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Seed reference collections and archaeobotany

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Summary

Advice is given on how to collect modern seeds to aid the identification of ancient ones. Voucher pressed-plant specimens are essential; arrangements should be made to give them to a herbarium in exchange for identification. Careful collecting notes are very important and a sample form is given. After drying, seeds should be frozen for 48 hours to kill insects. Seeds can be stored best for easy reference in transparent boxes in shallow-drawered filing cabinets. Detailed plans are also given for an alternative storage system that uses glass test-tubes in wooden racks. A small label in each tube gives basic provenance data.

Introduction

Although it is essential for archaeobotanical work, the building up of a seed reference collection is a time-consuming and potentially expensive business. Perhaps because of this, little guidance is available on how to do it in an efficient manner (Bohrer and Adams 1977, 43–6; Gunn 1972; Pearsall 1989). Conversations with fellow archaeobotanists suggest that many of us (even those with a background in taxonomic botany) make the same mistakes when we start. This paper draws on five years' experience as user and curator of one of the larger seed collections, that of the British Institute of Archaeology at Ankara, Turkey, and offers practical recommendations for every stage of collecting. Although my experience has been gained in the Near East, the procedures given here are equally applicable, with adaptation, to other areas, and to other types of material (vegetative parts, phytoliths, charcoal) not discussed in detail here.

Why are reference collections necessary?

Although seed identification manuals exist (see Nesbitt and Greig (1989) for a full bibliography), they all too frequently concentrate on the most common seeds of one particular region, and many of the characters given apply only to fresh material. The kind of treatment needed for archaeobotanical purposes—focused on one or a few genera, with coverage of all the species that might appear in ancient material, and taking into account the effects of charring, waterlogging and other preservation processes—usually does not exist, although one outstanding example of such a work is Körber-Grohne's (1964) identification key to waterlogged grass fruits and rush seeds. Even where such treatments exist (and it is up to archaeobotanists to write them) there is no substitute for looking at ancient and modern material side-by-side, especially if dissection is needed to confirm an identification.

Identification should be based on comparison not only with what the archaeobotanist considers 'likely' taxa, but also with other closely related ones. The presumption that what today is the most common species was likewise most common in the past is widespread, but runs the risk of leading to a 'self-fulfilling prophecy'. In order to develop valid, consistent, identification criteria it is necessary to have to hand reasonable-sized samples of modern seeds from a number of different populations (so that both intra- and inter-population variability can be studied) of all the possible species concerned. The only way of doing this is to have a large enough seed reference collection.

Looking at seed on pressed plant specimens in herbaria is not a satisfactory alternative, as it would take far too long to pull out each specimen; herbarium specimen collectors tend to prefer flowering (rather than seeding) material, and even if there are seeds on the specimen there are usually too few to allow a good number to be removed. Looking at seeds in a herbarium can be a useful last resort, but

it cannot be the everyday method.

Funding of reference collections

Setting up a reference collection is not necessarily enormously expensive, but it does need a consistent level of effort over a number of years. Only a few institutions have given steady support to archaeobotanists, and therefore the number of good reference collections housed in institutions is very small. Part of the reason for this is the tendency in Britain to contract out bioarchaeological work to free-lance specialists, each of whom builds up their own collection. However it is only in institutions that adequate secretarial, technical and financial resources are likely to be available to curate collections properly and, above all, permanently. Additionally, institutional collections can (like herbaria) acquire specimens from more than one person, and thereby build up large and wide-ranging collections.

Given that a bioarchaeological laboratory wishes to get a collection going, how can material be obtained?

(i) By sponsoring collecting trips, perhaps as part of an associated activity such as an excavation. A clear understanding should be made between the collector and the institution that in exchange for assistance, the collector will collect duplicate seed collections for the institution. This is the system operating in Ankara, where the Institute gives me time off, pays some travelling costs, and all curation expenses, and in exchange all of my seed collections are split with the Institute's collection.

