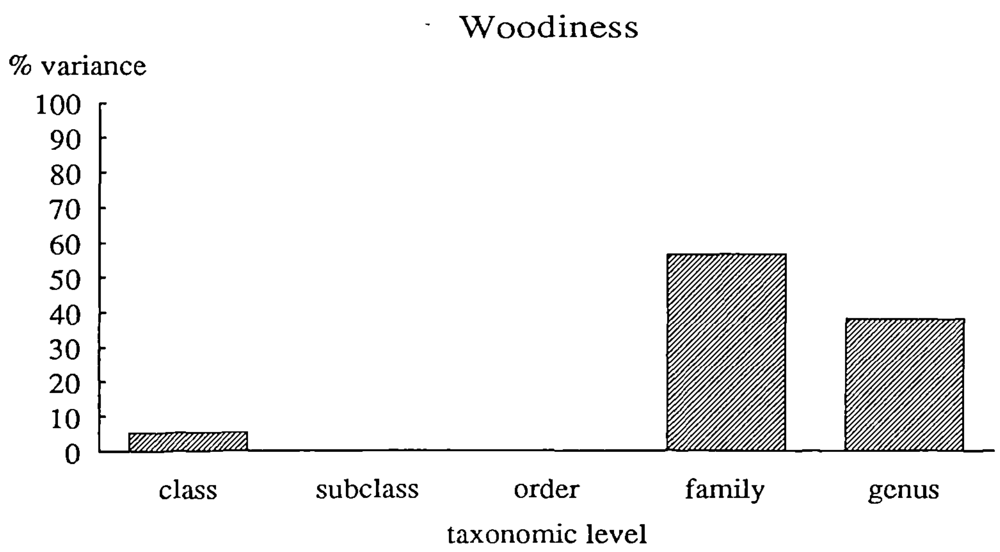


Figure 4.17 - The percentage variance at each taxonomic level in the proportion of species/genus that are woody.

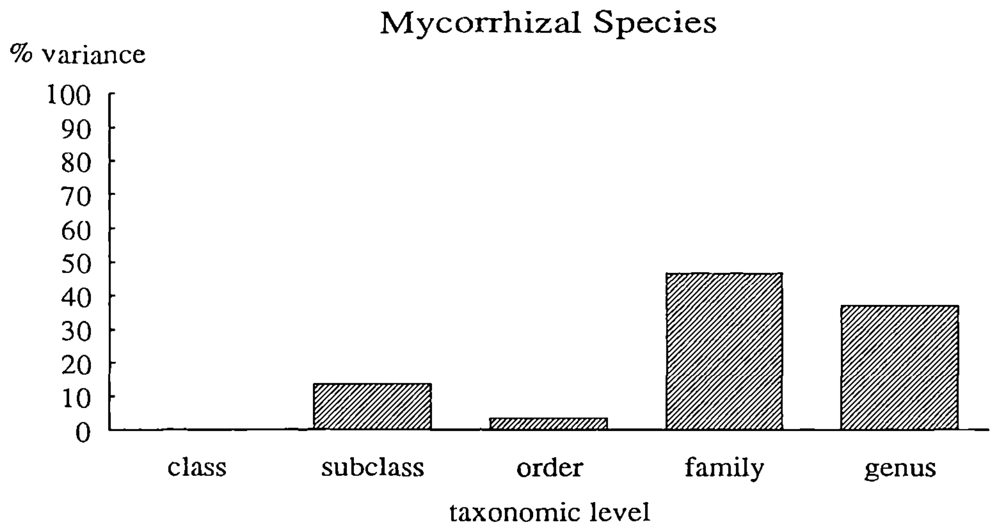


Figure 4.18 - The percentage variance at each taxonomic level in the proportion of species/genus that are normally mycorrhizal.

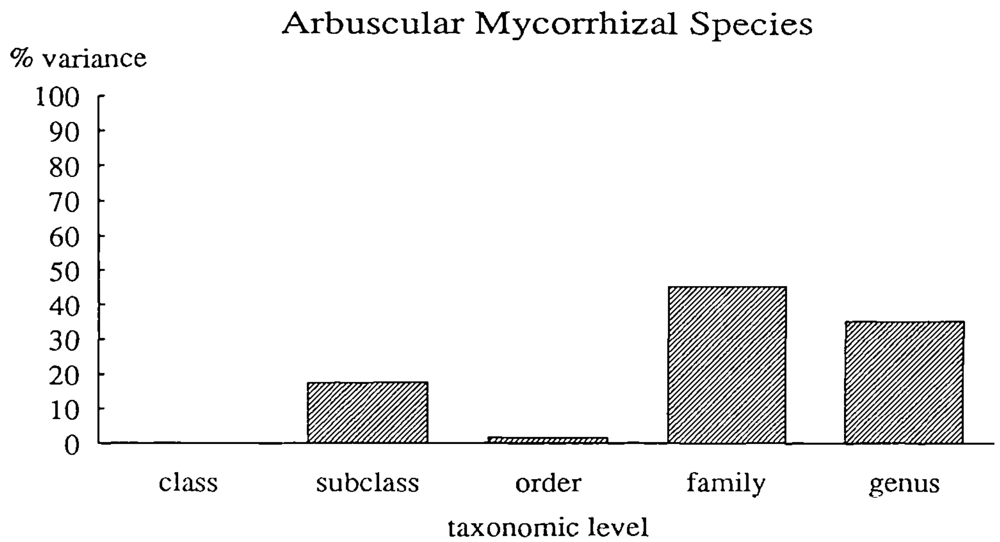


Figure 4.19 - The percentage variance at each taxonomic level in the proportion of species/genus that are normally arbuscular mycorrhizal.

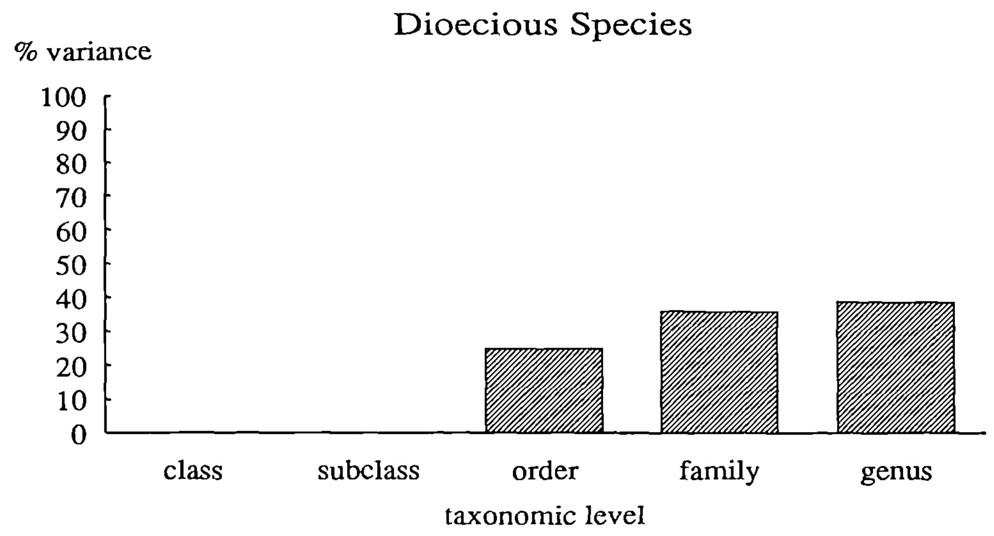


Figure 4.20 - The percentage variance at each taxonomic level in the proportion of species/genus that are dioecious.

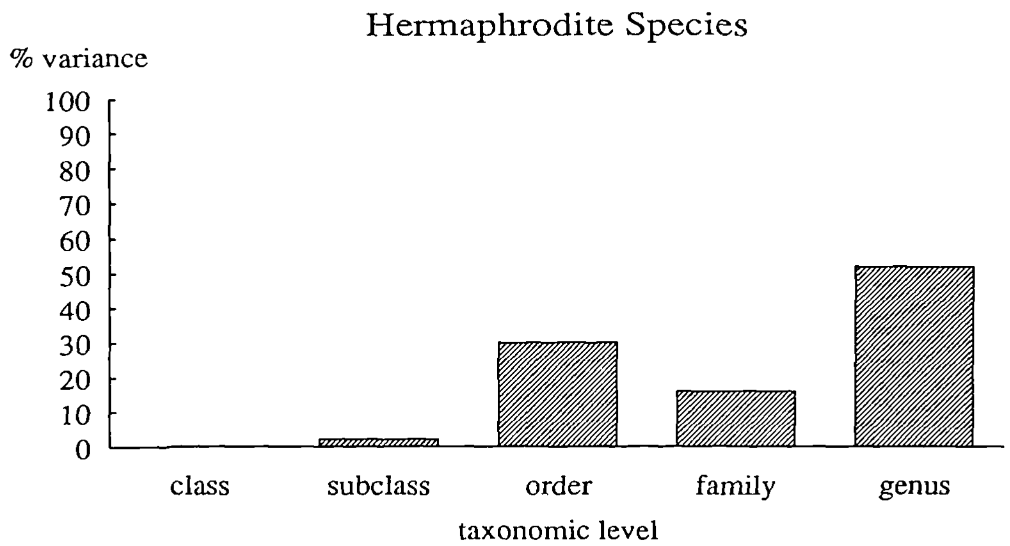


Figure 4.21 - The percentage variance at each taxonomic level in the proportion of species/genus that are hermaphrodite.

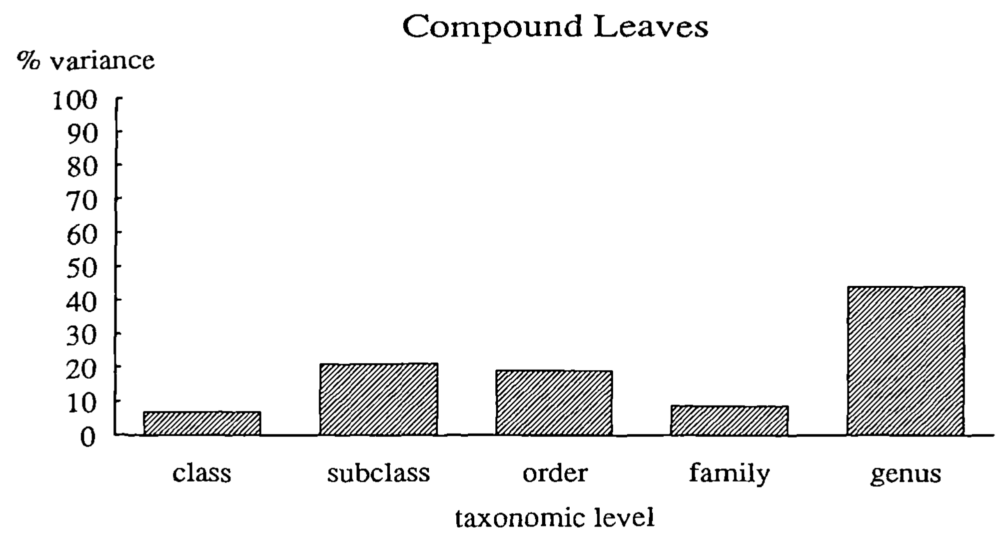


Figure 4.22 - The percentage variance at each taxonomic level in the proportion of species/genus that have compound leaves.

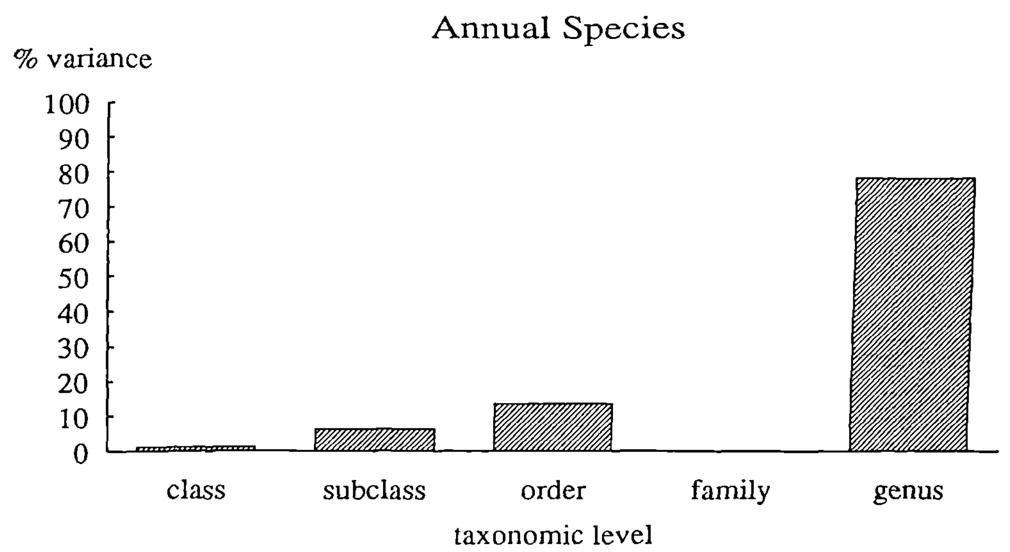


Figure 4.23 - The percentage variance at each taxonomic level in the proportion of species/genus that are annual.

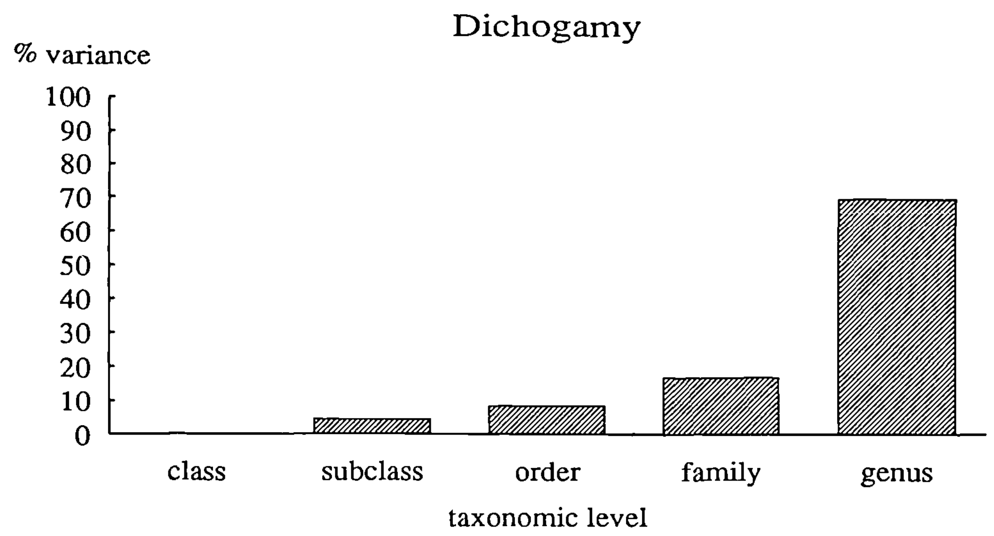


Figure 4.24 - The percentage variance at each taxonomic level in the proportion of species/genus that are dichogamous.

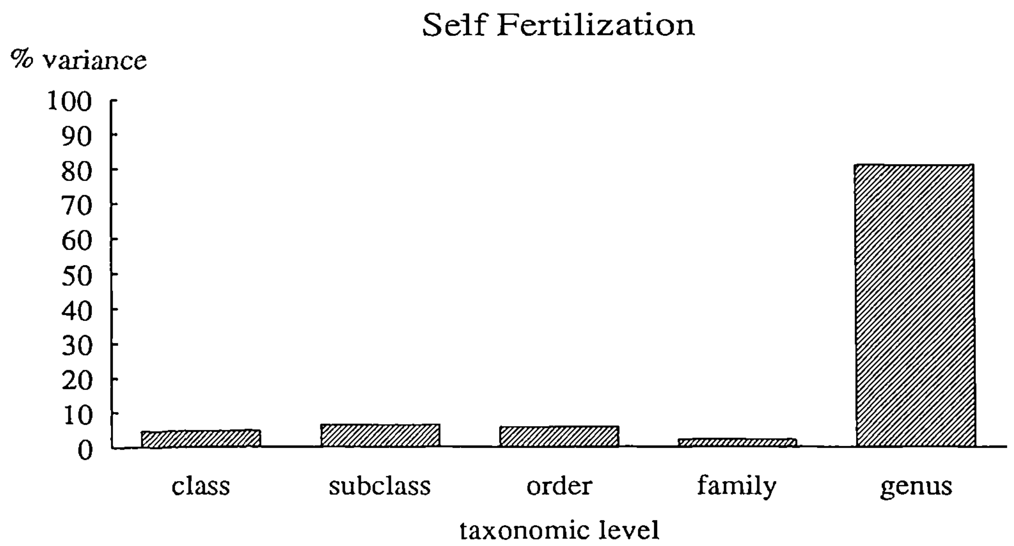


Figure 4.25 - The percentage variance at each taxonomic level in the proportion of species/genus that are commonly self-fertilized.

Discussion

The four control characteristics showed what was predicted - in all cases over 70% of the variance is found at the between species within genus level (Figures 4.1-4.4), proving that as far as it can be tested this method does give meaningful results. There is some variance at other taxonomic levels, mainly at the generic level for both 'number of database categories filled' and 'proportion of European countries a species is native in,' which is due to genera which are difficult to classify into species such as the apomictic taxa: *Taraxacum, Hieracium* and *Sorbus*. Very little information has been recorded down to species level in these genera so the database does not contain many records for any of the species in the genera. Equally, the difficulty in identifying down to a species level may mean they are under-recorded in many European countries.

None of the remaining quantitative characteristics has the majority of the variance at a taxonomic level higher than between families. Only maximum numbers of seeds per flower (Figure 4.6) and pollen diameter (Figure 4.7) have greater than 50% of the variance at one particular level - the between family within order level in both cases. This result is not surprising since the classification of angiosperm families is largely based on floral characters and particularly on characteristics of the gynoecium. The variance of stomatal distribution is bimodal with 40% at the family level and 44% at the species level (Figure 4.7) suggesting that evolution in this characteristic occurred when orders diverged into families and more recently when genera diverged into species. This may be due to phylogenetic constraints acting on species in some families: hypostomatous species for example may have lost the ability to develop stomata on the upper epidermis, while the location of stomata of species in other families has remained much more flexible and open to change due to natural selection. This characteristic is examined in much more detail in chapter 6.

The other quantitative characteristics show a more evenly spread variance over several taxonomic levels (Figures 4.8-4.13). It would appear that these characteristics have evolved steadily over time and while higher taxa may have evolved in a particular direction some plasticity in the characteristic remains right down at the within genus level. The spread of the variance over several taxonomic levels may occur for two reasons. Firstly, because the characteristic values in some taxa have become fixed, but the values in other taxa have not. Or, alternatively, because the values in taxa at one level, say families, have diverged to some extent, and further divergence has occurred at a lower taxonomic level, eg. genera. It will be seen in chapter 6, for example, that in some families, stomatal distribution has become more or less fixed with almost zero interspecific variance, whereas in other families there is a great deal of interspecific variance.

Chromosome number was the only characteristic where it was possible to include within species variation in the calculations and it was at this level that most of the variance was found (Figure 4.14). The high level of variance at this level is not surprising as different chromosome counts within species are often multiples of one another, whereas a genus may contain both species with very different chromosome numbers and species with similar chromosome numbers leading to less overall variance. The genus *Cerastium* for example includes *Cerastium diffusum* with chomosome counts of 36 and 72, *C. arvense* (36 chromosomes), *C. semidecandrum* (36 chromosomes), *C. arcticum* (72 and 108) chromosomes, and *C. alpinum* (54, 72 and 108 chromosomes).

The analyses of qualitative characteristics show that pollination mechanism is quite an ancient characteristic with the majority of the variance at the class and subclass level (Figures 4.15 and 4.16) . This suggests that in many taxa the pollination mechanism has become fixed, probably due to phylogenetic constraints, as adaptation to a particular pollination mechanism can involve complex changes to the flower structure. Once these complex changes have occurred a further alteration in pollination mechanism is unlikely to occur. There is, however, some variance at lower taxonomic levels which may be due to evolution occurring in taxa which have less specialised adaptations for pollination. For example, the Salicaceae contains the genera *Populus* which is wind pollinated and *Salix* which is insect pollinated, and *Artemisia* is a wind pollinated genus in the predominantly insect pollinated Asteraceae. Some species may even be both wind and insect pollinated, eg. *Calluna vulgaris, Thalictrum minus* and *Carex arenaria.*

Several of the qualitative characteristics show the greatest variance at the lowest, between genera within family level: the proportion of species/genus that are annual

(Figure 4.23), are dichogamous (Figure 4.24), and that often self-fertilize (Figure 4.25). These are all, therefore, characteristics which have repeatedly evolved in a diverse array of taxa and have not become fixed by phylogenetic constraints in any lineages. This suggests that radical changes in structure or development are not required for the evolution of any of these characteristics. For example, the morphological alterations in flower structure that are required for a shift from cross to self-fertilization are minimal and have frequently occurred in species that occupy pioneer habitats (Stebbins, 1974). Likewise, the evolution of dichogamy does not require any morphological adaptation but merely a change in the timing of development of the pollen/style (Richards, 1986). Life longevity is also easily altered, and there is even within species variation in annualness: some species can be therophytes or hemicryptophytes (eg. *Arabidopsis thaliana, Geranium robertianum, Poa annua*).

Dioecy, hermaphroditism and presence of compound leaves (Figures 4.20-4.22) have the variance spread over various taxonomic levels. This suggests that these characteristics have arisen, and been lost, independently in many lineages, becoming fixed in some but not in others. Dioecism, for example, occurs in 70 species in the British flora, and its distribution over different taxa varies widely. All species in the order Salicales are dioecious, whereas species in the genus *Mercurialis* are dioecious, but not all other species in the Euphorbiaceae, and *Carex dioica* is the only dioecious species in the genus *Carex*. There can even be variation within a species: *Empetrum nigrum ssp. nigrum* is dioecious and *ssp. hermaphroditum* hermaphrodite. Species in the order Papaverales all have compound leaves whereas those in the Cyperales all have simple leaves. Species belonging to the family Caryophyllaceae have simple leaves whereas species with either compound or simple leaves are found in the families Ranunculaceae and Rosaceae.

The remaining characteristics: woodiness and presence of mycorrhizas, show the majority of the variance at the family and genus level. Primitive angiosperms were woody and while herbaceous species have evolved from woody species the reverse has rarely occurred (Stebbins, 1974). This means once woodiness is lost in a lineage, it will remain lost, resulting in large taxonomic groups being entirely non-woody. The majority of families are entirely woody (eg. Ericaceae, Salicaceae) or non-woody (eg.

Apiaceae, Cyperaceae), but some families contain both woody (eg. *Cotoneaster* and *Prunus* in the Rosaceae) and non-woody genera (eg. *Alchemilla* and *Geum*). Many orders, however, contain both woody and non-woody families.

Mycorrhizas occur in most species but are typically absent in some families, such as the Brassicaceae and Caryophyllaceae, and some genera within typically mycorrhizal families such as *Spartina* in the Poaceae and *Sibbaldia* in the Rosaceae. The original vascular land plants are thought to have been mycorrhizal (Trappe, 1987) so it appears that, as in woodiness, mycorrhizal infection has been lost in several independent lineages. The distribution of mycorrhizal infection is discussed more thoroughly in chapter 7.

There are several points which must be born in mind when doing nested analyses such as these. Firstly, although modern classifications aim to represent evolutionary relationships, taxonomy is not fixed: different taxonomists may have different views on how to partition species into genera, families etc. The taxonomy of angiosperms is controversial, especially over which families belong to higher taxa such as orders and super-orders (see, for example, Cronquist, (1981) and Dahlgren, (1989)), and also over which species belong to the same genera - cf Clapham, Tutin and Moore (1987) and Stace (1991). The extent to which taxonomy affects the results of a nested ANOVA was tested by repeating the analysis for several characteristics using the angiosperm classification in Clapham, Tutin and Warburg (1952) rather than of Stace (1991). The results for 5 the characteristics tested are shown in Figures 4.26-4.30.

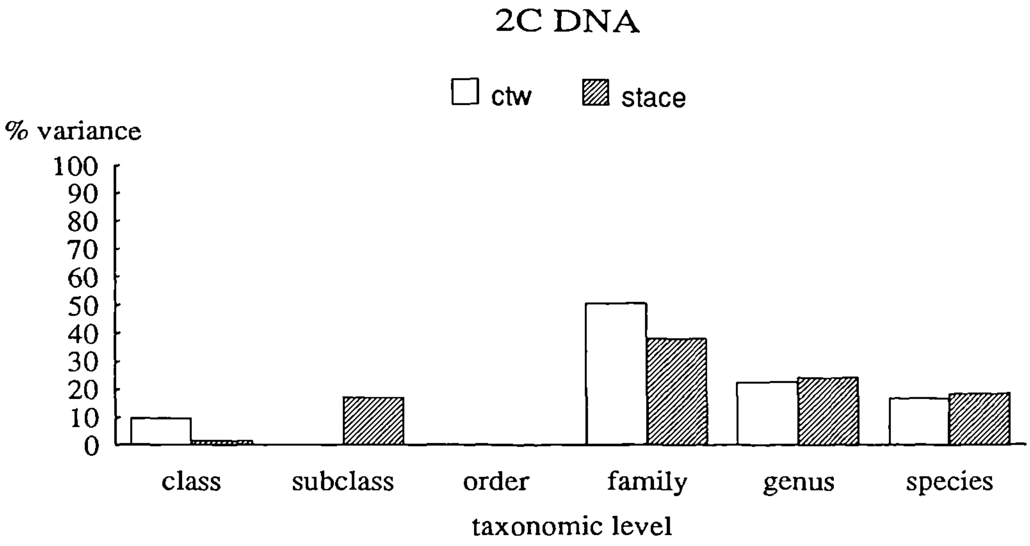


Figure 4.26 - The percentage variance at different taxonomic levels in 2C DNA using firstly the classification in Clapham, Tutin and Warburg (1952) - ctw, and secondly the classification in Stace (1991).

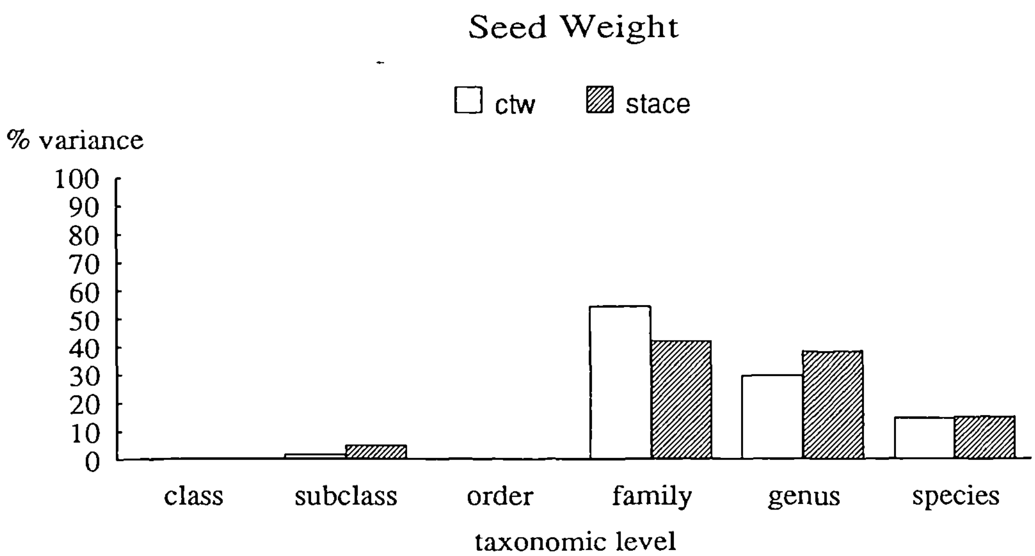


Figure 4.27 - The percentage variance at different taxonomic levels in seed weight using firstly the classification in Clapham, Tutin and Warburg (1952) - ctw, and secondly the classification in Stace (1991).

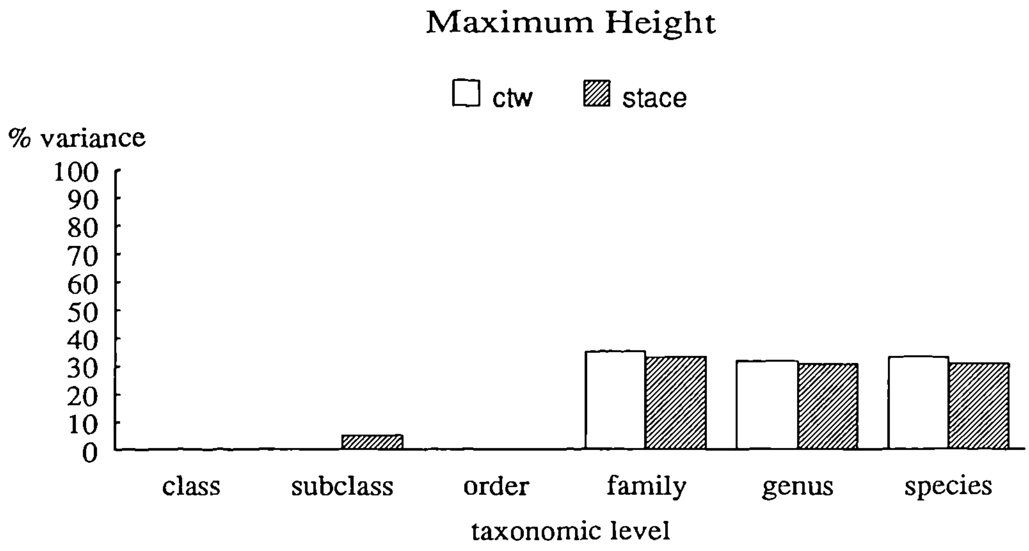


Figure 4.28 - The percentage variance at different taxonomic levels in maximum height using firstly the classification in Clapham, Tutin and Warburg (1952) - ctw, and secondly the classification in Stace (1991).

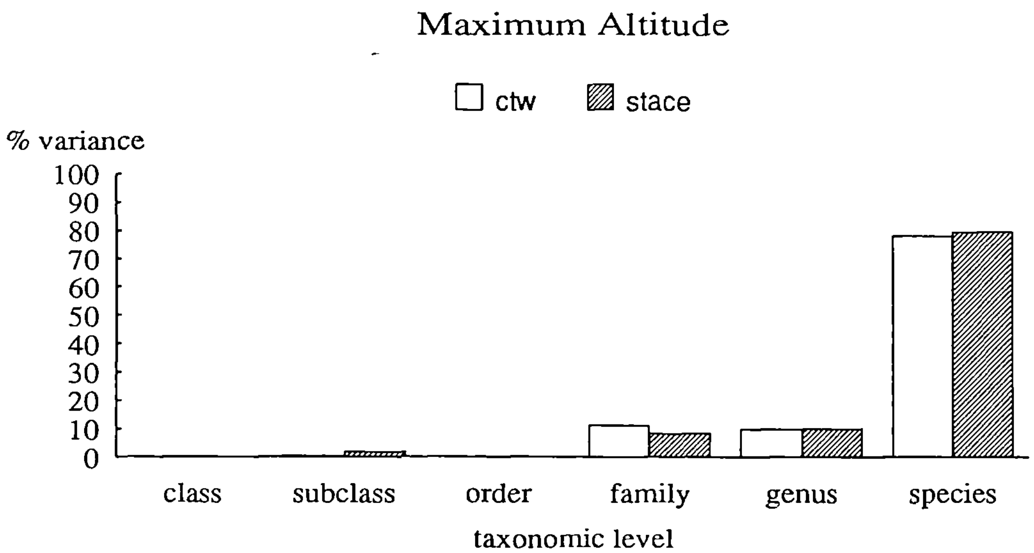


Figure 4.29 - The percentage variance at different taxonomic levels in maximum altitude using firstly the classification in Clapham, Tutin and Warburg (1952) - ctw, and secondly the classification in Stace (1991).

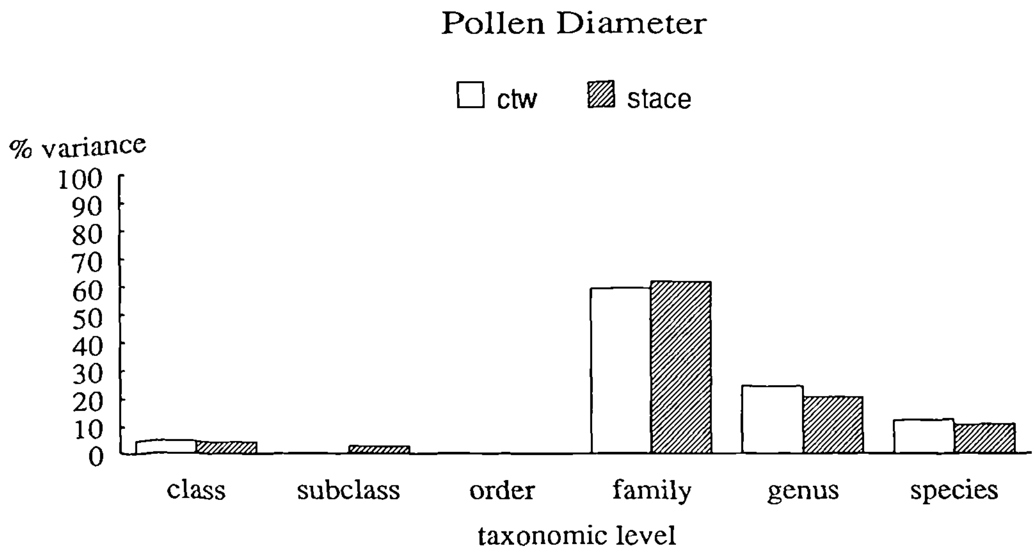


Figure 4.30 - The percentage variance at different taxonomic levels in pollen diameter using firstly the classification in Clapham, Tutin and Warburg (1952) - ctw, and secondly the classification in Stace (1991).

Approximately 5% of the species are classified into different genera or families in the two classifications and there is a further difference at the subclass level with Stace splitting the dicotyledons into 6 subclasses and the monocotyledons into 4, whereas in Clapham *et al.* the dicotyledons are only split into 2 subclasses and the monocotyledons are not split at all. The nested analyses of variance, however, seem to be quite robust to such changes in taxonomy; in none of the cases above would the use of the alternate taxonomy have given rise to radically different conclusions. The main difference is that the Stace classification tends to lead to more variance at the subclass level, but this is hardly surprising as there are more subclasses in this classification for there to be variation between.

Secondly, taxonomy is not an accurate representation of phylogeny as it does not take into account branching patterns or exactly when divergence between different species occurred. The nested analysis of variance assumes that each taxon of a particular level is monophyletic and that each member of the taxon is equally related to every other member (Losos, 1990). The amount of error this leads to, however, is impossible to calculate without a detailed knowledge of the phylogeny. Unfortunately the phylogeny of flowering plants is difficult to determine due both to the poor fossil record and the possibility of genetic material being exchanged between plant species by hybridisation or even the transfer of genes from other organisms such as bacteria or fungi (Heron, 1992). Taxonomy is thus the best available representation of phylogeny, so it would seem sensible to use it as a rough approximation of the phylogeny until better representations are available.

Thirdly, with the exception of chromosome number, only one data value per species was used in the analyses making it impossible to estimate within species variance. This means the between species within genera group also includes variance because of differences between populations within a species and because of errors in measurement or transcription. The effect of this on the results is difficult to estimate, although for characteristics such as first historical record it will be practically zero, and even in cases where there is within species variation this will have no effect on the ratio between the variances at other taxonomic levels assuming the data values used for each species are typical values.

The distribution of variance at different taxonomic levels has often been used in comparative analyses (eg. Clutton-Brock and Harvey, 1977; Read and Harvey, 1989). It is not always valid to compare directly the values of one characteristic in a large number of species with the values of a second characteristic because the different degrees of relatedness between species mean the data points are not independent of one another. Species with a high degree of shared ancestry may be more likely to have similar values for two characteristics than species with much less shared ancestry. The nested ANOVA, however, can be used to find out at which taxonomic level there is most variance. Comparative analyses are then done using mean values for the characteristics at this taxonomic level: this minimises the similarity between the two characteristics due to shared ancestry. Comparative analyses are discussed further in the next chapter.

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Chapter 5

Comparative Analyses of Ecological Characteristics

Introduction

Evolutionary ecologists frequently seek to explain the distribution of a particular trait, such as hypostomaty (Parkhurst, 1978) or seed weight (Baker, 1972), in adaptive terms typically by relating the trait to some other trait, or environmental factor, which may have influenced the evolution of the trait in question. Usually data on the two traits are collected for a large number of species in order to test for a significant correlation between the two. Givnish (1980) found such a correlation in gymnosperms: the majority of cone-bearing species, with wind dispersed seeds, were found to be monoecious and those with fleshy or showy fruits, dispersed by animals, dioecious. He used this result to discuss why seed dispersal has affected the evolution of mono/di-oecy. Parkhurst (1978) found a strong relationship between stomatal distribution and leaf thickness and suggested that leaf thickness depends on environmental water availability and stomatal distribution is subsequently affected by leaf thickness.

Comparative approaches such as these have recently come under scrutiny and criticism. The main problem is that often no attempt is made to take account of phylogeny. Two species may have similar values for one or more characteristics for two reasons: firstly, because they have evolved similarly as a result of the same evolutionary pressures; and secondly, because they share a common ancestor and evolution of the characteristic(s) has not occurred since the species diverged. It is the second explanation that causes problems in comparative analyses. Most of the methods used employ statistical tests which assume that the data values are independently and normally distributed with a common variance. These assumptions, however, are clearly violated when species are related to one another by differing degrees, and would only be true if there had been a simultaneous radiation of all species from a single ancestor followed by the same rate of evolutionary change in every species. This means that statistical tests using data values from species may employ too many degrees of freedom and as a consequence give spurious significant results. This problem is discussed comprehensively by Harvey and

Pagel (1991) who review many of the attempts that have been made to take account of phylogeny in comparative analyses.

The majority of comparative studies done recently using ecological characteristics of plant species, however, still largely ignore phylogeny (eg. Jurado *et al.*, 1991; Diemer *et al.*, 1992). An attempt has been made in this thesis to take some account of phylogeny when looking for correlations between plant characteristics. This chapter gives examples of two methods, both of which use a taxonomic hierarchy as an approximation to the phylogeny.

Statistical Approaches

Analysis of Higher Nodes

A simple way to circumvent the problem of data from species not being independent of one another is to do the comparative analysis at a higher taxonomic level (Clutton-Brock and Harvey, 1977; Bell, 1989). Mean values for a higher level are calculated from the species data, using the premise that these mean values are more likely to be independent of one another because there is far less shared ancestry between higher taxonomic levels. The taxonomic level chosen is the one which contributes the majority of the variance to the characteristics and is therefore assumed to represent a point of evolutionary divergence. This level can be found by doing a nested analysis of variance as outlined in chapter 4. This approach has been used quite frequently, especially for data from mammal and bird species (eg. Bennett and Harvey, 1987; Elgar and Harvey, 1987; Elgar *et al.*, 1988; Read and Harvey, 1989; Promislow and Harvey, 1990). Read and Harvey, for example, do their analyses across mammalian orders as on average 63% of the variance in life history traits was found among orders rather than within them.

The results of chapter 4 (Figures 4.1-4.25, pages 70-82), unlike many of the results obtained using mammalian characteristics, show that the variance in most of the plant characteristics analysed does not occur at a single taxonomic level, making it difficult to decide on a particular level to use in analyses. A decision would have to be taken over whether to use a lower level and include spurious degrees of freedom, or choose a higher level and lose some of the variation in the characteristic.

There are, however, ways to avoid this problem. For example, if the variance occurs at more than one level because a characteristic has become fixed in some taxa but not in others, then it is possible to split the data into species which have data values independent of one another and those which do not. This method is used in chapter 6, where it is shown that the proportion of stomata on the lower epidermis of the leaf has become more or less fixed in some families, whereas in others there is a high degree of interspecific variation. Only species in families with a large amount of interspecific variation were used to do comparative analyses at the species level.

Analysis of Covariance

Another solution to the problem is to extend the analysis of variance method from one to two characteristics and do an analysis of covariance (Bell 1989). This estimates the covariance between the two variables at each taxonomic level. The total covariance between two characteristics is partitioned in a similar way to the variance in a single characteristic (see chapter 4).

$$Cov_{[tot]} = Cov_{[sp(g)]} + Cov_{[g(f)]} + Cov_{[f(o)]} + Cov_{[o(sc)]} + Cov_{[sc(c)]} + Cov_{[c]}$$

$Cov_{[tot]}$ represents the total covariance between two characteristics and $Cov_{[sp(g)]}$, for example, represents the covariance of species within genera (tot = total, sp = species, g = genus, f = family, o = order, sc = subclass, c = class).

If it is assumed that each taxonomic group is monophyletic, then the within-groups covariance represents how much of the relationship between two characteristics is due to evolutionary changes and not to phylogeny. For example, all species within a genus are assumed to share the same phylogenetic history so any covariance is due to evolutionary change in both characteristics. Likewise the covariance contributed by all genera within families is due to evolutionary change.

For ease of interpretation the covariances can be converted into within group correlations (Kempthorne, 1963, chapter 13). This intraclass correlation, as the name suggests, is the correlation within classes and not between classes, ie. the correlation due solely to evolutionary change and not phylogeny. For each taxonomic level:

$$r_{xy} = \frac{\sigma_{xy}}{\sqrt{\sigma_x^2 \sigma_y^2}}$$

where :

r_{xy} = intraclass correlation between x and y at the chosen taxonomic level
σ_{xy} = covariance between x and y at the given level
σ_x^2 = variance in x at given taxonomic level
σ_y^2 = variance in y at given taxonomic level

It is not possible to estimate the intraclass correlation if the variance of either of the characteristics is equal to zero as in such cases the denominator of the equation given above would be zero.

Examples

Using a higher taxonomic level

Method

The amount of variance at each taxonomic level for 25 plant characteristics is given in chapter 4 (Figures 4.1-4.25, pages 70-82). Two characteristics - the proportion of species per genus which are annual and the proportion which can self-fertilize both show over 75% of the variance at the genus level (Figures 4.23, 4.25). It is therefore appropriate to test for a relationship between self-fertilization and life history (are annuals more often self-fertilizing than perennials?) at the genus level. Genera were classified into those containing > 90% annual species and < 10% annual species and into those containing > 90% and < 10% of species able to self-fertilize. Other genera were omitted from the analysis. χ^2 and odds ratio (Agresti, 1984) tests were conducted to test for a relationship between annualness and self-fertilization.

Results

A significant relationship was found between perenniality and selfing ability. χ^2 (1df) = 23.12, $p < 0.005$ and the odds ratio = 5.42 (95% confidence limits are 2.57 and 11.46); therefore, predominantly annual genera are more likely to be self-fertilizing and perennial genera cross-fertilizing (Table 5.1). Further examples of this method can be found in chapters 6 and 7.

species/genus	> 90% selfing	< 10% selfing
> 90% annual	120 (103.1)	135 (151.9)
< 10% annual	9 (25.9)	55 (38.1)

Table 5.1 - The number of genera which are predominantly annual/perennial and self/cross fertilizing. Figures in brackets are the expected number of genera assuming no relationship between annualness and self-fertilization.

Analysis of Covariance

Method

An analysis of covariance requires data from a reasonable number of species for two quantitative variables. Data were available in the Ecological Flora Database to conduct an analysis of covariance on:

1. seed weight and maximum number of seeds/flr;
2. 2C DNA and seed weight.

The 'nested' procedure of SAS version 6 was used to do the analysis.

Results

There is a negative correlation between seed weight and maximum number of seeds/flower, which is greatest at the between families within order level. Overall there is a small positive correlation between 2C DNA and seed weight but this is not consistent at all taxonomic levels. The within group correlations are given in Table 5.2.

taxonomic level	seed weight and seeds/flr	2C DNA and seed weight
total	-0.53 (244)	+0.18 (168)
class	NE	NE
subclass	NE	NE
order	NE	NE
family	-0.85 (23)	-0.25 (8)
genus	-0.30 (116)	+0.37 (70)
species	-0.25 (64)	+0.28 (61)

Table 5.2 - the intraclass correlations (see equation page 94) at each taxonomic level. NE means not estimable. The figure in brackets is the number of degrees of freedom at each level.

Seed weight and maximum number of seeds/flower

When all species are considered there is a negative correlation between seed weight and number of seeds/flower of c. 0.5. The correlation, however, is much stronger at the between families within orders level. This result corresponds well with previous research. The number of ovules per carpel has been used as a family attribute (Sporne 1980) and this characteristic will to a large extent determine both maximum seed size and number. Hodgson and Mackey (1986) found that families with one ovule per carpel tend to produce heavier seeds than those in which ovules were numerous.

2C DNA and seed weight

Significant positive relationships have been found between DNA amount and seed weight in several taxa: the genera *Allium, Vicia* and *Crepis*, 24 legume species and 32 grass species (Bennett 1987), but not in *Senecio* (Lawrence 1985). This analysis of 169 species shows that there is overall a slight positive relationship between the two characteristics but, as previously shown, the relationship is not consistent in all taxa. While there is a quite large positive correlation at the between genera within family level, the correlation at the between families within order level is negative.

