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Organisation and Management of Seed Reference Collections

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Abstract

Reference collections of accurately identified, recent seeds are an essential resource for seed identification in archaeobotany, agronomy, palaeoecology and studies of wildlife diet. Recommendations are given for sourcing of seed materials and storage systems. The usefulness of computer databases for cataloguing of seed collections is emphasised, and 18 core data fields (based on the HISPID data standard for herbarium collections) are proposed.

Keywords: Fruit, Macrofossil, Archaeobotany, Identification, Database, Data standard

Introduction

The London workshop

Reference collections of seeds from identified, recent plants are essential for the identification of unknown seeds. Until recently, seed collections were often treated as the Cinderella of natural history collections, poorly curated and often hidden away or lost. Two factors have done much to change this. The first is the growth of archaeobotany as a discipline. This has created a large group of researchers who need good reference collections and who, as well as creating new collections, have rediscovered old collections made for other purposes. The second factor is the revival of taxonomy, and a linked recognition of the importance of natural history collections as underpinning all studies of biodiversity. This has led to substantial funds becoming available for improved curation of natural history collections. A further factor is the widespread availability of relatively user-friendly database programmes, which make record-keeping and labelling of collections much easier than with paper-based systems.

In this context, many managers of seed reference collections are, or are about to, upgrade and catalogue their collections, usually with the assistance of a computerised database. As there has been no previous database standard for seed reference collections, and a paucity of publications on their management (cf. Gunn 1972; Jensen 1979; Nesbitt 1990; Pearsall 2000, 119–33), the time seemed right for a workshop to explore these topics. This was held at the Institute of Archaeology in London on 27 March 2000, with 35 participants, from the United Kingdom, Denmark, Sweden, Netherlands, Ireland and France. Most of the participants use seed identification either in archaeobotany, or in agronomy, for identifying weed seed contaminants in seed grain.

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Scope

This paper presents consensus views from the meeting on data standards for databases of seed reference collections, and on how best to organise a seed collection. Its recommendations are not intended to be prescriptive, but are intended as a useful resource for those curating or, especially, cataloguing a collection. This paper is not a guide to seed identification techniques or literature on seed identification (cf. Jensen 1998; Nesbitt and Greig 1989). Other types of plant material such as mosses, buds, leaves and wood are not covered.

Throughout this paper reference is made to Internet-based resources; the Web addresses for these are listed in Table 1.

Importance of seed identification

The identification of seeds (a term used here in its broadest sense to include fruits, caryopses, achenes etc.) is an essential tool in several ecological and archaeological disciplines. In archaeobotany identification of charred, waterlogged or desiccated seeds from archaeological excavations is a well-established tool for identifying remains of plants used by humans, and the weed floras of ancient crops. In agronomy, identification of the weed-seed component of seed grains is an important part of seed-quality control. In both these cases, there are significant numbers of workers in the field, and well-established research facilities.

Seed identification is also important in some other research fields, although with far fewer researchers involved. Holocene (and earlier Quaternary) seed remains from "natural" contexts such as lake and mire sediments are commonly studied by palaeoecologists, although the main focus is on pollen analysis. Studies of soil seed banks sometimes involve seed identification, although this is more usually carried out by germinating the seeds and identifying the seedlings (Thompson *et al.* 1997). Identification of seeds in animal faeces is an important tool in studies of diet, for example of primates and mammals, and in studies of seed dispersal, for example by birds (Fleming and Estrada 1993; Stiles 2000). Seeds are occasionally used in studies of flowering plant evolution and classification, although usually neglected compared to floral morphology. Seed identification is also sometimes necessary in forensic science and in identification of food contaminants.