(ii) By encouraging donation or exchange of relevant, *well documented* material by other collectors. If a large quantity of material is involved, some of the collecting expenses should be paid. Gifts of this kind will be encouraged by two factors: whether the material is quickly and efficiently added to the institution's collections, and secondly, whether the collection is freely available for consultation to all.

In general, there is perhaps an obligation on collectors who have made collections of seed with 'public' funds to give surplus material to a publicly accessible collection, but only if there is a collection willing to take the material and look after it properly.

Genebanks and botanical gardens

The seeds sold by commercial firms, and given away by botanical gardens and genebanks are a tempting source of material. However there are some major problems:

(i) Many of the seeds will be mis-identified, particularly (indeed almost invariably) those of crop plants. Even if there is a good crop plant taxonomist to hand (as at most genebanks) material is often mislabelled during harvesting and packing. All seeds received from these sources must be checked against reliably determined material and, if necessary, grown on.

(ii) Strange cross-breeding often takes place, if plots are sown too close to each other. I have seen many weird forms of wheat from botanical gardens that are artifacts of careless growing practices.

(iii) The application of irrigation and fertiliser, and the growing of the plant outside its native region, in nursery plots, will affect the size of the seed.

(iv) Often the area of origin of the seed material is not known. As seed size often varies with area of origin, misleading comparisons can be made. It is always best to work with material collected in the wild or in farmers' fields, preferably from the same region as the ancient plant remains.

Despite these difficulties, getting seeds from these sources is an easy way of filling gaps. It is important that the reference collection labels indicate the seeds are not from the wild.

Archaeobotanists should avoid swamping botanical gardens and genebanks with long lists of requests. Seed and offprints of publications should be offered in exchange. A personal approach is often helpful. The best way to see botanical garden seed-lists and to order from them is to contact your local herbarium or botanical garden. Lists of genebanks that store the seed of crop plants and their wild ancestors are published by the International Board for Plant Genetic Resources, an agency of the United Nations' Food and Agriculture Organisation (FAO) based in Rome. Curiously, although British

scientists did much to establish the principle of genebanks in the 1960s and 70s, there is virtually no germplasm stored in Britain.

Food and spice markets are always a useful source of minor crop plants and of wild medicinal and food plants, and when working on excavations in an area with good markets, time should be allowed for one or two days of systematic buying. It will be necessary to consult (beforehand if possible) handbooks to the spices and herbs of the area to identify the materials. With a good knowledge of the local language, or an interpreter, notes should be made on the uses and area of origin of such collections. Local university departments of pharmacy are usually a good source of reliable identifications. Even in western Europe, health food shops can be a good source for uncommon crops and spices.

The importance of voucher specimens

When one first collects, the temptation is often to just collect the seeds, perhaps with a scrap of flower or leaf to aid identification. This approach is only acceptable where the collector is confident of identifying the species at the time of collection, or where it is not possible to collect the whole plant. Such conditions really only apply to areas such as Britain, where the number of species is relatively small, good field books on identification are available, and the collector may well have a great deal of experience in the botany of the region. Also, in Britain and some other European countries, it is illegal to uproot plants without the permission of the landowner (and some are too rare to be uprooted at all); in this case, where necessary, voucher herbarium specimens can be collected by removing a small, diagnostic part of the plant.

In countries where the flora is very large, and the flora less well known (this includes all of the Near East) voucher herbarium specimens (i.e. pressed plants) are absolutely essential. Even in cases where the species appears obvious to the collector, later study of the relevant *Flora* often shows that two or three closely-related species or subspecies are involved, which can only be separated by vegetative characters. This is particularly the case with grasses (including the wild and cultivated cereals) and with edible fruits, but these are the two classes of plant where the temptation to collect just seed is greatest. The other major disadvantage is that the identification cannot be checked by later workers—and even the best botanist makes mistakes sometimes (for more on the importance of voucher specimens, see Bye 1986).