Discussion

The methods given in this chapter are relatively straight-forward to use, requiring simply a hierarchical taxonomic ranking. The drawback to these methods is that taxonomy is not an adequate representation of phylogeny. All members of a particular taxon will not be equally related to one another, nor are members of two sister taxa related by an equal evolutionary distance. This means that the results obtained from using these methods have to be interpreted with caution: higher taxonomic nodes will not be entirely independent from one another so analyses may include some spurious degrees of freedom, and the intraclass correlations found from analyses of covariance may not be due entirely to evolutionary changes.

Many other methods for including phylogeny in comparative analyses have been devised (e.g. Harvey and Pagel, 1991; Donoghue, 1989; Felsenstein, 1985), but all require either a detailed knowledge of both branching patterns and lengths, or the characteristic states of ancestors. As discussed in chapter 4 the knowledge of either for flowering plants is very scanty and in most cases taxonomy is the best available representation of phylogeny. Until a detailed and robust phylogeny of the flowering plants is available it is important to take at least some account of phylogeny by using taxonomic ranking, rather than ignoring it altogether.

The examples given here support the conclusions of other workers. Annuals were found more likely to be self-fertilizing than perennials, which reflects both their monocarpic nature - seed must be produced each year, and that annuals are often colonizers - making advantageous both maximum seed production and the ability to be able to reproduce if a conspecific is not available (Richards, 1986). As previously documented (Salisbury, 1942; Harper, Lovell and Moore, 1970), large-seeded species were found to produce fewer seeds per flower than small-seeded species, and this was shown to be an ancient evolutionary constraint since the correlation is strongest at a high taxonomic level. This relationship is not surprising as larger seeds require greater resources and so it would appear that seed size is typically increased at the expense of seed number. The reduced correlation between the seed size and number at lower taxonomic levels may be due to evolution of other characteristics such as number of flowers/inflorescence and number of inflorescences/plant which will also affect the total seed output of the plant. No consistent relationship between 2C DNA and seed weight across all taxa was found, and indeed conflicting results can be found in the literature (Bennett, 1987). The support in the literature for the results obtained using these methods is encouraging, allowing greater confidence in the results when new relationships between ecological variables are tested for, despite the assumptions that have to be made when using either method.

Chapters 6 and 7 use the higher taxonomic node method outlined here for comparative analyses involving the distribution of stomata over both leaf surfaces and the frequency of mycorrhizal infection in British angiosperms. No further use has been made of the analysis of covariance, however, as none of the analyses involved two quantitative characteristics.

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Chapter 6

A Comparative Study of the Distribution and Density of Stomata in the British Flora

Introduction

Stomata are of universal occurrence in terrestrial flowering plants. They permit gas exchange between the mesophyll and the atmosphere, which is prevented over much of a plant's surface due to a waxy cuticle with very low permeability to gases. They allow the uptake of CO_2 required for photosynthesis, but also the diffusion of water vapour out of the leaf. Stomata may be found on a variety of plant organs such as fruits, stems, flowers or tendrils, but are mainly associated with leaves. While the occurrence of stomata in terrestrial plants is universal, there is great variation between species as to where on the leaf the stomata are distributed. Leaves may be hypostomatous (ie. have all the stomata on the lower epidermis), hyperstomatous (all the stomata on the upper epidermis), or be amphistomatous (stomata distributed on both leaf epidermes). The distribution of stomata on the leaves of 457 British plant species is shown in Figure 6.1: there is wide inter-specific variation in stomatal distribution but around half of all species in the sample are hypostomatous.

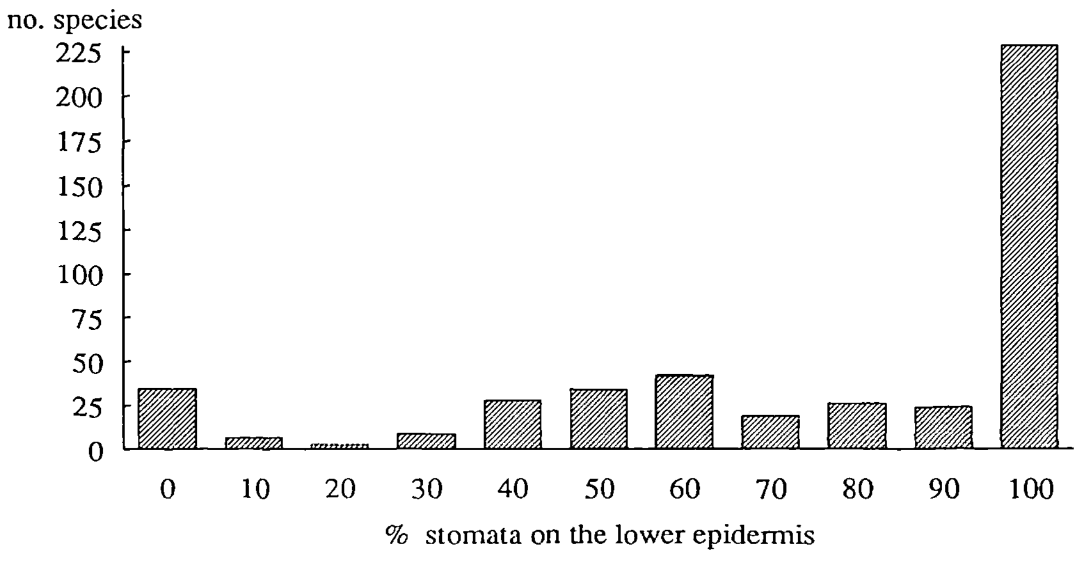

Figure 6.1 - The percentage of stomata on the lower epidermis of 457 species in the British Flora.

The diffusion of CO_2 into the leaf or water vapour out of the leaf involves a pathway comprising several different resistances. CO_2 has to diffuse through the boundary layer, the stomatal pore, intercellular space and finally the mesophyll cell wall. The boundary layer resistance is determined by leaf morphology and wind speed, the stomatal resistance by the pore area, and the intercellular mesophyll resistance by the distance from the stomatal cavity to a mesophyll cell. The diffusion of water vapour out of the leaf is affected by the boundary layer resistance and the stomatal resistance. There is no intercellular mesophyll resistance to water vapour because the sub-stomatal cavity is saturated with water vapour. The distribution of stomata will directly affect both the boundary layer resistance - amphistomatous leaves have two boundary layers in parallel through which CO_2 can diffuse whereas hypostomatous leaves only have one, and the intercellular mesophyll resistance as the mean distance between a stomatal pore and a mesophyll cell will be less. This resistance will also be decreased by a higher density of stomata as will the stomatal resistance.

Attempts have been made to explain the differences in distribution and density of stomata using comparative analyses (Salisbury, 1927; Parkhurst, 1978; Mott, Gibson and O'Leary, 1982), and by using models (Parkhurst, 1978; Jones, 1985; Foster and Smith, 1986).

Comparative methods have concentrated on one or two factors. Parkhurst (1978) considered leaf thickness and habitat classified according to water availability, using data from four families and 238 species. He found stomatal distribution to be associated with leaf thickness, with thicker leaves tending to be amphistomatous and thinner leaves hypostomatous. This can be explained on the basis that the intercellular mesophyll resistance will be much greater in thicker leaves, leading to selection for amphistomaty. Parkhurst also found a relationship between habitat and stomatal distribution: hypostomaty was commonest in mesic habitats and amphistomaty in wet and dry habitats, which he suggests is a secondary relationship caused by leaf thickness, as leaves were thicker in both wet and dry habitats than in mesic ones. Mott *et al.* (1982) also found a trend towards amphistomaty in species with thick leaves but concluded that the weakness of this trend suggests that this relationship is a secondary one, and they provided anecdotal evidence that light levels are an important determining factor.

Species living in unshaded environments where CO_2 is limiting the rate of photosynthesis may have evolved amphistomaty to increase maximum leaf conductance to CO_2. The density of stomata on each leaf surface in woodland species was investigated by Salisbury (1927). He found that densities in general were higher for trees and shrubs than for the ground flora, and for species living on the edges of woodlands than for those in more densely shaded habitats.

Various modelling approaches have been attempted. Parkhurst (1978) used models to search for an optimal stomatal distribution that gave maximum photosynthetic CO_2 uptake without allowing excessive water loss. He included many variables such as mesophyll thickness, transpiration rate, air temperature, relative humidity, boundary layer resistance and stomatal spacing in his models and found that amphistomatous leaves appeared to be better adapted than hypostomatous leaves under most conditions. Leaf thickness however was the most important determining factor in the models with hypostomaty being optimal for very thin leaves.

Jones (1985) used a similar approach, again looking for optimal stomatal distributions when other factors were varied. He found that amphistomaty may be advantageous as it allows greater CO_2 transfer through the mesophyll, especially in thicker leaves, and greater leaf conductance in high light conditions when CO_2 is limiting photosynthetic rate. However, the models found that hypostomaty would be advantageous when there are high boundary layer resistances (for example in large leaves or deep within a plant canopy), high humidity or a temperature gradient across the leaf. A temperature gradient across the leaf means the leaf to air vapour pressure gradient will be lower for the cooler lower surface. This conflicts, however, with amphistomaty being advantageous in thick leaves, as thicker leaves are likely to have a larger temperature gradient across them.

Foster and Smith (1986) took a slightly different approach. Instead of looking for an optimal stomatal distribution at a given amount of water loss they simulated the transpiration rate expected in horizontal, thin leaves at different wind speeds, leaf areas and stomatal distributions. They found that at high wind speeds (2 m s^{-1}) leaves with a high stomatal conductance to water vapour had the greatest transpiration rate when 50%

of the stomata were on each leaf epidermis. There was no difference in transpiration rate under these conditions when all the stomata were on either the bottom or top leaf surface. At zero wind speed however transpiration was lowest for hypostomatous leaves, greater for hyperstomatous leaves but maximal when 60-75% of the stomata were on the upper epidermis. This is because the boundary layer conductance to water vapour was greater on the top than the bottom leaf surface due to buoyancy effects (heat transfer from the bottom to the top leaf surface) and this coupled to the parallel loss of water from both leaf surfaces meant that maximum water loss occurred when the majority of stomata were on the upper surface. There does indeed appear to be a dearth of species with the majority of stomata on the upper epidermis (Figure 6.1).

Both the comparative analyses and the modelling approaches suggest that many factors will help determine the ideal stomatal distribution for a species. If the photosynthetic rate is limited by CO_2 availability, for example in an unshaded environment, then amphistomaty or a high density of stomata will be favoured. However, while a high stomatal conductance is ideal for CO_2 uptake it will also allow water loss. This means that species with a high density of stomata or with stomata on both leaf surfaces are likely to have a lower water use efficiency than species with a lower stomatal density or with stomata solely on one leaf surface. This may not be important in habitats where water is continually available but in dry habitats or in habitats with intermittent water availability the distribution/density of stomata may play a role in preventing excessive water loss.

No consistent trends between stomatal distribution and habitat water availability have, however, been found. Parkhurst (1978) found that amphistomaty was more common in xeric and hydric habitats and hypostomaty in mesic habitats, whereas Salisbury (1927) found that plants of moist habitats tend to have stomata on the upper epidermis more often than plants in dry habitats. Jones and Slatyer (1972) did some experiments on a single species, *Pelargonium hortorum*, which had six times as many stomata on the lower than on the upper epidermis and found that the ratio of the rates of CO_2 exchange through the lower and upper surfaces respectively was greater than the ratio of the corresponding rates of water vapour exchange. This may have been because firstly the palisade layer next to the upper epidermis is less well adapted to lateral diffusion of gases through intercellular spaces than is the spongy mesophyll next to the lower epidermis, and secondly because in this species the stomata on the upper epidermis are much more widely spread than those on the lower epidermis, so that cells in the upper epidermis are likely to be nearer to stomata on the lower epidermis than the upper and contribute to CO_2 uptake from these rather than from those on the upper surface. They conclude that if this result is applicable to other species then only hypostomatous species, or species with equal numbers of stomata on each leaf surface, will occur in habitats where water supply is an important factor influencing natural selection, which, presumably, will be habitats in which water is a scarce resource some, or all, of the time. Mott *et al.* (1982) suggest that species will tend to be amphistomatous if they live in permanently wet conditions or in conditions where water is only periodically available. They reason that if water is only periodically available there may be a competitive advantage to species that use water quickly, however inefficiently, when it is present to prevent its use by other species. More rapid water use will be facilitated by amphistomaty.

Another important factor is likely to be leaf morphology as this will largely determine the magnitude of the boundary layer. This layer is thinner over small leaves than over large leaves and also over lobed leaves than leaves of a similar area but entire. Compound leaves too will have a thinner boundary layer than simple leaves of the same total area (Nobel, 1981). The models of Jones (1985) indicate that hypostomatous leaves may have a higher rate of photosynthesis than otherwise identical but amphistomatous leaves if there is a high boundary layer resistance. This means that larger leaves may be more likely to be hypostomatous than smaller leaves, and entire leaves rather than lobed/compound leaves.

Any structures, such as trichomes, which project above the leaf surface may play an important role in controlling water loss from leaves, as they trap a layer of humid air, increase the boundary layer resistance and thus reduce the transpiration rate. Normally hairy leaves which have been shaved show substantially increased transpiration over unshaven leaves (Juniper and Jeffree, 1983). Many different types of trichome occur on leaf surfaces (Metcalfe and Chalk, 1979) and they may have a variety of functions. The hairs may be important in plant defence by protecting against phytophagous insects either by physical means or by secreting repellant compounds. They may also play a role in temperature regulation by increasing the reflectivity of leaves, and can be important secretory organs of, for example, digestive enzymes in carnivorous plants or salt in halophytes (Martin and Juniper, 1970). In many cases, therefore, reducing water loss will not be a primary function of trichomes but this does not necessarily lower their effectiveness at achieving reduced water loss. Some species have no trichomes and so will not benefit from a more protected boundary layer. The transpiration rate of these species is likely to be affected more directly by changes in wind speed or temperature. Hairs on the upper surface of the leaf, therefore, may reduce the main disadvantage of being amphistomatous, ie. increased water loss, so it is possible that glabrous species (ie. those with no hairs on the leaves) will have a greater tendency to be hypostomatous than species with hairy leaves.

It has long been recognised that temperate woody species are predominantly hypostomatous (eg. Salisbury, 1927). It is not known, however, whether this is an adaptive trait or simply a result of shared ancestry between woody and hypostomatous species.

The information compiled for the Ecological Flora Database made it possible to do much more extensive comparative studies than have been attempted before. Data concerning stomatal distribution and density, habitat variables such as shade and water availability and morphological variables such as woodiness, leaf shape, area and hairiness were available for a large number of species.

The Data

The Ecological Flora Database contains a large data set on stomatal distribution - the location (whether on top, bottom or both leaf surfaccs) is known for 457 species and the density on each surface for 337 species. Information on the distribution, therefore, is available for just over a quarter of the British flora (26% of species) including over 70% of all families. The distribution of these data over families is shown in Appendix F (page 219) which gives the number of species in each family for which stomatal data were available together with the total number of species in each family.

Salisbury (1927) found that while the density of stomata may vary widely due to environmental conditions such as humidity or illumination there is a strong positive correlation between the density on the lower surface and the density on the upper surface. This result is important, as it shows that while trends between the density of stomata and other factors in different species can be looked for, it is more important to consider the ratio of stomatal density on the upper and lower epidermes of the leaf as this is more characteristic of the species as a whole than is the density. This was taken account of by calculating the proportion of stomata occurring on the lower epidermis of the leaf. This will be referred to subsequently as the stomatal distribution. In most of the analyses conducted in this chapter either both the density and distribution of stomata, or else solely the distribution are considered.

The variance in the stomatal distribution occurs mainly at two taxonomic levels: between species within genera and between families within orders - see chapter 4 and Figure 6.2. This must be taken into account in any comparative analyses that are done because two species may have similar stomatal distributions either because they belong to the same family and share a common ancestor, or because they have both evolved in a similar fashion to the same selection pressures. This means an analysis using species data would use spurious degrees of freedom because of the lack of independence of species values in some families (Harvey and Pagel, 1991). Equally it would not be a good idea to conduct analyses using solely family means because information from the amount of variance at the species level is lost. To overcome this problem families were grouped in order to separate those families in which there was very little intra-familial variance and those with much greater intra-familial variance. Four groups were created according to the mean stomatal distribution of the family. The conditions for membership of each group are given in table 6.1, which also shows the mean stomatal distribution and variance of the species in each group.

Figure 6.2 - The % variance in stomatal distribution at different taxonomic levels. Stomatal distribution was measured as the % of stomata on the lower epidermis and the data were transformed by taking the arcsin square-root.

Group	mean distribution of family	mean distribution of group	standard deviation of distribution	number of species in the group
1 - hypostomatous families	> 0.92	0.98	0.0663	150
2 - mainly hypostomatous families	0.81-0.92	0.88	0.1555	52
3 - weakly hypostomatous families	0.60-0.80	0.72	0.2703	169
4 - amphistomatous families	< 0.60	0.31	0.2834	85

Table 6.1 - Characterisation of the four groups of families according to their stomatal distributions. The mean distribution of a family represents the criterion for group membership. Distributions given are the proportion of stomata on the lower epidermis of the leaf.

It would have been better to group the families according to the intra-familial variance in stomatal distribution but then there would have been a problem dealing with the families containing only one or very few species. There is, however, a strong negative correlation between the mean degree of amphistomaty in a family and the *variation* around the mean. If the mean degree of amphistomaty per family (using families where data were available for 3 or more species) is measured as $|0.5-p|$, where p is the proportion of stomata on the lower epidermis, the correlation between this and the variance in stomatal distribution is -0.633 (37 df, $p<0.001$). In other words, the mean stomatal distribution of a family is a good indicator of the amount of variance around that mean. Families are often entirely hypostomatous, but rarely entirely amphistomatous; families with a mean distribution between c. 0.3 and 0.75 tend to contain species with a wide range of stomatal distributions.

The nested analysis of variance of stomatal distribution at different taxonomic levels was repeated using only species in families in group 3, ie. those families with mean stomatal distribution of 0.6-0.8 (Figure 6.3). Almost all the variance in the species of this group occurs at the between species within genus level showing that analyses can be done using the data values for species, if only the species in this group are included. Factors such as habitat variables - shade, water availability etc. vary from species to species meaning it would not be relevant to calculate mean family values for such factors. Analyses involving these factors must be done at the species level. Therefore many of the analyses conducted concentrate on the species in families within group 3 - the weakly hypostomatous families, as the group is reasonably large (169 species) and the majority of the variance in stomatal distribution occurs at the between species within genus level.

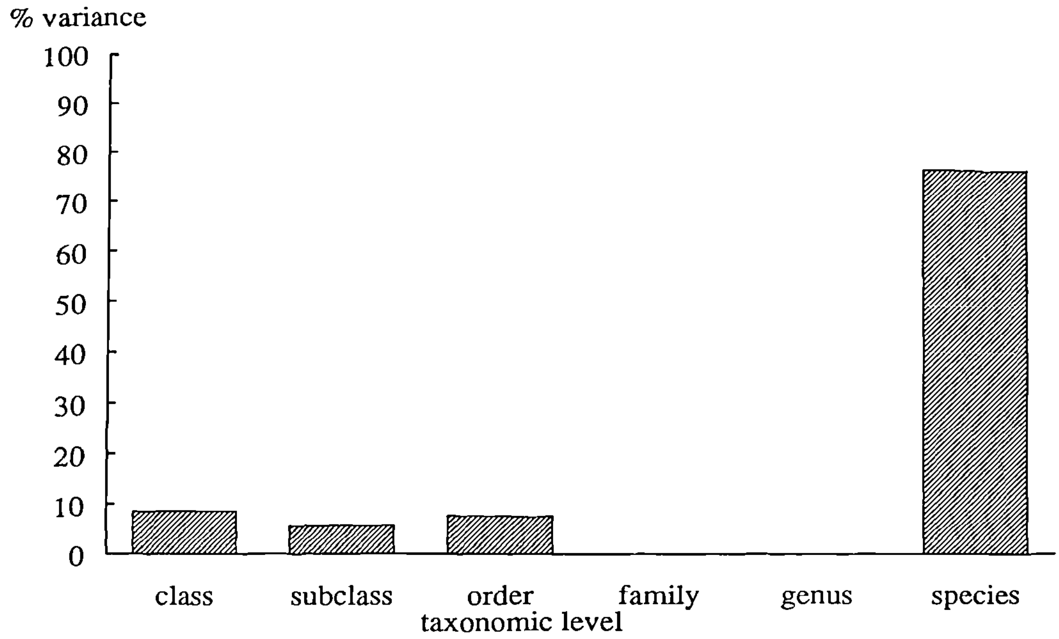

Figure 6.3 - The % variance in stomatal distribution of species belonging to families with on average 60-80% of stomata on the lower epidermis of the leaf

Methods

One-way analyses of variance were conducted to test whether there are significant relationships between stomatal distribution/density and the following variables: shade, water availability, leaf area, leaf type, leaf outline and leaf hairiness. Details of the tests are given in table 6.2 and the species used in each analysis are shown in Appendix H, page 226. In all cases the arcsin square-root of the proportion of stomata on the lower epidermis and the natural logarithm of the density data have been used.

The amount of shade species occur in was classified into zero, light, mid and deep using data originating from a variety of sources but predominantly Fitter (1978). Species' habitats were classified according to water availability into dry, moist, damp, wet and flooded/submerged using Ellenberg (1988). Leaf area data, classified into 0.1-1, 1-10, 10-100 and >100cm^2, came from a number of sources all of which are referenced in the Ecological Flora Database. Data on leaf morphology were retrieved from standard floras, such as Clapham, Tutin and Moore (1987). Leaf type was divided into simple and compound leaves, and leaf outline into entire margins, toothed margins, lobed

Stomatal data used	Species used (cf Table 6.1)	Second variable
distribution	group 3	shade
total density	group 1	shade
total density	group 3	shade
density on lower epidermis	group 1	shade
density on lower epidermis	group 3	shade
density on upper epidermis	group 3	shade
distribution	group 3	water availability
total density	group 3	water availability
density on lower epidermis	group 3	water availability
distribution	group 3 + species in the Fabaceae	leaf area
distribution	group 3 and Fabaceae species which occur in zero or lightly shaded environments	leaf area
distribution	group 3 and Fabaceae	leaf type
distribution	group 3 and Fabaceae species with leaf area < 10 cm^2	leaf outline
distribution	group 3 and Fabaceae species with leaf area > 10 cm^2	leaf outline
distribution	group 3	leaf hairiness

Table 6.2 - a list showing the data used in each of the one-way analyses of variance that were conducted. Distribution = proportion of stomata on the lower epidermis, density = number of stomata/mm^2 (total density = sum of densities on upper and lower leaf surfaces). Group 1 = species in families with on average 92-100% of stomata on the lower epidermis. Group 3 = species in families with on average 60-80% of stomata on the lower epidermis. Groups 2 and 4 were not used in any analyses, although the Fabaceae (a group 4 family containing species with a wide variety of stomatal distributions) were included in some of the analyses to increase the sample size.

margins, and lobed and toothed margins. For both the leaf area and leaf morphology analyses, data from the Fabaceae were included as well as species in the weakly hypostomatous families (group 3). This was done because the Ecological Flora Database does not have leaf area values for a sufficiently large number of species. The Fabaceae has a mean stomatal distribution of 0.5 with standard deviation 0.3 and barely alters the result of the nested analysis of variance on stomata distribution and taxonomic level of species in group 3 families shown in Figure 6.3. Information on leaf hairiness was extracted from standard floras such as Clapham, Tutin and Moore (1987) and Stace (1991). Species were classified into those with glabrous leaves, those which may have glabrous or hairy leaves and those with hairy leaves.

Woodiness was shown in chapter 4 to have the majority of the variance at the families within order level (Figure 4.17, page 78), so it is possible to analyse woodiness and stomatal distribution using mean family values for both stomatal distribution and woodiness. These family means are independent of one another as there is very little variance at taxonomic levels higher than families for either stomatal distribution or woodiness. Families were split into woody and non-woody families with non-woody families being those with 10% or less woody species and woody families being those with greater than 90% woody species. A chi-squared analysis was conducted to test whether woody families tended to have a different stomatal distribution from non-woody families.

Results

Stomatal distributions differ significantly between species living in habitats receiving different amounts of shade ($F_{3,161} = 9.17$, $P < 0.001$). Hypostomaty is more prevalent in species which live in deep shade and amphistomaty in species living in non-shaded environments (Figure 6.4).

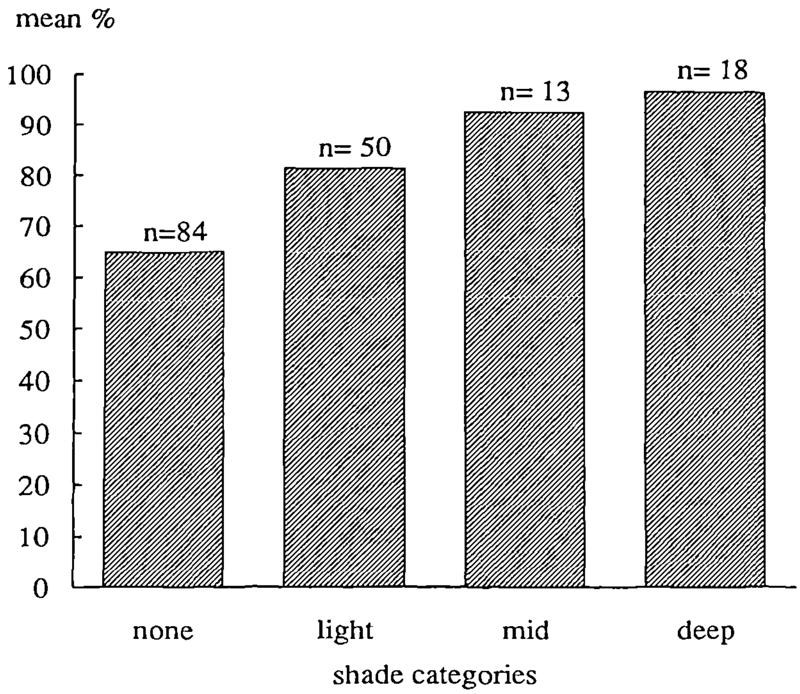

Figure 6.4 - mean stomatal distribution of species occurring in different shade categories. Data are for families with a mean of 60-80% of stomata on the lower epidermis of the leaf.

There is also a significant difference between total stomatal density and shade level both in species of families in group 3, the weakly hypostomatous families ($F_{3,133} = 10.83$, $P < 0.001$) and species of families in group 1, the hypostomatous families ($F_{3,81} = 5.27$, $P < 0.005$). The total number of stomata/mm^2 is greater in species of non-shaded environments than in species of shaded environments (Figures 6.5 - 6.6).

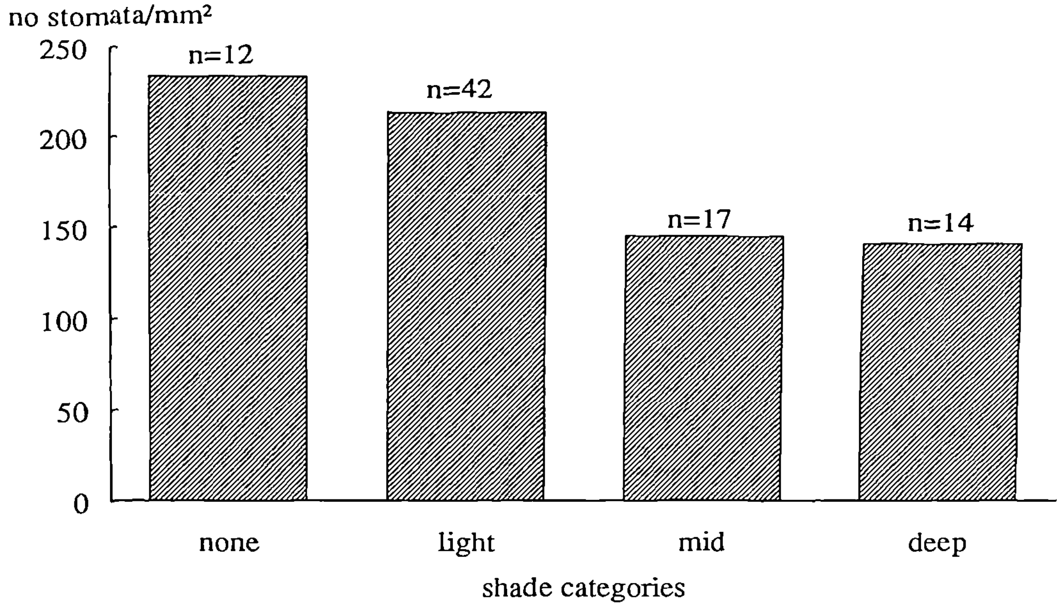

Figure 6.5 - Total stomatal density of species in hypostomatous families for different shade categories.

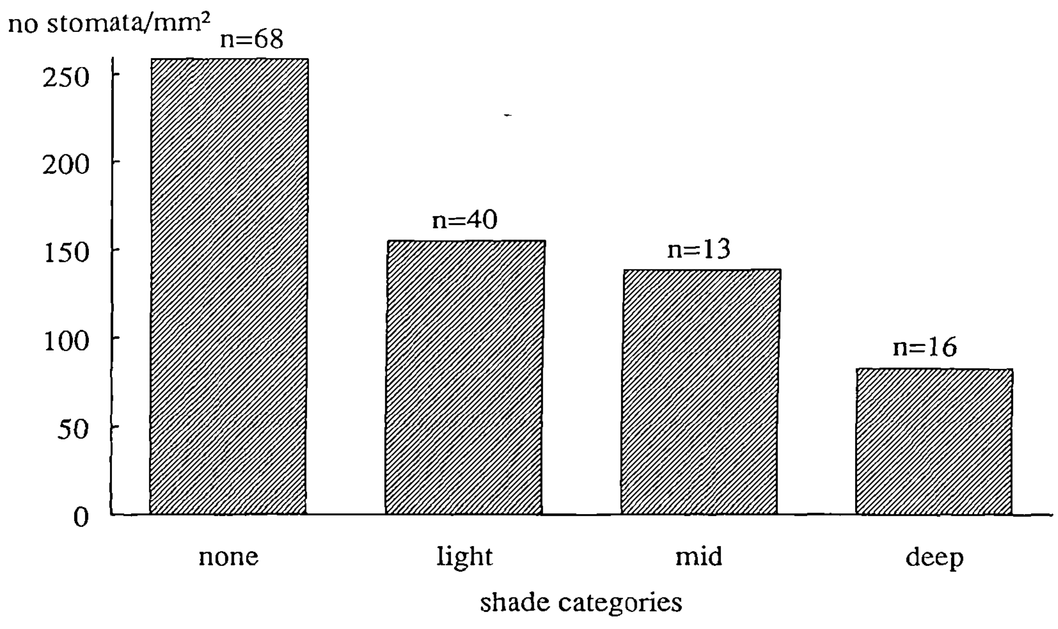

Figure 6.6 - Total stomatal density of species in weakly hypostomatous families for different shade categories

When the analyses were repeated using the density solely on the lower epidermis, the result for species in group 1 was still significant, as expected, since the majority of these species are hypostomatous ($F_{3,81} = 4.31$, $P < 0.01$). However, there were no differences between species in the weakly hypostomatous families of group 3 ($F_{3,133} = 1.71$, $P = 0.169$).

No significant differences were found between the typical water availability of a species' habitat and either the stomatal distribution ($F_{4,131} = 1.79$, $P = 0.135$) or the stomatal density (total density - $F_{4,108} = 1.83$, $P = 0.129$, density on the lower epidermis - $F_{4,108} = 1.16$, $P = 0.335$).

Species with leaves belonging to different leaf area categories have significantly different stomatal distributions ($F_{3,123} = 3.92$, $P = 0.01$). This is also the case when species living in shaded habitats are omitted ($F_{3,101} = 5.02$, $P < 0.005$). Larger-leaved species tend to have a higher proportion of stomata on the lower epidermis of the leaf than do species with smaller leaves(Figures 6.7 and 6.8).

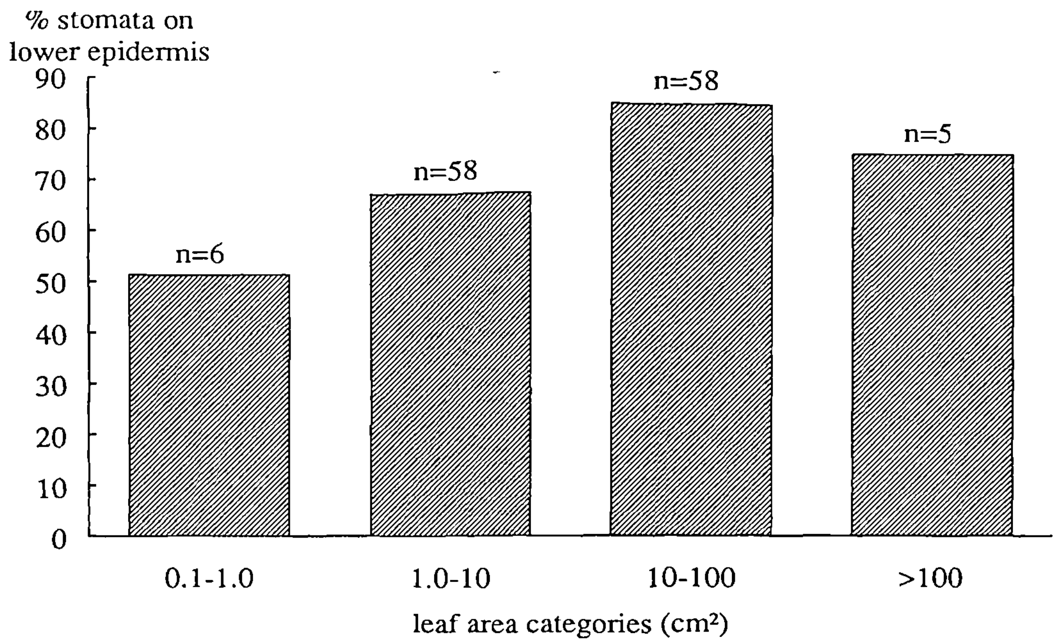

Figure 6.7 - Mean stomatal distribution of species in weakly hypostomatous families for different leaf area categories

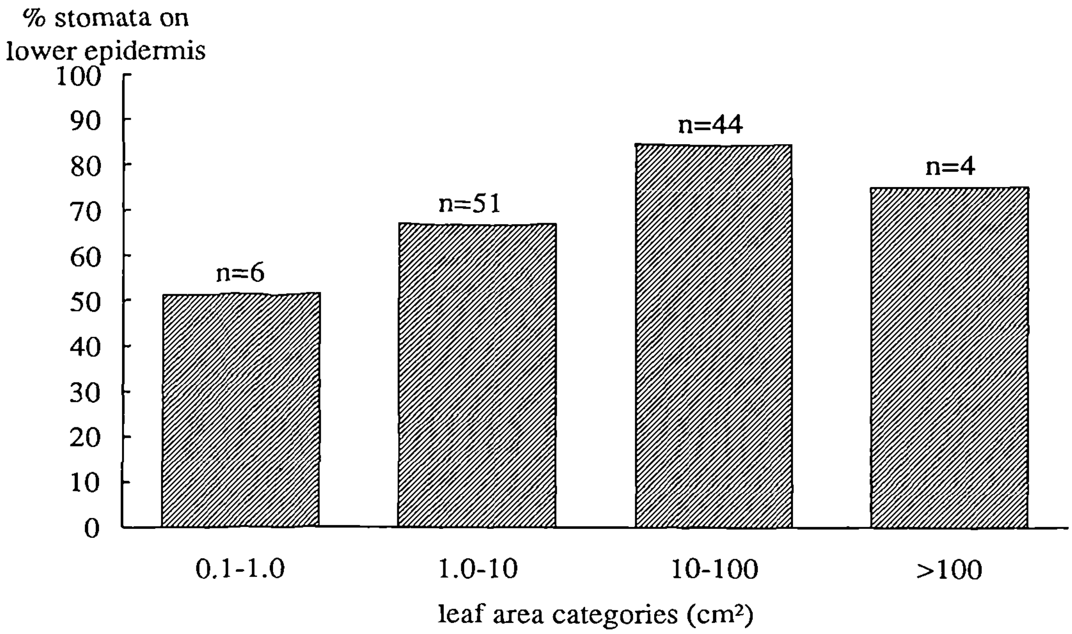

Figure 6.8 - Mean stomatal distribution of species in weakly hypostomatous families for different leaf area categories. Only species occurring in zero or lightly shaded environments are included.

The stomatal distribution of species with compound leaves and species with simple leaves does not differ ($F_{1,189}$ = 1.44, P = 0.231). Neither are there any significant differences in the stomatal distribution of species with leaf areas > 10 cm^2 having different types of leaf margin ($F_{3,51}$ = 0.03, P = 0.991). However, the analysis using only those species with leaf areas < 10 cm^2 was significant at the 5% level ($F_{3,54}$ = 3.35, P = 0.025). Species with an entire margin have a greater proportion of stomata on the lower epidermis than species with either toothed or lobed margins (Figure 6.9).

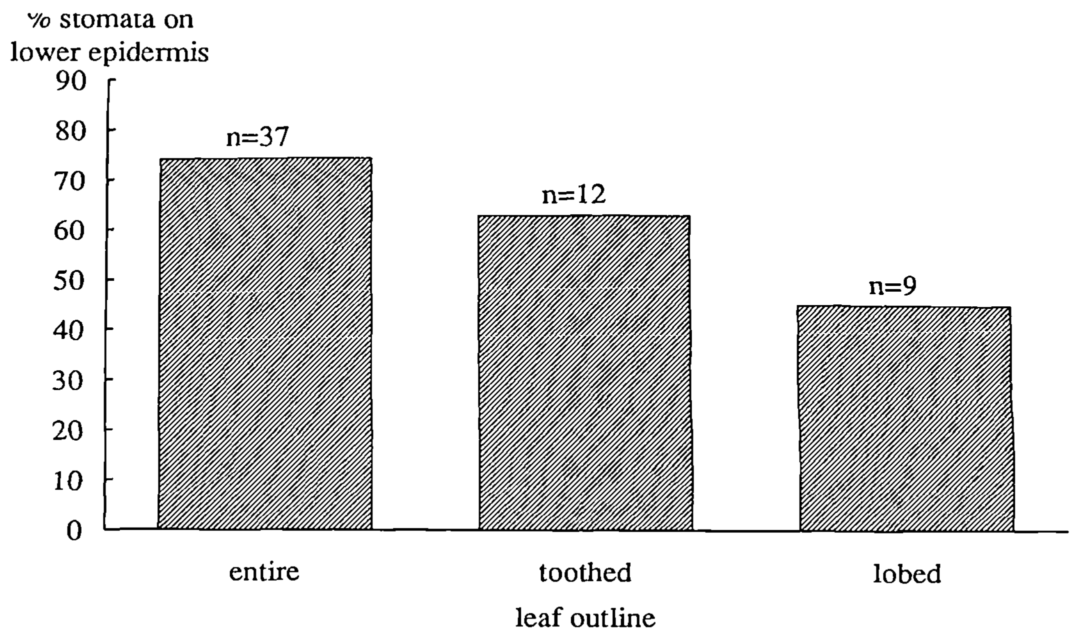

Figure 6.9 - Mean stomatal distribution of species in weakly hypostomatous families and with leaf areas < 10cm^2 classified according to leaf outline.

Species with glabrous leaves have a significantly higher proportion of stomata on the lower epidermis of the leaf than species with hairy leaves ($F_{2,132} = 3.68$, $P = 0.023$, Figure 6.10).

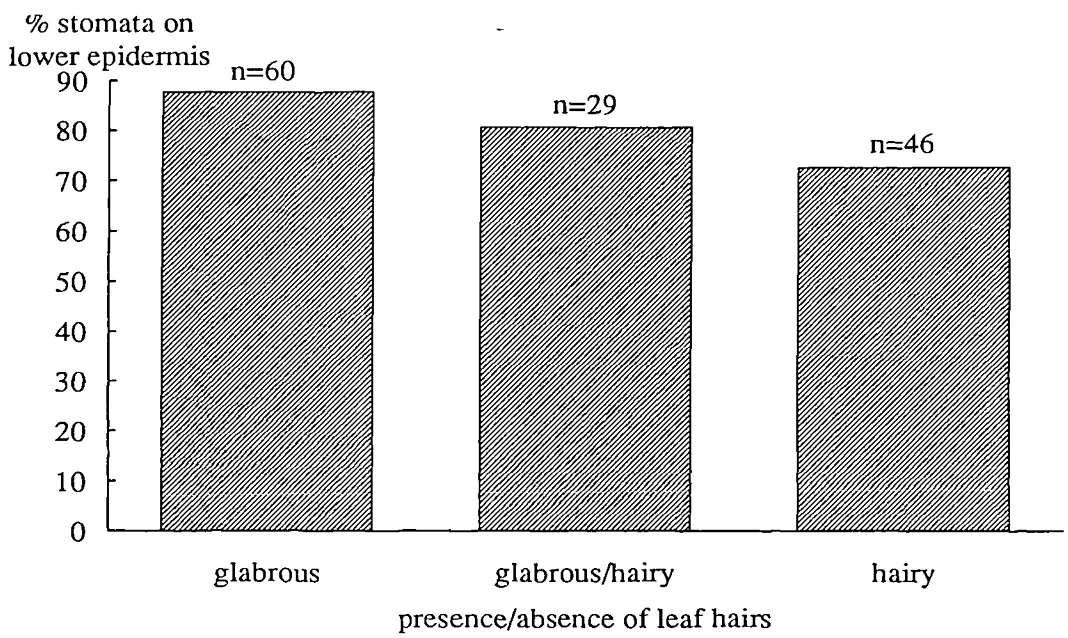

Figure 6.10 - Mean stomatal distribution of species in weakly hypostomatous families classified according to leaf hairiness.

Woody families have a significantly different stomatal distribution from non-woody families (Table 6.3). The number of families in each group indicate that this is due to woody families having a very strong tendency to be hypostomatous. Non-woody families however do not tend to any particular stomatal distribution.

% stomata on lower surface	no. woody families	no. non-woody families
92-100%	19	18
80-92%	0	7
60-80%	0	17
<60%	1	14

Table 6.3 - the number of woody/non-woody families having different mean stomatal distributions, measured as the percentage of stomata on the lower epidermis

χ^2 $(df=3) = 23.5$ $p < 0.005$

Discussion

The results presented here show that shade, leaf area, leaf outline of small leaves and leaf hairiness are important factors determining the distribution of stomata over the leaf surface.

The results of the analyses considering habitat shade levels support the suggestions of Mott *et al.* (1982). Species living in unshaded environments have a significantly lower proportion of stomata on the lower epidermis than species living in shaded environments (Figure 6.4). It does, therefore, appear that there is selection for amphistomaty in species living in unshaded habitats. The total density of stomata is also significantly greater in species living in unshaded habitats than in species living in shaded habitats (Figure 6.5 and 6.6). This is true both for species in group 1, ie those in families which are almost entirely hypostomatous, and species in group 3, weakly hypostomatous families which include species with a wide range of stomatal distributions. So, again it appears there has been selection for a morphology which will increase the uptake of CO_2 in situations where CO_2 availability is likely to limit the rate of photosynthesis. When, however, the density of stomata on the lower epidermis alone is considered, the species in weakly hypostomatous families (group 3) show no significant relationship between density and shade. This indicates that the increase in density in high-light habitats is generally achieved by adding stomata to the upper epidermis rather than to both epidermes.

There are two possible explanations for this result, depending on whether or not the species in the hypostomatous families (group 1) have the capacity to develop stomata on the upper surface and are hypostomatous because they would be at a selective disadvantage if they were not, or whether these species are unable to develop stomata on the upper surface due to phylogenetic constraints. If their hypostomaty is solely due to selection then these results suggest that species in the weakly hypostomatous families (group 3) living in high light environments do not suffer the same selective disadvantage as do the species in entirely hypostomatous families (group 1) in having stomata on the upper epidermis. For example, the upper epidermis of species in group 3 families may be better adapted in some way to avoid water loss than those in group 1. It has been shown that the species in weakly hypostomatous families (group 3) with hairy leaves are more likely to be amphistomatous than species with glabrous leaves (Figure 6.10), suggesting that the presence of leaf hairs is important in amphistomatous species. Again, however, there may be two explanations for this. Species with stomata on the upper surface could have evolved hairs because they reduce water loss; alternatively, species with hairy leaves may have been able to evolve stomata on the upper epidermis, whereas those with glabrous leaves could not because of the competitive disadvantage of extra water loss. Some insight into this problem may be gained by studying the function of the hairs on the leaves: for example, is reducing water loss an important function? In addition, species which may or may not have hairs on the leaves can be used to determine whether leaves with hairs have a different stomatal distribution from those which do not.

It is not, however, the case that the species in hypostomatous families (group 1) are unable to evolve stomata on the upper epidermis because they lack trichomes. There is no tendency in this group for species to have glabrous leaves: 35% of species are glabrous, 29% glabrous/hairy and 36% hairy. Unless there is some other feature preventing amphistomaty in the hypostomatous families this would suggest that species in these families have never evolved stomata on the upper epidermis - hypostomaty is thought to be the primitive condition (Mott *et al.*, 1982). If this is the case then the results of the shade analysis from the species in weakly hypostomatous families (group 3) indicate that there is a greater advantage in adding extra stomata onto a second surface rather than to the same surface. This may indeed be so as they will be benefitting from two parallel boundary layers. It is also possible that too high a density of stomata on a single surface may lead to the stomata interfering with one another. Parlange and Waggoner (1970) used models to infer that stomatal interference is negligible if interstomatal spacing is at least 3 times the stomatal length. If it is assumed that an average stoma is 20µm long and 10µm wide (typical figures for the length and maximal stomatal opening, Meidner and Mansfield, 1968), that there are 3 stomatal lengths/widths between each stomata and that stomata are rectangular, then there is space per square millimetre of leaf for c. 300 stomata. While this is an extreme simplification of a real leaf, it may not be a coincidence that 93% of the 337 British species for which density values are available have less than 300 stomata/mm^2 on the lower epidermis. There appear to be further constraints on the maximum density on the upper epidermis as 94% of species have less than 200 stomata/mm^2 on this surface. This may be because of greater water loss from stomata on the upper epidermis than from those on the lower epidermis, or because in many species there are often fewer air spaces in the upper layers of the mesophyll than in the lower.