Data standards	
Accession data	
HISPID3	http://www.rbgsyd.gov.au/HISCOM
General	
Taxonomic Database Working Group (TDWG)	http://www.tdwg.org
Geography	
ISO Country Codes	ftp://ftp.fu-berlin.de/pub/doc/iso
TDWG geographical names	http://www.bgbm.fu-berlin.de/TDWG/geo/default.htm
Genebanks	
IPGRI database of genebanks	http://www.ipgri.org/germplasm/dbases.htm
Legislation and collecting	
BSBI Code of Conduct	http://www.tpdb.org/bsbi/Code&of&Conduct.php
CBD (Convention on Biological Diversity)	http://www.biodiv.org
Storage	
Bisley Cabinets	http://www.bisley.co.uk
Stewart Group (boxes)	http://www.stewartcompany.co.uk
University Products (foil-backed labels)	http://www.universityproducts.com
Taxonomy	
Botanical Society of the British Isles database (UK plant names)	http://www.rbge.org.uk/data/BSBI/db
Global Plant Checklist Project (Species 2000)	http://www.species2000.org
GRIN (Economic Plants)	http://www.ars-grin.gov/npgs/tax
Index Herbariorum	http://www.nybg.org/bsci/ih/ih.html
Mansfeld's World Database of Agricultural and Horticultural Crops	http://mansfeld.ipk-gatersleben.de
World Taxonomist Database	http://www.eti.bio.uva.nl/Database/Database.html

Table 1. Useful web sites.

Challenges to identification

Seed identification presents some special challenges. The key factor that makes seed identification time-consuming (and difficult to learn) lies in the shape of seeds and the kind of characters that distinguish them. Seeds are usually not transparent (unlike pollen) and cannot be prepared so that key characteristics are flat (unlike wood). The subtle differences in shape and in underlying structure that differentiate seeds are difficult to describe in a standardised fashion, and this has proved a major barrier to the development of identification manuals. A further problem is that the multipart, complex structure of seeds and fruits means that the same fruit can generate plant parts of very different appearance, depending on how it breaks up and on taphonomic processes involved in deposition and recovery. For example, charring will burn off light elements such as hairs and parts of the seed coat, as well as rendering the seed black, while waterlogged seeds often lose their endosperm and some seed coat layers. A fruit may survive intact, or break up into seeds. These variations, together with difficulties in describing seed shape, are likely to continue to be a major barrier to the development of automated seed identification systems.

Role of reference collections

All workshop participants agreed that seed reference collections are, and will continue to be, a vitally important tool in seed identification. The key benefit of reference specimens is flexibility. They can be viewed in any orientation and, by dissection or treatments such as charring, any desired aspect of morphology or appearance can be viewed as required. For inexperienced workers, there is no substitute for looking at seeds to learn to identify both individual species and, as important, the seed characters that define plant families. Experienced workers will refresh their memory using reference material, and rely on it for critical identifications. Although not everyone will have constant access to a seed collection, everyone needs regular access to one. Various identification manuals are available, but it was agreed by all that these complement rather than replace reference collections. Published identifications of seeds should never be used as the sole basis of an unqualified identification.

Care should be taken in the development of seed reference collections. Proper curation and storage is expensive, and a collection comprising poorly provenanced or identified material (e.g. from botanic gardens), or put together with no clear function in mind, can be a millstone rather than an asset. Many such collections have been developed by herbaria and museums in the past, and today present a real challenge to collections management programmes.

Sources of Seed

Most seed collections derive from a variety of sources. This is often inevitable if, for example, all species in a genus are to be acquired, as this is often difficult to achieve from wild collected material. We summarise the advantages and disadvantages of the main seed sources as follows:

Field collections

By far the most reliable source of reference material is wild plants gathered from their natural habitat, or of crops gathered from farmers' fields. It is highly desirable that material is vouchered by herbarium specimens and documented by adequate collection notes. Well established procedures for this have been developed by botanists and should be learnt by those new to collecting (Bridson and Forman 1998; Womersley 1981). Such material will be well provenanced, and the voucher specimen will allow a secure identification. The only disadvantage of such material is that collecting and subsequent identification are both time-consuming. However, many creators of seed collections are, in any case, keen field botanists, and some archaeobotanists and agronomists will have good opportunity to collect during field trips. Indeed, an important benefit of collecting seeds is the training it provides in taxonomy and ecology. Time required for identification can be reduced by sending duplicate herbarium specimens, by prior arrangement, to taxonomic specialists for identification.

It is important that freshly-collected seed material is adequately dried before long-term storage, particularly if plastic or glass containers are to be used. Freezing at –20°C or below for three days is good practice for pest control, and can be repeated if insect problems develop later. If fleshy fruits are collected, some from each accession should be dissected before drying, to release the seeds.

In addition to following relevant national legislation, collectors should obviously be careful not to collect from rare plants. The Botanical Society of the British Isles (BSBI) Code of Conduct is a useful guide to sensible collecting (Table 1). In some cases plants that are rare in one area may be common elsewhere, and can better be obtained by exchange.