For these reasons I recommend that collectors *always* take good herbarium specimens at the same time as they collect seed material. A further, major, advantage of this is that identification can take place at a time and place convenient to the collector: herbarium specimens are easily stored and posted. Many herbaria will identify specimens free of charge, in exchange for the specimen. Best practice is to collect between two and four duplicate specimens of each plant, so that collections can be divided between different herbaria.

The archaeobotanist must often collect seed from mature plants which are desiccated and in poor condition. This difficulty is exacerbated if collecting takes place in the Near Eastern summer. However, although dry plant material is difficult to collect and press, it is perfectly feasible, and I have had only a handful of plants disintegrate in the press.

Should a seed reference collection should retain a set of voucher herbarium specimens? They will consume time, money and lots of space for mounting and storage cabinets. My view is that if, as is usually the case, a set of specimens can be given to a well-run *local* herbarium which will always be easily accessible, that is the best solution. Otherwise, a set should be kept so that identifications can easily be checked. However, I would not usually recommend that individuals build up private herbaria. This is only feasible given a large home and plenty of time—neither of which are usually available to archaeobotanists. In the special case of phytolith studies, where any part of the plant may be needed, a backup collection of specimens kept boxed in storage specifically for this purpose will be useful.

What should be collected?

Collections for a seed reference collection will often be primarily focused on the segetal and ruderal flora of the region of interest, but should also consider other kinds of vegetation that may have been used—e.g. grazing land and wetlands—and will also need to include plants from areas that are not under heavy

grazing pressure, as plants growing there may well have grown closer to village sites in past times. For example, woodland in the Near East is often restricted to relict patches on mountainsides distant from villages, and the flora in these will, like the woodland, have been more widespread in the past. Fenced areas—e.g. a university campus, factory or archaeological site—are always worth careful collecting. In summary, Bohrer and Adams (1977, 43) list the following locations that tend to retain higher proportions of plants sensitive to over-grazing:

- steep northern or northeastern slopes;
- loose scree or talus slopes;
- shelves, niches, terraces in canyon rims;
- rough, broken, rocky topography;
- areas fenced against grazing;
- beneath and among shrubs;
- sand bars in rivers protected by steep embankments;
- steep inner banks of irrigation ditches.

There is of course no need to aim for complete collection of a country's flora: alpine plants, for example, are unlikely to be relevant to most excavations. Judicious use of a flora and common sense generally suggest which areas should be botanised.

Surveying a vegetation map or transect around a site is usually best done after some of the archaeobotanical samples from the excavation have been studied; these will suggest specific areas of enquiry. Chapman and Moore (1986) and Kershaw and Looney (1985) are useful guides to techniques for recording vegetation. It is important that botanical fieldwork does not distract resources from the more important task of recovering good ancient samples—a full time job in itself at most excavations. If work can take place during university vacation then botany students (who often have access to travel grants) can be enlisted for assistance.

Particular attention should be given to cultivated plants and their weeds and wild relatives. All too little is known about weed ecology, and any observations on how the weed flora changes with different cultivation practice—e.g. irrigation, time of sowing—will be valuable. Specimens, with information on their husbandry and use, of all the cultivated plants (old *and* new) of a region should be collected. Special attention should be given to cultivars described by farmers as being of local origin, as opposed to those from agricultural extension services or commercial seed suppliers. The longevity of trees means that races of fruit and nut may stay in cultivation long after local varieties of annual crops have been lost (cf. Körber-Grohne 1984). Zeven and de Wets' (1982) *Dictionary of cultivated plants* is an excellent handbook to all the categories of crop plant to the found in the different regions of the world. Many ornamental garden plants are recent introductions, but selective collection (especially for anyone working on garden archaeology) may be worthwhile.