The models of both Parkhurst (1978) and Jones (1985) predict that hypostomaty will be advantageous over amphistomaty when there is a high boundary layer resistance. The results presented here provide evidence that this is indeed true. Species with large leaves or smaller leaves with an entire leaf margin have a significantly larger proportion of stomata on the lower epidermis than smaller/more dissected leaves (Figure 6.9). It is these such leaves which will have the largest boundary layer. Dissection of leaf margins will have a much larger effect on the effective leaf area of a small than of a large leaf and consequently also alter the boundary layer more. This may explain why a relationship is only found for small-leaved species. Species of shaded environments often have larger leaves than those in unshaded environments (Givnish, 1987) so it is possible that the relationship between shade and stomatal distribution caused the relationship between leaf area and stomatal distribution. This, however, is shown not to be the case since when species of shaded habitats were omitted from the analysis, species with larger leaves still had a significantly higher proportion of stomata on the lower epidermis than species with smaller leaves.

No evidence was found for any relationship between either stomatal distribution or density and habitat water availability. The lack of any relationship may be because plants can control water loss by opening and closing stomata so the morphological distribution of stomata over the leaf may not be the same as the functional distribution. It has been shown that stomata on the upper and lower epidermes can respond differently (Turner, 1979; Pospisilova and Solarova, 1980) and in general upper stomata are more sensitive and may often be shut while the lower ones are open. Other factors therefore may be far more important in determining the distribution and density of stomata than is habitat water availability. In addition, some wetland species have xeromorphic adaptations to reduce the transpiration rate and reduce uptake of toxic ions such as Fe^{2+} (Etheringtion, 1983). Parkhurst's models predict that stomatal location will have very little effect on CO_2 uptake when water stress is high and that in general climatic variables are relatively unimportant compared with differences in leaf structure for determining whether stomatal location is important.

The results also provide evidence that hypostomaty in woody species is an adaptive trait and not simply due to shared ancestry between woody and hypostomatous species. This may be because woody species often have a better developed canopy than herbaceous species and boundary layers of leaves protected by a plant canopy are likely to be greater than unprotected leaves. Furthermore, Parkhurst (1978) suggests that the air inside the canopy will become enriched with water vapour and reduced in CO_2 concentration, but will also have increased humidity. The proportional increase in humidity will be greater than the proportional decrease in CO_2 concentration, and pores on the lower surface on the leaf will tend to be more exposed to this favourable air than any on the upper surface. Amphistomaty is only likely to evolve if CO_2 is limiting the photosynthetic rate or if rapid water use is advantageous; in slow-growing woody species neither is likely to be the case. Amphistomaty is especially common in annual species - therophytes have, on average, 64% of their stomata on the lower surface of the leaf, whereas much slower growing species tend to be more hypostomatous - geophytes with 83% and phanerophytes with 97% of their stomata on the lower leaf surface.

There are many other factors which may play a role in determining the stomatal distribution. Leaf angle may be important with horizontal leaves perhaps being mainly hypostomatous to reduce water loss, and amphistomaty or even hyperstomaty being more common in vertical leaves. It would be quite easy to measure leaf angle in a variety of species and relate this to their stomatal distribution. Single species with different types of leaves eg. stem and rosette leaves could also be studied to see if these had different stomatal distribution. Pathogens might also be important as the stomata are natural openings in the cuticle of a leaf and may often be used by fungi, bacteria or viruses to gain entry into a leaf (Martin and Juniper, 1970). It is possible that the susceptibility of species to pathogens may vary according to the distribution and density of stomata. It is difficult to test whether or not this is the case because while a change in stomatal distribution may reduce pathogenic infection it is very unlikely to render a species totally resistant to infection. The best approach would probably be to investigate the problem experimentally using one or more species which can produce hypostomatous and amphistomatous leaves depending on the conditions they are grown in, eg. *Ambrosia cordifolia*, which is hypostomatous when grown in shaded conditions and amphistomatous in well-lit conditions (Mott and Michaelson, 1991), and then test whether there is a difference between these leaves in susceptibility to infection by introduced pathogens.

The analyses conducted here using data from the Ecological Flora Database suggest that hypostomaty is prevalent in woody species, species of shaded environments, species with large leaves or with smaller leaves but an entire leaf margin and species with glabrous leaves. Hypostomaty is likely to have been the primitive condition (Mott *et al.*, 1982) and it appears that while hypostomaty may be an adaptive condition in some species, there are others which have never evolved the capacity to produce stomata on the upper epidermis. Amphistomaty is selected for in conditions where CO_2 is likely to limit the photosynthetic rate, such as unshaded habitats and is also commoner in conditions were water loss from the leaf will be limited by, for example, structures on the leaf surface such as trichomes.

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Chapter 7

The Distribution of Mycorrhizas in the British Flora

Introduction

"The mycorrhizal symbiosis is not a rare speciality among plants but is characteristic of most land plants..." (Pankow *et al.*, 1991).

"There is now ample evidence to support the common assertion that most plants in natural ecosystems have mycorrhizal associations." (Brundrett, 1991).

Mycorrhizas, the association between the roots of vascular plants and a number of different groups of non-pathogenic fungi, are found in a wide variety of plant taxa. The association is generally believed to be mutualistic with the fungus gaining carbon from the host plant and the plant benefitting from increased nutrient absorption from the soil as the fungal hyphae ramify into areas not reached by the plant roots. The association has demonstrably evolved independently on a number of occasions and there are various types of mycorrhiza differentiated by the taxa of fungi involved and the morphology of connections between the plant and the fungus. The types include: arbuscular fungi (AM) in which hyphae of zygomycetous fungi (order Glomales) penetrate the root cortex cells and produce vesicles and arbuscules; ectomycorrhizas (ECM) where the fungi do not invade cells, but form a mantle enclosing the root from which hyphae radiate outwards into the soil and inwards between the cells of the outer root cortex forming a Hartig net; arbutoid mycorrhizas with a sheath, Hartig net and some penetration of the root cells; ericoid mycorrhizas in which the roots of species in the Ericales are surrounded by hyphae which also penetrate the root cells; monotropoid mycorrhizas with a sheath, Hartig net and hyphal penetration of the root cells; and orchid mycorrhizas in which hyphae of Basidomycetes penetrate the root cells (Harley and Smith, 1983). Arbuscular and ecto- mycorrhizas occur on a wide range of plant species while arbutoid and ericoid mycorrhizas are restricted to the Ericales, monotropoid mycorrhizas to the Monotropaceae and orchid mycorrhizas to the Orchidaceae.

Mycorrhizal associations, at least of the AM type, are very ancient. It has been suggested, for instance, that symbiotic associations between fungi and algae played a vital role in the colonization of land (Pirozynski and Malloch, 1975). There are fossil records of possible AM associations in the tissues of *Rhynia* and *Asteroxylon*, two early terrestrial plants of the Devonian period (Pirozynski, 1981) which contain structures very similar to present day vesicles. More convincingly vesicles, chlamydospores and arbuscules have been found in fossil roots from the Triassic (Stubblefield *et al.*, 1987). Despite mycorrhizas being present in the great majority of modern plant taxa and in almost all ecosystems, some species never form mycorrhizal associations and others do so rarely, sparsely or inconsistently (Newman and Reddell, 1987; Tester *et al.*, 1987). It was shown in chapter 4 (Figures 4.18 and 4.19, page 79) that the variance in the proportion of species per genus that are mycorrhizal occurs mainly at the family and genus level. Assuming, therefore, that the presence of mycorrhizal fungi was the ancient condition, then the association has been lost independently in a number of families and genera. For example, mycorrhizas are frequently absent or rare in species belonging to the families Brassicaceae, Caryophyllaceae and Cyperaceae and the genera *Oenanthe* (Apiaceae) and *Astragalus* (Fabaceae).

Why has the mycorrhizal association been lost in some taxa, while remaining in the majority? A number of workers have sought answers to this question by comparing mycorrhizal and non-mycorrhizal species to see if they differ ecologically or morphologically. A number of correlates of mycorrhizal status are widely recognised.

Root Structure

It is often held that the roots of non-mycorrhizal species are very fine (<0.1mm diameter) and covered in abundant root hairs, while mycorrhizal species, especially obligate mycorrhizal species have much coarser roots (>0.5mm) and no, or very few, root hairs (Baylis, 1975; St John, 1980). Thin roots represent a greater root length per unit root biomass and are thus able exploit a larger volume of soil

(Hetrick, 1991). Furthermore, root hairs increase the effective diameter of the roots and thus the volume of soil exploited, at a very low cost in biomass. Species, therefore, with very fine roots and/or many or long root hairs may not benefit from being mycorrhizal as the roots are already able to explore soil effectively.

Habitat disturbance

Colonizers of disturbed ground are often non-mycorrhizal (Reeves *et al.*, 1979), while the frequency of mycorrhizal species tends to increase as succession proceeds towards a more stable community (Janos, 1980). Habitat disturbance affects both the plant species composition and mycorrhizal infection potential of the soil. Highly competitive species give way to ruderal species (Grime, 1979) and there is a reduction in the number of viable mycorrhizal spores and a disruption of the mycelial network (Brundrett, 1991). Facultative or non-mycorrhizal species might be expected to be the first colonizers as they do not rely on becoming infected and they will avoid being out-competed by obligate mycorrhizal species.

Life form

Hydrophytic and helophytic species tend to be non-mycorrhizal (Malloch *et al.*, 1980; Read *et al.*, 1976). Khan (1974) found that very few mycorrhizal spores were present in permanently waterlogged soils and that species were often non-mycorrhizal when on waterlogged soil and mycorrhizal if growing on drier soil. Submerged and floating aquatic species can obtain inorganic nutrients from the water as well as the substrate, through both shoot and root surfaces (Sculthorpe, 1967). The presence of mycorrhizas in such species, therefore, may have little overall affect on nutrient absorption. Furthermore, wet habitats may be unsuitable for mycorrhizal association due to the poor aeration of the soil as oxygen is necessary for fungal growth (Crawford, 1991). Annual species are also often non-mycorrhizal (Trappe, 1987), possibly because they often occur in disturbed habitats.

Habitat

Soil fertility, water availability and pH may all be important factors in determining whether a plant benefits from being mycorrhizal. Possible benefits to plants are enhanced uptake of nutrient ions such as phosphate, and improved water relations (Fitter, 1991). If, therefore, mycorrhizal associations enhance nutrient absorption and water uptake, it could be predicted that mycorrhizal species will be commoner in infertile or dry habitats than non-mycorrhizal species. The soil pH determines the solubility of many nutrients such as iron, manganese, phosphorus, zinc and molybdenum and may therefore indirectly affect how much a plant benefits from being mycorrhizal.

The Ecological Flora Database, with information on over 100 ecological characteristics of British plants, including mycorrhizal associations, made it possible to investigate some of these differences on a larger scale than previously and also to look for new relationships. The following questions were posed.

1. Do mycorrhizal species have thicker/less hairy roots than non-mycorrhizal species?
2. Are annual species more frequently non-mycorrhizal than perennial species?
3. Do mycorrhizal species occur in less fertile habitats than non-mycorrhizal species?
4. Do mycorrhizal species occur in drier habitats than non-mycorrhizal species?
5. Does the soil pH of mycorrhizal species differ from that of non-mycorrhizal species?
6. Do mycorrhizal and non-mycorrhizal species occur in different habitat types?
7. Do mycorrhizal species differ in seed weight from non-mycorrhizal species?

Methods

The Data

The Ecological Flora Database holds information on the mycorrhizas present in British plant species. The type of mycorrhizal association and the frequency of its occurrence, whether normally, occasionally, rarely or never present (classified according to the number of records of mycorrhizal status for each species), is recorded. There are records for 968 species, over half the British flora. The majority of the information has been extracted from Harley and Harley (1987). Three quarters of the mycorrhizal associations recorded in the British Flora involve arbuscular mycorrhizas, so the analyses that are presented in this chapter concentrate on species which have either some degree of AM infection or else are non-mycorrhizal. Species which have no mycorrhizal infection because they are rootless, parasitic or floating aquatic species were also omitted from the data-set. This left 843 species - 48% of the British Flora, representing 88 families and 385 genera.

The majority of variance in the proportion of species per genus that have arbuscular mycorrhizas occurs at the genus and family levels (Figures 4.18 and 4.19, page 79). As a consequence two species may be similar due to shared ancestry rather than due to convergent evolution and this effect must be allowed for in comparative analyses (see chapter 5). Genera and families were classified into the same four categories as species by allocating each of the frequency categories a numerical code (never = 0, rarely = 1, occasionally = 2 and normally = 3), and calculating the mean value of this code for each family and genus. The means were rounded to the nearest whole number so the codes could be translated back into the original categories. These classifications allowed analyses to be conducted at the genus and family levels as well as at the species level. The hypotheses outlined above were tested using an appropriate taxonomic level, chosen according to the amount of variance present in the second characteristic in the analysis. If, for example, the majority of the variance occurred at the family level, then mean family values were used.

The Analyses

The species used in each analysis are given in Appendix H, page 226.

Root Structure

Data on root diameter were available for only 62 of the species in the mycorrhizal data-set. A χ^2 test was used to test for a difference in root diameter between species normally mycorrhizal and species less often mycorrhizal. Root diameter was categorised into diameter classes: <100, 100-150, 150-200, 200-300 or > 300 µm in diameter. Information on the presence or absence of root hairs was available for 111 species in the mycorrhizal data-set. A χ^2 analysis was conducted to test for a relationship between frequency of AM infection and the presence or absence of root hairs.

Life History

The percentages of species in seven life-form categories (therophytes, hemicryptophytes, helophytes, hydrophytes, geophytes, chamaephytes and phanerophytes) that are never/rarely, occasionally and normally mycorrhizal were calculated. The majority of variance in the proportion of species per genus that are annual occurs at the genus level (Figure 4.23, page 81). Therefore genera were split into those with > 90%, those with 10-90% and those with < 10% annual species. A χ^2 test was conducted to test for a relationship between the annual proportion and frequency of arbuscular mycorrhizas using the number of genera in each annual proportion and mycorrhizal frequency class.

Fertility

The Ecological Flora Database categorises soil fertility into very fertile, fertile, infertile and very infertile. Fertility data were available for most species from a variety of sources, including Ellenberg (1988) and Fitter (1978). Because more than one of these categories may apply to a single species, a numerical code was allocated to each alternative value and a mean fertility value for each species calculated. A χ^2 analysis was used to test for a relationship between soil fertility and degree of mycorrhizal infection. This analysis was done using species data because it was not possible to look at the variation in soil fertility at different taxonomic levels (as it is a qualitative variable with several alternative states). The results, however, could be biased by the Cyperaceae, a large family of species which occupy infertile habitats and are rarely mycorrhizal. To overcome this, the analysis was repeated omitting the Cyperaceae.

Water availability

Data on water availability was extracted from Ellenberg (1988) in which habitat moisture is divided into 12 categories from extremely dry to aquatic habitats. It is well known that species of very wet habitats are frequently non-mycorrhizal so only species occurring in the first seven of Ellenberg's categories, very dry - damp (but not wet) were included. A χ^2 analysis was used to test for a difference in AM frequency in species occurring in habitats with different degrees of soil moisture. Soil moisture was classified into dry (categories 1-3), moist (categories 4 and 5) and damp (categories 6 and 7). Again this analysis was done using species data as the variance at different taxonomic levels in response to water availability is not known.

pH

Data on extreme maximum and extreme minimum pHs were available in the Ecological Flora Database for over 200 of the species in the mycorrhizal data-set. Nested analyses of variance on extreme maximum pH and extreme minimum pH showed that the majority of variance in both these characteristics occurs at the species level (91% for extreme maximum pH and 78% for extreme minimum pH). Analyses on AM infection and pH, therefore, were conducted at the species level. One-way analyses of variance were calculated to test for relationships between the level of AM infection and the maximum and minimum soil pH that species occur in.

Habitat type

The Ecological Flora Database categorises habitat preferences of species using the CORINE classification (Moss, 1991). 120 habitat types are included and a species may occur in any number of these. The classification is hierarchical so habitats are split into broad categories, such as grassland or woodland, and these are then split into more detailed habitats, such as mixed Atlantic bluebell oak forests or Caledonian forest. The percentage of species which are normally mycorrhizal and the percentage which are never, or rarely, mycorrhizal in 27 broad habitat groups at the 2nd level of the hierarchy were calculated. The results section gives the habitat groups and the Corine codes each group represents.

The number of habitat types in which each species occurs was also investigated. A nested analysis of variance, using all 120 habitat types showed that 85% of the variance in the number of habitat types occupied occurred at the species level. Species data were therefore used for analyses concerning AM infection and number of habitat types. There is likely to be a link between the number of habitat types a species occurs in and its abundance, so any relationship found between frequency of mycorrhizal infection and number of habitat types could be secondary to a relationship between mycorrhizal infection and abundance. To allow for this, species abundance, measured by the number of vice-counties a species occurs in (from Clapham *et al.*, 1952), was included in all tests as a covariate. One-way analyses of covariance were calculating using the data-set on AM frequency, number of habitat types and number of vice-counties for annuals, perennials, and widespread perennial species (ie. those occurring in over 90% of all vice-counties). To ensure any relationship found was not due to non-mycorrhizal species being limited to a large extent to aquatic, wetland or saline habitats the analysis for perennial species was repeated but omitting any species that occur in Corine habitat groups C1 (coastal and halophytic communities, C2 (non-marine waters) and C5 (bogs and marshes). The number of habitats a species occurs in was transformed by taking the natural logarithm.

Seed Weight

The variance in maximum seed weight occurs mainly at the genus and family levels (Figure 4.12, page 76). The variance in proportion of species/genus with AM also occurs at the genus and family levels so analyses were conducted at both these levels, or, if data were available for less than 200 genera, using mean data values for genera only. Annuals have significantly lighter seeds than perennials (Silvertown, 1981), so annual and perennial species were analysed separately. Mean genus seed weights for annual and perennial species and mean family seed weights for perennial species were calculated and transformed by taking the natural logarithm. One-way analyses of variance were conducted using these mean seed weights and the mean frequency of mycorrhizal infection per family or genus. The analysis using mean family values was repeated but omitting families containing over 90% woody species as woody species also tend to have heavier seeds (Salisbury, 1942) and are almost invariably mycorrhizal (Brundrett, 1991). Further analyses were conducted using genera means of species occurring in different types of habitats: scrub and grassland habitats, woodland habitats, bog and marsh habitats and coastal habitats.

Results

Root Structure

There is a significant difference between the root diameter of normally mycorrhizal species and the root diameter of species less often mycorrhizal (χ^2=6.6 2df $p < 0.05$, Table 7.1). Species which are never, rarely or occasionally mycorrhizal have root diameters that are always < 300µm and usually < 150µm. Normally mycorrhizal species show a greater range in root diameters from < 100 µm to > 300µm (Figure 7.1). There is no evidence of a relationship between mycorrhizal frequency and presence/absence of root hairs (χ^2 = 2.0 2df, $p > 0.1$ - Table 7.2).

root diameter (µm)	not normally mycorrhizal	normally mycorrhizal
<100	11 (6.7)	5 (9.3)
100-200	10 (11.7)	18 (16.3)
>200	5 (7.5)	13 (10.5)

Table 7.1 - number of species which are normally mycorrhizal or less frequently/never mycorrhizal in different root diameter classes. Figures in brackets are the expected number of species.

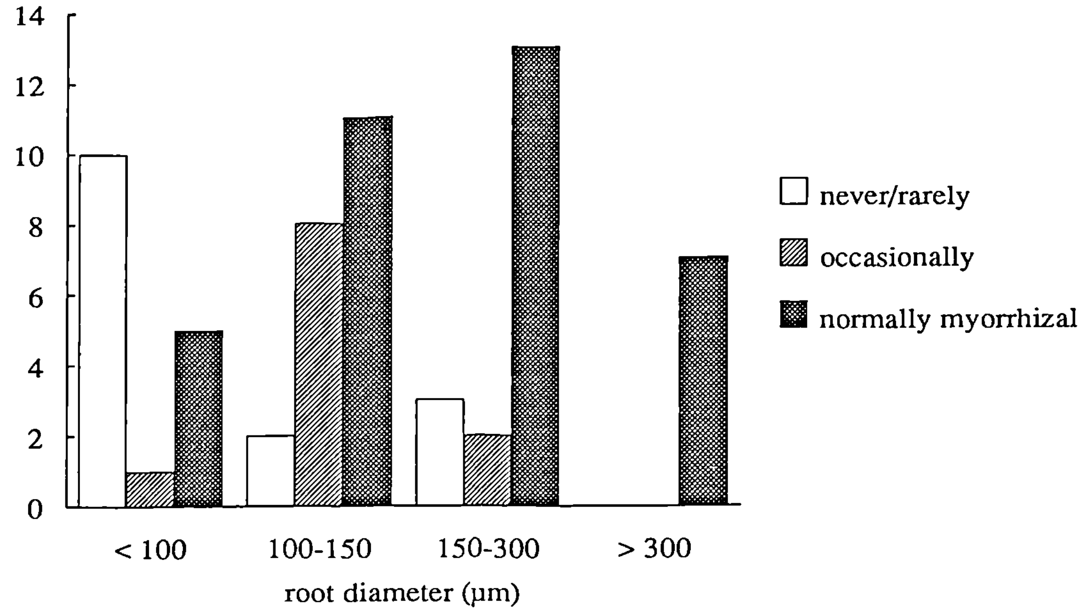

Figure 7.1 - a histogram showing the number of species that are normally, occasionally, rarely or never mycorrhizal in 4 root diameter classes.

	never/rarely mycorrhizal	occasionally mycorrhizal	normally mycorrhizal
root hairs	28 (28.4)	15 (17.0)	47 (44.69)
no root hairs	7 (6.6)	6 (4.0)	8 (10.4)

Table 7.2 - the number of species in different classes of AM frequency, with and without root hairs. The numbers in brackets are the expected number of species assuming no relationship between mycorrhizal association and presence of root hairs.

Hydrophytes tend to be non-mycorrhizal or rarely mycorrhizal and helophytes are typically rarely mycorrhizal whereas phanerophytes and geophytes are usually mycorrhizal. The majority of chamaephytes and hemicryptophytes are normally mycorrhizal although over a quarter of the species with these life forms are rarely mycorrhizal. The distribution of mycorrhizal infection in therophytes (annual species) is more evenly spread, although there is a slight majority of rarely mycorrhizal species (Figure 7.2). Annual species are more likely to be non-mycorrhizal than perennial species (Table 7.3).

	never/rarely mycorrhizal	occasionally mycorrhizal	normally mycorrhizal
> 90% annual spp/genus	21 (11.05)	8 (6.74)	13 (24.21)
10-90% annual spp/genus	20 (19.21)	12 (11.53)	41 (42.07)
< 10% annual spp/genus	59 (69.74)	41 (42.54)	165 (152.72)

χ^2 $(df=4) = 17.2$ $p < 0.005$

Table 7.3 - the number of genera that contain mainly annual species, mainly perennial species or a mixture of the two in different mycorrhizal frequency classes. The numbers in brackets are the expected number of genera in each class.

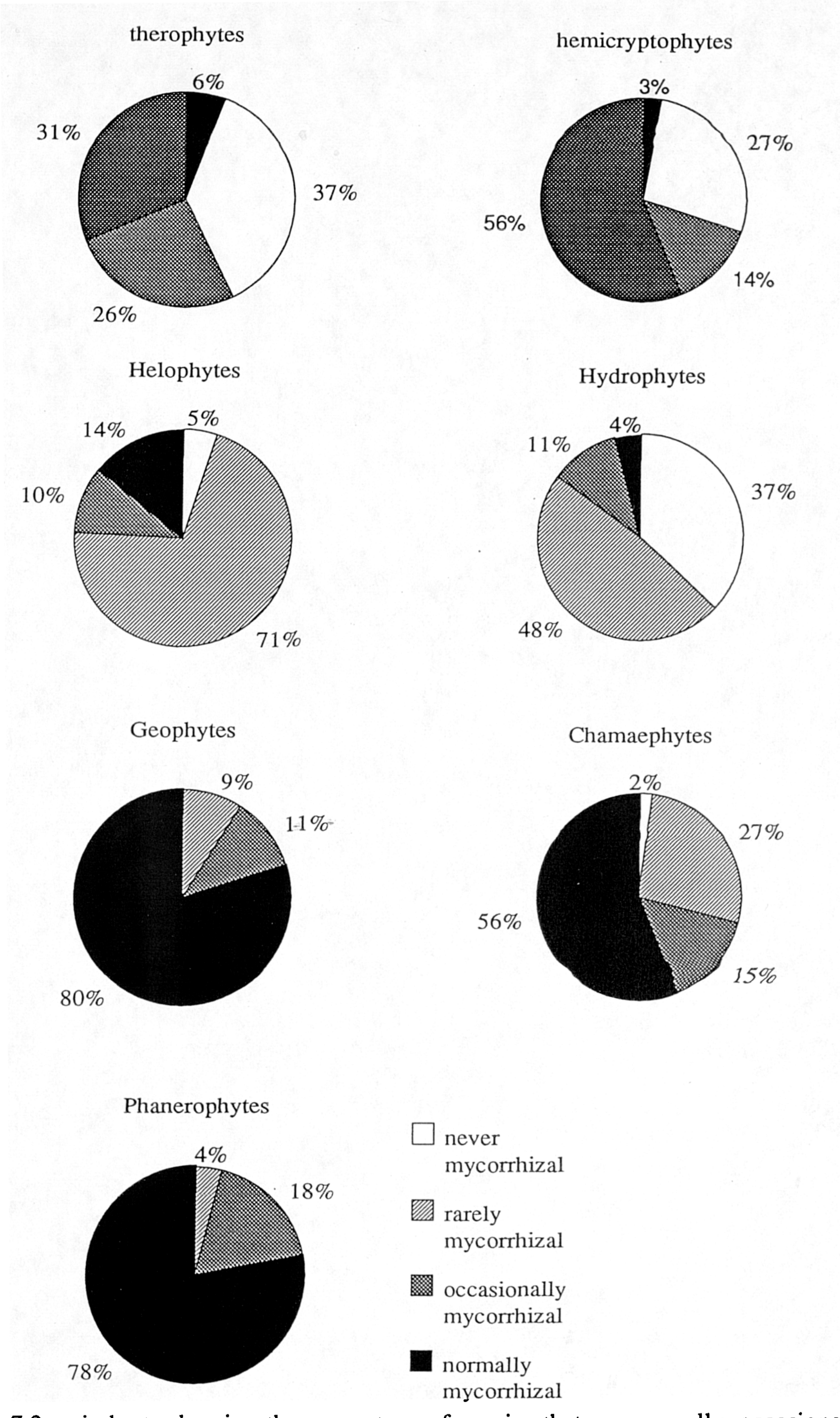

Figure 7.2 - piecharts showing the percentage of species that are normally, occasionally, rarely and never mycorrhizal in each life form category.

Fertility

When all species are included in the analysis there are slightly more rarely mycorrhizal species than expected occurring in habitats with low fertility soils and more normally mycorrhizal species than expected occurring in high fertility soils. The difference, however, is not quite significant at the $p = 0.05$ level ($\chi^2 = 8.93$ 4df, $p < 0.1$ - Table 7.4). When species in the Cyperaceae are omitted, even this weak (and counter-intuitive) relationship disappears and there is no relationship between mycorrhizal frequency and soil fertility ($\chi^2 = 1.53$ 4df, $p > 0.75$ - Table 7.5).

fertility	never/rarely mycorrhizal	occasionally mycorrhizal	normally mycorrhizal
low	71 (62.4)	33 (31.2)	91 (101.3)
mid	83 (73.3)	33 (36.7)	113 (119.0)
high	90 (108.2)	56 (54.1)	192 (175.7)

Table 7.4 - the number of species with different frequencies of mycorrhizal infection occurring in habitats with low, mid and high soil fertility. Figures in brackets are the expected number of species.

fertility	never/rarely mycorrhizal	occasionally mycorrhizal	normally mycorrhizal
low	36 (39.0)	33 (28.7)	91 (92.4)
mid	45 (46.7)	34 (34.4)	113 (110.8)
high	86 (81.3)	56 (59.9)	192 (192.8)

Table 7.5 - as table 7.4 omitting species in the Cyperaceae. Figures in brackets are the expected number of species.

Water availability

There is a weak relationship between water availability of the soil and degree of mycorrhizal infection ($\chi^2 = 9.02$ 4df, $p < 0.1$ - Table 7.6) with non- or rarely mycorrhizal species occurring less often than expected in very dry and more often in damp habitats.

soil moisture	never/rarely mycorrhizal	occasionally mycorrhizal	normally mycorrhizal
very dry	9 (14.0)	16 (11.7)	41 (40.3)
moist	49 (49.1)	32 (40.8)	150 (141.1)
damp	31 (25.9)	26 (21.6)	65 (74.5)

Table 7.6 - the number of species occurring in habitats with different degrees of soil moisture and having different amounts of mycorrhizal infection. Figures in brackets are the expected number of species.

pH

There is no difference in the extreme minimum pH tolerated by species with different levels of arbuscular mycorrhizas ($F_{3,204} = 0.81$, $P = 0.49$), whereas there is a significant difference in the extreme maximum pH ($F_{3,200} = 4.82$, $P = 0.003$, Figure 7.3). Species that are normally mycorrhizal are able to occupy habitats with a greater maximum pH than species that are not normally mycorrhizal.

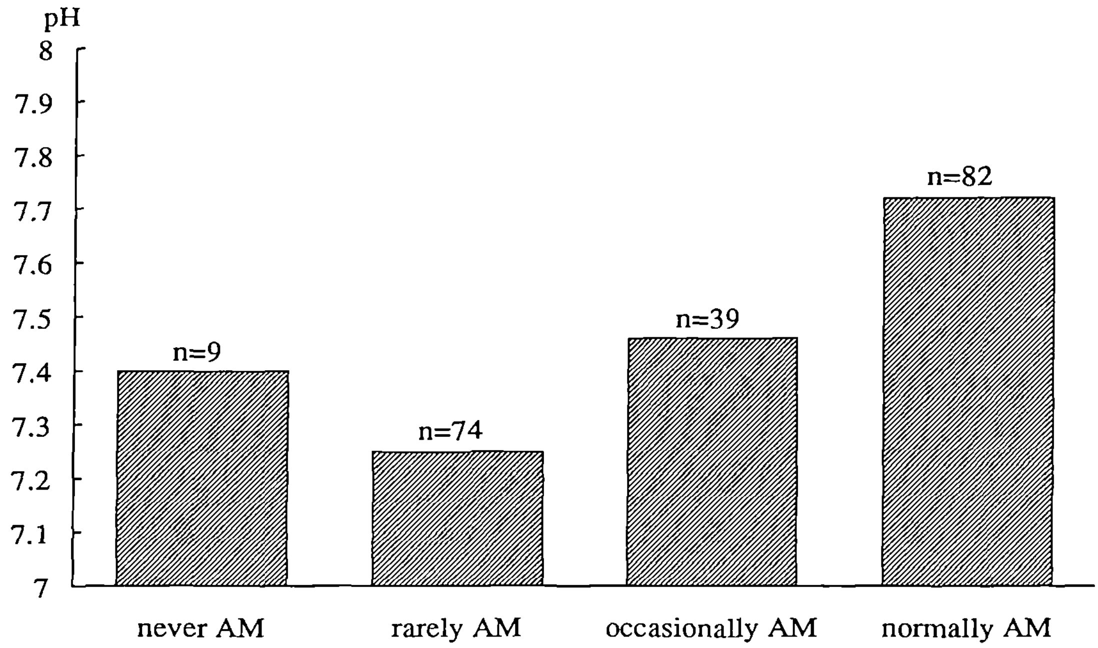

Figure 7.3 - the mean extreme maximum pH of species that are never, rarely, occasionally and normally mycorrhizal.

Habitat type

Mycorrhizas are often absent in species of aquatic/wet habitats, saline habitats and man-modified habitats. They are extremely frequent in woody and grassland habitats (Table 7.7).

Habitat	Corine Code	% spp rarely/never infected	% spp normally infected	No. species
Running water	C24	80.0	15.0	20
Standing fresh water	C22	57.4	23.5	68
Fens	C54	45.2	39.2	166
Bogs	C51, C52	44.1	37.3	59
Water fringe vegetation	C53	41.4	37.2	191
Standing brackish/salt water	C23	41.4	37.9	29
Intensive cropland	C82	40.3	38.8	67
Salt marsh	C15	34.1	44.3	88
Alpine grassland	C36	33.3	50.0	48
Fallow and wasteland	C87	33.1	51.7	151
Humid grassland	C37	30.5	49.3	203
Towns	C86	29.6	55.6	27
Wet forests	C44	26.0	53.8	173
Inland cliffs	C62	22.5	61.8	102
Dry siliceous grassland	C35	21.9	60.0	157
Sand dunes	C16	21.1	58.4	209
Heath and scrub	C31	21.0	62.5	267
Shingle beaches	C17	18.2	57.6	33
Cliff communities	C18	17.4	60.9	138
Dry calcareous grassland	C34	14.6	71.2	207
Mesophile grassland	C38	14.3	70.3	182
Screes	C61	13.6	81.8	22
Parks and gardens	C84, C85	12.8	66.7	39
Deciduous forest	C41	11.1	73.9	180
Improved grassland	C81	9.1	79.5	44
Machair	C1A	8.8	75.0	68
Coniferous forest	C42	0.0	92.1	38

Table 7.7 - A list of the percentage of species that are rarely/non-mycorrhizal and normally mycorrhizal in 27 habitat types. The percentages do not sum to 100 as species occasionally infected with arbuscular mycorrhizas have been omitted from the table.

Perennial species which are normally or occasionally mycorrhizal typically occur in almost twice as many habitat types as rarely or non-mycorrhizal perennials (Figure 7.4). There is a significant relationship between species abundance (number of vice-counties) and number of habitat types ($F_{1,636} = 652.57$, $P < 0.001$), but when this is included as a covariate, there is still a significant difference between the number of habitat types perennial species occur in and AM frequency ($F_{3,636} = 5.34$, $P = 0.001$). This is also true for widespread perennial species (those occurring in over 90% of vice-counties - $F_{3,220} = 3.27$, $p = 0.022$, Figure 7.5) and species that do not occur in aquatic, wetland and saline habitats ($F_{3,268} = 6.81$, $P < 0.001$, Figure 7.6). Annual species that are occasionally mycorrhizal occur in more habitat types than either species normally or species rarely mycorrhizal (Figure 7.7). This difference, however, seems to be a simple consequence of abundance since it is no longer significant when number of vice-counties is included as a covariate ($F_{3,109} = 0.93$, $P = 0.429$).

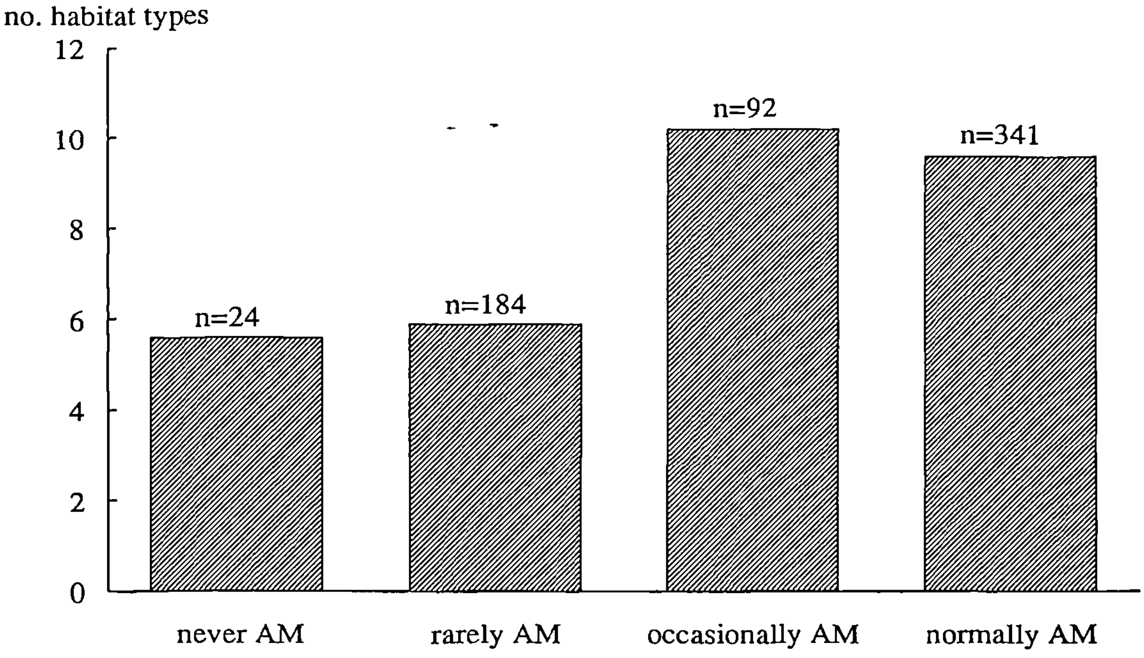

Figure 7.4 - the mean number of habitat types occupied by perennial species categorised according to the frequency of mycorrhizal infection.

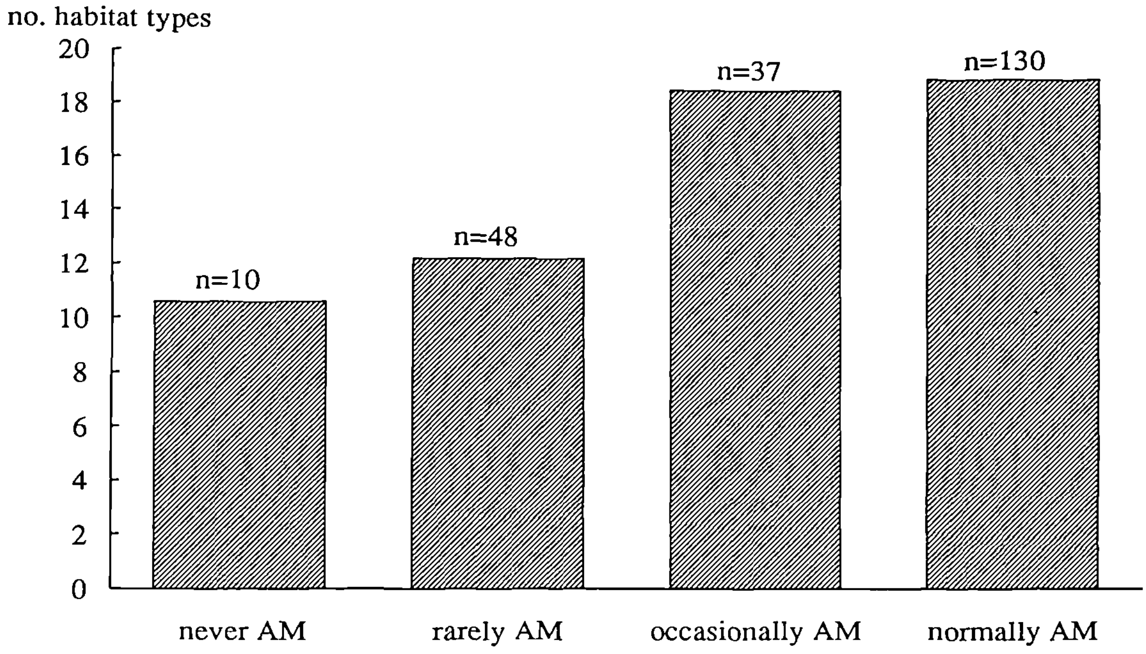

Figure 7.5 - the mean number of habitat types occupied by perennial species occurring in over 90% of vice-counties categorised according to the frequency of mycorrhizal infection.

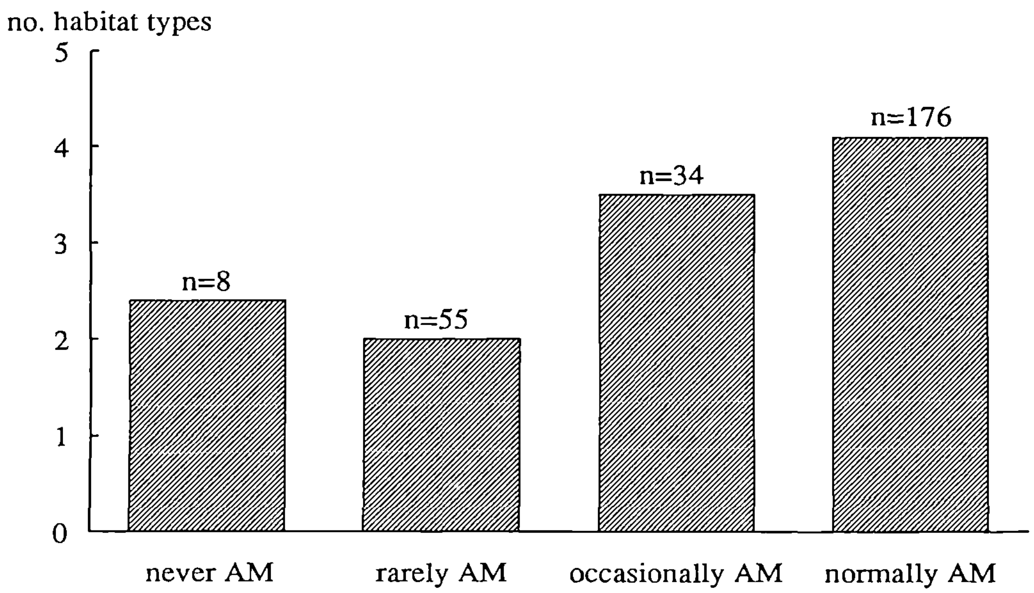

Figure 7.6 - the mean number of habitat types occupied by perennial species categorised according to the frequency of mycorrhizal infection. Perennials occurring in aquatic, wetland or saline habitats have been omitted.

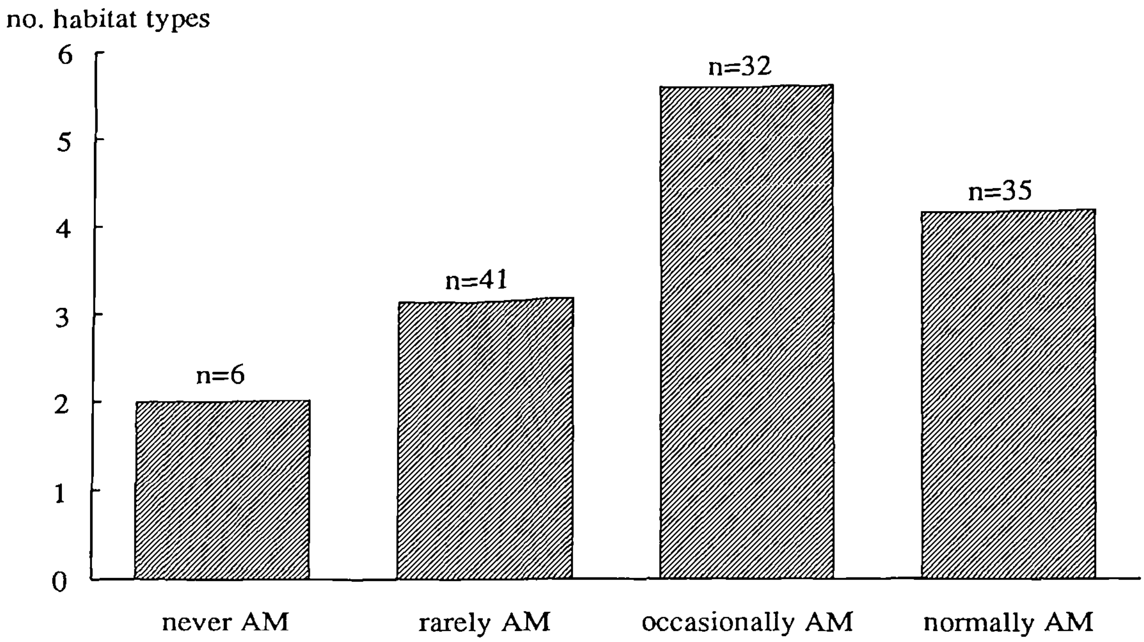

Figure 7.7 - the mean number of habitat types occupied by annual species categorised according to the frequency of mycorrhizal infection.

Seed Weight

Genera and families of perennial species that are typically mycorrhizal tend to have heavier seeds than genera and families with less mycorrhizal infection (genera means - $F_{3,244} = 7.67$, $P < 0.001$; family means - $F_{3,69} = 9.92$, $P < 0.001$; Figures 7.8 and 7.9). This is not due to woody species tending to have heavier seeds and being mycorrhizal since when families containing > 90% woody species are omitted from the analysis, typically mycorrhizal species still have significantly heavier seeds than families less frequently mycorrhizal ($F_{3,53} = 4.52$, $P < 0.005$, Figure 7.10). There is, however, no relationship between mycorrhizal infection of annuals and mean genus seed weight ($F_{3,24} = 0.4$, $P = 0.753$).