Herbaria

Seeds removed from pre-existing herbarium collections can be a good source of material. In some cases a herbarium may be willing to allow sampling from many specimens, but it is more usual that strict limits and conditions are applied. In this case, herbaria are best approached for material that has proved otherwise unobtainable. Many herbarium specimens do not bear mature seed, as botanists tend to favour material in flower, and the number of seeds that can be removed may be very low. Specialists in the taxonomy of particular plant groups can also be helpful; these can be located via the *Index Herbariorum* or the World Taxonomist Database (Table 1), or through local sources such as the *Botanical Society of the British Isles Yearbook*.

Genebanks

Most genebanks specialise in the long-term storage of crops and their wild relatives, and are an excellent source of such material. The International Plant Genetic Resources Institute (IPGRI) maintains a comprehensive Web-based guide to genebanks (Table 1). Many genebank catalogues can now be searched on the Web. Although such material is usually freely available, its primary function is to assist agricultural research, and we suggest being sparing in requests for reference purposes. Identifications are usually reliable, although errors in labelling do occur. Bear in mind that genebank material has usually been grown on before storage, and that seed size may not be representative of that in original habitats.

Botanic gardens

Most botanic gardens issue a seed exchange list (often known as an *Index Seminum*). These can be useful sources of wild material that has been cultivated in gardens. Copies of seed lists will be held by botanic gardens. Errors in identification are frequent, though perhaps rarer for perennial plants that do not have to be resown each year. Botanic gardens are a highly unreliable source of crops and their wild relatives, in part because these are very prone to hybridisation. It is usually sensible to grow on material from botanic gardens to check the identification.

Commercial sources

Some seed companies specialise in wild plants, herbs and "heritage" crops. These can be useful sources of material, but the same cautions apply as for botanic gardens.

Exchange

An important but often under-exploited source of seed material is exchange with other seed collections. We strongly encourage this, and note that the seed data standards proposed here would greatly ease exchange of provenance data alongside the actual seeds.

Archaeological material

Archaeological material sometimes has a place in seed reference collections. It can show the changes that occur with charring or waterlogging, and some taxa, such as *Lemna*, are more easily found in archaeological material than in the field.

Reliability

A key issue for all seed material is the reliability of the identification, particularly if no voucher specimen exists. Such a specimen can, of course, be easily created by planting some of the seeds (if not too old), although this is only worthwhile in critical cases. As far as possible, basic checks should be carried out on newly acquired material by consulting seed handbooks and floras. The main safeguard for seed identifications is multiple accessions of the same taxon. If seeds of the taxon from different sources look similar, this strengthens the case for a correct identification. Single accessions cannot be checked in this way, and cannot represent the range of inter-population variability in seed characteristics. We therefore strongly recommend that seed collections include multiple accessions of all species acquired.

Legislation

National laws and codes of conduct regarding plant collecting are long-standing. A new factor is the Convention on Biological Diversity (CBD), agreed at the 1992 Earth Summit in Rio de Janeiro (Table 1) and in force since December 1993, which recognises countries' sovereign rights to control access to their genetic resources. Since 1993, approximately 50 countries have drafted CBD laws and regulations that govern the way people may collect, use and supply biological material. The CBD does not strictly apply to material acquired before 1993. The main practical implication of the CBD is that a formal memorandum of understanding may be required before plant material is exported.

Storage

An ideal system should, on the one hand, make the seeds easily visible, while on the other protect them from insects. Collections divide into two types. In the first, an easy-reference collection in, for example, glass slides, is kept for quick scanning of material. If further investigation is needed, loose seed is obtained from a less accessible back-up system, for example stored in bags. In the second system, there is only one set of material, usually arranged to combine reasonable ease of scanning with the storage of adequate numbers of seeds. Either system is acceptable, and the choice is largely a matter of personal preference, governed by cost and available space. The following storage systems are known to be in use:

Plastic boxes

Widely used in Britain, this system uses clear plastic boxes 22 mm high, stored in 30-drawer metal Bisley cabinets (Table 1). The length and width of the box can be varied to fit the seed. The Stewart Group (Table 1) offer small boxes at 58 × 38 mm, medium at 79 × 47 mm, and large boxes at 124 × 82 cm for cereal ears. 17 medium boxes or 36 small boxes will fit into one drawer. In a collection made up equally of small and medium boxes, each cabinet would hold about 750 accessions; if all the boxes were small, 1080. Larger boxes can be used for nuts and other large seeds, but these will need to be stored in cabinets with deeper drawers. Labels can either be loose paper, or can be gummed to the base of the box. Conservation-grade gummed labels are available from University Products (Table 1). Different types of lid are available; sliding lids are the most secure, but push-fit lids are easier to handle. Samples should be tried before ordering large quantities.