Basic collecting practice

The budding collector must read one of many handbooks for the collection of plants and the maintenance of herbaria. The most recent is the reasonably priced *Herbarium handbook* of Forman and Bridson (1989), which should be owned by all archaeobotanists, although Fosberg and Sachet (1965) and Womersley (1981) are still worth looking at. Useful hints are also given by Davis (1961), and many herbaria produce their own short manuals. I do not intend to replicate the information found in these, but there are some points worth stressing.

In the field

Having arrived at one's chosen collecting location, the first step is to choose plants that have mature seed (the term 'seed' is used in this paper in the broadest sense, to include propagules of all types). If the seed is slightly immature, it will often ripen after collection. If plants with flowers can be found (perhaps in a shadier part of the collecting location) both flowering and fruiting material should be pressed; this will often aid identification. If a location can be visited twice, first for flowering species, and then later for fruiting material, so much the better. A collecting number should then be allocated, notes made and photograph taken. An on the spot list of photographs should be made in order to avoid guessing games a few months later.

Enough flowering/fruiting material of the plant should be collected, pressed and dried to fill the required number of herbarium sheets. Initially, collections are dried in newspaper folders, which are easily available, absorbent and much the same size as herbarium sheets. Care must be taken to include all the potentially diagnostic parts of the plant; this includes

the basal leaves and roots. Herbaria will not welcome plant scraps. The only case in which it is not necessary to collect the whole plant is when it is too large to press (e.g. trees).

Seed should be collected into an small top-sealing envelope (the kind sold as wage-packets), sealed with a paper-clip. Do not seal the envelope with gum and do not use self-sealing envelopes. If wood specimens are being taken, these should preferably be cut off from dead branches. Top quality secateurs are a wise investment. Care must be given to ensure that *everything* is indelibly labelled with the collecting number. Sufficient whole plants to fill 2–4 herbarium sheets should be pulled up (using a trowel or pick if necessary), labelled with collecting numbers on stringed tags, and either pressed straight away in newspaper folders, or put in individual plastic bags with a drop or two of water to keep them fresh until pressing.

Pressing

By deferring pressing to the end of the day, the quantity of specimens obtained can be greatly increased, but the collector is then condemned to catching up with pressing in the long, lonely hours of the night. In addition, plants pressed in preceding days will need to be checked and straightened out where necessary, and drying papers must be changed. Under no circumstances must the plants be left unpressed overnight. To quote Peter Davis (1961, 284): "Some collectors get up at dawn, others label and change their presses late into the night, but few can do both for long".

The number of specimens collected each day will vary with the richness of the habitats and the experience of the collectors. With a willing companion, I aim at between 30 and 40 species a day (good quality triplicate herbarium specimens, with seed, photographs and wood where appropriate) if the material is pressed immediately; 50–60 if pressing is deferred.

Immature seed

If the seeds are still quite immature, whole plants should be uprooted and placed in paper bags to dry, in the hope that the seeds will ripen further on the plant. This often works, but one can easily end up with several hundred paper bags of plants waiting to be winnowed. This technique is also useful for plants such as *Echium* that are too prickly to de-seed in the field.

Cereals

Cereals are best collected as ears and placed inside tall paper bags that will keep them upright and intact. I use specially made bags 33 cm high, 15 cm wide, with a pleat on each side. These bags are also useful for large seeds and fruits, and for permanent storage of cereal ears. The special problems of collecting crop plants are discussed by Hawkes (1980).

Fruit

When fleshy fruits are collected, some should be sun dried, and the seeds should be extracted from the rest. This is tedious work; a kitchen sieve is often helpful for washing seeds clean. When seeds are collected in capsules or pods, be sure to keep some of these along with the winnowed seed, as fragments are often found along with seed in ancient material.

Seeds and plants should never be stored for more than a few hours in plastic bags, or they will start to rot. Grain samples, on the other hand, can be kept in plastic bags, but must be left open to air-dry for several days.