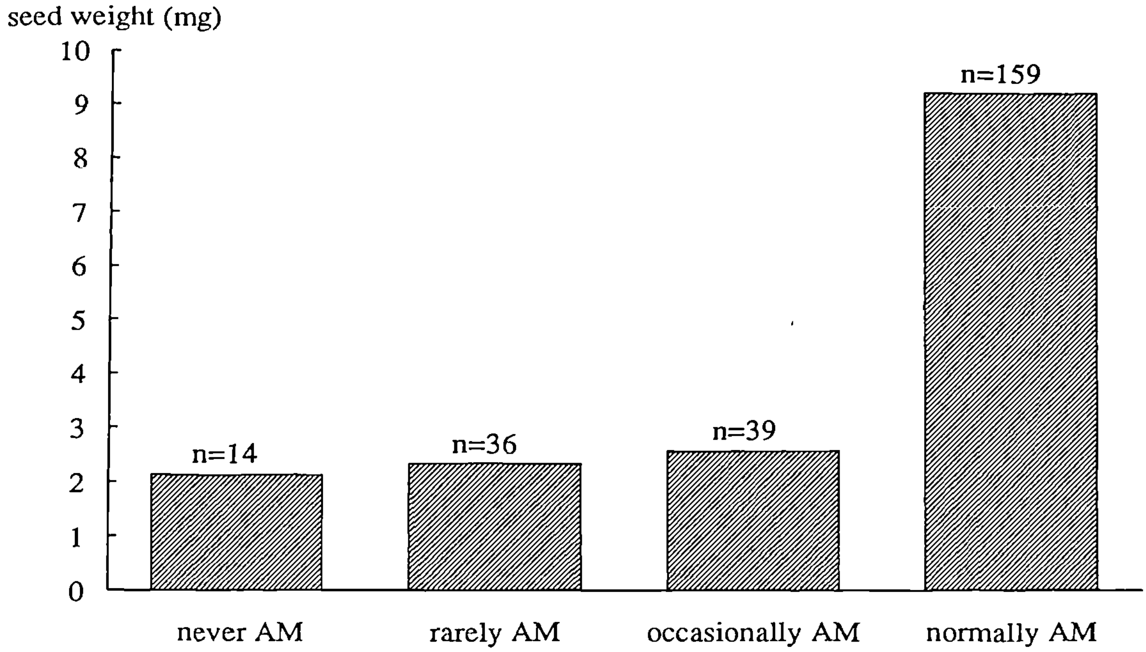

Figure 7.8 - the mean genus seed weight of perennial species that are normally, occasionally, rarely and never mycorrhizal.

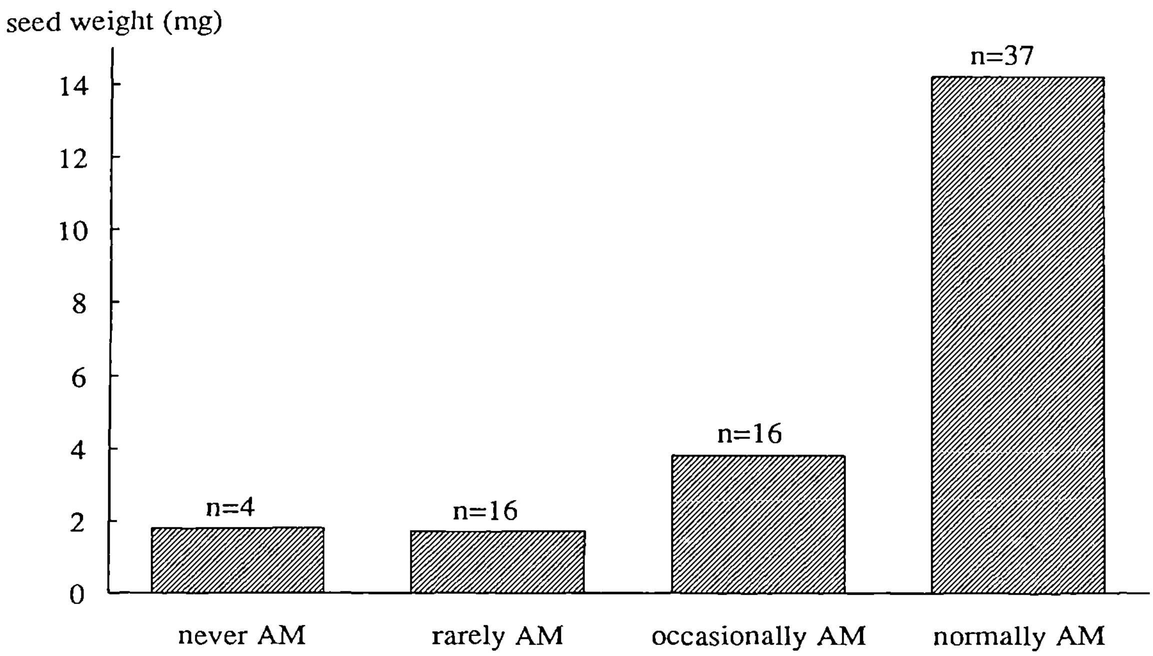

Figure 7.9 - the mean family seed weight of perennial species that are normally, occasionally, rarely and never mycorrhizal.

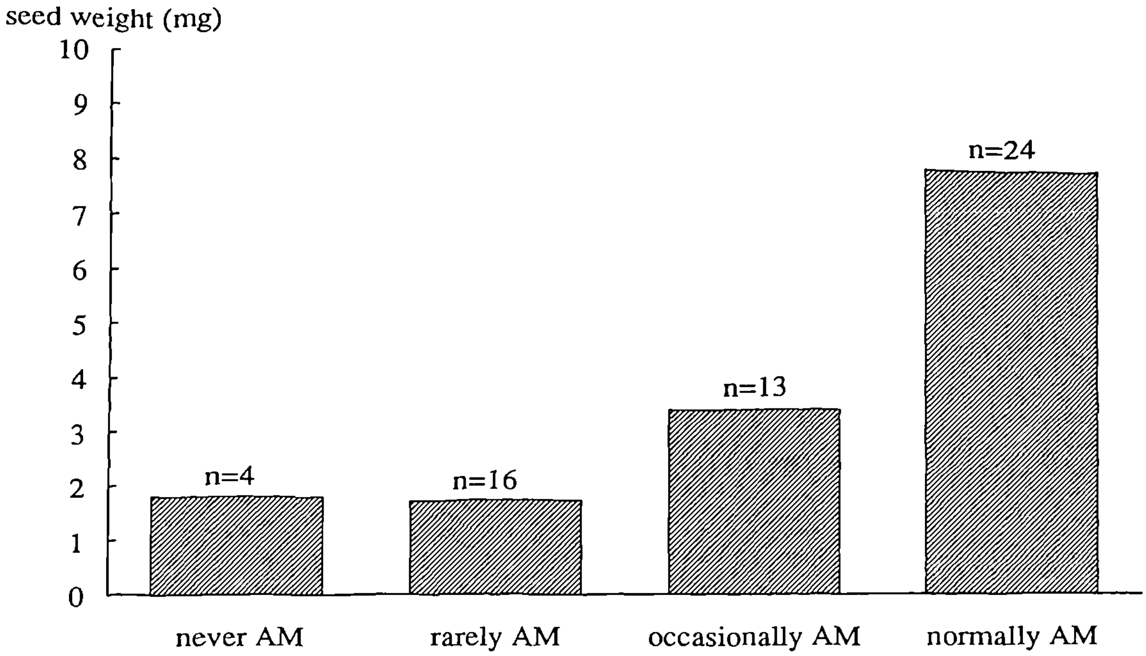

Figure 7.10 - the mean family seed weight of perennial species that are normally, occasionally, rarely and never mycorrhizal. Only families containing >90% non-woody species are included.

Habitat type, however, also has an effect on seed weight. When the analysis is restricted to species occurring in particular habitat types, the mean genus seed weight of perennial species occurring in woodland habitats tends to be greater if species in the genus are normally mycorrhizal than if they are non-, or rarely, mycorrhizal ($F_{3,123} = 6.41$, $P < 0.001$, Figure 7.11). The same is true of perennial species occurring in grassland habitats ($F_{3,178} = 6.48$, $F < 0.001$, Figure 7.12). There is, however, no relationship between mean genus seed weight and mycorrhizal infection of perennial species occurring in coastal and halophytic communities ($F_{3,115} = 2.48$, $P = 0.065$), or bogs and marshes ($F_{3,102} = 1.56$, $P = 0.204$).

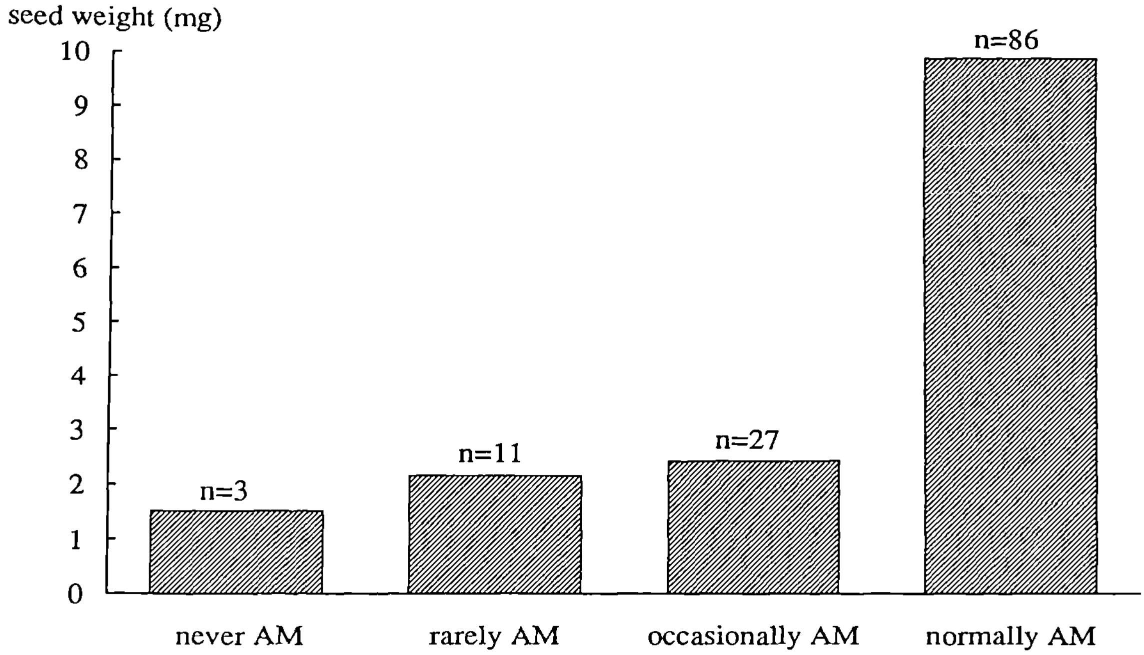

Figure 7.11 - the mean genus seed weight of perennial species occurring in woodland habitats that are normally, occasionally, rarely and never mycorrhizal.

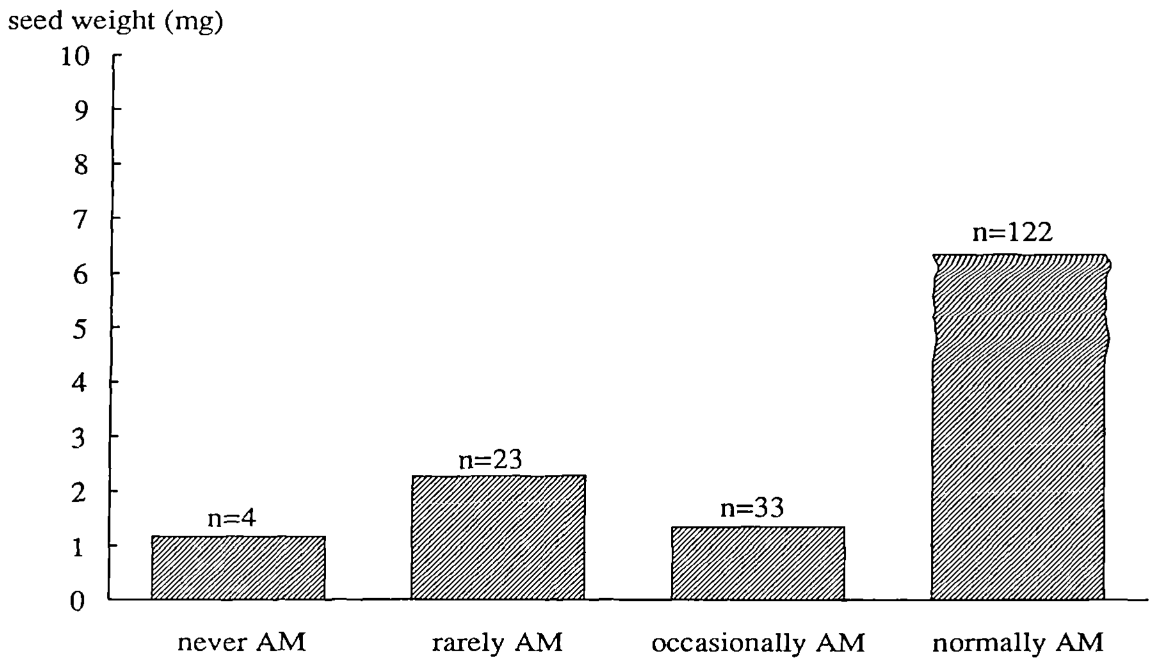

Figure 7.12 - the mean genus seed weight of perennial species occurring in grassland habitats that are normally, occasionally, rarely and never mycorrhizal.

Discussion

The analyses presented here confirm several well-established views: wetland species and annuals are often non-mycorrhizal, whereas thick-rooted species are always mycorrhizal. Others, however, were not confirmed: species with root hairs were not found to be more frequently mycorrhizal than species without root hairs, nor were mycorrhizal species found to occur more in infertile or drier habitats than non-mycorrhizal species. The root hair result is not very surprising as presence/absence of hairs is a very crude measurement; both the length and density of the hairs will determine how effective they are at nutrient uptake. These characters, however, are not fixed and may increase in response to reduced P levels (Foehse and Jungk, 1983), so data on level of mycorrhizal infection, root hair length and density in both multiple individuals of one species and multiple species are required to test this relationship thoroughly.

The lack of a relationship between soil fertility and mycorrhizal infection contrasts with the well-established view that mycorrhizal infection is heaviest on infertile soils (Read *et al.*, 1976). All species, however, show a range of co-adaptations to the fertility of the soil on which they grow; those of infertile soils typically have slower growth rates, smaller stature and longer-lived leaves than similar species of more fertile soils (Grime, 1979). Adaptations such as these mean that species of infertile habitats may have lower nutrient requirements, and thus gain no greater benefit from being mycorrhizal, than species of more fertile habitats. This may also explain why there is no relationship between soil moisture and frequency of AM infection because changes in plant-water relations due to mycorrhizal fungi may be secondary responses due to improved nutrition (Nelson, 1987). Furthermore, many species grow on soils with a wide range in fertility and/or moisture content and mycorrhizas may only be of benefit in some of these conditions.

In contrast to these results it was found that arbuscular mycorrhizal species are able to occupy habitats with a higher maximum pH than infrequently mycorrhizal species (Figure 7.3). This may reflect availability of plant nutrients: P, Fe, Mn, Zn, Cu and Co availabilities are reduced in soils with a high pH (Brady, 1990). Typically mycorrhizal species, therefore, might be at an advantage over rarely mycorrhizal species in such habitats. Alternatively, AM fungi might offer protection against toxicities in high pH soils, possibly to elements such as Mo. Arbuscular mycorrhizal species do not occur in habitats with a lower pH than non-mycorrhizal species but ECM and ericoid mycorrhizas do occur typically in more acid soils (Figure 7.13). Ericoid mycorrhizas help protect the Ericales against toxicity from Fe^{2+} and Al^{3+} ions which occur in solution at low pHs, and both ericoid and ecto mycorrhizas are able to mobilize nitrogen, a growth limiting nutrient in soils of low pH, from organic sources (Read, 1991).

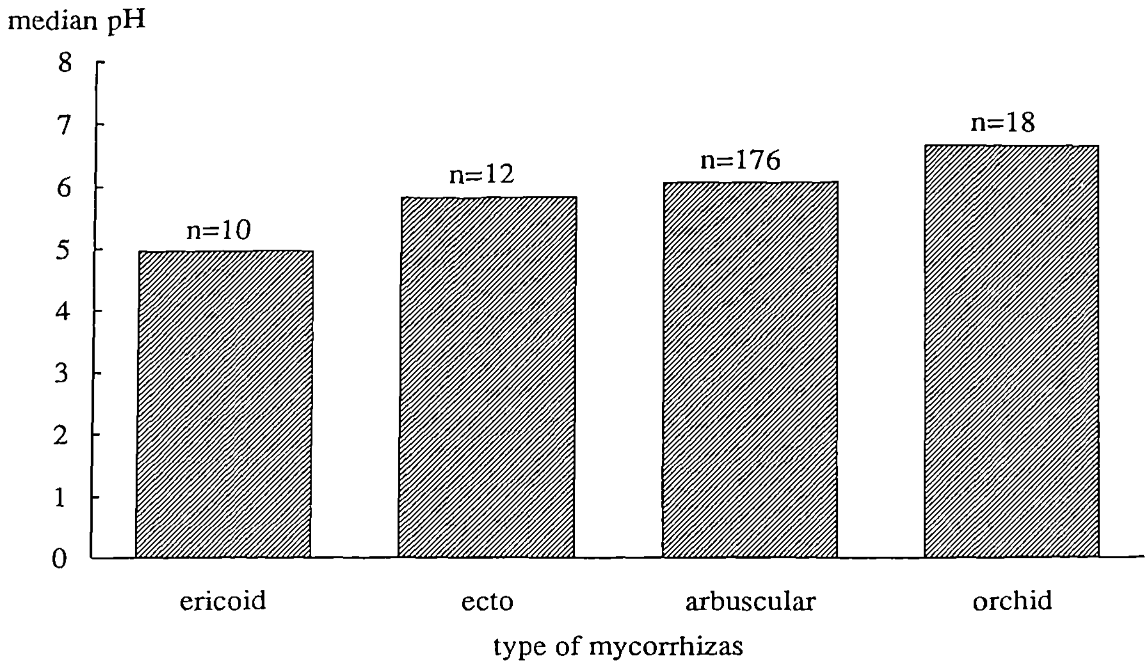

Figure 7.13 - The median pH of species which are associated with different types of mycorrhizas.

Perennial species normally, or occasionally, arbuscular mycorrhizal occur in almost twice as many habitat types as infrequently mycorrhizal perennials (Figure 7.4). This relationship is not due to non-mycorrhizal species being restricted to particular types of habitat, such as aquatic or saline habitats, because it holds when species occurring in these habitats are omitted from the analysis (Figure 7.6) and even common rarely mycorrhizal species occur in fewer habitat types than common mycorrhizal species (Figure 7.5). This is a potentially significant result because it suggests that mycorrhizas increase the niche width available to species. Benefits gained from being mycorrhizal, such as improved nutrition, protection from soil toxins and fungal pathogens (Fitter, 1991), may allow mycorrhizal perennials to out-compete non-mycorrhizal perennials in many situations. Furthermore the permanence of the mycelial network in most soils occupied by perennials means that the mycorrhizal condition will be the norm.

In contrast, annual species occupy the greatest number of habitat types if they are occasionally mycorrhizal (Figure 7.7), although there is no significant difference between the number of habitat types and mycorrhizal infection when abundance is taken into account. Annual species have to become re-infected with mycorrhizas each year and must therefore germinate in a habitat where mycorrhizal inoculum is present in order to become mycorrhizal. The level of mycorrhizal infection in annual species appears to be linked to the type of habitat they occur in. Annuals occurring in mesophilic grassland, dry grassland and heath/scrub habitats which are relatively undisturbed and contain a large proportion of mycorrhizal perennials, tend to be normally mycorrhizal. In contrast, frequently disturbed habitats, such as fallow, waste and cropland contain mainly non-mycorrhizal annuals, probably because disturbance causes both a disruption of the mycelial network in the soil and a scarcity of already infected species. It is not surprising that facultatively mycorrhizal annuals are able to exploit the widest range of habitat types.

Annual species also differ from perennials in that there is no relationship between arbuscular mycorrhizal frequency and seed weight of annuals, whereas mycorrhizal perennials tend to have heavier seeds than rarely mycorrhizal perennials (Figures 7.8 and 7.9). Annuals, because they are reliant on reproduction by seed each year, tend to produce large numbers of light seeds to maximise dispersal, so improved nutrition due to mycorrhizal infection is unlikely to result in the production of heavier seeds.

Allsopp and Stock (1991) predicted that non-mycorrhizal species will produce larger seeds than mycorrhizal species to ensure establishment. They tested this prediction in South African heathland species and found that small-seeded species responded better to arbuscular mycorrhizas than did large-seeded species. However, the different degrees of relatedness between species was ignored and two of the families they included

(Proteaceae and Restionaceae) are both non-mycorrhizal and large-seeded, so data from species in these families may have biased the results. Janos (1980), however, found in the lowland tropics, that obligately arbuscular mycorrhizal species (ie. species which are unable to reach reproductive maturity if uninfected with mycorrhizas) tended to have large seeds. He suggests that large seeds enable these species to establish a large pre-infection root system to help ensure inoculation, and also an adequate photosynthetic capability to support the carbon drain once infected.

Janos's result is supported by the analysis on seed weight and the presence of arbuscular mycorrhizas in British perennials of grass and woodland habitats. Large seed reserves will aid seeds to become established in competitive environments such as grassland and woodland habitats where perennials predominate. The lack of any relationship in species occurring in marsh habitats or in coastal habitats may be because there are other constraints acting on seed size in these habitats, such as dispersal mechanism or germination requirements.

The results presented in this chapter provide evidence that mycorrhizas are beneficial, at least to many perennial species, allowing mycorrhizal species to occupy wider niche ranges than non-mycorrhizal species (higher maximum pHs and a greater number of habitat types). Non-mycorrhizal species, however, persist, with most habitat types containing over 10% of species never or rarely infected with mycorrhizas (Table 7.7). A species can be uninfected, or rarely infected, with mycorrhizas for several reasons: first, because it occupies a habitat in which there is no inoculum, second because the habitat is unsuitable for mycorrhizal fungi, or third because it is able to resist infection by some chemical or physical mechanism. The first two reasons can explain many occurrences of non-mycorrhizal species: there is a high proportion of non-mycorrhizal species in aquatic and wetland habitats (unsuitable for mycorrhizal fungi), in disturbed habitats, rich in annuals, such as sand dunes, urban, waste and cultivated lands, and in habitats lacking soil such as walls and rock ledges. There remains, however, a body of species that are typically non-mycorrhizal and do not occur in any of these habitats (Table 7.8). There is no reason to suspect that these species occur in habitats lacking in inoculum, or unable to support mycorrhizal fungi, so it is most probable that they are able to resist infection in some way. Various mechanisms have been suggested: chemical methods such as production of fungitoxic compounds in root cortical tissues or root exudates or physical methods such as structural alteration of the cell wall or middle lamella to prevent invasion by fungi (Tester *et al.*, 1987). Such resistance may have been a consequence of an evolutionary response to some other selection pressure, for example, invasion of the root by pathogenic fungi. If so, the benefits from such generalised resistances must have outweighed any disadvantages arising from their non-mycorrhizal status. The question still remains as to how both mycorrhizal and non-mycorrhizal species co-exist in most habitats.

Family	Species
Chenopodiaceae	Chenopodium bonus-henricus
Caryophyllaceae	Stellaria nemorum
Caryophyllaceae	Stellaria graminea
Caryophyllaceae	Sagina subulata
Caryophyllaceae	Lychnis viscaria
Papaveraceae	Chelidonium majus
Brassicaceae	Alliaria petiolata
Brassicaceae	Isatis tinctoria
Brassicaceae	Barbarea vulgaris
Brassicaceae	Armoracia rusticana
Brassicaceae	Cardamine bulbifera
Brassicaceae	Arabis petraea
Brassicaceae	Arabis hirsuta
Brassicaceae	Arabis alpina
Saxifragaceae	Saxifraga granulata
Saxifragaceae	Chrysosplenium alternifolium
Rosaceae	Sibbaldia procumbens
Fabaceae	Astragalus glycyphyllos
Fabaceae	Securigera varia
Linaceae	Linum perenne
Clusiaceae	Hypericum calycinum
Clusiaceae	Hypericum hirsutum
Clusiaceae	Hypericum montanum
Clusiaceae	Hypericum humifusum

Table 7.8 - a list of species that are never or rarely infected with arbuscular mycorrhizas. The list does not include annuals or species of wetland habitats.

Family	Species
Boraginaceae	Lithospermum officinale
Lamiaceae	Ballota nigra
Buddlejaceae	Buddleja davidii
Scrophulariaceae	Scrophularia vernalis
Adoxaceae	Adoxa moschatellina
Valerianaceae	Centranthus ruber
Campanulaceae	Campanula trachelium
Asteraceae	Artemisia absinthium
Poaceae	Festuca altissima
Poaceae	Festuca gigantea
Cyperaceae	Carex divulsa
Cyperaceae	Carex remota
Cyperaceae	Carex ovalis
Cyperaceae	Carex pallescens
Cyperaceae	Carex digitata
Cyperaceae	Carex ornithopoda
Cyperaceae	Carex humilis
Cyperaceae	Carex ericetorum
Cyperaceae	Carex montana

Table 7.8 (continued) - a list of species that are never or rarely infected with arbuscular mycorrhizas. The list does not include annuals or species of wetland habitats.

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Chapter 8

Discussion

The Ecological Flora database now holds all the information I was able to extract from published and unpublished sources. Data have been extracted from over 1000 sources including 99 different journal titles, c.120 books and personal communications from 63 different workers. Appendix G (page 222) gives a list of all characteristics and the number of species there are data for. The coverage in the database is very patchy - values for some characteristics are available for most species, while for other characteristics there are data for very few species. For example, there are extensive data for above ground morphological characters such as height and leaf shape and some reproductive characteristics such as breeding system, pollen vector and method of fertilization, but much fewer data for underground morphology such as root diameter and presence/absence of root hairs, or other reproductive characteristics such as percentage inbreeding, pollen/ovule ratio or seed/ovule ratio.

The coverage for different species is equally as patchy. There are, on average, entries for 40 different characteristics for each species in the plant_characteristic table (which holds the bulk of the information) but this varies from *Juncus squarrosus* and *Calluna vulgaris* (both with entries for over 90 distinct characteristics) to *Cymbalaria pallida* and *Vaccinium macrocarpon* (3 entries each). The species for which there is least information tend to be recently naturalised. This is because the species list was amended after the publication of Stace (1991), so a number of additional naturalised species were added quite late on in the project; information on these may have been missed during the literature searching phase. There are also native species for which there is very little information. Most of these belong to genera where there is difficulty distinguishing between species, for example *Hieracium, Dactylorhiza* and *Utricularia.*

There is a correlation between the number of distinct entries in the database and the number of vice-counties (taken from Clapham *et al.*, 1952) species occur in, with more entries for widely distributed species and less for rarer species (Figure 8.1). A nested analysis of covariance (see chapter 5) on the number of distinct entries in the plant_characteristic table and the number of vice-counties a species occurs in, gives an intraclass correlation of 0.59 (833 df) at the species level and 0.49 (420 df) at the genus level. A few rare plants have been well studied, eg. *Pulsatilla vulgaris* (82 records) and *Hypochaeris maculata* (83 records), but many, such as the endemic *Sorbus spp.*, have been very poorly studied. Species occurring in over 90% of all vice-counties, however, have usually been quite well studied: there are less than 40 entries in the database for only 10% of these species.

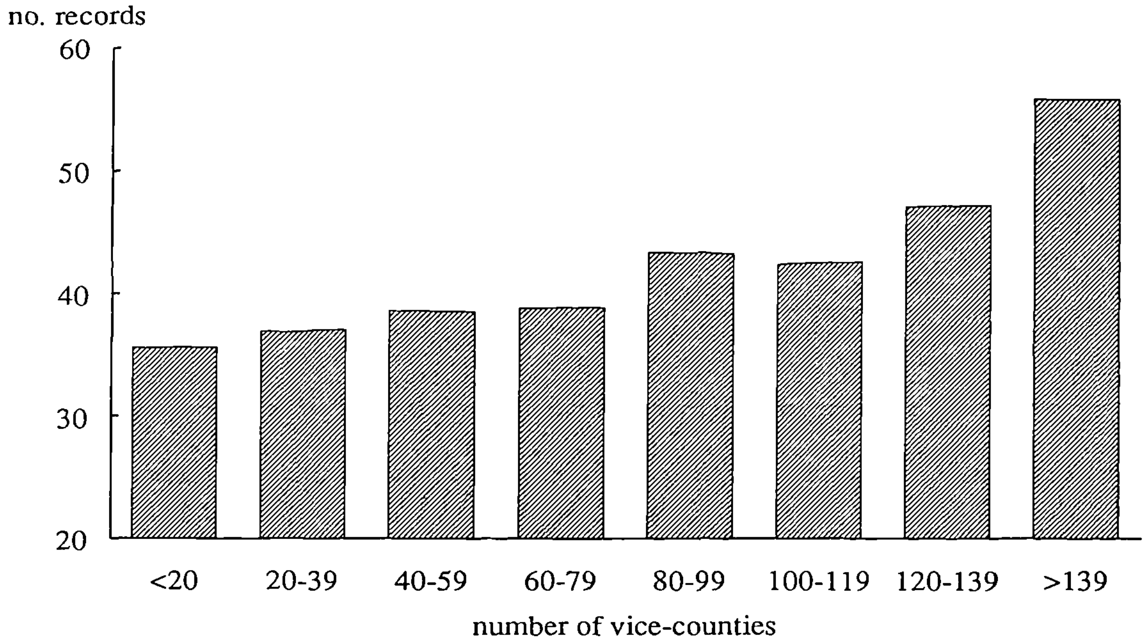

Figure 8.1 - the mean number of records in the plant_characteristic table for species occurring in different numbers of vice-counties.

Comparative analyses in two areas are included in this thesis. Stomatal distribution was chosen, first, because it was an area in which there were data for several hundred species, and second, because modelling approaches had led to various hypotheses regarding the causes of different stomatal distributions. There have not, however, been many other large-scale comparative studies conducted, and none which have accounted for phylogeny in any way. Similarly the frequency of mycorrhizal infection was analysed as, again, there have been few comparative analyses using large data-sets, despite great interest in why some species are mycorrhizal and others non-mycorrhizal and a number of theories as to possible factors (eg. root structure, habitat).

Many other areas, however, could also be studied. Several comparative analyses have investigated relationships between seed weight and variables such as seed number, life form, habitat, germination characteristics and phenology (Salisbury, 1942; Baker, 1972; Silvertown, 1981; Hodgson and Mackey, 1966; Mazer, 1989). Data from the Ecological Flora database could be used to investigate further variables and also to test if significant relationships found by other workers still hold if phylogeny is included in analyses; only the studies by Mazer and Hodgson & Mackey take any account of phylogeny, and that was by including the similarity between species in the same family in their analyses. 2C DNA is another characteristic for which previous comparative analyses (Bennett, 1987; Grime and Mowforth 1982) could be extended using the Ecological Flora database to consider both a larger data-set and more variables. The data could also analysed using multivariate techniques to see which characteristics tend to co-occur. A clustering technique, for example, was used by Grime *et al.* (1989) on the data collated for *Comparative Plant Ecology*, which resulted in 46 significant correlations between characteristics being found. The success of such a technique using the Ecological Flora data, however, may be limited due to the large number of missing values for some of the characteristics.

One advantage of a large data-set including many different types of variables is that it makes it easier to determine whether a relationship found between two variables is simply a product of a relationship between the two variables and a third variable. For example, Mazer (1989) studied seed weight in Indiana dune angiosperms and measured several possible correlates (habitat, life history, phenology and native/alien status), but she stated that other factors that were not measured may also be important (eg. seed predators, abundance of mycorrhizas). She could not include these in her analyses as her data were extracted from Floras or else measured using herbarium specimens. In a large data-set such as that collated for the Ecological Flora project a larger number of variables likely to be important can be analysed.

There are, however, problems associated with using data that have been extracted from a wide variety of sources. First, different workers may have measured quantitative characteristics using different techniques. For example, published 2C DNA amounts for the same species may differ widely depending both on the method that has been used to estimate it and the accuracy of the measurement (Bennett and Smith, 1976). Second, there may be problems in interpreting the published data. For example, the database includes the two characteristics dispersule length and propagule length, but it is not always clear in the literature which of the two has been measured when a worker has recorded a value for seed length. This means there is likely to be larger error associated with data for any one characteristic in the database than if a single worker had made all the measurements using standard conditions and protocols. It is not, however, possible to measure the magnitude of this error, so a choice has to be made between using a large pre-assembled data-set containing an unknown degree of error (although presumably someone knowledgeable about a subject area will be able to pick out any data that seem especially dubious), or spending time and resources on measuring exactly what is required under chosen conditions. It is very unlikely, however, that any major trends and relationships will be masked due to this error component.

Another problem that has to be dealt with in comparative analyses, is that a single species may have more than one value for a particular characteristic. For some characteristics this is because the species fulfils more than one of the possible alternatives, eg. a species may be native in several continents and all of these will be listed in the database. In other cases it may be because different authors have recorded different values for a characteristic eg. average seed weight, (more than one value has been included in the database if authors differ substantially in their measurements of a characteristic). There are various ways of coping with the duplicates and the method chosen would depend on the type of analysis. Some examples of methods follow.

1. Use the number of records for a particular characteristic rather than the values. This would be appropriate for characteristics such as continents where native/introduced, dispersal mechanisms or habitat types, where the number of continents, dispersal mechanisms, or habitat types may be more relevant than the actual values themselves.

2. Use an average value. This is easily calculated for quantitative characteristics, but can also be calculated for ordered qualitative characteristics by giving each alternative value a numerical code. With shade for example, the alternatives could be given the values none=0, light=1, mid=2, deep=3, and then an average shade value for each species calculated.
3. Select one of the values above the others. This method is relevant if there is some doubt over a particular value. The method could be used in a automated way by always selecting the most recent record if it was felt that, for a particular characteristic, the latest measurements of it are likely to be the most reliable. It must, however, be borne in mind that the different values may be caused by natural variation in the characteristic.
4. Use each value of the characteristic individually. This is really a last resort method as in most analyses each species should only appear once. It is perhaps the only way to deal with characteristics such as chromosome number, or pollen diameter of species with dimorphic pollen, where calculating an average or selecting one value over another would not be meaningful. This method, however, would be appropriate in comparative analyses using the analysis of covariance method (chapter 5) as this method allows intraspecific variation to be included.

The first two of these solutions have been used predominantly in this thesis - eg. the number of habitat types (chapter 7) and the mean shade value (chapter 6). It was, however, possible to include all chromosome numbers in the hierarchical analysis of variance of chromosome numbers (chapter 4), whereas species with more than one value for other characteristics were omitted from the respective analyses included in chapter 4.

The importance of taking account of phylogeny in all comparative analyses has been stressed throughout this thesis, although the methods that have been used are not ideal. At a recent conference entitled 'Phylogenetic Approaches to Ecological Problems' at the Natural History Museum, London in September 1992, Jonathan Coddington, of the Smithsonian Institute, Washington, asserted the futility of using taxonomic hierarchies saying they were "arbitrary, biased, misleading, inadequate and frequently wrong." There is no evidence, however, in the literature to suggest that comparative analyses using taxonomic hierarchies to account for phylogeny result in different conclusions from analyses using an actual phylogenetic tree. Harvey and Pagel (1991) tested the relationship between age at maturity and life expectation among mammals using both the higher nodes method (genera means were used) and a method employing the most recent phylogenetic reconstruction. In both tests a highly significant correlation between life expectation at maturity and age at maturity was found. In the absence of both an adequate alternative method, or any actual evidence that the use of taxonomies should be avoided, then it is surely preferable to use taxonomy as an approximation to phylogeny than to ignore phylogeny altogether. Certainly in the case of the angiosperms no better representation of phylogeny exists and a comparison of two different classifications (chapter 4) produced almost identical results.

It is hoped that the Ecological Flora database will become a valuable resource to British plant ecologists. The data it holds will be of use to anyone with an interest in individual species, such as conservationists trying to protect plant species, or agriculturists trying to suppress the growth of weeds, and invaluable to evolutionary biologists or anyone interested in doing comparative studies. It is, also, a good indicator of which species in the British Flora have been well-studied and which have been largely ignored, and of the type of studies/measurements plant ecologists have tended to make. It is perhaps the sort of resource envisaged by Clapham who said in his Presidential Address to the British Ecological Society:

> *"Our main concern as plant ecologists is to know why a plant of this species and not of that, is growing in a given spot; that whatever views we might entertain about the community as organism, or quasi-organism, or as a mere assemblage of individuals, we should show ourselves to be interested primarily in autecological problems, that is in enlarging our knowledge and understanding of the biology of individual species of plants"* Clapham (1956)

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Appendix A

A list of members of the editorial board. These members have helped to oversee the Ecological Flora Project and will participate in the publication of a book based on data from the database.

M J Crawley, Department of Pure and Applied Biology, Silwood Park.

A J Davy, Department of Biological Sciences, University of East Anglia.

L Farrell, English Nature, Peterborough.

A J Gray, Institute of Terrestrial Ecology, Furzebrook Research Station.

P J Grubb, Botany School, Cambridge.

J G Hodgson, Department of Plant and Animal Sciences, University of Sheffield.

M J Hutchings, School of Biological Sciences, University of Sussex.

J A Lee, Department of Environmental Biology, University of Manchester.

G F Peterken, English Nature, Peterborough.

J Proctor, Department of Biological and Molecular Sciences, University of Stirling.

L K Ward, Institute of Terrestrial Ecology, Furzebrook Research Station.

T C E Wells, Institute of Terrestrial Ecology, Monks Wood Experimental Station.

B D Wheeler, Department of Plant and Animal Sciences, University of Sheffield.

Appendix B

A list of the species included in the Ecological Flora database. The number in front of the species name is the code number used to refer to each species in many of the database tables. Nomenclature follows Stace CA, 1991, New Flora of the British Isles, Cambridge University Press.

800150010	Acaena anserinifolia (Forster & G. Forster) Druce
800150019	Acaena novae-zelandiae T. Kirk
950010030	Acer campestre L.
950010010	Acer platanoides L.
950010050	Acer pseudoplatanus L.
2030250010	Aceras anthropophorum (L.) Aiton Fil.
1690580240	Achillea millefolium L.
1690580170	Achillea ptarmica L.
610110110	Aconitum napellus L.
1950010010	Acorus calamus L.
610080010	Actaea spicata L.
610180070	Adonis annua L.
1650010010	Adoxa moschatellina L.
1290260010	Aegopodium podagraria L.
1290350010	Aethusa cynapium L.
1830370010	Agapanthus praecox Willd.
800110020	Agrimonia eupatoria L.
800110030	Agrimonia procera Wallr.
570260010	Agrostemma githago L.
1930870010	Agrostis canina L.
1930870190	Agrostis capillaris L.
1930870250	Agrostis castellana Boiss. & Reuter
1930870030	Agrostis curtisii Kerguelen
1930870200	Agrostis gigantea Roth
1930870220	Agrostis stolonifera L.
1930870020	Agrostis vinealis Schreber
900010010	Ailanthus altissima (Miller) Swingle
1930760020	Aira caryophyllea L.
1930760010	Aira praecox L.
1510010100	Ajuga chamaepitys (L.) Schreber
1510010030	Ajuga pyramidalis L.
1510010040	Ajuga reptans L.
800230510	Alchemilla acutiloba Opiz
800230040	Alchemilla alpina L.
800230570	Alchemilla filicaulis Buser
800230830	Alchemilla glabra Neygenf.
800230210	Alchemilla glaucescens Wallr.
800230690	Alchemilla glomerulans Buser
800230530	Alchemilla gracilis Opiz.
800230580	Alchemilla minima Walters
800230410	Alchemilla monticola Opiz
800230480	Alchemilla subcrenata Buser
800230770	Alchemilla wichurae (Buser) Stefansson
800230540	Alchemilla xanthochlora Rothm.

1700040030	Alisma gramineum Lej.
1700040020	Alisma lanceolatum With.
1700040010	Alisma plantago-aquatica L.
680060010	Alliaria petiolata (Bieb.) Cavara & Grande
1830380710	Allium carinatum L.
1830380280	Allium neapolitanum Cirillo
1830380630	Allium oleraceum L.
1830380230	Allium roseum L.
1830380180	Allium schoenoprasum L.
1830380870	Allium scorodoprasum L.
1830380900	Allium sphaerocephalon L.
1830380350	Allium triquetrum L.
1830380390	Allium ursinum L.
1830380950	Allium vineale L.
340020020	Alnus glutinosa (L.) Gaertner
1930940040	Alopecurus aequalis Sobol.
1930940070	Alopecurus borealis Trin.
1930940050	Alopecurus bulbosus Gouan
1930940030	Alopecurus geniculatus L.
1930940100	Alopecurus myosuroides Hudson
1930940010	Alopecurus pratensis L.
1060070040	Althaea officinalis L.
680500070	Alyssum alyssoides (L.) L.
800300038	Amelanchier lamarckii F.-G. Schroeder
1930900010	Ammophila arenaria (L.) Link
1480260010	Amsinckia lycopsoides (Lehm.) Lehm.
2030280010	Anacamptis pyramidalis (L.) L.C.M. Richard
1350120040	Anagallis arvensis L.
1350120010	Anagallis minima (L.) E.H.L. Krause
1350120030	Anagallis tenella (L.) L.
1480210220	Anchusa arvensis (L.) Bieb.
1320160010	Andromeda polifolia L.
610140010	Anemone nemorosa L.
1290800030	Angelica archangelica L. -
1290800020	Angelica sylvestris L.
1930440010	Anisantha diandra (Roth) Tutin Ex Tzvelev
1930440030	Anisantha sterilis (L.) Nevski
1930440040	Anisantha tectorum (L.) Nevski
1690260010	Antennaria dioica (L.) Gaertner
1690570270	Anthemis arvensis L.
1690570390	Anthemis cotula L.
1930820010	Anthoxanthum odoratum L.
1290130060	Anthriscus caucalis Bieb.
1290130010	Anthriscus sylvestris (L.) Hoffm.
810630150	Anthyllis vulneraria L.
1540100170	Antirrhinum majus L.
1930320020	Apera interrupta (L.) Beauv.
1930320010	Apera spica-venti (L.) Beauv.
800240010	Aphanes arvensis L.
800240020	Aphanes inexspectata Lippert
1290590010	Apium graveolens L.
1290590040	Apium inundatum (L.) Reichenb. Fil.
1290590020	Apium nodiflorum (L.) Lag.
1290590030	Apium repens (Jacq.) Lag.
610220040	Aquilegia vulgaris L.
680080010	Arabidopsis thaliana (L.) Heynh.
680430320	Arabis alpina L.
680430330	Arabis caucasica Schlecht.

680430010	Arabis glabra (L.) Bernh.
680430080	Arabis hirsuta (L.) Scop.
680420020	Arabis petraea (L.) Lam.
680430270	Arabis scabra All.
1320120010	Arbutus unedo L.
1691120020	Arctium lappa L.
1691120040	Arctium minus Bernh.
1320130020	Arctostaphylos alpinus (L.) Sprengel
1320130010	Arctostaphylos uva-ursi (L.) Sprengel
800120010	Aremonia agrimonioides (L.) Dc
570010220	Arenaria ciliata L.
570010210	Arenaria norvegica Gunnerus
570010330	Arenaria serpyllifolia L.
450020060	Aristolochia clematitis L.
1360040010	Armeria maritima (Miller) Willd.
680390010	Armoracia rusticana Gaertner, Meyer & Scherb.
1691510010	Arnoseris minima (L.) Schweigger & Koerte
1930640010	Arrhenatherum elatius (L.) Beauv. Ex J. & C. Presl
1690880040	Artemisia absinthium L.
1690880560	Artemisia campestris L.
1690880260	Artemisia norvegica Fries
1690880020	Artemisia verlotiorum Lamotte
1690880010	Artemisia vulgaris L.
1950060010	Arum italicum Miller
1950060020	Arum maculatum L.
1830480130	Asparagus officinalis L.
1440040310	Asperula cynanchica L.
1690070250	Aster linosyris (L.) Bernh.
1690070040	Aster novae-angliae L.
1690070070	Aster novi-belgii L.
1690070190	Aster tripolium L.
810380380	Astragalus alpinus L.
810380270	Astragalus danicus Retz.
810380430	Astragalus glycyphyllos L.
480060180	Atriplex glabriuscula Edmondston
480060110	Atriplex laciniata L.
480060130	Atriplex littoralis L.
480060190	Atriplex longipes Drejer
480060150	Atriplex patula L.
480070030	Atriplex pedunculata L.
480070010	Atriplex portulacoides L.
480060196	Atriplex praecox Hulphers
480060179	Atriplex prostrata Boucher Ex Dc.
1520030010	Atropa bella-donna L.
1930600100	Avena fatua L.
1930600130	Avena sterilis L.
1700020010	Baldellia ranunculoides (L.) Parl.
1510150070	Ballota nigra L.
680360040	Barbarea intermedia Boreau
680360020	Barbarea stricta Andrz.
680360030	Barbarea verna (Miller) Ascherson
680360010	Barbarea vulgaris R. Br.
1540310010	Bartsia alpina L.
1690050020	Bellis perennis L.
630050010	Berberis vulgaris L.
1290280010	Berula erecta (Hudson) Coville
480020010	Beta vulgaris L.