This system offers the advantages that each drawer can be removed from the cabinet and the seeds easily scanned through the clear boxes. If it is desired to examine material further, a box can easily be opened. If insects are present in one box, they cannot spread to the others. The main disadvantages of this system are the space required, and the cost of the boxes and cabinets. However, Bisley cabinets can often be obtained second-hand.

Specialist boxes

In the past special boxes, for example made from card or steel, with a glass window in the lid, were often used. However, these are now superseded by plastic boxes.

Glass tubes

Where the amounts of seed are relatively small, and the number of accessions large, storage in glass specimen tubes can provide compact storage space. For example, at Kew one drawer of a 30-drawer Bisley cabinet will hold 92 tubes, a total of 2760 in one cabinet. The disadvantages are the limited number of seeds that can be stored for each accession, and the tendency of tubes to roll and change position if one is removed. A brightly coloured empty tube can be used as a spacer to replace the tube that is removed for examination.

Slides

Traditionally seed has often been stored on glass slides, in a small glass-topped cell that contains far fewer seeds than tubes or boxes. This offers easy storage and visibility, but has the disadvantage that seeds cannot be handled for viewing or dissection. Slides may demand considerable labour in production and mounting, depending on design.

Bags

Storage in paper bags or envelopes is cheap and uses space efficiently, but does not allow easy browsing through or handling of seed reference collections. This has been addressed in some collections by the use of cellophane fronted envelopes or (if the seeds are sufficiently dry) plastic bags. A card in each bag can provide stiffening as well as bearing the label. Cellophane envelopes have a limited lifespan because cellophane becomes brittle. However the main disadvantage of a bag-based system is its greater vulnerability to insect damage. Such a collection may require yearly freezing to control pest damage.

Multiple displays

A number of systems have been used in which groups of seeds are mounted on glass or card bases, to allow easy comparison of a number of taxa (usually within a family) at the same time. These are intended as a supplement to, not replacement of, the systems described above.

Seed viability

If it is desired to keep seed material viable, arrangements should be made with a genebank for long-term storage of a subsample of material. Seed viability of many species can be maintained for many years under conditions of low humidity and temperature (below –20°C).

Arrangement

Seed collections can be arranged in one of two ways: an alphabetic sequence, or a taxonomic (and thus evolutionary) sequence.

A taxonomic sequence has the major advantage that closely related taxa will be placed near each other – very helpful for identification purposes. However, a satisfactory taxonomic sequence must be available for the region covered by the collection. This could be a national Flora, such as the *Flora of Turkey* (Davis 1965–1988), or a regional flora such as *Flora Europaea* (Tutin *et al.* 1964–1980). It is essential that the Flora is of good quality, and highly preferable that it will not change substantially in the near future. As the seeds will not be ordered alphabetically, a numerical system must be used. Many Floras include this as standard, with running numbers for families, genera and species. A disadvantage of the taxonomic system is that until the user is familiar with it, the family/genus number will have to be looked up in an index.

Species not included in the Flora can be added at the end of the relevant genus. Economic species are often omitted from or poorly treated by Floras; web-based checklists of standard names have been issued by the United States Department of Agriculture (Table 1: GRIN) and the Gatersleben genebank (Table 1: Mansfeld).

If a collection covers different regions, or if a satisfactory local Flora is not available, then a simple alphabetic sequence of families, genera and species may be most suitable. Users should be able to go directly to material, if drawers are well labelled. If material from different regions is housed in one sequence, labels can be colour-coded to indicate area of origin.

Data Standards

Although a seed collection need not be recorded on a database, an electronic record can prove a valuable management tool that amply repays the effort invested. The main advantages of a database are:

- lists of accessions can be easily selected, organised and displayed according to varying criteria.
- a database forces consistent data entry, allowing gaps in data (e.g. missing collection numbers or incomplete identifications) to be easily identified.
- accession data (often "hidden" in collecting notes) is easily viewed and securely held
- clear labels can be printed.
- lists of accessions can be easily sent to other researchers (or placed on the Web through a search interface). If seeds are exchanged, accession data can be sent with them.
- lists of missing taxa (i.e. those still needed for the collection) can be generated, if the database incorporates a full list of taxa occurring in the region.