Documentation in the field

Good recording practice greatly increases the value of specimens, as well as facilitating their identification. It is absolutely crucial that field notes are made at the time and place of collection; what seems an important fact will soon be forgotten in the collecting fray if not written down.

The standard botanical practice of using a small notebook, with one or a few collections on each page, is not suitable for the special needs of reference collections. The information in a botanist's typical notebook is transferred to herbarium labels; thereafter the notebooks are no longer needed. In a reference collection, however, it would be quite impossible to fit all the data onto a tiny label in a tube of seeds. Instead, basic information is put on the label (identification, collector number, Flora number), and the user can then refer to the detailed notes elsewhere. Small notebooks also have the disadvantage of being wasteful to photocopy, fiddly to handle and easy to lose. The cramped pages can easily degenerate into untidiness.

The efficient collector has two choices: a large notebook with hand-ruled columns, or a specially printed form. In Ankara we use A4 printed forms (Fig. 4, which may be freely copied). The column headings remind the collector to note all necessary data; the format is flexible and economical (*c.* 10 collections per page), and the pages are easily removed from a ring-binder for photocopying. Whichever system is chosen, it is essential that permanent black India ink is used, and that sufficient blank margins for good photocopying are left.

An excellent discussion of field records is given by Womersley (1981, 1–16). All collectors need to be familiar with correct, detailed, recording procedures. Only a brief summary of what is needed is given here:

1. All collections must be allocated a unique collecting number. Standard practice is that collectors use *one* series throughout their career. A new series should not be started for each trip or for each year. Maintaining one series does require a little forethought—it is easy to set off on a trip without noting one's latest number—but this is by far the best system. If a number of people are collecting together, the numbers should be allocated from one person's series. Since a unique number identifies all collected material, it is important that no labelling errors are made.

All accessions to a collection should be given a collecting number, whether or not they come from the wild.

2. Date of collection.

3. Field identification—even just to family is helpful.

4. Locality. Country, administrative region, village, distance from a point located on a readily available map (city and/or main road).

5. Altitude: an altimeter (which need not be expensive) is useful here.

6. Aspect and slope: e.g. NW, 40°.

7. Taxonomic notes: anything that might not be preserved or obvious once the plants have dried (e.g. flower colour, or form and height of tree).

8. Frequency, using the *dafor* scale (dominant; abundant; frequent; occasional; rare), qualified by 'local' where appropriate.

9. Habitat notes: geology, soil, landform type, plant cover type, drainage features, disturbance factors such as grazing. These ecological notes will be useful for the interpretation of ancient material too.

10. Ethnobotanical notes. Local names and uses should not be noted unless you know the language well enough to be sure this information is correctly recorded.

11. Material collected: at Ankara we use the following codes: H—herbarium specimen; S—seed or fruit; C—cereal packet specimen; W—wood specimen; P—slide photograph; BW-black and white photograph.

Identification

Once the seeds and the plants are back in the laboratory, safely dried and labelled, the question of identification arises. In countries with a relatively small, well-known flora (e.g. Britain) the archaeobotanist should be able to identify most herbarium specimens soon after collection. Where a larger flora is concerned this is a hopeless prospect: even if the archaeobotanist is a good herbarium taxonomist, he or she is most unlikely to have time to identify everything. It is, of course, essential to invest some time in identifying the commoner species, both so as to develop a good working acquaintance with the flora of the region, and to hone up the skills necessary for checking identifications. However, this is the point at which all the labour expended on good duplicate herbarium specimens becomes worthwhile. Most herbaria offer identification of pressed plant specimens in exchange for the gift of the specimens. Not all identifications are of equal value. The only really certain ones are those made by a specialist on the genus, but for most purposes a determination by a competent taxonomic botanist is sufficient. It must be stressed that the identification of difficult taxa requires comparison with other, reliably determined, specimens, as well as the use of a Flora.