340010040	Betula nana L.
340010010	Betula pendula Roth
340010020	Betula pubescens Ehrh.
1690410050	Bidens cernua L.
1690410020	Bidens connata Mahl. Ex Willd.
1690410060	Bidens frondosa L.
1690410010	Bidens tripartita L.
1400030010	Blackstonia perfoliata (L.) Hudson
1990020010	Blysmus compressus (L.) Panzer Ex Link
1990020020	Blysmus rufus (Hudson) Link
1930450020	Brachypodium pinnatum (L.) Beauv.
1930450010	Brachypodium sylvaticum (Hudson) Beauv.
680880100	Brassica napus L.
680880190	Brassica nigra (L.) Koch
680880041	Brassica oleracea L.
680880110	Brassica rapa L.
1930350010	Briza media L.
1930350030	Briza minor L.
1930440110	Bromopsis benekenii (Lange) Holub
1930440120	Bromopsis erecta (Hudson) Fourr.
1930440100	Bromopsis ramosa (Hudson) Holub
1930440250	Bromus commutatus Schrader
1930440270	Bromus hordeaceus L.
1930440290	Bromus lepidus Holmberg
1930440210	Bromus pseudosecalinus P.M. Sm.
1930440260	Bromus racemosus L.
1930440220	Bromus secalinus L.
1170030020	Bryonia dioica Jacq.
1530010010	Buddleja davidii Franchet
1990010030	Bulboschoenus maritimus (L.) Palla
680160020	Bunias orientalis L.
1290210010	Bunium bulbocastanum L.
1290560110	Bupleurum baldense Turra
1290560290	Bupleurum falcatum L.
1290560230	Bupleurum tenuissimum L.
1710010010	Butomus umbellatus L.
1020010010	Buxus sempervirens L.
681000010	Cakile maritima Scop.
1930910040	Calamagrostis canescens (Weber) Roth
1930910010	Calamagrostis epigejos (L.) Roth
1930910050	Calamagrostis purpurea (Trin.) Trin.
1930910070	Calamagrostis scotica (Druce) Druce
1930910060	Calamagrostis stricta (Timm) Koeler
1500010110	Callitriche brutia Petagna
1500010100	Callitriche hamulata (Kutz. Ex Koch) Clapham
1500010010	Callitriche hermaphroditica L.
1500010060	Callitriche obtusangula Le Gall
1500010080	Callitriche platycarpa Kutz.
1500010050	Callitriche stagnalis Scop.
1500010020	Callitriche truncata Guss.
1320030010	Calluna vulgaris (L.) Hull
610100010	Caltha palustris L.
1460040040	Calystegia pulchra Brummitt & Hayw.
1460040020	Calystegia sepium (L.) Junger
1460040030	Calystegia silvatica (Kit. Ex Schrader) Griseb.
1460040010	Calystegia soldanella (L.) R. Br.
680660010	Camelina sativa Auct. Ital. Pro Parte

1680010700	Campanula glomerata L.
1680010990	Campanula latifolia L.
1680010150	Campanula patula L.
1680010900	Campanula portenschlagiana Schultes
1680010910	Campanula poscharskyana Degen
1680011010	Campanula rapunculoides L.
1680011410	Campanula rotundifolia L.
1680011000	Campanula trachelium L.
680680010	Capsella bursa-pastoris (L.) Medicus
680410130	Cardamine amara L.
680410010	Cardamine bulbifera (L.) Crantz
680410350	Cardamine flexuosa With.
680410360	Cardamine hirsuta L.
680410330	Cardamine impatiens L.
680410200	Cardamine pratensis L.
1691170120	Carduus crispus L.
1691170050	Carduus nutans L.
1691170440	Carduus tenuiflorus Curtis
1990121680	Carex acuta L.
1990120510	Carex acutiformis Ehrh.
1990120040	Carex appropinquata Schumacher
1990121620	Carex aquatilis Wahlenb.
1990120120	Carex arenaria L.
1990121460	Carex atrata L.
1990121400	Carex atrofusca Schkuhr
1990121630	Carex bigelowii Torrey Ex Schweinitz
1990120870	Carex binervis Sm.
1990121480	Carex buxbaumii Wahlenb.
1990120670	Carex capillaris L.
1990121110	Carex caryophyllea Latourr.
1990120190	Carex chordorrhiza L. Fil.
1990120400	Carex curta Good.
1990120780	Carex depauperata Curtis Ex With.
1990120050	Carex diandra Schrank
1990121060	Carex digitata L.
1990120300	Carex dioica L.
1990120880	Carex distans L.
1990120150	Carex disticha Hudson
1990120200	Carex divisa Hudson
1990120110	Carex divulsa Stokes
1990120290	Carex echinata Murray
1990121640	Carex elata All.
1990120330	Carex elongata L.
1990121190	Carex ericetorum Pollich
1990120920	Carex extensa Good.
1990121170	Carex filiformis L.
1990120720	Carex flacca Schreber
1990120960	Carex flava L.
1990120480	Carex hirta L.
1990120940	Carex hostiana Dc.
1990121090	Carex humilis Leysser
1990120340	Carex lachenalii Schkuhr
1990120840	Carex laevigata Sm.
1990120500	Carex lasiocarpa Ehrh.
1990121420	Carex limosa L.
1990121440	Carex magellanica Lam.
1990120240	Carex maritima Gunnerus
1990121700	Carex microglochin Wahlenb.

1990121210	Carex montana L.
1990120100	Carex muricata L.
1990121670	Carex nigra (L.) Reichard
1990121500	Carex norvegica Retz
1990121070	Carex ornithopoda Willd.
1990120070	Carex otrubae Podp.
1990120270	Carex ovalis Good.
1990121030	Carex pallescens L.
1990120740	Carex panicea L.
1990120030	Carex paniculata L.
1990121710	Carex pauciflora Lightf.
1990120620	Carex pendula Hudson
1990121240	Carex pilulifera L.
1990120540	Carex pseudocyperus L.
1990121780	Carex pulicaris L.
1990120900	Carex punctata Gaudin
1990121430	Carex rariflora (Wahlenb.) Sm.
1990121580	Carex recta Boott
1990120250	Carex remota L.
1990120530	Carex riparia Curtis
1990120550	Carex rostrata Stokes
1990121720	Carex rupestris All.
1990120580	Carex saxatilis L.
1990120090	Carex spicata Hudson
1990120700	Carex strigosa Hudson
1990120640	Carex sylvatica Hudson
1990120750	Carex vaginata Tausch
1990120570	Carex vesicaria L.
1990120989	Carex viridula Michaux
1990120060	Carex *vulpina L.*
1691060060	Carlina vulgaris L.
350010010	Carpinus betulus L.
520030020	*Carpobrotus edulis (L.) N.E. Br.*
1290710030	Carum verticillatum (L.) Koch
360020010	Castanea sativa Miller
1930300010	Catabrosa aquatica (L.) Beauv.
1930120020	Catapodium marinum (L.) C.E. Hubb.
1930120030	Catapodium rigidum (L.) C.E. Hubb.
1691381480	Centaurea calcitrapa L.
1691382200	Centaurea cyanus L.
1691381870	Centaurea nigra L.
1691380490	Centaurea scabiosa L.
1691381570	Centaurea solstitialis L.
1400040020	Centaurium erythraea Rafn
1400040050	Centaurium littorale (D. Turner) Gilmour
1400040110	Centaurium pulchellum (Swartz) Druce
1400040010	Centaurium scilloides (L. Fil.) Samp.
1400040120	Centaurium tenuiflorum (Hoffmanns. & Link) Fritsch
1660050010	Centranthus ruber (L.) Dc.
2030030010	Cephalanthera damasonium (Miller) Druce
2030030020	Cephalanthera longifolia (L.) Fritsch
2030030050	Cephalanthera rubra (L.) L.C.M. Richard
570090260	Cerastium alpinum L.
570090270	Cerastium arcticum Lange
570090220	Cerastium arvense L.
570090430	Cerastium brachypetalum Pers.
570090010	Cerastium cerastoides (L.) Britton
570090490	Cerastium diffusum Pers.

570090380	Cerastium fontanum Baumg.
570090440	Cerastium glomeratum Thuill.
570090271	Cerastium nigrescens (H. Watson) Edmondston Ex H. Watson
570090480	Cerastium pumilum Curtis
570090470	Cerastium semidecandrum L.
660100010	Ceratocapnos claviculata (L.) Liden
1930440370	Ceratochloa carinata (Hook. & Arn.)
600010010	Ceratophyllum demersum L.
600010020	Ceratophyllum submersum L.
1540130100	Chaenorhinum minus (L.) Lange
1290120120	Chaerophyllum temulum L.
1690590010	Chamaemelum nobile (L.) All.
1230050018	Chamerion angustifolium (L.) Holub
660060010	Chelidonium majus L.
480030210	Chenopodium album L.
480030060	Chenopodium bonus-henricus L.
480030110	Chenopodium chenopodioides (L.) Aellen
480030170	Chenopodium ficifolium Sm.
480030090	Chenopodium glaucum L.
480030120	Chenopodium hybridum L.
480030160	Chenopodium murale L.
480030200	Chenopodium opulifolium Schrader Ex Koch & Ziz
480030130	Chenopodium polyspermum L.
480030100	Chenopodium rubrum L.
480030150	Chenopodium urbicum L.
480030140	Chenopodium vulvaria L.
1930020061	Chimonobambusa quadrangularis (Fenzi) Makino
1690660010	Chrysanthemum segetum L.
730030010	Chrysosplenium alternifolium L.
730030030	Chrysosplenium oppositifolium L.
1400010010	Cicendia filiformis (L.) Delarbre
1691700010	Cicerbita alpina (L.) Wallr.
1691700020	Cicerbita macrophylla (Willd.) Wallr.
1691460010	Cichorium intybus L.
1290630010	Cicuta virosa L.
1230020030	Circaea alpina L.
1230020010	Circaea lutetiana L.
1230020020	Circaea x intermedia Ehrh.
1691180440	Cirsium acaule Scop.
1691180600	Cirsium arvense (L.) Scop.
1691180300	Cirsium dissectum (L.) Hill
1691180150	Cirsium eriophorum (L.) Scop.
1691180470	Cirsium heterophyllum (L.) Hill
1691180570	Cirsium palustre (L.) Scop.
1691180320	Cirsium tuberosum (L.) All.
1691180280	Cirsium vulgare (Savi) Ten.
1990080010	Cladium mariscus (L.) Pohl
550020020	Claytonia perfoliata Donn Ex Willd.
550020030	Claytonia sibirica L.
610170020	Clematis vitalba L.
1510260040	Clinopodium acinos (L.) Kuntze
1510270030	Clinopodium calamintha (L.) Stace
1510270020	Clinopodium menthifolium (Host) Stace
1510280010	Clinopodium vulgare L.
680630070	Cochlearia anglica L.
680630010	Cochlearia danica L.
680630036	Cochlearia micacea E.S. Marshall
680630020	Cochlearia officinalis L.

680630038	Cochlearia pyrenaica Dc.
2030180010	Coeloglossum viride (L.) Hartman
680920050	Coincya monensis (L.) Greuter & Burdet
680920040	Coincya wrightii (O. Schulz) Stace
1830160140	Colchicum autumnale L.
810330010	Colutea arborescens L.
1290470010	Conium maculatum L.
1290220010	Conopodium majus (Gouan) Loret
1830420010	Convallaria majalis L.
1460050190	Convolvulus arvensis L.
1690090010	Conyza canadensis (L.) Cronq.
1690090039	Conyza sumatrensis (Retz.) E. Walker
2030310010	Corallorhiza trifida Chatel.
1270010010	Cornus sanguinea L.
1270010050	Cornus suecica L.
680820030	Coronopus didymus (L.) Sm.
680820020	Coronopus squamatus (Forskal) Ascherson
570140010	Corrigiola litoralis L.
350030010	Corylus avellana L.
1930840010	Corynephorus canescens (L.) Beauv.
800310129	Cotoneaster bullatus Bois
800310149	Cotoneaster dielsianus E. Pritzel Ex Diels
800310159	Cotoneaster divaricatus Rehder & E. Wilson
800310139	Cotoneaster franchetii Bois
800310010	Cotoneaster horizontalis Decne
800310030	Cotoneaster integerrimus Medicus
800310110	Cotoneaster integrifolius (Roxb.) Klotz
800310169	Cotoneaster lacteus W. Smith
800310179	Cotoneaster salicifolius Franchet
800310020	Cotoneaster simonsii Baker
800310189	Cotoneaster x watereri Exell
1690830010	Cotula coronopifolia L.
681030010	Crambe maritima L.
720010020	Crassula aquatica (L.) Schoenl.
720010049	Crassula helmsii (T. Kirk) Cockayne
720010010	Crassula tillaea Lester-Garland
800340050	Crataegus laevigata (Poiret) Dc.
800340140	Crataegus monogyna Jacq.
1691780220	Crepis biennis L.
1691780600	Crepis capillaris (L.) Wallr.
1691780510	Crepis foetida L.
1691780130	Crepis mollis (Jacq.) Ascherson
1691780040	Crepis paludosa (L.) Moench
1691780430	Crepis praemorsa (L.) F. Walther
1691780660	Crepis vesicaria L.
1290290010	Crithmum maritimum L.
1880110019	Crocosmia paniculata (Klatt) Goldblatt
1880090020	Crocosmia x crocosmiiflora (Lemoine Ex Burb. & Dean) N.E. Br
1880070340	Crocus nudiflorus Sm.
1880070070	Crocus vernus (L.) Hill
1440070010	Cruciata laevipes Opiz
570290010	Cucubalus baccifer L.
1460010120	Cuscuta epithymum (L.) L.
1460010060	Cuscuta europaea L.
1540150010	Cymbalaria muralis Gaertner, Meyer & Scherb.
1540150050	Cymbalaria pallida (Ten.) Wettst.
1931260010	Cynodon dactylon (L.) Pers.
1480340040	Cynoglossum germanicum Jacq.

1480340010	Cynoglossum officinale L.
1930280010	Cynosurus cristatus L.
1930280020	Cynosurus echinatus L.
1990070110	Cyperus fuscus L.
1990070030	Cyperus longus L.
2030010010	Cypripedium calceolus L.
810110018	Cytisus nigricans L.
810120200	*Cytisus scoparius (L.) Link*
1320110010	Daboecia cantabrica (Hudson) C. Koch
1930260010	Dactylis glomerata L.
2030190120	Dactylorhiza fuchsii (Druce) Soo
2030190040	Dactylorhiza incarnata (L.) Soo
2030190081	Dactylorhiza lapponica (Hartman) Soo
2030190110	Dactylorhiza maculata (L.) Soo
2030190060	Dactylorhiza majalis (Reichenb.) P.F. Hunt & Summerhayes
2030190061	Dactylorhiza praetermissa (Druce) Soo
2030190062	Dactylorhiza purpurella (Stephenson & T.A. Stephenson) Soo
2030190080	Dactylorhiza traunsteineri (Sauter) Soo
1700060010	Damasonium alisma Miller
1931110010	Danthonia decumbens (L.) Dc.
1070010040	Daphne laureola L.
1070010010	Daphne mezereum L.
1520140010	Datura stramonium L.
1291080080	Daucus carota L.
1930740010	Deschampsia cespitosa (L.) P. Beauv.
1930740050	Deschampsia flexuosa (L.) Trin.
1930740030	Deschampsia setacea (Hudson) Hackel
680040010	Descurainia sophia (L.) Webb Ex Prantl
570360890	Dianthus armeria L.
570360630	Dianthus deltoides L.
570360280	Dianthus gratianopolitanus Vill.
570360520	Dianthus plumarius L.
1300010010	Diapensia lapponica L.
1540170020	Digitalis purpurea L.
1931370040	Digitaria ischaemum (Schreber) Muhl.
680870090	Diplotaxis muralis (L.) Dc.
680870040	Diplotaxis tenuifolia (L.) Dc.
1670030030	Dipsacus fullonum L.
1670030070	Dipsacus pilosus L.
1690940080	Doronicum pardalianches L.
680590010	Draba aizoides L.
680590380	Draba incana L.
680590390	Draba muralis L.
680590280	Draba norvegica Gunnerus
520080019	Drosanthemum floribundum (Haw.) Schwantes
710020030	Drosera intermedia Hayne
710020020	Drosera longifolia L.
710020010	Drosera rotundifolia L.
800160010	Dryas octopetala L.
1480140110	Echium plantagineum L.
1480140100	Echium vulgare L.
1720040010	Egeria densa Planchon
1150020070	Elatine hexandra (Lapierre) Dc.
1150020020	Elatine hydropiper L.
1990040030	Eleocharis acicularis (L.) Roemer & Schultes
1990040100	Eleocharis austriaca Hayek

1990040140	Eleocharis multicaulis Sm.
1990040080	Eleocharis palustris L.
1990040020	Eleocharis parvula (Roemer & Schultes) Link Ex Bluff, Nees & Schauer
1990040010	Eleocharis quinqueflora (F.X. Hartmann) O. Schwarz
1990040120	Eleocharis uniglumis (Link) Schultes
1990010168	Eleogiton fluitans (L.) Link
1720050020	Elodea callitrichoides (Rich.) Caspary
1720050010	Elodea canadensis Michx
1720050030	Elodea nuttallii (Planchon) St John
1930480050	Elymus caninus (L.) L.
1930480170	Elytrigia atherica (Link) Kerguelen Ex Carreras Mart.
1930480220	Elytrigia juncea (L.) Nevski
1930480180	Elytrigia repens (L.) Desv. Ex Nevski
1330020010	Empetrum nigrum L.
1230050230	Epilobium alsinifolium Vill.
1230050200	Epilobium anagallidifolium Lam.
1230050279	Epilobium brunnescens (Cockayne) Raven & Engelhorn
1230050268	Epilobium ciliatum Rafin.
1230050050	Epilobium hirsutum L.
1230050100	Epilobium lanceolatum Sebastiani & Mauri
1230050080	Epilobium montanum L.
1230050130	Epilobium obscurum Schreber
1230050150	Epilobium palustre L.
1230050060	Epilobium parviflorum Schreber
1230050140	Epilobium roseum Schreber
1230050120	Epilobium tetragonum L.
2030020080	Epipactis atrorubens (Hoffm.) Besser
2030020020	Epipactis helleborine (L.) Crantz
2030020030	Epipactis leptochila (Godfery) Godfery
2030020010	Epipactis palustris (L.) Crantz
2030020070	Epipactis phyllanthes G.E. Sm.
2030020060	Epipactis purpurata Sm.
2030020109	Epipactis youngiana A. Richards & A. Porter
2030050010	Epipogium aphyllum Swartz
610020010	Eranthis hyemalis (L.) Salisb.
1320010020	Erica ciliaris L.
1320010060	Erica cinerea L.
1320010150	Erica erigena R. Ross
1320010100	Erica lusitanica Rudolphi
1320010030	Erica mackaiana Bab.
1320010040	Erica tetralix L.
1320010110	Erica vagans L.
1690080030	Erigeron acer L.
1690080110	Erigeron borealis (Vierh.) Simmons
1690080189	Erigeron glaucus Ker Gawler
1690080020	Erigeron karvinskianus Dc.
1540180010	Erinus alpinus L.
1920010010	Eriocaulon aquaticum (Hill) Druce
1990030010	Eriophorum angustifolium Honckeny
1990030030	Eriophorum gracile Koch Ex Roth
1990030020	Eriophorum latifolium Hoppe
1990030040	Eriophorum vaginatum L.
830020250	Erodium cicutarium (L.) L'Her.
830020251	Erodium lebelii Jordan
830020080	Erodium maritimum (L.) L'Her.
830020260	Erodium moschatum (L.) L'Herit.
680600013	Erophila glabrescens Jordan
680600011	Erophila majuscula Jordan

680600010	Erophila verna (L.) Chevall.
1290070240	Eryngium campestre L.
1290070080	Eryngium maritimum L.
680180380	Erysimum cheiranthoides L.
680260010	Erysimum cheiri (L.) Crantz
760010020	Escallonia macrantha Hook. & Arn.
1000010010	Euonymus europaeus L.
1690010010	Eupatorium cannabinum L.
870071030	Euphorbia amygdaloides L.
870071010	Euphorbia cyparissias L.
870070340	Euphorbia dulcis L.
870070990	Euphorbia esula L.
870070640	Euphorbia exigua L.
870070550	Euphorbia helioscopia L.
870070220	Euphorbia hyberna L.
870070940	Euphorbia paralias L.
870070020	Euphorbia peplis L.
870070670	Euphorbia peplus L.
870070500	Euphorbia platyphyllos L.
870070720	Euphorbia portlandica L.
870070510	Euphorbia serrulata Thuill.
1540290050	Euphrasia anglica Pugsley
1540290110	Euphrasia arctica Lange Ex Rostrup
1540290270	Euphrasia cambrica Pugsley
1540290320	Euphrasia campbelliae Pugsley
1540290160	Euphrasia confusa Pugsley
1540290260	Euphrasia foulaensis Townsend Ex Wettst.
1540290250	Euphrasia frigida Pugsley
1540290346	Euphrasia heslop-harrisonii Pugsley
1540290290	Euphrasia marshallii Pugsley
1540290330	Euphrasia micrantha Reichenb.
1540290130	Euphrasia nemorosa (Pers.) Wallr.
1540290000	Euphrasia officinalis agg.
1540290280	Euphrasia ostenfeldii (Pugsley) Yeo
1540290150	Euphrasia pseudokerneri Pugsley
1540290040	Euphrasia rivularis Pugsley
1540290030	Euphrasia rostkoviana Hayne
1540290300	Euphrasia rotundifolia Pugsley
1540290410	Euphrasia salisburgensis Funck
1540290340	Euphrasia scottica Wettst.
1540290120	Euphrasia tetraquetra (Breb.) Arrondeau
360010010	Fagus sylvatica L.
470030018	Fallopia convolvulus (L.) A. Lovemoq.
470030028	Fallopia dumetorum (L.) J. Holub
470040010	Fallopia japonica (Houtt.) Ronse Decraene
470040020	Fallopia sachalinensis (F. Schmidt Ex Maxim.) Ronse Decraene
1930040060	Festuca altissima All.
1930040100	Festuca arundinacea Schreber
1930041680	Festuca brevipila Tracey
1930041020	Festuca filiformis Pourret
1930040080	Festuca gigantea (L.) Vill.
1930040560	Festuca heterophylla Lam.
1930040730	Festuca juncifolia St-Amans
1930041140	Festuca lemanii Bast.
1930041160	Festuca longifolia Thuill.
1930041030	Festuca ovina L.
1930040090	Festuca pratensis Hudson

1930040660	Festuca rubra L.
1930041500	Festuca vivipara (L.) Sm.
1690130050	Filago lutescens Jordan
1690150038	Filago minima (Sm.) Pers
1690130070	Filago pyramidata L.
1690130010	Filago vulgaris Lam.
800060020	Filipendula ulmaria (L.) Maxim.
800060010	Filipendula vulgaris Moench
1290400010	Foeniculum vulgare Miller
800210010	Fragaria vesca L.
1030040010	Frangula alnus Miller
1140010050	Frankenia laevis L.
1390040030	Fraxinus excelsior L.
1830230010	Fritillaria meleagris L.
1230010010	Fuchsia magellanica Lam.
660120140	Fumaria bastardii Boreau
660120090	Fumaria capreolata L.
660120230	Fumaria densiflora Dc.
660120170	Fumaria muralis Sonder Ex Koch
660120020	Fumaria occidentalis Pugsley
660120250	Fumaria officinalis L.
660120330	Fumaria parviflora Lam.
660120110	Fumaria purpurea Pugsley
660120150	Fumaria reuteri Boiss
660120310	Fumaria vaillantii Loisel.
1830200210	Gagea bohemica (Zauschner) Schultes & Schultes Fil.
1830200030	Gagea lutea (L.) Ker-Gawler
1850040010	Galanthus nivalis L.
1510100040	Galeopsis angustifolia Ehrh. Ex Hoffm.
1510100090	Galeopsis bifida Boenn.
1510100010	Galeopsis segetum Necker
1510100060	Galeopsis speciosa Miller
1510100080	Galeopsis tetrahit L.
1690520010	Galinsoga parviflora Cav.
1690520020	Galinsoga quadriradiata Ruiz Lopez & Pavon
1440051320	Galium aparine L.
1440050060	Galium boreale L.
1440050150	Galium constrictum Chaub.
1440050380	Galium mollugo L.
1440050100	Galium odoratum (L.) Scop.
1440050160	Galium palustre L.
1440051390	Galium parisiense L.
1440051030	Galium pumilum Murray
1440051180	Galium saxatile L.
1440051090	Galium sterneri Ehrend.
1440050130	Galium uliginosum L.
1440050260	Galium verum L.
1440050270	Galium x pomeranicum Retz.
1930880010	Gastridium ventricosum (Gouan) Schinz & Thell.
1930660010	Gaudinia fragilis (L.) Beauv.
1320150010	Gaultheria mucronata (L.F.) Hook. & Arn.
1320140010	Gaultheria shallon Pursh
810160280	Genista anglica L.
810160160	Genista pilosa L.
810160010	Genista tinctoria L.
1400050280	Gentiana nivalis L.
1400050070	Gentiana pneumonanthe L.

1400050220	Gentiana verna L.
1400060100	Gentianella amarella (L.) Borner
1400060120	Gentianella anglica (Pugsley) E.F. Warburg
1400060080	Gentianella campestris (L.) Borner
1400060030	Gentianella ciliata (L.)Borkh
1400060190	Gentianella germanica (Willd.) E.F. Warburg
1400060110	Gentianella uliginosa (Willd.) Borner
830010340	Geranium columbinum L.
830010350	Geranium dissectum L.
830010090	Geranium endressii Gay
830010360	Geranium lucidum L.
830010310	Geranium molle L.
830010150	Geranium phaeum L.
830010070	Geranium pratense L.
830010380	Geranium purpureum Vill.
830010330	Geranium pusillum L.
830010290	Geranium pyrenaicum Burm. Fil.
830010370	Geranium robertianum L.
830010300	Geranium rotundifolium L.
830010060	Geranium sanguineum L.
830010080	Geranium sylvaticum L.
830010100	Geranium versicolor L.
800170050	Geum rivale L.
800170090	Geum urbanum L.
1880100010	Gladiolus illyricus Koch
660050010	Glaucium flavum Crantz
1350110010	Glaux maritima L.
1510190010	Glechoma hederacea L.
1930420070	Glyceria declinata Breb.
1930420080	Glyceria fluitans (L.) R. Br.
1930420030	Glyceria maxima (Hartman) Holmberg
1930420100	Glyceria notata Chevall.
1930420110	Glyceria x pedicellata Townsend
1690230010	Gnaphalium luteoalbum L.-
1690230028	Gnaphalium norvegicum Gunn.
1690230068	Gnaphalium supinum L.
1690200018	Gnaphalium sylvaticum L.
1690220018	Gnaphalium uliginosum L.
2030090010	Goodyera repens (L.) R. Br.
1770020010	Groenlandia densa (L.) Fourr.
1240010010	Gunnera tinctoria L.
2030150010	Gymnadenia conopsea (L.) R. Br.
2030350010	Hammarbya paludosa (L.) O. Kuntze
1540220010	Hebe salicifolia (G. Forster) Pennell
1540220049	Hebe x franciscana (Eastw.) Souster
1280010010	Hedera helix L.
1120040110	Helianthemum apenninum (L.) Miller
1120040230	Helianthemum canum (L.) Baumg.
1120040090	Helianthemum nummularium (L.) Miller
1930620160	Helictotrichon pratense (L.) Besser Ex Pilger
1930620010	Helictotrichon pubescens (Hudson) Pilger
610010010	Helleborus foetidus L.
610010050	Helleborus viridis L.
1290920090	Heracleum mantegazzianum Sommier & Levier
1290920050	Heracleum sphondylium L.
2030110010	Herminium monorchis (L.) R. Br.
570160060	Herniaria ciliolata Melderis

570160050	Herniaria glabra L.
680200030	Hesperis matronalis L.
1691810776	Hieracium acuminatum Jordan
1691811066	Hieracium anglicum Fries
1691810876	Hieracium argenteum Fries
1691810816	Hieracium britannicum F.J. Hanb.
1691810747	Hieracium caesiomurorum Lindeb.
1691810890	Hieracium caledonicum F.J. Hanb.
1691811596	Hieracium calenduliflorum Backh.
1691812367	Hieracium dewarii Syme
1691810796	Hieracium diaphanoides Lindeb.
1691810790	Hieracium diaphanum Fries
1691810656	Hieracium grandidens Dahlst.
1691811597	Hieracium hanburyi Pugsley
1691811589	Hieracium holosericeum Backh.
1691811566	Hieracium iricum Fries
1691810806	Hieracium lasiophyllum Koch
1691812436	Hieracium latobrigorum (Zahn) Roffey
1691810730	Hieracium maculatum Sm.
1691812366	Hieracium mirandum P.D. Sell & C. West
1691810696	Hieracium oistophyllum Pugsley
1691810746	Hieracium orcadense W.R. Linton
1691810657	Hieracium pellucidum Laest.
1691812260	Hieracium prenanthoides Vill.
1691812437	Hieracium reticulatum (Lindeb.) Lindeb.
1691812546	Hieracium rigens Jordan
1691810807	Hieracium schmidtii Tausch
1691811630	Hieracium senescens Backh.
1691812586	Hieracium sparsifolium Lindeb.
1691812570	Hieracium umbellatum L.
1691812547	Hieracium vagum Jordan
1691810710	Hieracium vulgatum Fries
1930810020	Hierochloe odorata (L.) Beauv.
2030260010	Himantoglossum hircinum (L.) Sprengel
810660030	Hippocrepis comosa L.
1080010010	Hippophae rhamnoides L.
1260010010	Hippuris vulgaris L.
1930830010	Holcus lanatus L.
1930830040	Holcus mollis L.
570080010	Holosteum umbellatum L.
1690910010	Homogyne alpina (L.) Cass.
570040010	Honckenya peploides (L.) Ehrh.
1930580010	Hordelymus europaeus (L.) C.O. Harz
1930570110	Hordeum jubatum L.
1930570050	Hordeum marinum Hudson
1930570040	Hordeum murinum L.
1930570100	Hordeum secalinum Schreber
680710010	Hornungia petraea (L.) Reichenb.
1350060010	Hottonia palustris L.
390010010	Humulus lupulus L.
1830280010	Hyacinthoides non-scripta (L.) Chouard Ex Rothm.
1720060010	Hydrilla verticillata (L. Fil.) Royle
1720010010	Hydrocharis morsus-ranae L.
1290010030	Hydrocotyle vulgaris L.
1520050010	Hyoscyamus niger L.
1090010050	Hypericum androsaemum L.
1090010010	Hypericum calycinum L.
1090010600	Hypericum canadense L.

1090010320	Hypericum elodes L.
1090010140	Hypericum hirsutum L.
1090010500	Hypericum humifusum L.
1090010480	Hypericum linarifolium (Vahl) Rouy & Fouc.
1090010530	Hypericum maculatum Crantz
1090010230	Hypericum montanum L.
1090010540	Hypericum perforatum L.
1090010160	Hypericum pulchrum L.
1090010510	Hypericum tetrapterum Fries
1090010520	Hypericum undulatum Schousboe Ex Willd.
1691580080	Hypochaeris glabra L.
1691580050	Hypochaeris maculata L.
1691580090	Hypochaeris radicata L.
680770100	Iberis amara L.
990010010	Ilex aquifolium L.
570170010	Illecebrum verticillatum L.
980010020	Impatiens capensis Meerb.
980010040	Impatiens glandulifera Royle
980010010	Impatiens noli-tangere L.
980010030	Impatiens parviflora Dc.
1690310160	Inula conyzae (Griess.) Meikle
1690310190	Inula crithmoides L.
1690310040	Inula salicina L.
1880030050	Iris foetidissima L.
1880030060	Iris pseudacorus L.
1880030070	Iris versicolor L.
680140070	Isatis tinctoria L.
1990010148	Isolepis cernua (Vahl) Roemer & Schultes
1990010128	Isolepis setacea (L.) R. Br.
1680130010	Jasione montana L.
1890010420	Juncus acutiflorus Ehrh. Ex Hoffm.
1890010030	Juncus acutus L.
1890010468	Juncus alpinoarticulatus Chaix
1890010288	Juncus ambiguus Guss.
1890010490	Juncus articulatus L.
1890010090	Juncus balticus Willd.
1890010500	Juncus biglumis L.
1890010260	Juncus bufonius L.
1890010390	Juncus bulbosus L.
1890010310	Juncus capitatus Weigel
1890010530	Juncus castaneus Sm.
1890010170	Juncus compressus Jacq.
1890010130	Juncus conglomeratus L.
1890010120	Juncus effusus L.
1890010070	Juncus filiformis L.
1890010240	Juncus foliosus Desf.
1890010180	Juncus gerardi Loisel.
1890010110	Juncus inflexus L.
1890010010	Juncus maritimus Lam.
1890010300	Juncus planifolius R. Br.
1890010350	Juncus pygmaeus L.C.M. Richard
1890010160	Juncus squarrosus L.
1890010340	Juncus subnodulosus Schrank
1890010190	Juncus tenuis Willd.
1890010150	Juncus trifidus L.
1890010510	Juncus triglumis L.

280050020	Juniperus communis L.
1320080010	Kalmia angustifolia L.
1320080020	Kalmia polifolia Wangenh.
1540160030	Kickxia elatine (L.) Dumort.
1540160040	Kickxia spuria (L.) Dumort.
1670060290	Knautia arvensis (L.) Coulter
1990110020	Kobresia simpliciuscula (Wahlenb.) Mackenzie
1930680050	Koeleria macrantha (Ledeb.) Schultes
1930680010	Koeleria vallesiana (Honckeny) Gaudin
470010010	Koenigia islandica L.
810080010	Laburnum anagyroides Medicus
1691690110	Lactuca saligna L.
1691690090	Lactuca serriola L.
1691690130	Lactuca virosa L.
1720070010	Lagarosiphon major (Ridley) Moss
1930730010	Lagurus ovatus L.
1510120010	Lamiastrum galeobdolon (L.) Ehrend. & Polatschek
1510110070	Lamium album L.
1510110130	Lamium amplexicaule L.
1510110120	Lamium confertum Fries
1510110110	Lamium hybridum Vill.
1510110100	*Lamium purpureum L.*
520070029	Lampranthus *falciformis* (Haw.) N.E. Br.
1691770010	Lapsana communis L.
1540390010	Lathraea squamaria L.
810510540	Lathyrus aphaca L.
810510040	Lathyrus japonicus Willd.
810510190	Lathyrus linifolius (Reichard) Baessler
810510030	Lathyrus niger (L.) Bernh.
810510530	Lathyrus nissolia L.
810510230	Lathyrus palustris L.
810510200	Lathyrus pratensis L.
810510320	Lathyrus sylvestris L.
1060060030	Lavatera arborea L.
1060060010	Lavatera cretica L.
1320060010	Ledum palustre L.
1931300010	Leersia oryzoides (L.) Swartz
1680050030	Legousia hybrida (L.) Delarbre
1960020020	Lemna gibba L.
1960020030	Lemna minor L.
1960020069	Lemna minuta Kunth
1960020010	Lemna trisulca L.
1691590040	Leontodon autumnalis L.
1691590120	Leontodon hispidus L.
1691590250	Leontodon saxatilis Lam.
680800010	Lepidium campestre (L.) R. Br.
680810010	Lepidium draba L.
680800030	Lepidium heterophyllum Bentham
680800190	Lepidium latifolium L.
680800130	Lepidium ruderale L.
1690810010	Leucanthemum vulgare Lam.
1850030080	Leucojum aestivum L.
1850030070	Leucojum vernum L.
1640050010	Leycesteria formosa Wall.
1930470010	Leymus arenarius (L.) Hochst.
1290770070	Ligusticum scoticum L.

1390060010	Ligustrum vulgare L.
1830240010	Lilium martagon L.
1830240040	Lilium pyrenaicum Gouan
1360050190	Limonium bellidifolium (Gouan) Dumort.
1360050679	Limonium binervosum agg.
1360050180	Limonium humile Miller
1360050170	Limonium vulgare Miller
1540040010	Limosella aquatica L.
1540040030	Limosella australis R. Br.
1540140151	Linaria dalmatica (L.) Miller
1540140270	Linaria purpurea (L.) Miller
1540140300	Linaria repens (L.) Miller
1540140520	Linaria supina (L.) Chaz.
1540140340	Linaria vulgaris Miller
1640040010	Linnaea borealis L.
860010230	Linum bienne Miller
860010360	Linum catharticum L.
860010180	Linum perenne L.
2030330010	Liparis loeselii (L.) L.C.M. Richard
2030070020	Listera cordata (L.) R. Br.
2030070010	Listera ovata (L.) R. Br.
1480060048	Lithospermum arvense L.
1480040010	Lithospermum officinale L.
1480060018	Lithospermum purpurocaerulea L.
1630020010	Littorella uniflora (L.) Ascherson
1830190010	Lloydia serotina (L.) Reichenb.
1680140020	Lobelia dortmanna L.
1680140010	Lobelia urens L.
680560010	Lobularia maritima (L.) Desv.
1320090010	Loiseleuria procumbens (L.) Desv.
1930050020	Lolium multiflorum Lam.
1930050010	Lolium perenne L.
1640060150	Lonicera caprifolium L.
1640060170	Lonicera periclymenum L. -
1640060080	Lonicera xylosteum L.
810590160	Lotus angustissimus L.
810590070	Lotus corniculatus L.
810590010	Lotus glaber Miller
810590090	Lotus pedunculatus Cav.
810590150	Lotus subbiflorus Lag.
1230040030	Ludwigia palustris (L.) Elliott
810280100	Lupinus arboreus Sims
810280080	Lupinus nootkatensis Donn Ex Sims
810280090	Lupinus polyphyllus Lindley
1700030010	Luronium natans (L.) Rafin.
1890020050	Luzula arcuata Swartz
1890020010	Luzula campestris (L.) Dc.
1890020300	Luzula forsteri (Sm.) Dc.
1890020220	Luzula luzuloides (Lam.) Dandy & Wilmott
1890020020	Luzula multiflora (Retz.) Lej.
1890020030	Luzula pallidula Kirschner
1890020290	Luzula pilosa (L.) Willd.
1890020080	Luzula spicata (L.) Dc.
1890020150	Luzula sylvatica (Hudson) Gaudin
570250070	Lychnis alpina (L.) G. Don Fil.
570250040	Lychnis flos-cuculi L.
570250060	Lychnis viscaria L.
1520020040	Lycium barbarum L.

1510340010	Lycopus europaeus L.
1950030010	Lysichiton americanus Hulten & St John
1350080010	Lysimachia nemorum L.
1350080060	Lysimachia nummularia L.
1350080070	Lysimachia punctata L.
1350080040	Lysimachia terrestris (L.) Britton, Sterns & Poggenb.
1350080130	Lysimachia thyrsiflora L.
1350080030	Lysimachia vulgaris L.
1190010070	Lythrum hyssopifolia L.
1190010120	Lythrum portula (L.) D.A. Webb
1190010010	Lythrum salicaria L.
630060010	Mahonia aquifolium (Pursh) Nutt.
1830430010	Maianthemum bifolium (L.) F.W. Schmidt
800270060	Malus domestica Borkh.
800270030	Malus sylvestris Miller
1060050060	Malva moschata L.
1060050120	Malva neglecta Wallr.
1060050080	Malva sylvestris L.
1510050100	Marrubium vulgare L.
1690610038	Matricaria discoidea Dc.
1690610018	Matricaria recutita L.
680290010	Matthiola incana (L.) R. Br.
680290020	Matthiola sinuata (L.) R. Br.
660020010	Meconopsis cambrica (L.) Vig.
810560300	Medicago arabica (L.) Hudson
810560010	Medicago lupulina L.
810560370	Medicago minima (L.) Bartal.
810560310	Medicago polymorpha L.
810560050	Medicago sativa L.
1540270030	Melampyrum arvense L.
1540270010	Melampyrum cristatum L.
1540270240	Melampyrum pratense L.
1540270210	Melampyrum sylvaticum L.
1930400010	Melica nutans L.
1930400030	Melica uniflora Retz.
810540030	Melilotus albus Medicus
810540020	Melilotus altissima Thuill
810540050	Melilotus officinalis (L.) Pallas
1510070010	Melittis melissophyllum L.
1510350090	Mentha aquatica L.
1510350050	Mentha arvensis L.
1510350020	Mentha pulegium L.
1510350140	Mentha spicata L.
1510350110	Mentha suaveolens Ehrh.
1510350060	Mentha x verticillata L.
1510350116	Mentha x villosa nm alopecuroides (Hull) Briq.
1410010010	Menyanthes trifoliata L.
870040040	Mercurialis annua L.
870040060	Mercurialis perennis L.
1480250010	Mertensia maritima (L.) S.F. Gray
800330010	Mespilus germanica L.
1290450010	Meum athamanticum Jacq.
1930340010	Mibora minima (L.) Desv.
1931020010	Milium effusum L.
1540050010	Mimulus guttatus Dc.
1540050020	Mimulus luteus L.
1540050030	Mimulus moschatus Douglas Ex Lindley

570030050	Minuartia hybrida (Vill.) Schischkin
570030260	Minuartia recurva (All.) Schinz & Thell.
570020430	Minuartia rubella (Wahlenb.) Hiern
570030560	Minuartia sedoides (L.) Hiern
570030440	Minuartia stricta (Swartz) Hiern
570030420	Minuartia verna (L.) Hiern
1540120010	Misopates orontium (L.) Rafin
570020010	Moehringia trinervia (L.) Clairv.
570100010	Moenchia erecta (L.) Gaertner, Meyer & Scherb.
1931130010	Molinia caerulea (L.) Moench
1310030010	Moneses uniflora (L.) A. Gray
1310050010	Monotropa hypopitys L.
550020010	Montia fontana L.
470100029	Muehlenbeckia complexa (Cunn.) Meissner
1830360110	Muscari neglectum Guss. Ex Ten.
1691720010	Mycelis muralis (L.) Dumort.
1480290210	Myosotis alpestris F.W. Schmidt
1480290060	Myosotis arvensis (L.) Hill
1480290090	Myosotis discolor Pers.
1480290350	Myosotis laxa Lehm.
1480290070	Myosotis ramosissima Rochel
1480290360	Myosotis scorpioides L.
1480290300	Myosotis secunda A. Murray
1480290320	Myosotis stolonifera (Dc.) Gay Ex Leresche & Levier
1480290170	Myosotis sylvatica Hoffm.
570110010	Myosoton aquaticum L.
610210010	Myosurus minimus L.
320010010	Myrica gale L.
1240020030	Myriophyllum alterniflorum Dc.
1240020020	Myriophyllum spicatum L.
1240020010	Myriophyllum verticillatum L.
1290150010	Myrrhis odorata (L.) Scop.
1820010020	Najas flexilis (Willd.) Rostk. & W.L.E. Schmidt
1820010010	Najas marina L.
1850060220	Narcissus pseudonarcissus L.
1931160010	Nardus stricta L.
1830020010	Narthecium ossifragum (L.) Hudson
2030220010	Neotinea maculata (Desf.) Stearn
2030060010	Neottia nidus-avis (L.) L.C.M. Richard
1510180130	Nepeta cataria L.
580020010	Nuphar lutea (L.) Sibth. & Sm.
580020020	Nuphar pumila (Timm) Dc.
580010010	Nymphaea alba L.
1410020010	Nymphoides peltata (S.G. Gmelin) O. Kuntze
1540300150	Odontites vernus (Bellardi) Dumort.
1290330130	Oenanthe aquatica (L.) Poiret
1290330110	Oenanthe crocata L.
1290330030	Oenanthe fistulosa L.
1290330120	Oenanthe fluviatilis (Bab.) Coleman
1290330090	Oenanthe lachenalii C.C. Gmelin
1290330040	Oenanthe pimpinelloides L.
1290330070	Oenanthe silaifolia Bieb.
1230030010	Oenothera biennis L.
1230030099	Oenothera cambrica Rostanski
1230030050	Oenothera glazioviana Micheli Ex C. Martius
1230030120	Oenothera stricta Ledeb. Ex Link

810710210	Onobrychis viciifolia Scop.
810530120	Ononis reclinata L.
810530330	Ononis repens L.
810530320	Ononis spinosa L.
1691250020	Onopordum acanthium L.
2030300190	Ophrys apifera Hudson
2030300160	Ophrys fuciflora (F.W. Schmidt) Moench
2030300010	Ophrys insectifera L.
2030300060	Ophrys sphegodes Miller
2030240180	Orchis mascula (L.) L.
2030240120	Orchis militaris L.
2030240030	Orchis morio L.
2030240140	Orchis purpurea Hudson
2030240110	Orchis simia Lam.
2030240070	Orchis ustulata L.
1510320030	Origanum vulgare L.
1830250240	Ornithogalum angustifolium Boreau
1830250300	Ornithogalum nutans L.
1830250010	Ornithogalum pyrenaicum L.
810640030	Ornithopus perpusillus L.
810640040	Ornithopus pinnatus (Miller) Druce
1600020140	Orobanche alba Stephan Ex Willd.
1600020260	Orobanche artemisiae-campestris Vaucher Ex Gaudin
1600020310	Orobanche caryophyllacea Sm.
1600020340	Orobanche elatior Sutton
1600020290	Orobanche hederae Duby
1600020270	Orobanche minor Sm.
1600020090	Orobanche purpurea Jacq.
1600020410	Orobanche rapum-genistae Thuill.
1600020150	Orobanche reticulata Wallr.
1310020010	Orthilia secunda (L.) House
1690650010	Otanthus maritimus (L.) Hoffmanns. & Link
820010060	Oxalis acetosella L.
820010050	Oxalis articulata Savigny
820010010	Oxalis corniculata L.
820010100	Oxalis pes-caprae L.
820010040	Oxalis stricta L.
470060010	Oxyria digyna (L.) Hill
810390110	Oxytropis campestris (L.) Dc.
810390180	Oxytropis halleri Bunge Ex Koch
660010100	Papaver argemone L.
660010030	Papaver dubium L.
660010130	Papaver hybridum L.
660010020	Papaver rhoeas L.
1930970010	Parapholis incurva (L.) C.E. Hubbard
1930970040	Parapholis strigosa (Dumort.) C.E. Hubbard
1540320010	Parentucellia viscosa (L.) Caruel
400030028	Parietaria judaica Sensu Boiss., Non L.
1830470010	Paris quadrifolia L.
740010010	Parnassia palustris L.
1290910010	Pastinaca sativa L.
1540340180	Pedicularis palustris L.
1540340200	Pedicularis sylvatica L.
1480220010	Pentaglottis sempervirens (L.) Tausch Ex L.H. Bailey
470020270	Persicaria amphibia (L.) Gray
470020320	Persicaria bistorta (L.) Samp.
470020230	Persicaria hydropiper (L.) Spach

470020260	Persicaria lapathifolia (L.) Gray
470020220	Persicaria laxiflora (Weihe) Opiz
470020250	Persicaria maculosa Gray
470020200	Persicaria minor (Hudson) Opiz
470020340	Persicaria vivipara (L.) Ronse Decraene
470020360	Persicaria wallichii Greuter & Burdet
1690900010	Petasites albus (L.) Gaertner
1690900080	Petasites fragrans (Vill.) C. Presl
1690900020	Petasites hybridus (L.) P. Gaertner, B. Meyer & Scherb.
1690900090	Petasites japonicius (Siebold & Zucc.) Maxim.
570350140	Petrorhagia nanteuilii (Burnat) P. Ball & Heyw.
570350130	Petrorhagia prolifera Auct. Eur. Occid. Pro Parte
1290600020	Petroselinum segetum (L.) Koch
1290900010	Peucedanum officinale L.
1290900260	Peucedanum ostruthium (L.) Koch
1290900240	Peucedanum palustre (L.) Moench
1930990010	Phalaris arundinacea L.
1930990070	Phalaris paradoxa L.
1930930020	Phleum alpinum L.
1930930080	Phleum arenarium L.
1930930011	Phleum bertolonii Dc.
1930930040	Phleum phleoides (L.) Karsten
1930930010	Phleum pratense L.
1830130016	Phormium cookianum Le Jolis
1830130010	Phormium tenax J.R. & G. Forster
1931090010	Phragmites australis (Cav.) Trin. Ex Steudel
1320100010	Phyllodoce caerulea (L.) Bab.
1290460010	Physospermum cornubiense (L.) Dc.
1680090130	Phyteuma orbiculare L.
1680090010	Phyteuma spicatum L.
1691600020	Picris echioides L.
1691600090	Picris hieracioides L.
1691810480	Pilosella aurantiaca (L.) F. Schultz & Schultz-Bip
1691810140	Pilosella flagellaris (Willd.) Sell & C. West
1691810100	Pilosella officinarum F. Schultz & Schultz-Bip
1691810070	Pilosella peleteriana (Merat) F. Schultz & Schultz-Bip.
1290250130	Pimpinella major (L.) Hudson
1290250160	Pimpinella saxifraga L.
1610010110	Pinguicula grandiflora Lam.
1610010010	Pinguicula lusitanica L.
1610010120	Pinguicula vulgaris L.
260070020	Pinus pinaster Aiton
260070070	Pinus sylvestris L.
780010010	Pittosporum crassifolium Putterlick
1630010040	Plantago coronopus L.
1630010200	Plantago lanceolata L.
1630010010	Plantago major L.
1630010080	Plantago maritima L.
1630010120	Plantago media L.
2030130010	Platanthera bifolia (L.) L.C.M. Richard
2030130020	Platanthera chlorantha (Custer) Reichenb.
1930160430	Poa alpina L.
1930160090	Poa angustifolia L.
1930160010	Poa annua L.
1930160350	Poa bulbosa L.
1930160150	Poa chaixii Vill.
1930160230	Poa compressa L.
1930160190	Poa flexuosa Sm.