The key disadvantage of electronic databases is vulnerability. If the institution has a secure central server, this will usually provide a safe home for data. If this is not available, every effort should be made to duplicate data, for example on CD-ROM, colleagues' computers, and on the Web.

Some of the effort needed to enter data can be reduced if the taxonomic data (i.e. plant names) can be downloaded from another database. This is often the case: for example, a standard list of British taxa is available from the Botanical Society of the British Isles (Table 1), while the Flora Europaea is held on a database at the Royal Botanic Garden, Edinburgh.

Although no data standard exists specifically for seed reference collections, a well-established standard does exist for herbarium specimens, HISPID. This was developed by the Herbarium Information Systems Committee in Australia, and is currently in its third version, HISPID 3. It is widely used as the basis for many herbarium data standards world-wide, and is presented in detail on the web (Table 1). It is therefore a good basis for a seed collection data standard (Table 2). We have selected from HISPID 3 a set of 18 "core fields", in other words those that that contain the essential information which should accompany exchange of seed material and which is needed for production of labels. Equally important, these are the fields on which searches are most likely to be carried out on a database: for example, which seeds came from a certain country, a certain collector, or a certain taxonomic group. Standardisation is not only important for the users of a single database, but will in future enable Web-based interfaces to search several databases at once.

Additional fields

The core fields in Table 2 are only a starting point and most databases will consist of a much wider range of optional fields. For example, there is only one core field concerning collection location: country. Most databases will also include more detailed information, for example county/region, exact locality, and latitude/longitude. The purpose of this data standard for core fields is to ensure that regardless of how many data fields are chosen for a specific database, the essential fields are always present and contain data in a standard format. Suitable data formats for many other additional fields are given in the HISPID 3 standard (Table 1).

Two elementary points are, first, that data fields should not be amalgamated. For example, locality and country, or collector name and collection number, should always be separate. It is much easier to amalgamate separate fields at a later stage