Choice of herbarium

The ideal herbarium is one that is actively working on the plants of the country concerned. Where this is not the case (e.g. for Turkey, where the *Flora of Turkey* project at Edinburgh has now ended), considerable care is needed in choosing an institution. Most of the great National Herbaria are interested in

Collector:

Date	Locality	Alt. m.	General Habitat	Asp.	Coll. no.	Binomial	Taxonomic Notes	FQ	Specific habitat	Mtl

Fig. 4. Form for collecting notes. Key to abbreviations: Alt.–altitude; Coll. no.–Collection number; FQ–frequency; Mtl–(Type of) Material.

plants from all over the world, but unless there is a specialist interested in your region, you may wait a long time for identifications. A smaller herbarium may well be interested in your material, and offer a more personal service.

For example, my own material goes to Reading University, with further duplicates from two difficult groups sent to specialists in Southampton and Berlin. This enables me to devote enough time to identifying taxa such as the cereals in which I have a special interest. Initial contact should always be established with herbaria before specimens are sent. Addresses of herbaria are given in the *Index Herbariorum*. When collecting abroad it is an important courtesy to deposit a set of specimens at a herbarium in the host country (with labels and identifications).

Export of specimens

Help in arranging the export of herbarium specimens is usually best obtained from local herbaria. There is a well-established tradition in taxonomic botany of unrestricted exchange of herbarium material. Ministries of Agriculture tend to be more concerned with commercial collectors of plant material, and with the political issues of germplasm, and can therefore be unhelpful. Herbarium specimens may be posted to most countries (including the UK) provided they are addressed to *The Curator* at an established herbarium.

Preparation of labels

Many herbaria input collecting notes into a computer database and use this to print labels for the herbarium specimens. This saves the collector a great deal of time in typing up labels, and is highly recommended. The labels can be photocopied and sent to the other herbaria where material has been deposited. If these facilities are not available from the herbarium, and many specimens need labelling, the collector may find it worthwhile setting up a computer database in the laboratory.

Documentation in the laboratory

Paperwork after collection must be kept to the minimum. The main function of a seed reference collection is as an aid to seed identification, it is not an end in itself. At the same time, there must be a simple system to check the identification and collection notes of each specimen, and which can also cope with later additions.

The system in Ankara fits in two A4 ring binders. One contains a copy of all the collecting notes; one contains our special 'identification forms' (Fig. 5). After seed material is collected, it is either placed straight into a test-tube with a temporary hand-written label, or it is stored in an envelope. When a definite identification has been made, either by the collector or by a herbarium, the identification, together with any comments, is noted on the appropriate identification form. A separate sheet is used for each genus. A special label (Fig. 6) is filled in with the identification, the collection number, and the Flora of Turkey number (see below for an explanation of this).

This system has two advantages. There is a listing of all accessions, in *Flora of Turkey* order, on the identification forms, which also note where seed and herbarium specimens have been deposited. Also, firmly identified material can be easily distinguished from provisionally identified by the special labels. The alternative to special identification forms is simply to write the firm identifications on the collecting notes. However it would be necessary to leave ample space for these and for identification comments.

If sufficient secretarial assistance is available, both the collection notes and the identification notes can be entered onto a computer database. I doubt whether this is worth the time and expense in most cases, unless it is planned to produce herbarium labels. The paper-based system outlined above is perfectly adequate and reasonably time-efficient. However, in Ankara we are now setting up a computer database of identifications (but not collecting locations) with the specific aim of printing test-tube labels for the seed collection. A useful subsidiary product will be a catalogue of the collection.