1930160260	Poa glauca Vahl
1930160070	Poa humilis Ehrh. Ex Hoffm.
1930160020	Poa infirma Kunth
1930160270	Poa nemoralis L.
1930160250	Poa palustris L.
1930160080	Poa pratensis L.
1930160040	Poa trivialis L.
1930160470	Poa x jemtlandica (Almq.) K. Richter
1450010010	Polemonium caeruleum L.
570190010	Polycarpon tetraphyllum (L.) L.
920010320	Polygala amarella Crantz
920010300	Polygala calcarea F.W. Schultz
920010260	Polygala serpyllifolia J.A.C. Hose
920010240	Polygala vulgaris L.
1830460040	Polygonatum multiflorum (L.) All.
1830460050	Polygonatum odoratum (Miller) Druce
1830460010	Polygonatum verticillatum (L.) All.
470020180	Polygonum arenastrum Boreau
470020150	Polygonum aviculare L.
470020160	Polygonum boreale (Lange) Small
470020050	Polygonum maritimum L.
470020130	Polygonum oxyspermum C.A. Meyer & Bunge Ex Ledeb.
470020170	Polygonum rurivagum Jordan Ex Boreau
1930890010	Polypogon monspeliensis (L.) Desf.
310020010	Populus alba L.
310020129	Populus candicans Aiton
310020080	Populus nigra L.
310020040	Populus tremula L.
310020020	Populus x canescens (Aiton) Sm.
550010010	Portulaca oleracea L.
1770010180	Potamogeton acutifolius Link
1770010070	Potamogeton alpinus Balbis
1770010150	Potamogeton berchtoldii Fieber
1770010030	Potamogeton coloratus Hornem.
1770010170	Potamogeton compressus L.
1770010190	Potamogeton crispus L.
1770010100	Potamogeton epihydrus Rafin.
1770010200	Potamogeton filiformis Pers.
1770010110	Potamogeton friesii Rupr.
1770010060	Potamogeton gramineus L.
1770010050	Potamogeton lucens L.
1770010010	Potamogeton natans L.
1770010040	Potamogeton nodosus Poiret
1770010140	Potamogeton obtusifolius Mert. & Koch
1770010220	Potamogeton pectinatus L.
1770010090	Potamogeton perfoliatus L.
1770010020	Potamogeton polygonifolius Pourret
1770010080	Potamogeton praelongus Wulfen
1770010130	Potamogeton pusillus L.
1770010120	Potamogeton rutilus Wolfg.
1770010160	Potamogeton trichoides Cham. & Schlecht.
800190530	Potentilla anglica Laicharding
800190040	Potentilla anserina L.
800190180	Potentilla argentea L.
800190430	Potentilla crantzii (Crantz) G. Beck Ex Fritsch
800190520	Potentilla erecta (L.) Rauschel
800190010	Potentilla fruticosa L.
800190490	Potentilla neumanniana Reichb.

800190240	Potentilla norvegica L.
800190030	Potentilla palustris (L.) Scop.
800190280	Potentilla recta L. Sensu Lato
800190540	Potentilla reptans L.
800190050	Potentilla rupestris L.
800190720	Potentilla sterilis (L.) Garcke
1350010020	Primula elatior (L.) Hill
1350010040	Primula farinosa L.
1350010080	Primula scotica Hooker
1350010030	Primula veris L.
1350010010	Primula vulgaris Hudson
1510210010	Prunella laciniata (L.) L.
1510210030	Prunella vulgaris L.
800350140	Prunus avium L.
800350100	Prunus domestica L.
800350210	Prunus laurocerasus L.
800350160	Prunus mahaleb L.
800350170	Prunus padus L.
800350180	Prunus serotina Ehrh.
800350080	Prunus spinosa L.
660100030	Pseudofumaria lutea (L.) Borkh.
2030160010	Pseudorchis albida (L.) A. & D. Love
1930020038	Pseudosasa japonica (Siebolk & Zucc. Ex Steudel) Makino Ex Naki
1930210010	Puccinellia distans (Jacq.) Wahlenb.
1930210030	Puccinellia fasciculata (Torrey) E.P. Bicknell
1930210040	Puccinellia maritima (Hudson) Parl.
1930210120	Puccinellia rupestris (With.) Fernald & Weatherby
1690330020	Pulicaria dysenterica (L.) Bernh.
1690330030	Pulicaria vulgaris Gaertner
1480150110	Pulmonaria longifolia (Bast.) Boreau
1480150020	Pulmonaria officinalis L.
610160070	Pulsatilla vulgaris Miller
1310010020	Pyrola media Swartz
1310010010	Pyrola minor L.
1310010040	Pyrola rotundifolia L.
800260010	Pyrus cordata Desv.
360030090	Quercus cerris L.
360030120	Quercus petraea (Mattuschka) Liebl.
360030150	Quercus robur L.
860020010	Radiola linoides Roth
610190080	Ranunculus acris L.
610191270	Ranunculus aquatilis L.
610190380	Ranunculus arvensis L.
610190680	Ranunculus auricomus L.
610191230	Ranunculus baudotii Godron
610190310	Ranunculus bulbosus L.
610191300	Ranunculus circinatus Sibth.
610190830	Ranunculus ficaria L.
610191010	Ranunculus flammula L.
610191310	Ranunculus fluitans Lam.
610191190	Ranunculus hederaceus L.
610191040	Ranunculus lingua L.
610190360	Ranunculus muricatus L.
610191200	Ranunculus omiophyllus Ten.
610191050	Ranunculus ophioglossifolius Vill.
610190390	Ranunculus parviflorus L.

610191240	Ranunculus peltatus Schrank
610191258	Ranunculus penicillatus (Dumort.) Bab.
610190060	Ranunculus repens L.
610191020	Ranunculus reptans L.
610190320	Ranunculus sardous Crantz
610190780	Ranunculus sceleratus L.
610191280	Ranunculus trichophyllus Chaix
610191210	Ranunculus tripartitus Dc.
681080010	Raphanus raphanistrum L.
681010010	Rapistrum perenne (L.) All.
681010020	Rapistrum rugosum (L.) Bergeret
690010170	Reseda lutea L.
690010010	Reseda luteola L.
1030030080	Rhamnus catharticus L.
1540350230	Rhinanthus angustifolius C.C. Gmelin
1540350020	Rhinanthus minor L.
1320050010	Rhododendron luteum Sweet
1320050020	Rhododendron ponticum L.
1990090010	Rhynchospora alba (L.) Vahl
1990090020	Rhynchospora fusca (L.) Aiton Fil.
770010080	Ribes alpinum L.
770010050	Ribes nigrum L.
770010020	Ribes rubrum Sensu Jancz. Et Auct. Recent. Nonnull., Non L.
770010030	Ribes spicatum Robson
770010060	Ribes uva-crispa L.
810300010	Robinia pseudoacacia L.
1880080080	Romulea columnae Sebastiani & Mauri
680380020	Rorippa amphibia (L.) Besser
680380010	Rorippa austriaca (Crantz) Besser
680380050	Rorippa islandica (Oeder) Borbas
680400020	Rorippa microphylla (Boenn.) N. Hylander Ex A. & D. Love
680400010	Rorippa nasturtium-aquaticum (L.) Hayek
680380058	Rorippa palustris (L.) Besser
680380040	Rorippa sylvestris (L.) Besser
800100410	Rosa agrestis Savi
800100020	Rosa arvensis Hudson
800100258	Rosa caesia Smith
800100180	Rosa canina L.
800100420	Rosa micrantha Borrer Ex Sm.
800100360	Rosa mollis Sm.
800100280	Rosa obtusifolia Desv.
800100050	Rosa pimpinellifolia L.
800100390	Rosa rubiginosa L.
800100340	Rosa sherardii Davies
800100150	Rosa stylosa Desv.
800100320	Rosa tomentosa Sm.
1440090010	Rubia peregrina L.
800090750	Rubus caesius L.
800090010	Rubus chamaemorus L.
800090000	Rubus fruticosus Sens. Lat.
800090070	Rubus idaeus L.
800090090	Rubus phoenicolasius Maxim.
800090040	Rubus saxatilis L.
800090060	Rubus spectabilis Pursh
1690440020	Rudbeckia laciniata L.
470080140	Rumex acetosa L.
470080030	Rumex acetosella L. Sensu Stricto, Emend. A. Love
470080240	Rumex aquaticus L.

470080380	Rumex conglomeratus Murray
470080360	Rumex crispus L.
470080220	Rumex frutescens Thouars
470080320	Rumex hydrolapathum Hudson
470080300	Rumex longifolius Dc.
470080460	Rumex maritimus L.
470080430	Rumex obtusifolius L.
470080450	Rumex palustris Sm.
470080350	Rumex patientia L.
470080230	Rumex pseudoalpinus Hoefft
470080420	Rumex pulcher L.
470080400	Rumex rupestris Le Gall
470080390	Rumex sanguineus L.
1780010020	Ruppia cirrhosa (Petagna) Grande
1780010010	Ruppia maritima L.
1830490010	Ruscus aculeatus L.
570120120	Sagina apetala Ard.
570120116	Sagina boydii Buchanan-White
570120130	Sagina maritima G. Don Fil.
570120020	Sagina nivalis (Linblad) Fries
570120010	Sagina nodosa (L.) Fenzl
570120110	Sagina procumbens L.
570120090	Sagina saginoides (L.) Karsten
570120060	Sagina subulata (Swartz) C. Presl
570120100	Sagina x normaniana Lagerh.
1700010010	Sagittaria sagittifolia L.
480210070	Salicornia dolichostachya Moss
480210010	Salicornia europaea L.
480210060	Salicornia fragilis P.W. Ball & Tutin
480210050	Salicornia nitens P.W. Ball & Tutin
480210016	Salicornia obscura P.W. Ball & Tutin
480210040	Salicornia pusilla J. Woods
480210020	Salicornia ramosissima J. Woods
310010030	Salix alba L.
310010520	Salix arbuscula L.
310010410	Salix aurita L.
310010420	Salix caprea L.
310010390	Salix cinerea L.
310010408	Salix cinerea oleifolia Macreight
310010020	Salix fragilis L.
310010070	Salix herbacea L.
310010230	Salix lanata L.
310010590	Salix lapponum L.
310010298	Salix myrsinifolia Salisb.
310010130	Salix myrsinites L.
310010010	Salix pentandra L.
310010250	Salix phylicifolia L.
310010630	Salix purpurea L.
310010490	Salix repens L.
310010060	Salix reticulata L.
310010050	Salix triandra L.
310010600	Salix viminalis L.
480250080	Salsola kali L.
1510400210	Salvia pratensis L.
1510400290	Salvia verbenaca L.
1640010010	Sambucus ebulus L.
1640010020	Sambucus nigra L.

1640010030	Sambucus racemosa L.
1350130010	Samolus valerandi L.
800130060	Sanguisorba minor Scop.
800130010	Sanguisorba officinalis L.
1290040010	Sanicula europaea L.
570330090	Saponaria officinalis L.
480200018	Sarcocornia perennis (Miller) A.J. Scott
700010010	Sarracenia purpurea L.
1930010010	Sasa palmata (Burbidge) Camus
1691140070	Saussurea alpina (L.) Dc.
730010350	Saxifraga aizoides L.
730010920	Saxifraga cernua L.
730010680	Saxifraga cespitosa L.
730010860	Saxifraga granulata L.
730010220	Saxifraga hirculus L.
730010100	Saxifraga hirsuta L.
730010710	Saxifraga hypnoides L.
730010020	Saxifraga nivalis L.
730010930	Saxifraga oppositifolia L.
730010910	Saxifraga rivularis L.
730010700	Saxifraga rosacea Moench.
730010080	Saxifraga spathularis Brot.
730010050	Saxifraga stellaris L.
730010270	Saxifraga tridactylites L.
730010130	Saxifraga x urbium D.A. Webb
1670080380	Scabiosa columbaria L.
1290140030	Scandix pecten-veneris L.
1730010010	Scheuchzeria palustris L.
1990010040	Schoenoplectus lacustris (L.) Palla
1990010088	Schoenoplectus triqueter (L.) Palla
1990100020	Schoenus ferrugineus L.
1990100010	Schoenus nigricans L.
1830270150	Scilla autumnalis L.
1830270060	Scilla verna Hudson
1990010118	Scirpoides holoschoenus (L.) Sojak
1990010010	Scirpus sylvaticus L.
570130020	Scleranthus annuus L.
570130010	Scleranthus perennis L.
1691610090	Scorzonera humilis L.
1540080190	Scrophularia auriculata L.
1540080180	Scrophularia nodosa L.
1540080080	Scrophularia scorodonia L.
1540080200	Scrophularia umbrosa Dumort.
1540080010	Scrophularia vernalis L.
1510030040	Scutellaria altissima L.
1510030110	Scutellaria galericulata L.
1510030130	Scutellaria minor Hudson
810650060	Securigera varia (L.) Lassen
720100140	Sedum acre L.
720100250	Sedum album L.
720100290	Sedum anglicum Hudson
720100110	Sedum forsteranum Sm.
720110018	Sedum rosea (L.) Scop.
720100100	Sedum rupestre L.
720100160	Sedum sexangulare L.
720100070	Sedum spurium Bieb.
720100040	Sedum telephium L.
720100390	Sedum villosum L.

1290760010	Selinum carvifolia (L.) L.
1690960450	Senecio aquaticus Hill
1690960500	Senecio cambrensis Rosser
1690960041	Senecio cineraria Dc.
1690960460	Senecio erucifolius L.
1690960160	Senecio fluviatilis Wallr.
1690960440	Senecio jacobaea L.
1690960171	Senecio ovatus (P. Gaertner, Meyer & Scherb.) Willd.
1690960210	Senecio paludosus L.
1690960300	Senecio smithii Dc.
1690960480	Senecio squalidus L.
1690960620	Senecio sylvaticus L.
1690960600	Senecio vernalis Waldst. & Kit.
1690960640	Senecio viscosus L.
1690960650	Senecio vulgaris L.
1690880090	Seriphidium maritimum (L.) Polj.
1691300010	Serratula tinctoria L.
1290320010	Seseli libanotis (L.) Koch
1930360220	Sesleria caerulea (L.) Ard.
1440020010	Sherardia arvensis L.
800200010	Sibbaldia procumbens L.
1540240010	Sibthorpia europaea L.
1290430010	Silaum silaus (L.) Schinz & Thell.
570280900	Silene acaulis (L.) Jacq.
570281640	Silene conica L.
570281060	Silene dioica (L.) Clairv.
570281530	Silene gallica L.
570280010	Silene italica (L.) Pers.
570281050	Silene latifolia Poiret
570281040	Silene noctiflora L.
570280150	Silene nutans L.
570280440	Silene otites (L.) Wibel
570280561	Silene uniflora Roth
570280560	Silene vulgaris (Moench) Garcke
1830100010	Simethis planifolia (L.) Gren.
680890030	Sinapis alba L.
680890010	Sinapis arvensis L.
1930020018	Sinarundinaria anceps (Mitf.) C.S. Chao & Renvoize
1290620010	Sison amomum L.
680010120	Sisymbrium altissimum L.
680010030	Sisymbrium irio L.
680010040	Sisymbrium loeselii L.
680010180	Sisymbrium officinale (L.) Scop.
680010130	Sisymbrium orientale L.
1880010010	Sisyrinchium bermudiana L.
1290270010	Sium latifolium L.
1290200010	Smyrnium olusatrum L.
1520100070	Solanum dulcamara L.
1520100010	Solanum nigrum L.
1520100040	Solanum sarachoides Sendtner
1520100050	Solanum triflorum Nutt.
400040010	Soleirolia soleirolii (Req.) Dandy
1690030030	Solidago canadensis L.
1690030040	Solidago gigantea Aiton
1690030010	Solidago virgaurea L.
1691660070	Sonchus arvensis L.
1691660010	Sonchus asper (L.) Hill
1691660030	Sonchus oleraceus L.

1691660050	Sonchus palustris L.
800280109	Sorbus anglica Hedl.
800280050	Sorbus aria (L.) Crantz
800280096	Sorbus arranensis Hedl.
800280020	Sorbus aucuparia L.
800280166	Sorbus bristoliensis Wilmott
800280167	Sorbus devoniensis E.F. Warburg
800280066	Sorbus eminens E.F. Warburg
800280069	Sorbus hibernica E.F. Warburg
800280150	Sorbus intermedia (Ehrh.) Pers.
800280067	Sorbus lancastriensis E.F. Warburg
800280056	Sorbus leptophylla E.F. Warburg
800280097	Sorbus leyana Wilmott
800280090	Sorbus minima (A. Ley) Hedl.
800280065	Sorbus porrigentiformis E.F. Warburg
800280136	Sorbus pseudofennica E.F. Warburg
800280070	Sorbus rupicola (Syme) Hedl.
800280168	Sorbus subcuneata Wilmott
800280030	Sorbus torminalis (L.) Crantz
800280076	Sorbus vexans E.F. Warburg
800280068	Sorbus wilmottiana E.F. Warburg
1970010040	Sparganium angustifolium Michx
1970010030	Sparganium emersum Rehmann
1970010010	Sparganium erectum L.
1970010060	Sparganium natans L.
1931270040	Spartina alterniflora Loisel.
1931270030	Spartina anglica C.E. Hubbard
1931270010	Spartina maritima (Curtis) Fernald
1931270020	Spartina x townsendii H. & J. Groves
570220010	Spergula arvensis L.
570230150	Spergularia bocconii (Scheele) Ascherson & Graebner
570230070	Spergularia marina (L.) Griseb.
570230068	Spergularia media (L.) C. Presl
570230120	Spergularia rubra (L.) J. & C. Presl
570230030	Spergularia rupicola Lebel Ex Le Jolis
800030020	Spiraea alba Duroi
800030010	Spiraea salicifolia L.
2030080030	Spiranthes romanzoffiana Cham.
2030080010	Spiranthes spiralis (L.) Chevall.
1960030018	Spirodela polyrhiza (L.) Schleiden
1510160070	Stachys alpina L.
1510160560	Stachys arvensis (L.) L.
1510160080	Stachys germanica L.
1510160030	Stachys officinalis (L.) Trevisan
1510160250	Stachys palustris L.
1510160240	Stachys sylvatica L.
570060100	Stellaria graminea L.
570060060	Stellaria holostea L.
570060030	Stellaria media (L.) Vill.
570060040	Stellaria neglecta Weihe
570060010	Stellaria nemorum L.
570060050	Stellaria pallida (Dumort.) Pire
570060080	Stellaria palustris Retz.
570060070	Stellaria uliginosa Murray
1720020010	Stratiotes aloides L.
480230070	Suaeda maritima (L.) Dumort.
480230010	Suaeda vera J.F. Gmelin
680830010	Subularia aquatica L.

1670040010	Succisa pratensis Moench
1640030010	Symphoricarpos albus (L.) S.F. Blake
1480180080	Symphytum grandiflorum Dc.
1480180010	Symphytum officinale L.
1480180120	Symphytum orientale L.
1480180040	Symphytum tuberosum L.
1480180030	Symphytum x uplandicum Nyman
1860030010	Tamus communis L.
1690690110	Tanacetum parthenium (L.) Schultz Bip.
1690690010	Tanacetum vulgare L.
1691730160	Taraxacum adamii Claire
1691730150	Taraxacum croceum Dahlst.
1691730260	Taraxacum fulvum Raunk.
1691730230	Taraxacum obliquum (Fries) Dahlst.
1691730300	Taraxacum officinale agg.
1691730170	Taraxacum palustre (Lyons) Symons
1691730130	Taraxacum praestans H. Lindb. Fil.
1691730250	Taraxacum simile Raunk.
1691730120	Taraxacum spectabile
1691730140	Taraxacum unguilobum Dahlst.
290010010	Taxus baccata L.
680730010	Teesdalia nudicaulis (L.) R. Br.
730050019	Tellima grandiflora (Pursh) Douglas Ex Lindley
1690960330	Tephroseris integrifolia (L.) Holub
810600010	Tetragonolobus maritimus (L.) Roth
1510020180	Teucrium botrys L.
1510020150	Teucrium scordium L.
1510020110	Teucrium scorodonia L.
610230070	Thalictrum alpinum L.
610230130	Thalictrum flavum L.
610230090	Thalictrum minus L.
420030140	Thesium humifusum Dc.
680740020	Thlaspi alliaceum L.
680740010	Thlaspi arvense L.
680740050	Thlaspi caerulescens J.S. & C. Presl
680740030	Thlaspi perfoliatum L.
1510330560	Thymus polytrichus A. Kerner Ex Borbas
1510330610	Thymus pulegioides L.
1510330650	Thymus serpyllum L.
1050010050	Tilia cordata Miller
1050010030	Tilia platyphyllos Scop.
1830010010	Tofieldia pusilla (Michx) Pers.
730040019	Tolmiea menziesii (Pursh) Torrey & Gray
1291020030	Torilis japonica (Houtt.) Dc.
1291020010	Torilis nodosa (L.) Gaertner
1480240010	Trachystemon orientalis (L.) Don
1691620110	Tragopogon pratensis L.
1990010180	Trichophorum cespitosum (L.) Hartman
1350090010	Trientalis europaea L.
810570490	Trifolium arvense L.
810570420	Trifolium aureum Pollich
810570520	Trifolium bocconei Savi
810570440	Trifolium campestre Schreber
810570460	Trifolium dubium Sibth.
810570290	Trifolium fragiferum L.
810570220	Trifolium glomeratum L.
810570140	Trifolium hybridum L.

810570620	Trifolium incarnatum L.
810570622	Trifolium incarnatum molinerii (Balbis Ex Hornem.) Syme
810570740	Trifolium medium L.
810570470	Trifolium micranthum Viv.
810570110	Trifolium occidentale D.E. Coombe
810570850	Trifolium ochroleucon Hudson
810570010	Trifolium ornithopodioides L.
810570630	Trifolium pratense L.
810570100	Trifolium repens L.
810570580	Trifolium scabrum L.
810570930	Trifolium squamosum L.
810570480	Trifolium striatum L.
810570050	Trifolium strictum L.
810570970	Trifolium subterraneum L.
810570230	Trifolium suffocatum L.
1750010010	Triglochin maritimum L.
1750010020	Triglochin palustre L.
1290570010	Trinia glauca (L.) Dumort.
1690600058	Tripleurospermum inodorum (L.) Schultz Bip.
1690600048	Tripleurospermum maritimum (L.) Koch
1930700130	Trisetum flavescens (L.) Beauv.
610060010	Trollius europaeus L.
1120030040	Tuberaria guttata (L.) Fourr.
1830220010	Tulipa sylvestris L.
1690890010	Tussilago farfara L.
1980010010	Typha angustifolia L.
1980010050	Typha latifolia L.
810240010	Ulex europaeus L.
810240030	Ulex gallii Planchon
810240020	Ulex minor Roth
370010010	Ulmus glabra Hudson
370010030	Ulmus minor Miller
370010020	Ulmus procera Salisb.
720030040	Umbilicus rupestris (Salisb.) Dandy
400010020	Urtica dioica L.
400010060	Urtica urens L.
1610020060	Utricularia australis R. Br.
1610020040	Utricularia intermedia Hayne
1610020030	Utricularia minor L.
1610020042	Utricularia ochroleuca R. Hartman
1610020041	Utricularia stygia Thor
1610020050	Utricularia vulgaris L.
1320180099	Vaccinium corymbosum L.
1320180030	Vaccinium macrocarpon Aiton
1320180020	Vaccinium microcarpum (Turcz. Ex Rupr.) Schmalh.
1320180060	Vaccinium myrtillus L.
1320180010	Vaccinium oxycoccos L.
1320180050	Vaccinium uliginosum L.
1320180040	Vaccinium vitis-idaea L.
1660040090	Valeriana dioica L.
1660040010	Valeriana officinalis L.
1660040060	Valeriana pyrenaica L.
1660020120	Valerianella carinata Loisel.
1660020160	Valerianella dentata (L.) Pollich
1660020180	Valerianella eriocarpa Desv.
1660020100	Valerianella locusta (L.) Laterrade

1660020170	Valerianella rimosa Bast.
1720090010	Vallisneria spiralis L.
1540070820	Verbascum lychnitis L.
1540070850	Verbascum nigrum L.
1540070720	Verbascum pulverulentum Vill
1540070340	Verbascum thapsus L.
1540070070	Verbascum virgatum Stokes
1490030030	Verbena officinalis L.
1540210520	Veronica agrestis L.
1540210050	Veronica alpina L.
1540210390	Veronica anagallis-aquatica L.
1540210460	Veronica arvensis L.
1540210130	Veronica austriaca L.
1540210360	Veronica beccabunga L.
1540210400	Veronica catenata Pennell
1540210300	Veronica chamaedrys L.
1540210560	Veronica filiformis Sm.
1540210060	Veronica fruticans Jacq.
1540210570	Veronica hederifolia L.
1540210340	Veronica montana L.
1540210270	Veronica officinalis L.
1540210490	Veronica peregrina L.
1540210550	Veronica persica Poiret
1540210530	Veronica polita Fries
1540210420	Veronica praecox All.
1540210350	Veronica scutellata L.
1540210030	Veronica serpyllifolia L.
1540210620	Veronica spicata L.
1540210430	Veronica triphyllos L.
1540210470	Veronica verna L.
1640020020	Viburnum lantana L.
1640020010	Viburnum opulus L.
810490430	Vicia bithynica (L.) L.
810470100	Vicia cracca L.
810490310	Vicia hirsuta (L.) S.F. Gray
810490470	Vicia lathyroides L.
810490510	Vicia lutea L.
810490010	Vicia orobus Dc.
810490350	Vicia parviflora Cav.
810490460	Vicia sativa L.
810490420	Vicia sepium L.
810490160	Vicia sylvatica L.
810490360	Vicia tetrasperma (L.) Schreber
1420040050	Vinca major L.
1420040010	Vinca minor L.
1100010800	Viola arvensis Murray
1100010200	Viola canina L.
1100010630	Viola cornuta L.
1100010060	Viola hirta L.
1100010810	Viola kitaibeliana Schultes
1100010210	Viola lactea Sm.
1100010740	Viola lutea Hudson
1100010010	Viola odorata L.
1100010270	Viola palustris L.
1100010220	Viola persicifolia Schreber
1100010150	Viola reichenbachiana Jordan Ex Boreau
1100010180	Viola riviniana Reichenb.
1100010140	Viola rupestris F.W. Schmidt

1100010780	Viola tricolor L.
430020020	Viscum album L.
1040010010	Vitis vinifera L.
1930060080	Vulpia bromoides (L.) S.F. Gray
1930060110	Vulpia ciliata Dumort.
1930060050	Vulpia fasciculata (Forskal) Samp.
1930060100	Vulpia myuros (L.) C.C. Gmelin
1930060120	Vulpia unilateralis (L.) Stace
1680110010	Wahlenbergia hederacea (L.) Reichenb.
1960010010	Wolffia arrhiza L.
1810020010	Zannichellia palustris L.
1800010020	Zostera angustifolia (Hornem.) Reichenb.
1800010010	Zostera marina L.
1800010030	Zostera noltii Hornem.

Appendix C

A List of the Database Characteristics

The first section lists the characteristics and their codes that are used in the plant_characteristic and distribution tables in the database. This is followed by information that is held in other tables such as mycorrhizas and hybrids. Alternative values or units of measurements are given for each characteristic

1.01	Soil nutrients	very fertile fertile infertile very infertile
1.01A	Water nutrients	eutrophic mesotrophic oligotrophic
1.02	Soil moisture: 1. water table	permanently high periodically high permanently low
1.03	Soil moisture: 2. drainage	free-draining slow-draining
1.04	Soil moisture: 3. supply	continuous seasonal intermittent
1.05	Salinity	fresh salt-affected brackish saline
1.06	Soil pH: 1. extreme maximum	value?
1.06A	Water pH: 1. extreme maximum	value?
1.07	Soil pH: 2. extreme minimum	value?
1.07A	Water pH: 2. extreme minimum	value?
1.08	Soil pH: 3. typical maximum	value?
1.08A	Water pH: 3. typical maximum	value?
1.09	Soil pH: 4. typical minimum	value?

1.09A	Water pH: 4. typical minimum	value?
1.10	Shade	none light mid deep
1.10A	Maximum depth of leaves	<0.5m >0.5m
1.11	Exposure	exposed indifferent sheltered
1.12	Altitude: 1. maximum recorded	value? (m)
1.13	Altitude: 2. minimum recorded	value? (m)
1.14	Altitude: 4. typical minimum	value? (m)
1.15A	Flow	nil slight mid rapid
2.01	Status	native naturalised
2.02	Typical abundance where naturally occurring	dominant frequent occasional rare
2.03	Dynamics	increasing stable declining
2.04	First historical record: 1. date	value? (yr)
2.05	First historical record: 2. site	value (place name)
2.06	Fossil record: 1. earliest record	value?
2.07	Fossil record: 2. earliest postglacial record	value?
2.08	Fossil record: 3. postglacial frequency	value? (no. sites)
2.09	Range: 1. European countries where native	value? (country)
2.10	Range: 2. European countries where introduced	value? (country)

2.11	Range: 3. continents where native	Europe Africa Macaronesia Asia North America South America Australasia
2.12	Range: 4. continents where introduced	Europe Africa Macaronesia Asia North America South America Australasia
3.01	Stems: 1. woodiness	non-woody woody at base woody
3.02	Stems: 2. support	creeping decumbent procumbent scrambling self-supporting twining tendrils climbs by adventitious roots
3.02A	Leaf position	emergent floating submerged
3.03	Height: 1. extreme maximum	value? (cm)
3.04	Height: 2. extreme minimum	value? (cm)
3.05	Height: 3. typical maximum	value? (cm)
3.06	Height: 4. typical minimum	value? (cm)
3.07	Spread	height > width height = width height < width not applicable (submurged aquatics)
3.08	Heterophylly	not applicable (leafless species) none developmental environmental

3.09	Leaf shape: 1. type	simple compound absent modified (carnivorous plants)
3.10	Leaf shape: 2. outline	not applicable (leafless species) entire crenate toothed lobed lobed and toothed serrulate
3.11	Leaf shape: 3. pointed/round	not applicable (leafless species) pointed rounded mucronate emarginate
3.12	Leaf shape: 4. length versus breadth	not applicable (leafless species) >3 times as long as wide 1-3 times as long as wide length = width shorter than broad
3.13	Leaf shape: 5. leaf base	not applicable (leafless species) sagittate cordate rounded truncate parallel-sided cuneate central
3.14	Leaf shape: 6. petiole	not applicable (leafless species) petiolate subsessile sessile connate sheathing clasping
3.15	Leaf shape: 7. minimum petiole length	value? (mm)
3.16	Leaf shape: 8. maximum petiole length	value? (mm)

3.17	Leaf area (cm^2)	<0.1 0.1-1 1-10 10-100 100-1000 >1000
3.18	Leaf lamina thickness (mm)	<0.2 0.2-0.5 0.5-1.0 1.0-2.0 >2.0
3.19	Stomata: 1. surfaces present	both lower upper none stem
3.20	Stomata: 2. density on lower surface	value? (no/mm^2)
3.21	Stomata: 3. density on upper surface	value? (no/mm^2)
3.22	Leaf longevity: 1. type	deciduous aestival vernal hibernal semi-evergreen evergreen
3.23	Leaf longevity: 2. number of months	0-2 2-6 6-12 12-24 >24
3.24	Root system	absent tap root fibrous adventitious contractile
3.25	Root depth: 1. type	shallow deep
3.26	Root depth: 2. depth (cm)	0-10 10-50 50-100 >100

3.27	Fine root diameter (µm)	<100 100-150 150-200 200-300 300-500 500-1000 >1000
3.28	Root hairs	present absent
3.29	Root hair length (mm)	<0.1 0.1-0.5 0.5-1.0 1.0-5.0 >5.0
3.30	Root persistence	<1 1 >1
4.01	Seedling growth rate - initial	value? (/d)
4.02	Photosynthetic pathway	C3 CAM C4
4.03	Mature leaf N concentration (mg/g)	<5 5-10 10-20 20-30 >30
4.04	Mature leaf P concentration (mg/g)	<1 1-2 2-3 >3
4.05	Heavy metal resistence	none pseudometallophyte local metallophyte absolute metallophyte
4.06	Carnivory	leaves traps kills insects but not carnivorous
4.07	Nutrition	mycotrophic hemi-parasitic parasitic

4.08	Response to drought	resists wilts and recovers wilts and dies wilts
4.09	Response to frost (non-woody tissue)	very resistant resistant sensitive
4.10	Response to frost (seedlings)	very resistant resistant sensitive
5.01	Life-form	therophyte hemicryptophyte helophyte hydrophyte geophyte chamaephyte phanerophyte epiphyte
5.02	Longevity of stems (yrs)	<1 1-2 2-10 10-100 100-500 >500
5.03	Age at first flowering	<6 weeks 6-12 weeks 12-24 weeks 24-52 weeks 1-2 yrs 2-5 yrs 5-20 yrs >20 yrs
5.04	Mono/poly-carpic	monocarpic facultatively polycarpic polycarpic

5.05	Vegetative reproduction/persistence: 1. method	buds bulbils bulbs corms pseudobulbs rhizomes root buds rooting stem nodes rooting twigs stolons turions tubers
5.06	Vegetative reproduction/persistence: 2. pattern	adjacent ramets ramets connected but well-dispersed ramets not connected no ramets
5.07	Flowering time: 1. earliest month	value? (month)
5.08	Flowering time: 2. latest month	value? (month)
5.09	Flowering time: 3. peak month	value? (month)
5.10	Photoperiodism: 1. type	long-day day-neutral *short-day*
5.11	*Photoperiodism: 2. threshold value*	*value? (h)*
5.12	Pollen: 1. mono/di-morphic	monomorphic dimorphic trimorphic
5.13	Pollen: 2. diameter	value? (µm)
5.14	Pollen viability	high variable low inviable
5.15	Pollen vector	insect wind water none selfed

5.16	Dicliny	hermaphrodite andromonoecious monoecious gynomonoecious dioecious androdioecious gynodioecious subandroecious subgynoecious subdioecious trioecious polygamous gynoandromonoecious
5.17	Dichogamy	entirely protandrous protandrous markedly protandrous weakly protandrous homogamous weakly protogynous markedly protogynous protogynous entirely protogynous
5.18	Heteromorphy	homomorphic dimorphic trimorphic
5.19	Fertilization	obligatory cross normally cross cross and self cross or automatic self normally self viviparous apomictic no seed produced in Britain
5.20	Cleistogamy	entirely cleistogamous usually cleistogamous some cleistogamous flowers sometimes cleistogamous pseudo-cleistogamous cleistogamy not recorded
5.21	Inbreeding	value? (%)
5.22	Incompatibility systems	none gametophytic, 1 locus gametophytic, 2 loci gametophytic, >2 loci di-allelic sporophytic multi-allelic sporophytic present, mechanism unknown
5.23	Pollen/ovule ratio	value?

5.24	Seed/ovule ratio	value?
5.25	Chromosome number(s): 1. number	value?
5.26	2C DNA content	value? (pg)
5.27	Appendages on dispersal unit	elaisome mucilage wings pappus plume of hairs hooks
5.28	Time of seed dispersal (season)	spring summer autumn winter
5.29	Annual seed dispersal	regular alternate mast irregular
5.30	Dispersule size - length of longest axis	value? (mm)
5.31	Seed size - length of longest axis	value? (mm)
5.32	Seed weight: 1. maximum	value? (mg)
5.33	Seed weight: 2. minimum	value? (mg)
5.34	Seed weight: 3. mean	value? (mg)
5.35	Seed production: 1. maximum (/flower)	value?
5.36	Seed production: 2. typical range (/flower)	1 1-10 10-100 100-1000 >1000
5.37	Seed production: 3. typical range (/plant)	1-10 10-100 100-1000 1000-10000 >10000

5.38	Dispersal agent	unspecialised water rainwash wind carried by mammals carried by birds ants eaten by birds eaten by mammals explosive mechanism man
5.39	Time of germination (season)	spring summer autumn winter not observed
5.40	After-ripening requirement	none partial absolute
5.41	Maximum temperature of germination	value? (°C)
5.42	Maximum temperature at which 50% seeds germinate	value? (°C)
5.43	Minimum temperature germination	value? (°C)
5.44	Minimum temperature at which 50% seeds germinate	value? (°C)
5.45	Germination requirements 1. chilling	none partial absolute
5.46	Germination requirements 2. light	none partial absolute
5.47	Germination requirements 3. temperature fluctuation	none partial absolute
5.48	Germination type	epigeal hypogeal
5.49	Seed viability	high some non-viable much non-viable
5.50	Seedbank longevity	<3 months 3-12 months 1-5 yrs 5-20 yrs >20 yrs
5.51	Seedbank density: recorded values	value? (seeds/m^2) no seedbank recorded

5.52	Normal method of propagation	seed seed and vegetative vegetative
6.01	Response to vertebrate grazing	decreases neutral increases
6.02	Physical defences on leaves	dense hairs glabrous glandular hairs prickles soft hairs spines stiff hairs stinging hairs thick cuticle viscid
6.03	Physical defences on stems	dense hairs glabrous glandular hairs prickles soft hairs spines stiff hairs stinging hairs thick cuticle viscid
6.04	Physical defences on flowers/fruits	dense hairs glabrous glandular hairs prickles soft hairs spines stiff hairs stinging hairs thick cuticle viscid
6.05	Physical defences on buds	dense hairs glabrous glandular hairs prickles soft hairs spines stiff hairs stinging hairs thick cuticle viscid

Habitat

Habitat type	corine code

Mycorrhizas

1.	Type of mycorrhizal infection	VA Ecto Orchid Ericoid Arbutoid Pyroloid Monotropoid Absent
2.	Frequency of infection	normally present occasionally present rarely present not present

Pathogenic Fungi

1.	Fungus	species name
2.	Plant part infected	leaves stems bark wood flowers/fruits/seeds roots
3.	Alternate hosts	species name(s)
4.	Number of hosts	monophagous oligophagous polyphagous
5.	Status	very common common frequent occasional rare
6.	Disease	+ -
7.	Type of Attack	blight, blister, canker, defoliator, gall, mildew, necrosis, patches, rot, rust, senescence, smut, spots, warts, wilt, wounds

Hybrids

1.	Parents	species names
2.	Hybrid name	name if there is one
3.	Distribution	widespread with and without parents common with and without parents common where parents occur occasional where parents occur scattered rare non-British no recent records in Britain hybrid artificial/planted records of hybrid dubious

Appendix D

A list of some of the characteristics that were omitted from the database with reasons for their omission.

Soil pH - NW versus SE

No data available.

Soil type

It was difficult to interpret vague statements in the literature into definable categories.

Altitude - normal maximum

Lack of data and difficult in this case to interpret 'normal'.

Disturbance - 1. type

The meaning of this characteristic was not defined enough to make it clear that it meant disturbance that is beneficial to the species, not simply disturbance the species is often subject to. As information given by species experts did not definately relate to the first meaning, the characteristic was omitted. It could be reinstated if new data were collected according to the correct definition.

Leaf lamina *thickness 2. in full light, 3. in shade*

Very little data were available on leaf thickness in specific light conditions. Data would be best collected for this characteristic using an experimental approach and controlled lighting conditions.

Photosynthetic rate

Stomatal transpiration rate

Maximum leaf conductance

While data were available in the literature for all three of these characteristics, `there was difficulty in interpreting the data. These characteristics tend to be measured experimentally and the conditions in each experiment are likely to be very different making it invalid to compare the data between different species. Again data on these would be useful, but a controlled experimental approach is required.

Secondary Compounds

It had originally been planned to collect data on plant chemicals, the tissue they occurred in and their concentrations. This is quite a substantial area of study and had to be omitted due to lack of time.

Appendix E

A list of the protocols that were sent to volunteers interesting in collecting new data for the Ecological Flora Project.

Protocols

Since neither published nor unpublished information on many characters for British plants will be available, we hope to encourage other workers, whether amateurs, students or professionals, to make appropriate measurements, perhaps supported in some cases by small funds raised from other sources. For this is to be useful, it is essential to standardise the techniques used.

This list contains suggested protocols for techniques to determine 22 characters which are likely to be difficult to obtain from the literature. Most are measurable with simple (or no) equipment, but a few require more sophisticated techniques. They are graded as follows:

1 can be carried out with no specialist equipment; suitable for amateurs and schools.

2 requires standard equipment (e.g. microscopes, balances); suitable for schools, colleges and undergraduate projects).

3 requires specialist equipment; suitable for University or Polytechnic final year projects or MSc courses, or research groups.