	Field Name	Transfer Code	Description of data format
1	Accession identifier	accid	The unique number of the record. Useful as it ensures that even specimens without a collector number can be uniquely identified.
2	Family	fam	The family name appropriate to the Genus name field, entered in full with capitalisation of the first letter only. If the name of the plant family is unknown, then this field may contain the value UNKNOWN (in uppercase).
3	Genus	gen	The name of the genus of a plant entered in full. Capitalisation of the first letter only. Separate fields can be provided for author name for genus, species and infraspecific ranks, but are only necessary if not following a named checklist.
4	Species epithet	sp	The species epithet of the plant entered in full. Any valid species name, all lowercase, no embedded spaces.
5	First infraspecific epithet	isp	Subspecies. Some recording systems only record the lowest infraspecific epithet (with a field beforehand indicating rank). Although many botanical databases only record the lowest infraspecific epithet, in a seed collection it is useful to see both the subspecies and variety on the label. It is therefore suggested that they are recorded in separate fields.
6	Second infraspecific epithet	isp2	Variety
7	Cultivar Name	culnam	The cultivar name of the plant. A useful field for crop plants.
8	Rank Qualified Flag	rkql	The rank of the lowest name/epithet of the taxon qualified by the entry in Identification Qualifier field. F (Family), G (Genus), S (Species), I (first Infraspecific Epithet), J (second Infraspecific Epithet), C (Cultivar). This is an important field as it enables indication of uncertainty. In HISPID 3 this field is followed by the Identification Qualifier field, which indicates the precise degree of uncertainty, e.g. as aff., cf. etc. It is suggested that these precise measures are inappropriate for seed collections, and that a qualified rank should simply be treated as "?".
9	Name Comments	namcom	Any comments about the name of the plant are transferred in this field.
10	Kind of Collection	ckin	If the database contains records relating to different types of material (e.g. seed, wood), then the collection kind must be indicated in this field. Standard terms in HISPID include Pollen, Seed and Wood.
11	Country	cou	If full ISO country names are used (use cou as the field name), it is recommended that the spelling of the country should be as recognised by the International Standards Organization (ISO). If the name of the country where the plant was collected is unknown, then this field should contain the value 'UNKNOWN' (in uppercase).
	Choose *one* format (cou or iso) for use in the database	iso	If ISO codes are used (use iso as the field name), the code must consist of 2 uppercase letters (A-Z), or XX Country unknown XY Country not applicable Notes: The 'XX' code should be used when no 'Country of Origin' information is provided. The 'XY' code should be used for non-specific collection localities, e.g. Africa, South East Asia.
12	Collectors name	cnam	Any valid collector's name, primary collector's family name (surname) followed by comma and space (,) then initials (all in uppercase and each separated by fullstops). All initials and first letter of the collector's family name in uppercase. For example, Chambers, P.F. Rules for joint collections and complex names are given in the HISPID guidelines.
13	Collectors identifier	cid	The sequential or other codified number given to the specimen at the time of collection, by the primary collector(s), usually as on specimen label.
14	Collection date	cdat	The date on which the material was collected, as represented by this record. Any format can be used for dates so long as they can be converted to this format for data exchange purposes. Integer; year (4 digits) followed by month (2 digits) and the day (2 digits), without spaces between them. For example, 19970327 1. In this notation, leading zeroes must be included for months and days, ie. March is coded as '03' not '3' and the 6th day is coded as '06' not '6'. 2. If the day of the month is not known, the last two digits should be omitted. 3. If the day and the month are not known, the last four digits should be omitted and just the 4 digits of the year information interchanged
15	Donor	don	The person, institution or business from which the accession was obtained. For herbaria and botanical gardens standard codes (e.g. K for Royal Botanic Gardens, Kew) apply. HISPID 3 gives instructions on how to enter other donors.
16	Verification Level Flag		The level to which the identification of the record has been verified: 0 (zero) The name of the record has not been checked by any authority (e.g. field identifications) 1 The name of the record determined by use of a key or local knowledge, but not confirmed against documented herbarium or living material. 2 The name of the record determined by a taxonomist or by other competent persons using herbarium and/or library and/or documented living material 3 The name of the plant determined by taxonomist engaged in systematic revision of the group Note: level 1 has been altered from the HISPID 3 standard.
17	determined by		1. The verifier's family name (surname; with initial letter uppercase) followed by comma and space (,) then initials of given names (in uppercase and each followed by a full stop, without spaces).
18	determined date		Format as collection date.

Table 2. Data standard for seed reference collections. Both the names of the core data fields and the descriptions closely follow the HISPID3 standard (Table 1). The HISPID 3 transfer codes could be used as field names.

than to split single fields. Second, care must be taken to follow standard formats for data entry. Use of drop-down lists for data entry is strongly recommended, to ensure that, for example, collector names and country names are entered correctly.

Additional fields likely to be useful for seed collections include records for the existence of voucher herbarium specimens and separate fields to record different kinds of material, such as seeds and wood.

Future Developments in Seed Identification

The future of seed reference collections looks good, particularly within archaeological institutions. Substantial investment in cataloguing, housing and expansion is being matched by official recognition of curation as an integral part of an archaeobotanist's job. Under these circumstances it is less likely that collections will be lost or neglected if the archaeobotanist in charge leaves. Greater institutional involvement in collections often leads to a clarification of who actually owns (and thus takes responsibility for) a collection. In museums and herbaria the development of formal collections policies is leading to the rediscovery and enhanced curation of older collections.

During the London meeting, we also discussed future trends in seed identification. This is a difficult topic to predict, but these points emerged:

- Despite some 15 years of research on artificial vision systems, automated identification of seeds is still in its infancy. Its future is most likely to be in separating small numbers of known taxa, for example as contaminants of crop seed.
- The development of digital storage of images, for example on CD-ROMs and on the Internet, may allow the cheap production of new seed manuals that simply present pictures of seeds. Several such manuals are under development.
- There is an urgent need to build on Martin's (1946) classic manual on seed anatomical characteristics for identification to family level. These are most valuable for entirely unknown seeds. New work could document more taxa and include a much wider range of illustrations.
- There is an urgent need for detailed studies of critical taxa at genus and species level. Particular problem areas are the Brassicaceae, Caryophyllaceae, Chenopodiaceae, Cyperaceae, and Fabaceae (especially tribe Trifolieae). The development of good seed reference collections is essential to underpin this type of project.

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