Pest control

Pests in herbarium material are not usually an immediate worry, so long as the specimens are properly dried. Herbaria will use their own control methods before accessing material. With seeds, problems are likely: it is remarkable how quickly a bag of vetch seeds,

BRITISH INSTITUTE OF ARCHAEOLOGY AT ANKARA HERBARIUM (B.I.A.)						DET.		DATE / /											
COLL. NO.	COLL. NOTES	FLORA OF TURKEY NO.			SPECIES NAME & AUTHORITY	COMMENTS		1 SHELF NO.	2 HERB B.I.A.	3 HERB ANK.	4 SEED HERB.	5 SEED B.I.A.	6 SEED LON.	7 SEED R.M.N.	8 WOOD	CHARCOAL©	10	11	12

Fig. 5. Form for noting final identifications.

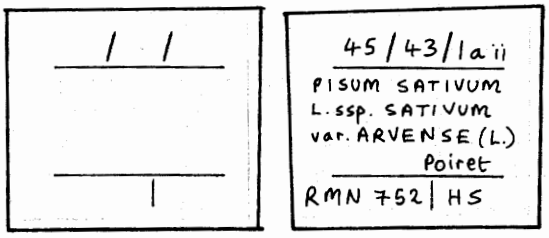

Fig. 6. Label for test-tubes, blank and filled in.

acorns or cereal grains can turn into a seething colony of bruchid beetles and maggots. There is a very simple solution: deep freeze the seeds (once they have had a several days to dry out) at –20°C for 48 hours. If a good domestic freezer is not available, the ice compartment of a refrigerator can be used as a temporary substitute. After freezing, we put small chunks of Vapona moth killer (a product widely available for protecting clothes) inside bags of grain for further protection. All grain samples are stored in three layers of polythene bag, to avoid insect contamination.

Naphthalene (as in old-fashioned white crystalline mothballs) should not be used as it can cause cataracts. Further guidance on pest control can be found in Zucherman (1988) and Forman and Bridson (1989, 13–19). In the unlikely event that insects are active in a seed tube, this will be indicated by the presence of frass, and the tube can be frozen.

Arrangement of reference material

Two decisions need to made concerning the storage of a collection: arrangement, and the type of container to be used.

Four considerations will affect the choice of system of arrangement: seed material should be located quickly; containers should be easily returned or added in the correct sequence, even by those with relatively little botanical knowledge; evolutionarily related material should be placed close together, and the system should not be based on a classification that will soon be out of date, and thus unfamiliar to those using the collections in 50 years time. As changing the ordering system is a very time consuming process, it is worth investing much thought at the outset.

Ordering of the material will be determined in part by the scope of the collection. It is highly advisable to keep geographically separate collections apart: for example, New World and Old World plants should not be mixed in the same cabinets. It would be equally unwise to split up collections into too narrow regions. In most cases, for example, a single sequence for European or Near Eastern plants would be sensible, but a single sequence for Europe and the Near East together would grow too unwieldy.

Many seed collections are divided into two series, a main one with two or three examples of each species, stored in easily accessible glass containers, and a separate 'back-up' series of further collections, kept in cheaper containers and available if needed. My own experience is that the more accessions that are to hand, the better, and I would prefer to have all material integrated into the main collection, with the reserve collection simply holding extra quantities of material beyond what will fit into the standard containers (*cf.* the cereal packets described below).

Most collections are still based on the flora of one country or region. Where a good flora has been published, and is unlikely to change much, it forms a very convenient basis. For example, in Ankara we follow the arrangement of the *Flora of Turkey* (Davis 1965–89). This Flora gives every family, genus and species a series of running numbers; for subspecies and varieties, which are not numbered by the Flora, we allocate letters (a,b, etc) and numbers (i, ii etc). Thus 45/43/1/a ii is the code for Leguminosae/ *Pisum*/ *sativum*/ ssp. *sativum*/ var. *arvense*. Having the seed tubes arranged exactly as the Flora is highly convenient, and means that closely related taxa will be found next to each other. There is a space on the test-tube labels for the Flora number (Fig. 6). We can follow the Flora both because it incorporates a sensible numbering system, and because it is unlikely to be replaced in the next 50–100 years. Newly described species, and other taxa not in the Flora, are simply placed at the end of each genus or family sequence.