If you are interested in helping in this way, it would be helpful if you could inform the Ecological Flora office at York, so that we can co-ordinate this activity. Please bear in mind the provisions of the Wildlife and Countryside Act: in particular no work should be performed on scheduled species (we can advise on whether a species is protected in this way) that involves damaging the plant, without permission from the Nature Conservancy Council. The Act also makes it illegal to uproot *any* wild plant without the permission of the owner or occupier of the land.

The Ecological Flora project may have limited funds available to facilitate some of this work; if such assistance is necessary please contact us. Although we hope to use any data collected under the auspices of the project in compiling the database, investigators will be free to use it in other ways (e.g. publication) and its origin will be acknowledged by the Flora.

1. **Soil pH (2)**

Sampling: use fresh soil from root zone; at each site take at least 10 measurements.

Measurement:
(a) Add 2 parts by volume of deionised (or distilled) water to 1 part soil. Allow to settle for 20 minutes after stirring. Standardise pH meter with 2 buffers; ensure temperature of buffers and samples are the same.

(b) Use probe-type electrode directly into root-zone soil in field; moisten with deionised or distilled water if necessary.

2. **Leaf size (1/2)**

Sampling:
(a) Trees and large shrubs: take 10 leaves from each of 10 plants. Avoid sucker shoots, sprouts low on trunk or other regenerating or damaged growth.
(b) Herbs and small shrubs: use largest leaf on each of 20 plants. Avoid obviously diseased or damaged plants.

Measurement:
(a) use leaf area meter if available; precision of ±5% acceptable. For compound leaves, give number of leaflets per leaf and mean area per leaflet.
(b) estimates of area using squared paper acceptable if meters not available.

3. **Leaf thickness (2)**

Sampling: select leaves as for leaf size; use turgid leaves only. If sun and shade leaves may be present, sample separately.

Measurement: use razor-blade sections and eye-piece micrometer. Take measurements away from midrib. Precision of ±10% acceptable.

4. **Stomatal distribution (2)**

Sampling: select leaves as for leaf size.

Measurement: use nail-varnish copies or fresh epidermal peels of both upper and lower surfaces. Place sample on mm-square grid; count number of cells along four sides of square, and number of stomata within square (if touching sides of square, only count N and E edges). Express results as number of stomata per mm^2 and numbers of stomata per 100 cells (stomatal index).

5. **Time of budburst (1)**

This measurement is only applicable to woody plants: mark buds on several twigs on each of 10-20 trees/bushes. Ensure that both terminal and lateral buds are sampled. Record date of leaf appearance, noting especially whether leaf emergence is simultaneous or staggered over the growing season.

6. **Root depth (1)**

(a) Field measurements
Sampling: choose 10 mature plants. Avoid exceptionally large or small specimens, or those growing in unusual places. If plants are found in contrasting soils, sample from as many of these as possible, but this technique is only really practicable in light soils. Note that this is a destructive measurement and should only be used with care and in locations where environmental damage can be minimised.

Measurement: carefully excavate soil around plant and determine (i) the main rooting depth (i.e. that within which 80% of the root system is encountered) and (ii) the maximum root depth if possible.

(b) Experimental approach
As an alternative to the above, plants can be grown from seed (or vegetative fragments) in long tubes. Drainpipes are ideal for this, and the diameter should be appropriate to plant size. Pipes can be slit longitudinally, filled with soil and planted. Measurements of root penetration (see above) can be made at intervals. Plants should be allowed to grow for at least one complete season.

7. **Root radius (2)**

Sampling: collect young, white roots from plants growing in as many different soil conditions as possible. Store in water at low temperature if necessary.

Measurement: Measure radius midway between tip and first branch of 10 roots per plant. Use micrometer eyepiece in microscope. Precision of ±10% sufficient.

8. **Root hair length and density (2)**

Sampling: collect roots as in 7; hairs may be attached to soil particles, so these should be soaked off using minimum disturbance.

Measurement: cut thick roots longitudinally in half with a scalpel or razor blade and place cut side down on slide. Measure length of at least 10 hairs per root sample using micrometer eyepiece in microscope. Density can be estimated along a defined length of root (1 mm ideal) from number visible on upper surface (use focus) multiplied by two.

9. **Relative growth rate (3)**

Measure initial maximum rate (see Grime, J.P. & Hunt, R. 1975. *Journal of Ecology*, 63, 393).

10. Light-saturated photosynthetic rate (3)

Measurements of either healthy plants under field conditions or plants in controlled environments under light-saturating conditions. Standard IRGA techniques.

11. Leaf N, P, etc concentration (3)

Sampling: select healthy, mature leaves of at least 5 plants in each habitat; sample as many habitats as feasible.

Measurement: dry leaf tissue at 80°C for 3 days. Wet ash in H_2SO_4/H_2O2 following Allen, S.E. (1974). *Chemical Analysis of Ecological Material.* Blackwell, Oxford.

12. Maximum stomatal transpiration rate (2/3)

Measure on plants grown under standard conditions, e.g. in glasshouse, under full illumination, well-watered. Use healthy, mature leaves; at least 2 leaves per plant, 5 plants. Use automatic porometer (e.g. Delta-T or LiCor).

13. Flowering time (1)

Field measurements of earliest, peak and latest flowering of defined natural populations. Estimates of flower density (fls/plant) valuable if possible.

14. Dichogamy (1)

Daily field observations on marked flowers on at least 10 plants. Note time of unfolding or exposure of stigmatic surface and of anther dehiscence.

15. Self-compatibility (1)

Can be detected using a combination of open pollination and artificial crossing. If plants are raised from seed (so that they are genetically distinct, i.e. different genets) and grown in isolation, then seed will not be set by self-incompatible (*si*) species, but will usually be set by self-compatible (*sc*) species. Secondly, artificial crosses can be made between genets, by transferring pollen from one plant to another, in which case both *si* and *sc* plants should set seed. Finally, artificial self-pollination on bagged flowers should give no seed from *si* plants, but seed set on *sc* plants. For further details see Richards, A.J. (1986), *Plant Breeding Systems*, Allen & Unwin.

16. Seed weight (1)

Collect seed from plants in field, preferably from a range of sites, and air-dry for 2 weeks before weighing. Sample size depends on seed size and accuracy of balance. Data on variation in seed weight valuable.

17. Seed production per flower (1)

Collect at least 50 fruits or fruiting heads for composite flowers and determine number of seeds. Express as mean, standard error and maximum. Data from range of habitats valuable.

18. Flowers per plant (1)

Select plants at random from within population; count all flowers and, if necessary, mark and return at weekly intervals to score new flowers. "Plant" should be defined as a discrete, above-ground unit (i.e. ignore below-ground connections).

19. Time of germination (1)

(i) *Field observations:* record appearance of seedlings in field to nearest month. If necessary, bring seedlings into glasshouse culture to determine identity.

(ii) *Experimental determination:* collect fresh seed from plants in field; sow in trays of potting compost and leave outside. Maintain watering, etc. Record seedling appearance at monthly intervals (may take over 1 year).

20. Dormancy breaking requirements (2)

Use freshly collected seed where possible. If necessary, air-dry and store at low temperature (≈5°C). Carry out tests in petri dishes on moist filter paper.
(i)*light:* keep seeds in total darkness (e.g. black polythene), alternating dark and light, and light (clear polythene). Record germination every 24 h in light, and examine dark seeds one week after maximum germination achieved in light.
(ii) *chilling:* place seeds in moist sand at 5°C; remove samples at monthly intervals and test germination in glasshouse.
(iii) *temperature fluctuation*: requires growth facility with fluctuating temperature.

21. Seedbank density (1)

Take surface (0-5 cm) soil samples in spring and spread out to depth of 1 cm on surface of potting compost in seed trays. Compost should be of appropriate type for soil used. Keep trays of compost as controls to check for invaders and seeds surviving in compost. Remove seedlings and plant on for identification. After every three months, stir soil. May need to continue for >1 year.

22. Nitrogen fixation rates (3)

^{15}N technique preferred, but ARA also acceptable. Use standard protocols.

Appendix F

This appendix gives a list of all families in the database and comparative figures for the total number of species in the family and the number of species for which data were available concerning the proportion of stomata on the lower epidermis of the leaf.

Family	Number of species stomatal data was available for	Number of species in family
Aceraceae	3	3
Adoxaceae	1	1
Aizoaceae	0	3
Alismataceae	2	7
Apiaceae	15	57
Apocynaceae	1	2
Aquifoliaceae	1	1
Araceae	1	4
Araliaceae	1	1
Aristolochiaceae	0	1
Asteraceae	36	176
Balsaminaceae	1	4
Berberidaceae	1	2
Betulaceae	6	6
Boraginaceae	6	28
Brassicaceae	11	85
Buddlejaceae	0	1
Butomaceae	0	1
Buxaceae	1	1
Callitrichaceae	0	7
Campanulaceae	6	15
Cannabaceae	0	1
Caprifoliaceae	5	11
Caryophyllaceae	16	78
Celastraceae	1	1
Ceratophyllaceae	0	2
Chenopodiaceae	4	33
Cistaceae	1	4
Clusiaceae	7	13
Convolvulaceae	2	5
Cornaceae	1	2
Crassulaceae	3	14
Cucurbitaceae	1	1
Cupressaceae	0	1
Cuscutaceae	0	2
Cyperaceae	22	100
Diapensiaceae	1	1
Dioscoreaceae	0	1
Dipsacaceae	3	5
Droseraceae	1	3
Elaeagnaceae	0	1
Elatinaceae	0	2
Empetraceae	0	1
Ericaceae	7	29

Eriocaulaceae	0	1
Euphorbiaceae	2	15
Fabaceae	20	84
Fagaceae	3	5
Frankeniaceae	1	1
Fumariaceae	1	12
Gentianaceae	3	16
Geraniaceae	6	19
Grossulariaceae	3	6
Gunneraceae	0	1
Haloragaceae	0	3
Hippuridaceae	1	1
Hydrocharitaceae	3	9
Iridaceae	0	10
Juncaceae	25	35
Juncaginaceae	1	2
Lamiaceae	14	51
Lemnaceae	3	6
Lentibulariaceae	1	9
Liliaceae	12	43
Linaceae	1	4
Lythraceae	1	3
Malvaceae	4	6
Menyanthaceae	1	2
Monotropaceae	0	1
Myricaceae	0	1
Najadaceae	0	2
Nymphaeaceae	2	3
Oleaceae	2	2
Onagraceae	10	22
Orchidaceae	4	49
Orobanchaceae	0	10
Oxalidaceae	1	5
Papaveraceae	2	7
Pinaceae	1	2
Pittosporaceae	0	1
Plantaginaceae	4	6
Plumbaginaceae	0	5
Poaceae	40	148
Polemoniaceae	1	1
Polygalaceae	0	4
Polygonaceae	14	38
Portulacaceae	1	4
Potamogetonaceae	1	22
Primulaceae	5	18
Pyrolaceae	2	5
Ranunculaceae	22	40
Resedaceae	1	2
Rhamnaceae	1	2
Rosaceae	20	107
Rubiaceae	3	17
Ruppiaceae	0	2
Salicaceae	10	24
Santalaceae	0	1
Sarraceniaceae	1	1
Saxifragaceae	3	20
Scheuchzeriaceae	0	1
Scrophulariaceae	15	85

Simaroubaceae	0	1
Solanaceae	4	8
Sparganiaceae	0	4
Taxaceae	1	1
Thymelaeaceae	2	2
Tiliaceae	2	2
Typhaceae	0	2
Ulmaceae	0	3
Urticaceae	1	4
Valerianaceae	1	9
Verbenaceae	1	1
Violaceae	4	14
Viscaceae	0	1
Vitaceae	0	1
Zannichelliaceae	0	1
Zosteraceae	0	3

Appendix G

A list of all the characteristics in the database and the number of species which have a value for each characteristic

1.01	Soil nutrients	1460
1.01A	Water nutrients	122
1.02	Soil moisture: 1. water table	111
1.03	Soil moisture: 2. drainage	226
1.04	Soil moisture: 3. supply	98
1.05	Salinity	337
1.06	Soil pH: 1. extreme maximum	296
1.06A	Water pH: 1. extreme maximum	173
1.07	Soil pH: 2. extreme minimum	298
1.07A	Water pH: 2. extreme minimum	173
1.08	Soil pH: 3. typical maximum	204
1.08A	Water pH: 3. typical maximum	127
1.09	Soil pH: 4. typical minimum	209
1.09A	Water pH: 4. typical minimum	127
1.10	Shade	1572
1.10A	Maximum depth of leaves	19
1.11	Exposure	84
1.12	Altitude: 1. maximum recorded (m)	947
1.13	Altitude: 2. minimum recorded (m)	947
1.14	Altitude: 4. typical minimum (m)	824
1.15A	Flow	138
2.01	Status	1774
2.02	Typical abundance where naturally occurring	81
2.03	Dynamics	268
2.04	First historical record: 1. date	1307
2.05	First historical record: 2. site	896
2.09	Range: 1. European countries where native	1623
2.10	Range: 2. European countries where introduced	514
2.11	Range: 3. continents where native	1693
2.12	Range: 4. continents where introduced	404

3.01	Stems: 1. woodiness	1709
3.02	Stems: 2. support	1644
3.02A	Leaf position	117
3.03	Height: 1. extreme maximum (cm)	300
3.04	Height: 2. extreme minimum (cm)	122
3.05	Height: 3. typical maximum (cm)	1634
3.06	Height: 4. typical minimum (cm)	1258
3.07	Spread	1679
3.08	Heterophylly	1680
3.09	Leaf shape: 1. type	1701
3.10	Leaf shape: 2. outline	1668
3.11	Leaf shape: 3. pointed/round	1646
3.12	Leaf shape: 4. length versus breadth	1656
3.13	Leaf shape: 5. leaf base	1638
3.14	Leaf shape: 6. petiole	1624
3.15	Leaf shape: 7. minimum petiole length	1113
3.16	Leaf shape: 8. maximum petiole length	910
3.17	Leaf area (cm2)	298
3.18	Leaf lamina thickness: 1. range	60
3.19	Stomata: 1. surfaces present	543
3.20	Stomata: 2. density on lower surface(no/mm2)	361
3.21	Stomata: 3. density on upper surface (no/mm2)	384
3.22	Leaf longevity: 1. type	687
3.23	Leaf longevity: 2. number of months	113
3.24	Root system	365
3.25	Root depth: 1. type	254
3.26	Root depth: 2. depth (cm)	239
3.27	Fine root diameter (um)	76
3.28	Root hairs	147
3.29	Root hair length (mm)	18
3.30	Root persistence	60
4.01	Seedling growth rate - maximum (/d)	130
4.02	Photosynthetic pathway	34
4.03	Mature leaf N concentration (mg/g)	114
4.04	Mature leaf P concentration (mg/g)	113
4.05	Heavy metal resistence	46

4.06	Carnivory	19
4.07	Nutrition	48
4.08	Response to drought	142
4.09	Response to frost (non-woody tissue)	188
4.10	Response to frost (seedlings)	91
5.01	Life-form	1699
5.02	Longevity of stems (yrs)	1233
5.03	Age at first flowering	228
5.04	Mono/poly-carpic	418
5.05	Vegetative reproduction/persistence: 1. method	616
5.06	Vegetative reproduction/persistence: 2. pattern	99
5.07	Flowering time: 1. earliest month	1632
5.08	Flowering time: 2. latest month	1617
5.09	Flowering time: 3. peak month	111
5.10	Photoperiodism: 1. type	111
5.11	Photoperiodism: 2. threshold value (h)	14
5.12	Pollen: 1. mono/di-morphic	14
5.13	Pollen: 2. diameter (um)	406
5.14	Pollen viability	64
5.15	Pollen vector	1601
5.16	Dicliny	1549
5.17	Dichogamy	846
5.18	Heteromorphy	46
5.19	Fertilization	945
5.20	Cleistogamy	197
5.21	Inbreeding (%)	17
5.22	Incompatibility systems	667
5.23	Pollen/ovule ratio	39
5.24	Seed/ovule ratio	17
5.25	Chromosome number(s): 1. number	1637
5.26	2C DNA content (pg)	313
5.27	Appendages on dispersal unit	259
5.28	Time of seed dispersal (season)	501
5.29	Annual seed dispersal	201
5.30	Dispersule size - length of longest axis (mm)	767
5.31	Seed size - length of longest axis (mm)	874

5.32	Seed weight: 1. maximum (mg)	84
5.33	Seed weight: 2. minimum (mg)	78
5.34	Seed weight: 3. mean (mg)	807
5.35	Seed production: 1. maximum (/flower)	414
5.36	Seed production: 2. typical range (/flower)	604
5.37	Seed production: 3. typical range (/plant)	356
5.38	Dispersal agent	746
5.39	Time of germination (season)	869
5.40	After-ripening requirement	281
5.41	Maximum temperature of germination	31
5.42	Maximum temperature at which 50% seeds germinate	147
5.43	Minimum temperature germination	31
5.44	Minimum temperature at which 50% seeds germinate	124
5.45	Germination requirements 1. chilling	283
5.46	Germination requirements 2. light	349
5.47	Germination requirements 3. temperature fluctuation	188
5.48	Germination type	390
5.49	Seed viability	170
5.50	Seedbank longevity	186
5.51	Seedbank density: recorded values	81
5.52	Normal method of propagation	482
6.01	Response to vertebrate grazing	98
6.02	Physical defences on leaves	1362
6.03	Physical defences on stems	1140
6.04	Physical defences on flowers/fruits	353
6.05	Physical defences on buds	33
	Mycorrhizal data	968
	Fungal data	742
	Hybrid data	711
	Habitat type	1614

Appendix H

Stomatal Analyses:
Stomatal information, the location of stomata and in some cases the density, was available for the following species. The asterisks indicate which species were used for each analysis described in chapter 6. The table below, modified from table 6.2 page 112, shows which column of asterisks refers to which analysis.

Stomatal data used	Second variable	Species used
distribution	shade	a
total density	shade	b
total density	shade	c
density on lower epidermis	shade	b
density on lower epidermis	shade	c
density on upper epidermis	shade	b
distribution	water availability	d
total density	water availability	e
density on lower epidermis	water availability	e
distribution	leaf area	f
distribution	leaf area	g
distribution	leaf type	h
distribution	leaf outline	i
distribution	leaf outline	j
distribution	leaf hairiness	k

	a	b	c	d	e	f	g	h	i	j	k
Aceraceae											
Acer campestre			*								
Acer platanoides											
Acer pseudoplatanus			*								
Adoxaceae											
Adoxa moschatellina			*								
Alismataceae											
Alisma plantago-aquatica											
Baldellia ranunculoides											
Apiaceae											
Aegopodium podagraria											
Angelica sylvestris											
Anthriscus sylvestris											
Chaerophyllum temulum											
Conium maculatum											
Daucus carota											
Eryngium maritimum											

	a	b	c	d	e	f	g	h	i	j	k
Heracleum mantegazzianum											
Heracleum sphondylium											
Hydrocotyle vulgaris											
Ligusticum scoticum											
Myrrhis odorata											
Pimpinella major											
Sanicula europaea											
Sison amomum											
Apocynaceae											
Vinca minor			*								
Aquifoliaceae											
Ilex aquifolium			*								
Araceae											
Arum maculatum	*	*		*	*	*		*		*	*
Araliaceae											
Hedera helix			*								
Asteraceae											
Achillea millefolium	*	*		*	*	*	*	*	*		
Achillea ptarmica	*	*		*	*	*	*	*	*		*
Anthemis arvensis	*	*		*	*			*			*
Anthemis cotula	*	*		*	*			*			*
Arctium minus	*	*		*	*	*		*		*	*
Artemisia vulgaris	*			*		*	*	*		*	*
Aster tripolium	*	*		*	*	*	*	*	*		*
Bellis perennis	*	*				*	*	*	*		*
Centaurea nigra	*	*		*	*	*	*	*		*	*
Centaurea scabiosa	*	*		*	*	*	*	*		*	
Cirsium acaule	*	*		*	*	*	*	*		*	*
Cirsium palustre	*	*		*	*	*	*	*		*	*
Crepis capillaris	*	*		*	*	*	*	*		*	*
Crepis paludosa	*	*		*	*			*			*
Gnaphalium norvegicum	*	*		*	*			*			*
Hypochaeris maculata	*	*						*			*
Hypochaeris radicata	*	*		*	*	*	*	*		*	*
Inula conyzae	*	*		*	*	*	*	*		*	*
Leucanthemum vulgare	*	*		*	*	*	*	*	*		*
Matricaria discoidea	*	*		*	*	*	*	*	*		
Mycelis muralis	*	*		*	*	*		*		*	*
Petasites hybridus	*			*		*	*	*		*	*
Pilosella officinarum	*	*		*	*	*	*	*	*		*
Saussurea alpina	*	*		*	*	*	*	*		*	*
Senecio jacobaea	*	*		*	*	*	*	*		*	*
Senecio vulgaris	*	*		*	*	*	*	*		*	*
Serratula tinctoria	*	*		*	*			*			*
Solidago virgaurea	*	*		*	*	*	*	*	*		*
Sonchus arvensis	*	*		*	*			*			*
Sonchus asper	*			*		*	*	*		*	*
Sonchus oleraceus	*			*		*	*	*		*	*
Tanacetum vulgare	*	*		*	*	*	*	*	*		*

	a	b	c	d	e	f	g	h	i	j	k
Tephroseris integrifolia	*	*						*			*
Tragopogon pratensis	*	*		*	*	*	*	*	*		*
Tripleurospermum inodorum	*	*				*	*	*	*		*
Tussilago farfara	*			*		*	*	*		*	*
Balsaminaceae											
Impatiens glandulifera	*	*		*	*	*		*		*	*
Berberidaceae											
Berberis vulgaris			*								
Betulaceae											
Alnus glutinosa			*								
Betula nana											
Betula pendula											
Betula pubescens			*								
Carpinus betulus			*								
Corylus avellana			*								
Boraginaceae											
Cynoglossum officinale											
Lithospermum officinale											
Lithospermum purpurocaerulea											
Myosotis alpestris											
Myosotis scorpioides											
Pulmonaria officinalis											
Brassicaceae											
Alliaria petiolata	*	*		*	*	*	*	*		*	
Arabis scabra	*	*						*			*
Barbarea vulgaris	*	*		*	*			*			*
Brassica oleracea	*	*						*			*
Brassica rapa	*	*						*			*
Capsella bursa-pastoris	*	*				*	*	*		*	*
Cardamine bulbifera	*	*		*	*			*			*
Cardamine pratensis	*	*		*	*	*	*	*	*		*
Raphanus raphanistrum	*	*		*	*			*			*
Rorippa sylvestris	*	*		*	*			*			
Sisymbrium officinale	*	*		*	*	*	*	*	*		
Buxaceae											
Buxus sempervirens			*								
Campanulaceae											
Campanula latifolia											
Campanula rotundifolia											
Campanula trachelium											
Jasione montana											
Lobelia urens											
Phyteuma spicatum											
Caprifoliaceae											
Linnaea borealis			*								
Lonicera periclymenum			*								
Sambucus nigra			*								
Viburnum lantana			*								
Viburnum opulus			*								

	a	b	c	d	e	f	g	h	i	j	k
Caryophyllaceae											
Agrostemma githago	*	*				*	*	*	*		*
Cerastium alpinum	*	*		*	*	*	*	*	*		*
Cerastium cerastoides	*	*		*	*	*	*	*	*		
Corrigiola litoralis	*	*		*	*			*			*
Lychnis viscaria	*	*				*	*	*	*		*
Moehringia trinervia	*	*		*	*	*		*	*		*
Myosoton aquaticum	*	*		*	*	*	*	*	*		
Saponaria officinalis	*	*		*	*	*	*	*	*		*
Silene dioica	*	*		*	*	*	*	*		*	*
Silene latifolia	*	*		*	*	*	*	*		*	
Silene uniflora	*	*				*	*				
Silene vulgaris	*	*		*	*	*	*	*	*		*
Stellaria graminea	*	*		*	*	*	*	*	*		*
Stellaria holostea	*	*		*	*	*	*	*	*		
Stellaria media	*	*		*	*	*	*	*	*		*
Stellaria nemorum	*			*		*		*	*		*
Celastraceae											
Euonymus europaeus			*								
Chenopodiaceae											
Chenopodium bonus-henricus	*	*		*	*			*			*
Chenopodium ficifolium	*	*		*	*	*	*	*	*		*
Chenopodium rubrum	*	*		*	*	*	*	*	*		*
Suaeda maritima	*	*		*	*	*	*	*	*		*
Cistaceae											
Tuberaria guttata	*	*				*	*	*	*		*
Clusiaceae											
Hypericum androsaemum			*								
Hypericum hirsutum			*								
Hypericum humifusum			*								
Hypericum linarifolium			*								
Hypericum perforatum			*								
Hypericum pulchrum			*								
Hypericum tetrapterum											
Convolvulaceae											
Calystegia sepium	*	*		*	*	*	*	*		*	*
Convolvulus arvensis	*	*		*	*	*	*	*	*		*
Cornaceae											
Cornus sanguinea											
Crassulaceae											
Sedum acre											
Sedum album											
Sedum telephium											
Cucurbitaceae											
Bryonia dioica			*								
Cyperaceae											
Carex acuta								*			*
Carex acutiformis	*			*		*	*	*		*	*
Carex arenaria	*	*		*	*			*			*

	a	b	c	d	e	f	g	h	i	j	k
Carex atrata	*			*				*			*
Carex bigelowii	*							*			*
Carex buxbaumii	*							*			*
Carex divulsa	*	*		*	*			*			
Carex echinata	*			*				*			*
Carex filiformis	*							*			
Carex flacca	*			*		*	*	*	*		*
Carex flava	*			*				*			*
Carex hirta	*			*				*			*
Carex montana	*			*				*			*
Carex muricata	*							*			*
Carex nigra	*			*		*	*	*	*		
Carex paniculata	*			*				*			*
Carex pendula	*	*		*	*			*			*
Carex remota	*			*				*			*
Carex spicata	*	*						*			
Carex sylvatica	*	*		*	*			*			*
Eriophorum angustifolium	*			*		*	*	*		*	
Scirpus sylvaticus	*	*		*	*	*		*		*	*
Diapensiaceae											
Diapensia lapponica											
Dipsacaceae											
Dipsacus fullonum											
Dipsacus pilosus											
Succisa pratensis											
Droseraceae											
Drosera rotundifolia											
Ericaceae											
Arctostaphylos uva-ursi											
Calluna vulgaris											
Erica cinerea											
Erica erigena											
Erica tetralix											
Loiseleuria procumbens											
Vaccinium myrtillus		*									
Euphorbiaceae											
Euphorbia amygdaloides		*									
Mercurialis perennis		*									
Fabaceae											
Anthyllis vulneraria							*				
Astragalus glycyphyllos							*				
Cytisus scoparius							*				
Hippocrepis comosa							*				
Lathyrus japonicus							*				
Lathyrus linifolius					*	*	*		*		
Lathyrus nissolia							*				
Lathyrus pratensis					*	*	*	*			
Lathyrus sylvestris							*				
Lotus corniculatus					*	*	*	*			

	a	b	c	d	e	f	g	h	i	j	k
Medicago lupulina						*	*	*	*		
Medicago sativa								*			
Onobrychis viciifolia								*			
Ononis spinosa								*			
Trifolium hybridum								*			
Trifolium pratense						*	*	*	*		
Trifolium repens						*	*	*	*		
Vicia hirsuta								*			
Vicia sepium						*	*	*		*	
Vicia sylvatica								*			
Fagaceae											
Castanea sativa											
Fagus sylvatica			*								
Quercus robur			*								
Frankeniaceae											
Frankenia laevis											
Fumariaceae											
Pseudofumaria lutea											
Gentianaceae											
Blackstonia perfoliata	*	*				*	*	*	*		
Gentiana verna	*	*		*	*	*	*	*	*		*
Gentianella amarella	*	*				*	*	*	*		*
Geraniaceae											
Geranium dissectum			*								
Geranium phaeum			*								
Geranium pratense											
Geranium pyrenaicum			*								
Geranium robertianum			*								
Geranium versicolor			*								
Grossulariaceae											
Ribes nigrum			*								
Ribes rubrum											
Ribes uva-crispa											
Hippuridaceae											
Hippuris vulgaris											
Hydrocharitaceae											
Elodea canadensis											
Hydrocharis morsus-ranae											
Stratiotes aloides											
Juncaceae											
Juncus acutiflorus											
Juncus acutus											
Juncus alpinoarticulatus											
Juncus biglumis											
Juncus bufonius											
Juncus bulbosus											
Juncus capitatus											
Juncus castaneus											
Juncus compressus											

	a	b	c	d	e	f	g	h	i	j	k
Juncus gerardi											
Juncus maritimus											
Juncus planifolius											
Juncus pygmaeus											
Juncus squarrosus											
Juncus subnodulosus											
Juncus tenuis											
Juncus trifidus											
Juncus triglumis											
Luzula arcuata											
Luzula campestris											
Luzula forsteri			*								
Luzula luzuloides											
Luzula multiflora											
Luzula pilosa			*								
Luzula sylvatica			*								
Juncaginaceae											
Triglochin maritimum											
Lamiaceae											
Ajuga reptans			*								
Ballota nigra			*								
Galeopsis tetrahit			*								
Glechoma hederacea			*								
Lamiastrum galeobdolon			*								
Lamium album											
Mentha aquatica											
Nepeta cataria			*								
Origanum vulgare			*								
Prunella vulgaris			*								
Stachys officinalis			*								
Stachys sylvatica			*								
Teucrium scorodonia			*								
Thymus serpyllum			*								
Lemnaceae											
Lemna minor											
Spirodela polyrhiza											
Wolffia arrhiza											
Lentibulariaceae											
Utricularia vulgaris											
Liliaceae											
Allium ursinum	*	*		*	*	*	*	*		*	
Colchicum autumnale	*	*		*	*			*			*
Convallaria majalis	*	*		*	*	*		*		*	*
Gagea lutea	*	*		*	*	*		*		*	*
Galanthus nivalis	*	*		*	*	*	*	*	*		
Hyacinthoides non-scripta	*	*		*	*	*		*		*	*
Lilium martagon	*	*		*	*			*			*
Narcissus pseudonarcissus	*	*		*	*	*		*		*	
Paris quadrifolia	*	*		*	*	*		*		*	*

	a	b	c	d	e	f	g	h	i	j	k
Polygonatum multiflorum	*	*		*	*	*		*	*		*
Polygonatum odoratum	*	*		*	*	*		*	*		*
Polygonatum verticillatum	*	*		*	*	*		*	*		*
Linaceae											
Linum catharticum											
Lythraceae											
Lythrum salicaria											
Malvaceae											
Lavatera arborea	*	*				*	*	*		*	*
Malva moschata	*	*		*	*			*			*
Malva neglecta	*	*		*	*	*	*	*		*	*
Malva sylvestris	*	*		*	*	*	*	*		*	*
Menyanthaceae											
Nymphoides peltata											
Nymphaeaceae											
Nuphar lutea											
Nymphaea alba											
Oleaceae											
Fraxinus excelsior			*								
Ligustrum vulgare			*								
Onagraceae											
Chamerion angustifolium	*			*		*	*	*		*	
Circaea alpina	*	*		*	*	*		*	*		*
Circaea lutetiana	*	*		*	*	*		*		*	*
Epilobium alsinifolium	*	*		*	*	*	*	*	*		*
Epilobium anagallidifolium	*	*		*	*	*	*	*	*		*
Epilobium hirsutum	*			*		*	*	*		*	*
Epilobium montanum	*	*		*	*	*	*	*		*	*
Epilobium palustre	*	*		*	*	*	*	*	*		*
Epilobium tetragonum	*	*		*	*	*	*	*	*		*
Oenothera biennis	*	*		*	*	*	*	*		*	*
Orchidaceae											
Listera ovata			*								
Ophrys apifera			*								
Orchis mascula			*								
Orchis militaris			*								
Oxalidaceae											
Oxalis acetosella			*								
Papaveraceae											
Glaucium flavum	*	*						*			*
Papaver rhoeas	*	*		*	*	*	*	*		*	*
Pinaceae											
Pinus sylvestris											
Plantaginaceae											
Plantago lanceolata											
Plantago major											
Plantago maritima											
Plantago media											

	a	b	c	d	e	f	g	h	i	j	k
Poaceae											
Agrostis curtisii											
Agrostis stolonifera											
Ammophila arenaria											
Anisantha sterilis											
Arrhenatherum elatius											
Brachypodium pinnatum											
Brachypodium sylvaticum											
Bromopsis ramosa											
Corynephorus canescens											
Deschampsia cespitosa											
Deschampsia flexuosa											
Elytrigia repens											
Festuca altissima											
Festuca arundinacea											
Festuca gigantea											
Festuca ovina											
Festuca pratensis											
Glyceria fluitans											
Helictotrichon pratense											
Helictotrichon pubescens											
Holcus lanatus											
Holcus mollis											
Hordelymus europaeus											
Hordeum jubatum											
Hordeum murinum											
Lolium perenne											
Melica nutans											
Melica uniflora											
Milium effusum											
Phalaris arundinacea											
Phleum alpinum											
Phleum pratense											
Phragmites australis											
Poa alpina											
Poa nemoralis											
Sesleria caerulea											
Spartina alterniflora											
Spartina anglica											
Spartina maritima											
Spartina x townsendii											
Polemoniaceae											
Polemonium caeruleum			*								
Polygonaceae											
Fallopia convolvulus	*	*				*	*	*		*	
Fallopia japonica				*		*		*		*	*
Oxyria digyna	*	*		*	*	*	*	*	*		*
Persicaria amphibia	*			*		*	*	*		*	*
Persicaria hydropiper	*			*		*	*	*		*	*

	a	b	c	d	e	f	g	h	i	j	k
Persicaria lapathifolia	*	*		*	*	*	*	*		*	*
Persicaria maculosa	*	*		*	*	*	*	*		*	*
Persicaria vivipara	*	*		*	*	*	*	*	*		*
Polygonum aviculare	*	*				*	*	*	*		*
Rumex acetosa	*	*				*	*	*		*	*
Rumex acetosella	*	*		*	*	*	*	*	*		
Rumex crispus	*	*		*	*	*	*	*		*	
Rumex crispus	*	*		*	*	*	*	*		*	
Rumex obtusifolius	*	*				*	*	*		*	*
Rumex obtusifolius	*	*				*	*	*		*	*
Rumex sanguineus	*	*		*	*			*			
Portulacaceae											
Portulaca oleracea											
Potamogetonaceae											
Potamogeton gramineus											
Primulaceae											
Lysimachia nemorum											
Lysimachia nummularia											
Lysimachia vulgaris											
Primula vulgaris											
Trientalis europaea											
Pyrolaceae											
Pyrola minor			*								
Pyrola rotundifolia			*								
Ranunculaceae											
Aconitum napellus	*	*		*	*			*			*
Actaea spicata	*	*		*	*			*			*
Anemone nemorosa	*	*				*		*		*	
Aquilegia vulgaris	*	*		*	*			*			*
Caltha palustris	*	*		*	*	*	*	*		*	*
Clematis vitalba	*	*		*	*	*	*	*	*		*
Helleborus foetidus	*	*		*	*			*			
Helleborus viridis	*	*						*			
Pulsatilla vulgaris	*	*		*	*			*			*
Ranunculus acris	*					*	*	*	*		*
Ranunculus auricomus	*	*		*	*			*			
Ranunculus bulbosus	*	*		*	*	*	*	*	*		*
Ranunculus ficaria	*	*		*	*	*		*	*		*
Ranunculus flammula	*	*		*	*	*	*	*	*		
Ranunculus hederaceus	*					*	*	*	*		
Ranunculus lingua	*	*		*	*	*	*	*		*	
Ranunculus omiophyllus	*					*	*	*	*		
Ranunculus parviflorus	*	*						*			*
Ranunculus repens	*	*		*	*	*	*	*		*	*
Ranunculus sceleratus	*	*		*	*	*	*	*		*	*
Thalictrum alpinum	*							*			*
Thalictrum flavum	*	*		*	*			*			
Resedaceae											
Reseda luteola	*	*		*	*	*	*	*	*		*

	a	b	c	d	e	f	g	h	i	j	k
Rhamnaceae											
Rhamnus catharticus											
Rosaceae											
Agrimonia eupatoria			*								
Crataegus monogyna			*								
Dryas octopetala											
Filipendula ulmaria											
Fragaria vesca			*								
Geum rivale			*								
Malus domestica											
Potentilla erecta			*								
Potentilla fruticosa											
Potentilla sterilis			*								
Prunus avium			*								
Prunus spinosa			*								
Rosa canina			*								
Rubus chamaemorus											
Rubus fruticosus											
Rubus saxatilis											
Sanguisorba officinalis											
Sibbaldia procumbens			*								
Sorbus aria			*								
Sorbus aucuparia			*								
Rubiaceae											
Galium aparine											
Galium boreale											
Galium mollugo			*								
Salicaceae											
Populus nigra			*								
Populus tremula			*								
Salix arbuscula											
Salix caprea			*								
Salix cinerea											
Salix lanata											
Salix myrsinites											
Salix phylicifolia											
Salix reticulata											
Salix viminalis											
Sarraceniaceae											
Sarracenia purpurea											
Saxifragaceae											
Parnassia palustris	*			*		*	*	*	*		*
Saxifraga aizoides	*	*		*	*			*			*
Saxifraga stellaris	*	*		*	*	*	*	*	*		*
Scrophulariaceae											
Digitalis purpurea											
Euphrasia confusa											
Linaria purpurea											
Linaria vulgaris											

	a	b	c	d	e	f	g	h	i	j	k
Mimulus guttatus											
Pedicularis palustris											
Scrophularia auriculata											
Scrophularia nodosa											
Sibthorpia europaea											
Veronica alpina											
Veronica beccabunga											
Veronica chamaedrys											
Veronica montana											
Veronica officinalis											
Veronica persica											
Solanaceae											
Atropa bella-donna	*	*		*	*	*		*		*	*
Datura stramonium	*	*		*	*	*	*	*		*	*
Solanum dulcamara	*	*		*	*	*		*		*	*
Solanum nigrum	*	*		*	*			*			*
Taxaceae											
Taxus baccata			*								
Thymelaeaceae											
Daphne laureola			*								
Daphne mezereum			*								
Tiliaceae											
Tilia cordata											
Tilia platyphyllos			*								
Urticaceae											
Urtica dioica											
Valerianaceae											
Valeriana officinalis											
Verbenaceae											
Verbena officinalis											
Violaceae											
Viola canina			*								
Viola hirta			*								
Viola odorata			*								
Viola reichenbachiana			*								

Mycorrhizal Analyses

Information was available for the following species, regarding whether or not they have mycorrhizas, the type of mycorrhizal infection and whether any infection was normally, occasionally or rarely present. The asterisks indicate which species were used for each analysis described in chapter 7.

Analyses

a. Species with arbuscular mycorrhizas or no mycorrhizal infection omitting those which are parasitic, floating aquatic or rootless.

All other analyses used only the species in group a.

b. Root diameter.
c. Root hairs.
d. Life form (theropyte/hemicryptophyte/hydrophyte/helophyte/geophyte/chamaephyte/phanerophyte).
e. Soil fertility.
f. Habitat water availability.
g. Extreme maximum pH of soil.
h. Extreme minimum pH of soil.
i. Number of habitat types perennials occur in.
j. Number of habitat types annuals occur in.
k. Number of habitat types common perennials occur in.
l. Number of habitat types perennials occur in, omitting species of wetland/saline habitats.
m. Seed weight of perennial species.
n. Seed weight of annual species.

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Aceraceae														
Acer campestre	*		*	*	*	*			*			*	*	
Acer platanoides														
Acer pseudoplatanus														
Adoxaceae														
Adoxa moschatellina	*			*	*	*			*			*	*	
Alismataceae														
Alisma lanceolatum	*			*	*									
Alisma plantago-aquatica	*		*	*	*				*		*		*	
Apiaceae														
Aegopodium podagraria	*	*		*	*	*			*		*	*	*	
Aethusa cynapium	*	*		*	*	*				*				*
Angelica archangelica	*			*	*									
Angelica sylvestris	*			*	*		*	*	*		*		*	
Apium graveolens	*			*	*				*				*	
Berula erecta	*			*	*		*	*	*					
Bupleurum falcatum	*			*	*	*			*			*		
Chaerophyllum temulum	*			*	*	*			*			*	*	
Conium maculatum	*			*	*	*			*		*	*		
Conopodium majus	*			*	*				*		*		*	
Daucus carota	*		*	*	*	*	*	*	*		*			

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Eryngium campestre	*			*	*	*			*			*		
Eryngium maritimum	*			*	*	*			*				*	
Heracleum sphondylium	*			*	*	*		*	*		*			
Hydrocotyle vulgaris	*		*	*	*		*	*	*		*		*	
Ligusticum scoticum	*			*	*				*					
Myrrhis odorata	*			*	*				*			*	*	
Oenanthe aquatica	*			*	*				*					
Oenanthe crocata	*			*	*				*					
Pastinaca sativa	*		*	*	*	*			*			*	*	
Peucedanum ostruthium	*			*	*	*			*					
Peucedanum palustre	*			*	*		*	*	*				*	
Pimpinella major	*			*	*	*			*			*	*	
Pimpinella saxifraga	*			*	*	*			*		*		*	
Sanicula europaea	*			*	*	*			*		*	*	*	
Scandix pecten-veneris	*			*	*	*				*				
Seseli libanotis	*			*	*	*			*			*	*	
Silaum silaus	*			*	*	*			*			*		
Sium latifolium	*			*	*		*	*	*					
Apocynaceae														
Vinca minor	*			*	*	*			*			*		
Aquifoliaceae														
Ilex aquifolium	*	*		*	*	*	*	*	*		*	*	*	
Araceae														
Acorus calamus	*			*	*				*				*	
Arum italicum	*			*	*				*			*	*	
Arum maculatum	*		*	*	*	*	*	*	*			*	*	
Araliaceae														
Hedera helix	*	*		*	*	*			*		*		*	
Asteraceae														
Achillea millefolium	*		*	*	*	*	*	*	*		*		*	
Achillea ptarmica	*			*	*		*	*	*		*		*	
Antennaria dioica	*			*	*	*			*			*		
Anthemis arvensis	*			*	*	*	*	*		*				
Arctium lappa	*			*	*	*			*			*	*	
Arctium minus	*			*	*	*			*		*	*		
Artemisia absinthium	*			*	*	*			*			*	*	
Artemisia campestris	*			*	*	*			*			*	*	
Artemisia vulgaris	*			*	*	*							*	
Aster linosyris	*			*	*	*			*			*		
Aster novi-belgii	*			*	*									
Aster tripolium	*			*	*		*	*	*					
Bellis perennis	*			*	*				*		*		*	
Bidens tripartita	*			*	*					*				*
Carduus crispus	*			*	*	*			*			*	*	
Carlina vulgaris	*		*	*	*	*			*				*	
Centaurea cyanus	*			*	*					*				*
Centaurea nigra	*			*	*	*			*		*		*	
Centaurea scabiosa	*			*	*	*			*				*	
Chrysanthemum segetum	*	*		*	*	*				*				*

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Cicerbita alpina	*			*	*	*			*			*		
Cichorium intybus	*			*	*	*			*			*	*	
Cirsium acaule	*		*	*	*			*	*				*	
Cirsium arvense	*			*	*				*		*		*	
Cirsium heterophyllum	*			*	*				*			*		
Cirsium palustre	*			*	*		*	*	*		*		*	
Cirsium vulgare	*			*	*	*			*		*		*	
Crepis biennis	*			*	*	*			*			*		
Crepis capillaris	*			*	*	*			*	*	*		*	*
Crepis paludosa	*			*	*		*	*	*					
Hieracium umbellatum	*			*	*	*								
Hieracium vulgatum	*			*					*					
Homogyne alpina	*			*		*								
Hypochaeris radicata	*			*	*	*	*	*	*		*		*	
Lapsana communis	*	*		*	*	*				*				*
Leontodon autumnalis	*			*	*	*			*		*		*	
Leontodon hispidus	*			*	*	*			*					
Mycelis muralis	*			*	*	*			*			*	*	
Onopordum acanthium	*			*		*								
Petasites albus	*			*		*								
Petasites hybridus	*			*	*				*		*	*	*	
Picris echioides	*			*	*				*	*				
Picris hieracioides	*			*	*	*			*			*		
Pilosella officinarum	*		*	*	*	*			*				*	
Saussurea alpina	*			*	*	*			*					
Senecio erucifolius	*			*	*				*				*	
Senecio jacobaea	*	*		*	*	*	*	*	*		*			
Senecio squalidus	*			*	*				*	*			*	*
Senecio sylvaticus	*			*	*	*				*				*
Senecio viscosus	*			*	*	*				*				*
Senecio vulgaris	*	*		*	*	*				*				*
Seriphidium maritimum	*			*	*	*			*					
Serratula tinctoria	*			*	*		*	*	*					
Sonchus arvensis	*		*	*	*	*			*		*		*	
Sonchus asper	*			*	*	*				*				*
Sonchus oleraceus	*	*		*	*	*	*	*	*		*		*	
Taraxacum officinale agg.	*	*		*		*							*	
Tragopogon pratensis	*			*	*	*			*					
Tussilago farfara	*			*	*	*	*		*		*		*	
Balsaminaceae														
Impatiens glandulifera	*			*	*					*				*
Impatiens noli-tangere	*			*	*	*				*				
Impatiens parviflora	*			*	*	*	*	*		*				*
Berberidaceae														
Berberis vulgaris	*			*	*	*			*			*	*	
Mahonia aquifolium	*			*									*	
Betulaceae														
Alnus glutinosa	*			*	*		*	*					*	
Betula nana														

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Betula pendula														
Betula pubescens														
Carpinus betulus														
Corylus avellana														
Boraginaceae														
Echium vulgare	*			*	*	*			*				*	
Lithospermum arvense	*			*	*					*				*
Lithospermum officinale	*			*	*				*			*	*	
Lithospermum purpurocaerulea		*			*	*				*			*	*
Myosotis alpestris	*			*	*		*	*					*	
Myosotis arvensis	*			*	*	*			*		*		*	
Myosotis discolor	*			*	*	*				*				
Myosotis laxa	*			*	*		*	*						
Myosotis ramosissima	*			*	*	*								*
Myosotis scorpioides	*		*	*	*		*	*	*		*		*	
Myosotis sylvatica	*			*	*	*			*			*		
Pulmonaria officinalis	*			*	*	*			*			*		
Symphytum officinale	*			*	*				*					
Symphytum tuberosum	*			*	*	*			*			*		
Brassicaceae														
Alliaria petiolata	*			*	*	*			*		*	*	*	
Arabidopsis thaliana	*			*	*	*			*	*	*	*	*	*
Arabis alpina	*			*	*	*			*			*	*	
Arabis hirsuta	*			*	*	*			*			*	*	
Arabis petraea	*			*	*				*			*		
Armoracia rusticana	*			*	*	*			*			*		
Barbarea vulgaris	*			*	*	*			*		*	*	*	
Brassica napus	*			*										
Brassica nigra	*			*	*					*				*
Brassica oleracea	*			*	*		*	*	*				*	
Brassica rapa	*			*	*				*	*	*	*		
Cakile maritima	*			*	*	*				*				*
Capsella bursa-pastoris	*	*		*	*					*				*
Cardamine amara	*			*	*				*				*	
Cardamine bulbifera	*			*	*				*			*		
Cardamine flexuosa	*			*	*		*	*	*		*		*	
Cardamine hirsuta	*	*		*	*	*								
Cardamine impatiens	*			*	*	*			*	*		*		
Cardamine pratensis	*			*	*	*	*	*	*		*		*	
Cochlearia anglica	*			*	*	*			*					
Cochlearia danica	*			*	*					*				
Diplotaxis muralis	*			*	*	*				*				*
Erysimum cheiranthoides	*	*		*	*					*				
Iberis amara	*			*	*					*				*
Isatis tinctoria	*			*	*	*			*			*		
Lepidium ruderale	*			*	*				*	*		*	*	*
Raphanus raphanistrum	*			*	*				*	*	*		*	*
Rorippa nasturtium-aquaticum	*		*	*									*	
Rorippa palustris	*			*	*								*	*

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Sinapis alba	*			*	*					*				*
Sisymbrium loeselii	*			*	*	*								
Sisymbrium officinale	*			*	*	*				*				
Sisymbrium orientale	*			*	*									*
Thlaspi arvense	*			*	*	*				*				*
Buddlejaceae														
Buddleja davidii	*			*	*									
Butomaceae														
Butomus umbellatus	*		*	*	*				*				*	
Buxaceae														
Buxus sempervirens	*			*	*	*			*			*	*	
Callitrichaceae														
Callitriche hamulata														
Campanulaceae														
Campanula glomerata	*			*	*	*			*			*	*	
Campanula patula	*			*	*	*								
Campanula rapunculoides	*			*	*	*			*			*	*	
Campanula rotundifolia	*			*	*	*	*		*		*		*	
Campanula trachelium	*			*	*	*			*			*	*	
Jasione montana	*			*	*	*	*	*	*					
Lobelia dortmanna	*		*	*	*		*	*	*					
Phyteuma orbiculare	*			*	*				*			*	*	
Phyteuma spicatum	*			*	*	*			*			*		
Cannabaceae														
Humulus lupulus	*			*	*				*			*		
Caprifoliaceae														
Linnaea borealis	*			*	*	*			*			*	*	
Lonicera caprifolium	*			*					*			*	*	
Lonicera periclymenum	*			*	*				*		*	*	*	
Lonicera xylosteum	*			*	*	*			*			*		
Sambucus nigra	*			*	*	*			*		*		*	
Sambucus racemosa	*			*	*	*								
Symphoricarpos albus	*			*										
Viburnum lantana	*			*	*	*			*			*	*	
Viburnum opulus	*			*	*				*		*	*	*	
Caryophyllaceae														
Agrostemma githago	*	*	*	*	*					*				*
Arenaria norvegica	*			*	*				*	*		*		
Arenaria serpyllifolia	*			*	*	*				*				*
Cerastium alpinum	*			*	*	*			*			*		
Cerastium arcticum	*			*	*				*			*		
Cerastium arvense	*			*	*	*			*				*	
Cerastium cerastoides	*			*	*				*					
Cerastium fontanum	*		*	*	*	*			*		*		*	
Cerastium semidecandrum	*			*	*	*				*				*
Dianthus deltoides	*			*	*	*			*				*	
Dianthus gratianopolitanus	*			*	*				*			*		
Honckenya peploides	*			*	*	*			*				*	
Lychnis flos-cuculi	*			*	*	*	*	*	*		*		*	

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Lychnis viscaria	*		*	*	*		*	*	*			*	*	
Minuartia hybrida	*			*	*									*
Minuartia verna	*			*	*	*			*				*	
Moehringia trinervia	*			*	*	*				*				*
Myosoton aquaticum	*			*	*				*				*	
Sagina apetala	*			*	*	*				*				*
Sagina procumbens	*			*	*	*			*		*		*	
Sagina subulata	*			*	*				*			*		
Saponaria officinalis	*			*	*	*							*	
Scleranthus annuus	*			*	*					*				*
Silene acaulis	*			*	*	*	*	*	*				*	
Silene dioica	*	*	*	*	*	*	*	*	*		*		*	
Silene latifolia	*	*	*	*	*	*	*	*	*				*	
Silene nutans	*			*	*	*	*	*	*				*	
Silene otites	*			*	*	*			*			*	*	
Silene vulgaris	*	*	*	*	*	*			*		*			
Spergula arvensis	*			*	*	*	*	*						*
Spergularia marina	*			*	*					*				*
Spergularia media	*			*	*	*			*					
Stellaria graminea	*			*	*	*			*		*	*		
Stellaria holostea	*			*	*	*			*		*	*	*	
Stellaria media	*	*	*	*	*	*		*		*				
Stellaria nemorum	*			*	*	*			*			*		
Stellaria pallida	*			*										
Stellaria palustris	*			*	*		*	*	*					
Stellaria uliginosa	*			*	*		*	*	*		*		*	
Celastraceae														
Euonymus europaeus	*			*	*	*			*			*		
Chenopodiaceae														
Atriplex glabriuscula	*			*	*					*				
Atriplex littoralis	*			*	*					*				
Atriplex patula	*			*	*	*				*				*
Atriplex portulacoides	*			*	*		*	*	*					
Atriplex prostrata	*			*	*					*				*
Beta vulgaris	*			*	*				*	*				
Chenopodium album	*	*		*	*	*								
Chenopodium bonus-henricus	*			*	*	*			*		*	*	*	
Chenopodium glaucum	*			*	*	*				*				
Chenopodium rubrum	*	*		*	*	*	*	*		*				*
Salicornia dolichostachya	*			*	*									
Salicornia europaea	*		*	*	*									
Salsola kali	*			*	*					*				
Suaeda maritima	*		*	*	*		*	*		*				
Suaeda vera	*			*	*				*					
Cistaceae														
Helianthemum apenninum	*		*	*	*	*	*	*					*	
Helianthemum canum	*		*	*	*	*	*	*	*			*	*	
Helianthemum nummularium	*		*	*	*	*	*	*	*				*	
Clusiaceae														

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Hypericum calycinum	*			*									*	
Hypericum hirsutum	*			*	*	*			*			*	*	
Hypericum humifusum	*			*	*	*			*		*	*		
Hypericum maculatum	*			*	*	*			*			*	*	
Hypericum montanum	*			*	*	*			*			*	*	
Hypericum perforatum	*		*	*	*	*			*		*	*	*	
Hypericum pulchrum	*			*	*	*			*		*		*	
Hypericum tetrapterum	*			*	*		*	*	*		*		*	
Convolvulaceae														
Calystegia sepium	*			*	*	*							*	
Calystegia soldanella	*			*	*				*					
Convolvulus arvensis	*			*	*	*			*		*		*	
Cornaceae														
Cornus sanguinea	*			*	*				*			*		
Crassulaceae														
Sedum acre	*			*	*	*			*		*		*	
Sedum album	*			*	*	*			*			*		
Sedum forsteranum	*			*	*				*			*	*	
Sedum rosea	*			*	*				*				*	
Sedum rupestre	*			*	*	*			*			*		
Sedum telephium	*			*	*	*	*	*	*					
Cucurbitaceae														
Bryonia dioica	*			*	*				*			*		
Cupressaceae														
Juniperus communis	*			*	*	*			*			*	*	
Cyperaceae														
Blysmus compressus	*		*	*	*				*					
Blysmus rufus	*			*	*	*			*					
Bulboschoenus maritimus	*			*					*					
Carex acuta	*			*					*					
Carex acutiformis	*		*	*	*				*				*	
Carex appropinquata	*			*	*		*	*	*					
Carex aquatilis	*			*	*		*	*	*					
Carex arenaria	*		*	*	*	*	*	*	*				*	
Carex atrata	*		*	*	*	*			*			*		
Carex atrofusca	*			*					*					
Carex bigelowii	*			*	*				*					
Carex binervis	*		*	*	*				*		*		*	
Carex buxbaumii	*			*					*					
Carex capillaris	*			*	*	*			*					
Carex caryophyllea	*			*	*	*			*		*		*	
Carex chordorrhiza	*			*	*		*	*						
Carex curta	*			*	*		*	*	*					
Carex depauperata	*			*			*	*						
Carex diandra	*			*	*		*	*	*					
Carex digitata	*			*	*	*	*	*	*			*		
Carex dioica	*			*	*		*	*	*					
Carex distans	*			*	*	*			*					
Carex disticha	*			*	*				*					

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Carex divisa	*			*					*					
Carex divulsa	*			*		*			*			*		
Carex echinata	*			*	*		*	*	*		*			
Carex elata	*			*	*		*	*	*					
Carex elongata	*			*	*				*			*		
Carex ericetorum	*			*	*	*			*			*		
Carex extensa	*			*	*	*			*					
Carex filiformis	*		*	*					*			*		
Carex flacca	*		*	*	*	*	*	*	*		*		*	
Carex flava	*			*	*				*					
Carex hirta	*			*	*	*			*		*			
Carex hostiana	*			*	*		*	*	*		*			
Carex humilis	*			*	*	*			*			*		
Carex lachenalii	*			*					*			*		
Carex laevigata	*			*	*				*			*		
Carex lasiocarpa	*			*	*		*	*	*					
Carex limosa	*			*	*		*	*	*					
Carex magellanica	*			*					*					
Carex maritima	*			*	*				*					
Carex microglochin	*			*	*				*					
Carex montana	*			*	*	*	*	*	*			*		
Carex muricata	*			*			*	*					*	
Carex nigra	*			*	*		*	*	*		*		*	
Carex norvegica	*			*	*				*			*		
Carex ornithopoda	*			*	*	*			*			*		
Carex otrubae	*			*	*				*				*	
Carex ovalis	*			*					*		*	*	*	
Carex pallescens	*			*	*	*			*			*		
Carex panicea	*			*	*	*			*		*		*	
Carex paniculata	*			*	*				*		*			
Carex pauciflora	*			*	*		*	*	*					
Carex pendula	*			*					*			*		
Carex pilulifera	*			*	*	*			*		*		*	
Carex pseudocyperus	*			*	*		*	*	*					
Carex pulicaris	*			*	*		*	*	*		*		*	
Carex punctata	*			*					*					
Carex rariflora	*			*	*				*					
Carex recta	*			*	*									
Carex remota	*	*		*	*				*		*	*	*	
Carex riparia	*			*	*		*	*	*				*	
Carex rostrata	*			*	*		*	*	*		*			
Carex rupestris	*			*					*			*		
Carex saxatilis	*			*					*					
Carex spicata	*			*			*	*	*			*	*	
Carex strigosa	*			*	*	*			*			*		
Carex sylvatica	*	*		*		*			*		*	*		
Carex vaginata	*			*	*				*					
Carex vesicaria	*			*	*		*	*	*					
Carex vulpina	*			*	*				*			*		

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Cladium mariscus	*			*	*		*	*	*					
Cyperus fuscus	*			*	*					*				*
Cyperus longus	*			*	*				*					
Eleocharis acicularis	*			*	*				*					
Eleocharis austriaca	*			*	*		*	*					*	
Eleocharis multicaulis	*			*			*	*	*					
Eleocharis palustris	*			*	*		*	*	*		*		*	
Eleocharis parvula	*			*					*					
Eleocharis quinqueflora	*			*	*		*	*						
Eleocharis uniglumis	*			*	*		*							
Eleogiton fluitans	*			*					*		*			
Eriophorum angustifolium	*		*	*	*		*	*	*		*		*	
Eriophorum gracile	*			*	*		*	*	*					
Eriophorum latifolium	*			*	*		*	*	*					
Eriophorum vaginatum	*			*	*		*	*	*				*	
Isolepis cernua	*			*	*					*				
Isolepis setacea	*			*	*				*	*	*			
Kobresia simpliciuscula	*			*	*				*					
Rhynchospora alba	*			*	*		*	*	*				*	
Rhynchospora fusca	*			*	*				*					
Schoenoplectus lacustris	*			*	*		*	*	*		*			
Schoenoplectus triqueter	*			*	*				*					
Schoenus ferrugineus	*			*	*		*	*	*					
Schoenus nigricans	*			*	*		*	*	*				*	
Scirpoides holoschoenus	*			*	*									
Scirpus sylvaticus	*			*	*				*			*		
Trichophorum cespitosum	*			*	*		*	*	*		*			
Diapensiaceae														
Diapensia lapponica														
Dioscoreaceae														
Tamus communis	*			*	*	*			*			*		
Dipsacaceae														
Dipsacus fullonum	*			*	*	*			*				*	
Knautia arvensis	*			*	*	*			*		*	*	*	
Scabiosa columbaria	*		*	*	*	*			*			*	*	
Succisa pratensis	*			*	*	*	*	*	*		*		*	
Droseraceae														
Drosera intermedia	*		*	*	*		*	*	*				*	
Drosera longifolia	*		*	*	*		*	*	*				*	
Drosera rotundifolia	*		*	*	*		*	*	*		*		*	
Elaeagnaceae														
Hippophae rhamnoides	*			*	*	*	*	*	*				*	
Empetraceae														
Empetrum nigrum														
Ericaceae														
Andromeda polifolia														
Arbutus unedo														
Arctostaphylos alpinus														
Arctostaphylos uva-ursi														

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Calluna vulgaris														
Daboecia cantabrica														
Erica cinerea														
Erica erigena														
Erica mackaiana														
Erica tetralix														
Erica vagans														
Ledum palustre														
Loiseleuria procumbens														
Phyllodoce caerulea														
Rhododendron ponticum														
Vaccinium microcarpum														
Vaccinium myrtillus														
Vaccinium oxycoccos														
Vaccinium uliginosum														
Vaccinium vitis-idaea														
Eriocaulaceae														
Eriocaulon aquaticum	*		*	*					*					
Euphorbiaceae														
Euphorbia amygdaloides	*			*	*	*			*			*	*	
Euphorbia cyparissias	*			*	*	*			*			*	*	
Euphorbia dulcis	*			*	*	*			*			*		
Euphorbia esula	*			*	*								*	
Euphorbia helioscopia	*			*	*	*				*				*
Euphorbia paralias	*			*	*				*				*	
Euphorbia peplus	*	*		*	*	*				*				*
Mercurialis annua	*			*	*	*				*				*
Mercurialis perennis	*	*	*	*	*		*	*	*			*	*	
Fabaceae														
Anthyllis vulneraria	*		*	*	*	*			*		*		*	
Astragalus glycyphyllos	*			*	*	*			*			*	*	
Cytisus scoparius	*	*		*	*	*			*		*	*	*	
Genista tinctoria	*			*	*	*			*				*	
Hippocrepis comosa	*		*	*	*	*	*	*	*				*	
Laburnum anagyroides	*			*	*									
Lathyrus japonicus	*			*	*		*	*	*				*	
Lathyrus linifolius	*			*	*	*			*		*	*	*	
Lathyrus niger	*			*	*	*								
Lathyrus pratensis	*			*	*	*	*	*	*		*		*	
Lotus corniculatus	*		*	*	*	*			*		*		*	
Lotus pedunculatus	*			*	*		*	*	*		*		*	
Medicago lupulina	*		*	*	*	*			*	*	*		*	*
Medicago polymorpha	*			*	*					*				*
Medicago sativa	*			*	*									
Melilotus albus	*			*	*	*			*	*		*	*	*
Melilotus officinalis	*			*	*	*			*			*	*	
Onobrychis viciifolia	*		*	*	*	*			*			*		
Ononis repens	*			*	*	*			*		*		*	
Ononis spinosa	*		*	*	*				*			*	*	

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Robinia pseudoacacia	*			*	*	*							*	
Securigera varia	*			*	*	*			*			*	*	
Trifolium dubium	*			*	*	*				*				*
Trifolium glomeratum	*			*	*					*				*
Trifolium hybridum	*			*	*	*			*			*	*	
Trifolium medium	*			*	*	*			*		*	*	*	
Trifolium pratense	*			*	*				*		*			
Trifolium repens	*			*	*			*	*		*		*	
Trifolium subterraneum	*			*	*									*
Ulex europaeus	*			*	*				*		*		*	
Vicia cracca	*			*	*	*			*		*		*	
Vicia hirsuta	*			*	*					*				*
Vicia sativa	*			*	*					*				*
Vicia sepium	*			*	*	*			*		*	*	*	
Vicia sylvatica	*			*	*				*					
Vicia tetrasperma	*			*	*	*				*				*
Fagaceae														
Castanea sativa														
Fagus sylvatica														
Quercus cerris														
Quercus petraea														
Quercus robur														
Frankeniaceae														
Frankenia laevis	*		*	*	*		*	*	*				*	
Fumariaceae														
Fumaria officinalis	*			*	*	*				*				*
Pseudofumaria lutea	*			*									*	
Gentianaceae														
Blackstonia perfoliata	*		*	*	*					*				*
Centaurium erythraea	*			*	*	*			*				*	
Centaurium littorale	*			*	*				*					
Centaurium pulchellum	*			*	*	*				*				*
Centaurium scilloides	*			*	*				*					
Centaurium tenuiflorum	*			*	*									
Cicendia filiformis	*			*	*					*				
Gentiana nivalis	*			*	*	*				*				*
Gentiana pneumonanthe	*			*	*	*	*	*	*				*	
Gentiana verna	*			*	*	*	*	*	*			*		
Gentianella amarella	*		*	*	*				*				*	
Gentianella anglica	*			*	*				*			*	*	
Gentianella campestris	*			*	*	*							*	*
Gentianella germanica	*			*	*	*			*			*	*	
Gentianella uliginosa	*			*					*	*				
Geraniaceae														
Erodium cicutarium	*			*	*									*
Geranium dissectum	*			*	*	*				*				
Geranium lucidum	*			*	*					*				*
Geranium molle	*	*		*	*					*				*
Geranium pratense	*			*	*	*			*			*	*	

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Geranium robertianum	*			*	*				*	*	*			
Geranium sanguineum														
Geranium sylvaticum	*			*	*	*			*			*		
Grossulariaceae														
Ribes alpinum	*			*	*				*			*		
Ribes nigrum	*			*	*				*			*		
Ribes rubrum	*			*	*				*			*	*	
Ribes uva-crispa	*			*	*				*			*		
Haloragaceae														
Myriophyllum alterniflorum	*			*					*		*			
Hydrocharitaceae														
Elodea canadensis	*		*	*					*					
Hydrilla verticillata	*			*					*					
Iridaceae														
Crocus vernus	*			*										
Iris foetidissima	*			*	*				*			*	*	
Iris pseudacorus	*			*	*		*	*	*		*		*	
Juncaceae														
Juncus acutiflorus	*			*	*				*		*		*	
Juncus alpinoarticulatus	*			*	*		*	*	*					
Juncus articulatus	*			*	*		*	*	*		*		*	
Juncus biglumis	*			*	*				*			*		
Juncus bufonius	*			*	*	*				*				*
Juncus bulbosus	*			*	*		*	*	*		*		*	
Juncus effusus	*			*	*	*	*	*	*		*		*	
Juncus filiformis	*		*	*	*		*	*	*				*	
Juncus gerardi	*			*	*	*			*				*	
Juncus inflexus	*		*	*	*	*	*	*	*				*	
Juncus maritimus	*			*					*					
Juncus squarrosus	*		*	*	*		*	*	*		*		*	
Juncus trifidus	*			*	*	*			*			*		
Luzula campestris	*		*	*	*	*			*		*		*	
Luzula luzuloides	*			*	*									
Luzula pallidula	*			*										
Luzula pilosa	*			*	*				*		*	*	*	
Luzula spicata	*			*	*	*			*					
Luzula sylvatica	*			*	*	*			*		*			
Juncaginaceae														
Triglochin maritimum	*		*	*	*	*			*				*	
Triglochin palustre	*			*	*		*	*	*		*			
Lamiaceae														
Ajuga reptans	*	*		*	*	*			*		*	*		
Ballota nigra	*			*	*	*			*			*	*	
Clinopodium vulgare	*			*	*	*			*			*	*	
Galeopsis segetum	*			*	*	*				*				
Galeopsis tetrahit	*			*	*	*								*
Glechoma hederacea	*	*		*	*	*			*		*		*	
Lamiastrum galeobdolon	*	*		*	*	*	*	*	*			*	*	
Lamium album	*	*		*	*	*			*			*	*	

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Lamium amplexicaule	*			*	*	*				*				*
Lycopus europaeus	*			*	*		*	*	*		*			
Melittis melissophyllum	*			*	*	*			*			*		
Mentha aquatica	*			*	*		*	*	*		*		*	
Mentha arvensis	*			*	*				*		*	*		
Mentha pulegium	*			*	*	*			*			*	*	
Nepeta cataria	*			*	*				*			*	*	
Origanum vulgare	*		*	*	*	*			*			*	*	
Prunella vulgaris	*			*	*				*		*		*	
Salvia pratensis	*			*	*	*			*			*		
Salvia verbenaca	*			*	*				*				*	
Scutellaria galericulata	*			*	*		*	*	*		*		*	
Stachys officinalis	*			*	*		*	*	*				*	
Stachys palustris	*			*	*	*	*	*	*		*		*	
Stachys sylvatica	*			*	*	*			*		*	*	*	
Teucrium scordium	*			*	*				*				*	
Teucrium scorodonia	*		*	*	*	*	*	*	*		*		*	
Thymus serpyllum	*		*	*	*	*								
Lemnaceae														
Lemna gibba														
Lemna minor														
Lemna trisulca														
Spirodela polyrhiza														
Wolffia arrhiza														
Lentibulariaceae														
Pinguicula vulgaris	*			*	*		*	*	*		*			
Utricularia intermedia														
Utricularia minor														
Utricularia vulgaris														
Liliaceae														
Allium oleraceum	*			*	*	*			*			*		
Allium schoenoprasum	*			*	*				*			*	*	
Allium scorodoprasum	*			*	*	*			*			*		
Allium sphaerocephalon	*			*	*		*	*	*			*	*	
Allium triquetrum	*			*	*				*			*		
Allium ursinum	*	*	*	*	*	*		*	*		*	*	*	
Asparagus officinalis	*			*	*				*					
Colchicum autumnale	*			*	*	*			*			*	*	
Convallaria majalis	*			*	*	*			*			*	*	
Gagea lutea	*			*	*	*			*			*		
Galanthus nivalis	*			*	*	*			*			*		
Hyacinthoides non-scripta	*	*	*	*	*	*	*	*	*		*			
Leucojum aestivum	*			*	*				*			*	*	
Leucojum vernum	*			*	*	*			*			*	*	
Lilium martagon	*			*	*	*								
Maianthemum bifolium	*			*	*				*			*		
Muscari neglectum	*			*	*				*			*		
Narcissus pseudonarcissus	*			*	*	*		*	*			*		
Narthecium ossifragum	*		*	*	*		*	*					*	

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Ornithogalum angustifolium	*			*	*				*			*		
Ornithogalum pyrenaicum	*			*	*				*			*	*	
Paris quadrifolia	*			*	*	*			*			*	*	
Polygonatum multiflorum	*			*	*	*			*			*		
Polygonatum odoratum	*			*	*	*			*			*	*	
Polygonatum verticillatum	*			*	*	*			*			*	*	
Ruscus aculeatus	*			*	*				*			*		
Scilla autumnalis	*			*	*				*				*	
Tofieldia pusilla	*			*	*		*	*	*					
Linaceae														
Linum catharticum	*		*	*	*				*		*		*	
Linum perenne	*			*	*		*	*	*			*	*	
Lythraceae														
Lythrum hyssopifolia	*		*	*	*	*				*				
Lythrum salicaria	*			*	*		*	*	*		*		*	
Malvaceae														
Althaea officinalis	*			*	*				*				*	
Malva sylvestris	*			*	*	*			*		*	*	*	
Menyanthaceae														
Menyanthes trifoliata	*			*	*		*	*	*		*		*	
Nymphoides peltata	*			*					*				*	
Monotropaceae														
Monotropa hypopitys														
Myricaceae														
Myrica gale	*			*	*		*	*	*				*	
Oleaceae														
Fraxinus excelsior	*			*	*	*			*		*	*	*	
Ligustrum vulgare	*			*	*				*			*		
Onagraceae														
Chamerion angustifolium	*	*	*	*	*	*			*				*	
Circaea alpina	*			*	*	*			*			*		
Circaea lutetiana	*			*	*	*			*		*	*	*	
Epilobium alsinifolium	*			*	*				*					
Epilobium anagallidifolium	*			*	*	*			*					
Epilobium ciliatum	*			*	*				*					
Epilobium hirsutum	*			*	*		*	*	*		*			
Epilobium lanceolatum	*			*	*									
Epilobium montanum	*			*	*	*			*		*	*	*	
Epilobium obscurum	*			*	*				*		*	*	*	
Epilobium palustre	*			*	*	*	*	*	*		*		*	
Epilobium parviflorum	*			*	*		*	*	*		*		*	
Epilobium roseum	*			*	*				*			*		
Epilobium tetragonum	*	*		*	*	*			*			*		
Oenothera biennis	*			*	*	*							*	
Oenothera glazioviana	*			*	*								*	
Orchidaceae														
Aceras anthropophorum														
Anacamptis pyramidalis														
Cephalanthera damasonium														

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Cephalanthera longifolia														
Cephalanthera rubra														
Coeloglossum viride														
Corallorhiza trifida														
Cypripedium calceolus														
Dactylorhiza fuchsii														
Dactylorhiza incarnata														
Dactylorhiza maculata														
Dactylorhiza majalis														
Epipactis atrorubens														
Epipactis helleborine														
Epipactis palustris														
Epipactis purpurata														
Epipogium aphyllum														
Goodyera repens														
Gymnadenia conopsea														
Hammarbya paludosa														
Herminium monorchis														
Himantoglossum hircinum														
Liparis loeselii														
Listera cordata														
Listera ovata														
Neotinea maculata														
Neottia nidus-avis														
Ophrys apifera														
Ophrys fuciflora														
Ophrys insectifera														
Ophrys sphegodes														
Orchis mascula														
Orchis militaris														
Orchis morio														
Orchis purpurea														
Orchis simia														
Orchis ustulata														
Platanthera bifolia														
Platanthera chlorantha														
Pseudorchis albida														
Spiranthes spiralis														
Oxalidaceae														
Oxalis acetosella	*	*		*	*	*	*	*	*		*	*	*	
Oxalis corniculata	*			*	*	*			*	*		*	*	*
Oxalis stricta	*			*	*				*	*		*		
Papaveraceae														
Chelidonium majus	*			*	*	*							*	
Papaver rhoeas	*	*		*	*	*				*				*
Pinaceae														
Pinus pinaster														
Pinus sylvestris														
Plantaginaceae														

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Littorella uniflora	*		*	*	*		*	*	*				*	
Plantago coronopus	*			*	*	*	*	*	*	*			*	*
Plantago lanceolata	*	*	*	*	*				*		*		*	
Plantago major	*	*		*	*	*			*		*		*	
Plantago maritima	*			*	*	*	*	*	*				*	
Plantago media	*		*	*	*	*			*			*	*	
Plumbaginaceae														
Armeria maritima	*	*		*	*	*			*					
Limonium vulgare	*			*	*	*			*					
Poaceae														
Agrostis canina	*			*	*				*		*		*	
Agrostis capillaris	*			*	*				*		*		*	
Agrostis gigantea	*			*	*				*			*	*	
Agrostis stolonifera	*			*	*	*	*	*	*		*		*	
Aira caryophyllea	*			*	*	*				*				*
Aira praecox	*			*	*	*				*				*
Alopecurus geniculatus	*			*	*				*		*		*	
Alopecurus myosuroides	*			*	*	*				*				*
Alopecurus pratensis	*			*	*	*			*		*		*	
Ammophila arenaria	*			*	*	*	*	*	*				*	
Anthoxanthum odoratum	*			*	*	*			*		*		*	
Apera spica-venti	*			*		*								*
Arrhenatherum elatius	*			*	*	*	*	*	*		*		*	
Avena fatua	*			*	*	*				*				*
Brachypodium pinnatum	*			*	*	*			*				*	
Brachypodium sylvaticum	*			*	*	*			*		*		*	
Briza media	*			*	*				*		*		*	
Briza minor	*			*	*					*				*
Bromopsis erecta	*		*	*	*	*			*			*	*	
Bromus hordeaceus	*			*	*								*	*
Calamagrostis canescens	*			*	*		*	*	*					
Calamagrostis epigejos	*			*	*		*	*	*					
Calamagrostis stricta	*			*	*		*	*	*					
Corynephorus canescens	*		*	*	*	*			*				*	
Cynodon dactylon	*			*	*	*			*					
Danthonia decumbens	*			*	*				*		*		*	
Deschampsia cespitosa	*	*		*	*	*	*	*	*		*			
Deschampsia flexuosa	*		*	*	*		*		*		*		*	
Elymus caninus	*			*	*	*			*			*	*	
Elytrigia atherica	*			*					*				*	
Elytrigia juncea	*			*	*	*			*					
Elytrigia repens	*			*	*	*			*		*		*	
Festuca altissima	*			*	*	*			*			*	*	
Festuca arundinacea	*			*	*	*			*		*			
Festuca gigantea	*			*	*	*			*		*	*	*	
Festuca juncifolia	*			*	*				*					
Festuca ovina	*			*	*	*							*	
Festuca pratensis	*			*	*	*			*		*	*	*	
Festuca rubra	*			*	*				*		*			

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Festuca vivipara	*			*	*		*	*						
Glyceria fluitans	*			*	*				*		*		*	
Glyceria maxima	*		*	*	*		*	*	*				*	
Glyceria notata	*			*					*					
Helictotrichon pratense	*		*	*	*	*	*	*	*				*	
Helictotrichon pubescens	*		*	*	*		*	*	*		*		*	
Hierochloe odorata	*			*					*					
Holcus lanatus	*	*	*	*	*	*	*	*	*		*		*	
Holcus mollis	*			*	*	*	*	*	*		*		*	
Hordeum murinum	*			*	*	*				*				
Koeleria macrantha	*			*	*	*			*				*	
Lagurus ovatus	*			*	*									
Leersia oryzoides	*			*	*				*				*	
Leymus arenarius	*			*	*		*	*	*				*	
Lolium multiflorum	*			*	*	*	*						*	*
Lolium perenne	*		*	*	*	*	*	*	*		*		*	
Melica nutans	*			*	*	*			*			*	*	
Milium effusum	*	*		*	*	*			*			*	*	
Molinia caerulea	*		*	*	*	*	*	*	*		*		*	
Nardus stricta	*			*	*				*		*		*	
Parapholis incurva	*			*	*					*				
Phalaris arundinacea	*			*	*		*	*	*		*		*	
Phleum alpinum	*			*	*	*			*					
Phleum phleoides	*			*		*			*			*		
Phleum pratense	*			*	*	*							*	
Phragmites australis	*			*	*		*	*	*		*		*	
Poa alpina	*	*		*	*	*			*			*	*	
Poa annua	*	*	*	*	*	*	*		*	*	*		*	*
Poa compressa	*			*	*	*			*			*	*	
Poa flexuosa	*			*					*			*		
Poa nemoralis	*			*	*	*			*			*	*	
Poa palustris	*			*	*				*					
Poa pratensis	*	*		*	*	*			*		*		*	
Poa trivialis	*			*	*	*			*		*		*	
Polypogon monspeliensis	*			*						*				
Puccinellia distans	*			*	*	*			*				*	
Puccinellia maritima	*			*	*				*				*	
Sesleria caerulea	*	*	*	*	*			*	*				*	
Spartina anglica	*			*	*								*	
Spartina x townsendii	*			*	*				*					
Trisetum flavescens	*			*	*				*		*		*	
Vulpia ciliata	*			*	*									*
Vulpia fasciculata	*			*	*		*			*				
Polemoniaceae														
Polemonium caeruleum	*		*	*	*	*	*	*	*			*	*	
Polygalaceae														
Polygala amarella	*			*	*				*			*		
Polygala calcarea	*			*	*				*			*		
Polygala serpyllifolia	*		*	*	*	*			*		*			

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Polygala vulgaris	*		*	*	*	*							*	
Polygonaceae														
Fallopia convolvulus	*	*		*	*					*				*
Oxyria digyna	*			*	*	*			*			*		
Persicaria amphibia	*			*	*		*	*	*		*		*	
Persicaria bistorta	*			*	*	*			*					
Persicaria hydropiper	*			*	*					*				*
Persicaria lapathifolia	*	*		*	*	*	*	*		*				*
Persicaria laxiflora	*			*	*					*				
Persicaria maculosa	*	*		*	*		*	*		*				*
Persicaria vivipara														
Polygonum aviculare	*	*		*	*					*				*
Rumex acetosa	*			*	*				*		*		*	
Rumex acetosella	*			*	*	*			*		*		*	
Rumex crispus	*			*	*	*			*		*		*	
Rumex obtusifolius	*	*		*	*				*		*		*	
Rumex palustris	*			*	*				*				*	
Rumex pseudoalpinus	*			*	*				*			*		
Portulacaceae														
Claytonia sibirica	*			*	*				*	*		*	*	*
Portulaca oleracea	*			*	*	*								*
Potamogetonaceae														
Potamogeton crispus	*			*					*		*			
Potamogeton natans	*			*					*		*		*	
Potamogeton polygonifolius	*			*			*	*	*		*			
Primulaceae														
Anagallis arvensis	*			*	*	*			*	*	*	*		
Anagallis tenella	*			*	*		*	*	*		*		*	
Glaux maritima	*			*	*	*			*					
Hottonia palustris	*			*	*									
Lysimachia nemorum	*			*	*	*			*		*	*	*	
Lysimachia nummularia	*			*	*	*			*			*	*	
Lysimachia thyrsiflora	*			*	*		*	*	*					
Lysimachia vulgaris	*			*	*		*	*	*					
Primula elatior	*			*	*	*			*			*	*	
Primula farinosa	*			*	*		*	*	*				*	
Primula scotica	*			*	*		*	*	*				*	
Primula veris	*		*	*	*	*			*		*		*	
Primula vulgaris	*		*	*	*	*		*	*		*		*	
Samolus valerandi	*			*	*				*				*	
Trientalis europaea	*		*	*	*				*				*	
Pyrolaceae														
Moneses uniflora														
Orthilia secunda														
Pyrola media														
Pyrola minor														
Pyrola rotundifolia														
Ranunculaceae														
Aconitum napellus	*			*	*	*			*			*	*	

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Actaea spicata	*			*	*	*			*			*	*	
Anemone nemorosa	*			*	*		*	*	*		*	*		
Aquilegia vulgaris	*			*	*	*			*			*	*	
Caltha palustris	*		*	*	*		*	*	*		*		*	
Clematis vitalba	*			*	*	*			*			*	*	
Helleborus foetidus	*			*	*	*			*			*	*	
Myosurus minimus	*			*	*	*				*				
Pulsatilla vulgaris	*		*	*	*	*	*	*	*			*	*	
Ranunculus acris	*			*	*		*	*	*		*		*	
Ranunculus auricomus	*			*	*	*			*			*	*	
Ranunculus bulbosus	*			*	*	*		*	*		*		*	
Ranunculus ficaria	*	*		*	*	*	*	*	*		*			
Ranunculus flammula	*			*	*		*	*	*		*		*	
Ranunculus fluitans	*			*	*									
Ranunculus lingua	*			*	*		*	*	*				*	
Ranunculus repens	*	*		*	*	*	*	*	*		*			
Ranunculus reptans	*			*	*				*					
Ranunculus sardous	*			*	*					*				
Ranunculus sceleratus	*			*	*				*	*	*		*	*
Thalictrum minus	*			*	*	*								
Trollius europaeus	*			*	*	*	*	*	*			*	*	
Resedaceae														
Reseda lutea	*			*	*	*			*				*	
Reseda luteola	*		*	*	*	*			*		*	*	*	
Rhamnaceae														
Frangula alnus	*			*	*	*	*	*	*				*	
Rhamnus catharticus	*			*	*	*	*	*	*			*		
Rosaceae														
Acaena novae-zelandiae	*			*			*	*					*	
Agrimonia eupatoria	*			*	*	*			*		*			
Alchemilla alpina	*			*	*	*			*					
Alchemilla glabra	*			*	*				*					
Alchemilla xanthochlora	*			*	*				*			*		
Aphanes arvensis	*			*	*	*								*
Cotoneaster integerrimus	*			*	*	*			*			*		
Crataegus laevigata	*			*	*	*			*			*	*	
Crataegus monogyna	*			*	*	*	*	*	*		*		*	
Dryas octopetala	*	*		*	*		*	*						
Filipendula ulmaria	*			*	*		*	*	*		*		*	
Fragaria vesca	*		*	*	*	*			*		*		*	
Geum rivale	*			*	*				*		*			
Geum urbanum	*	*		*	*	*			*		*	*	*	
Malus sylvestris	*			*	*	*			*		*	*	*	
Potentilla anglica	*			*	*				*		*	*		
Potentilla anserina	*			*	*	*			*		*		*	
Potentilla argentea	*			*	*	*			*			*		
Potentilla crantzii	*			*	*	*			*			*	*	
Potentilla erecta	*		*	*	*		*	*	*		*		*	
Potentilla fruticosa	*			*	*		*	*	*					

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Potentilla neumanniana	*			*	*				*			*		
Potentilla palustris	*			*	*		*	*	*		*			
Potentilla recta	*			*	*									
Potentilla reptans	*		*	*	*	*			*		*		*	
Potentilla sterilis	*			*	*	*			*		*	*	*	
Prunus avium	*			*	*	*			*		*	*		
Prunus domestica	*			*					*			*		
Prunus padus	*			*	*				*			*		
Prunus spinosa	*			*	*				*		*	*		
Rosa arvensis	*			*	*	*			*			*	*	
Rosa canina	*			*	*	*			*			*		
Rubus caesius	*			*	*	*			*				*	
Rubus chamaemorus	*			*	*				*					
Rubus fruticosus	*			*	*								*	
Rubus idaeus	*			*	*	*			*		*	*	*	
Rubus saxatilis	*			*	*	*			*			*		
Sanguisorba minor	*		*	*	*	*			*				*	
Sanguisorba officinalis	*			*	*	*	*	*	*			*		
Sibbaldia procumbens	*			*	*	*			*			*		
Sorbus aria	*			*	*	*			*			*		
Sorbus aucuparia	*			*	*				*		*	*		
Sorbus torminalis														
Rubiaceae														
Asperula cynanchica	*		*	*	*	*			*				*	
Cruciata laevipes	*			*	*	*			*					
Galium aparine	*			*	*	*				*				*
Galium boreale	*			*	*				*			*		
Galium mollugo	*			*	*	*			*			*	*	
Galium odoratum	*			*	*	*							*	
Galium palustre	*			*	*		*	*	*		*			
Galium saxatile	*		*	*	*				*		*		*	
Galium uliginosum	*			*	*		*	*	*					
Galium verum	*		*	*	*	*			*		*		*	
Rubia peregrina														
Salicaceae														
Populus nigra	*			*	*				*			*		
Populus tremula														
Populus x canescens														
Salix alba														
Salix arbuscula														
Salix aurita														
Salix caprea	*			*	*	*			*		*		*	
Salix cinerea	*			*	*		*	*					*	
Salix fragilis														
Salix herbacea														
Salix lapponum														
Salix myrsinites														
Salix phylicifolia														
Salix purpurea	*			*	*				*			*		

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Salix repens	*			*	*		*	*	*		*			
Salix reticulata														
Salix triandra														
Salix viminalis	*			*	*				*		*	*		
Santalaceae														
Thesium humifusum														
Saxifragaceae														
Chrysosplenium alternifolium	*			*	*	*			*			*		
Chrysosplenium oppositifolium		*			*	*				*		*		*
Parnassia palustris	*			*	*		*	*	*				*	
Saxifraga aizoides	*			*	*				*					
Saxifraga granulata	*			*	*				*			*	*	
Saxifraga oppositifolia	*			*	*		*	*	*				*	
Saxifraga stellaris	*			*	*				*					
Scrophulariaceae														
Bartsia alpina														
Chaenorhinum minus	*			*	*	*				*				*
Cymbalaria muralis	*			*	*	*			*			*		
Digitalis purpurea	*	*		*	*	*			*		*	*	*	
Euphrasia officinalis agg.														
Kickxia spuria	*			*	*	*				*				*
Linaria repens	*			*	*				*			*	*	
Linaria supina	*			*	*									
Linaria vulgaris	*			*	*	*			*				*	
Melampyrum arvense														
Melampyrum cristatum														
Melampyrum pratense														
Melampyrum sylvaticum														
Odontites vernus														
Pedicularis palustris														
Pedicularis sylvatica														
Rhinanthus angustifolius														
Scrophularia auriculata	*			*	*		*	*	*				*	
Scrophularia nodosa	*			*	*	*			*		*	*		
Scrophularia umbrosa	*			*	*									
Scrophularia vernalis	*			*	*				*			*		
Verbascum lychnitis	*			*	*	*			*			*	*	
Verbascum nigrum	*			*	*	*			*			*	*	
Verbascum thapsus	*		*	*	*	*			*		*	*	*	
Veronica agrestis	*			*	*	*				*				*
Veronica alpina	*			*	*	*			*			*		
Veronica anagallis-aquatica	*			*	*									
Veronica arvensis	*			*	*					*				*
Veronica beccabunga	*		*	*	*		*	*	*		*		*	
Veronica chamaedrys	*			*	*	*	*	*	*		*		*	
Veronica filiformis	*	*		*	*	*			*			*		
Veronica fruticans	*			*	*				*			*		
Veronica officinalis	*			*	*	*	*		*		*		*	
Veronica peregrina	*			*	*									*

	a	b	c	d	e	f	g	h	i	j	k	l	m	n
Veronica persica	*			*	*	*				*				*
Veronica serpyllifolia	*			*	*	*			*		*		*	
Veronica spicata	*			*	*	*	*	*					*	
Solanaceae														
Atropa bella-donna	*			*	*	*			*			*	*	
Lycium barbarum	*			*									*	
Solanum dulcamara	*			*	*				*		*			
Solanum nigrum	*		*	*	*	*				*				*
Sparganiaceae														
Sparganium erectum	*		*	*	*		*	*	*		*		*	
Taxaceae														
Taxus baccata	*			*	*	*			*			*	*	
Thymelaeaceae														
Daphne laureola	*			*	*	*			*			*		
Daphne mezereum	*			*	*	*			*			*	*	
Tiliaceae														
Tilia cordata	*			*	*								*	
Tilia platyphyllos														
Typhaceae														
Typha angustifolia	*			*	*		*	*	*					
Ulmaceae														
Ulmus glabra	*			*	*	*							*	
Urticaceae														
Parietaria judaica	*	*		*	*	*			*			*		
Urtica dioica	*	*	*	*	*	*	*	*	*		*		*	
Urtica urens	*			*	*									*
Valerianaceae														
Centranthus ruber	*			*	*	*			*			*		
Valeriana dioica	*			*	*		*	*	*					
Valeriana officinalis	*			*	*		*	*	*		*		*	
Verbenaceae														
Verbena officinalis	*			*	*	*			*			*	*	
Violaceae														
Viola arvensis	*	*		*	*					*				*
Viola canina	*			*	*	*			*		*			
Viola hirta	*		*	*	*	*			*			*	*	
Viola kitaibeliana	*			*	*									
Viola lutea	*		*	*	*		*	*	*			*	*	
Viola odorata	*	*		*	*	*			*			*		
Viola palustris	*			*	*		*	*	*		*			
Viola reichenbachiana	*			*	*	*			*			*		
Viola riviniana	*	*		*	*				*		*		*	
Viola rupestris	*			*	*	*	*	*	*			*	*	
Viola tricolor	*			*	*				*	*	*		*	*
Viscaceae														
Viscum album														