Other countries with an authoritative Flora that is unlikely to be superseded for many years include Israel, Jordan (*Flora Palaestina*), Iran (*Flora Iranica*), Iraq (*Flora of Iraq*), Syria

(*Nouvelle flore du Liban et de la Syrie*) and Cyprus (*Flora of Cyprus*). Relatively little taxonomic work is done in these regions, and therefore once the heroic effort of preparing a Flora has been made it is unlikely to be repeated. The situation is much more difficult where there is no Flora, or it is hopelessly behind schedule, or where the National Flora is regularly revised, with a different numbering system each time.

An alternative possibility for the Near East would be the *Conspectus Florae Orientalis* (Zohary *et al.* 1980–) which is making good progress. Although it lacks a numbering system, this could easily be added. For the Mediterranean countries there is the *Med-Checklist* (Greuter, Burdet and Long 1984–).

For the European countries one has three alternatives:

(a) To use the system of a national *Flora* and to ignore rearrangements in later editions on the basis that, in areas as botanically well known as Europe, these changes are unlikely to very significant. For example, a British collection could use the *Flora of the British Isles* (despite its expense and the mis-numbering of the families!), or could opt to wait for the second edition of J. E. Dandy's standard *List of British Vascular Plants* (due from the Botanical Society of the British Isles soon). Anyone contemplating using the *Flora Europaea* should bear in mind that a second edition has just started publication, and that the classifications adopted in some of the earlier volumes of the first edition are not always satisfactory.

(b) To follow many herbaria and arrange families and genera by one of the 'evolutionary' systems devised in the late nineteenth century by Engler, and Bentham and Hooker. The species are then arranged in alphabetical order. These have the disadvantage of being out of date and unfamiliar. The worst possible arrangement, although used by many herbaria, is to have families in evolutionary order, then genera and species in alphabetical order.

(c) To put families, genera and species in alphabetical order. This system is the easiest to arrange, but has the great disadvantage that it separates closely related species and genera—very unhelpful for identification purposes. This is a fine as a temporary system for collections, but is unsatisfactory in the long-term.

Cultivated plants are rarely well treated in Floras (indeed, some exclude them altogether). Where this happens, the collection curator will have to insert them at the appropriate place. In any case, most seed collections will have species that are no longer cultivated in the region. In Ankara this is mainly the case with the cereals, and we follow the sensible and comprehensive classification of these by van Zeist (1984).

Storage of reference collections

The most inexpensive system is to put seed envelopes in rows in boxes or drawers. The disadvantages are obvious, and most collections use glass jars, specimen tubes, test-tubes or plastic boxes. Standard specimen tubes are really too small and take up a lot of space. For collections in areas such as Europe, where the materials are easily available, a system based on small, transparent plastic boxes stored in shallow-drawered filing cabinets is recommended. For areas such as Turkey, where the boxes are not easily obtainable, glass test-tubes in wooden racks may be more suitable, and this is the system used in Ankara.

The advantages of using boxes in shallow drawers are that the boxes are easily scanned while in the drawer, and are easy to remove and replace. This is particularly important if specimens are to be handled by large numbers of inexperienced users. Compared with glass tubes, the system is less compact and a little more expensive, but these should not normally be the major factors guiding the choice of a storage system.

Transparent polystyrene boxes with sliding tops are widely available in at least two convenient sizes: small (75 mm long x 44 mm wide x 20 mm deep) and large (120 x 77 x 18). For most seeds the small boxes will be suitable. An example of a widely-available filing cabinet contains 15 drawers, each 371 x 233 x 44 mm. Assuming each drawer holds 24 boxes on the bottom and 10 on the second layer, each cabinet could comfortably hold about 500 boxes. The specimen labels simply sit inside the boxes. Care should be taken to ensure that the drawers are easily removable from the cabinet.

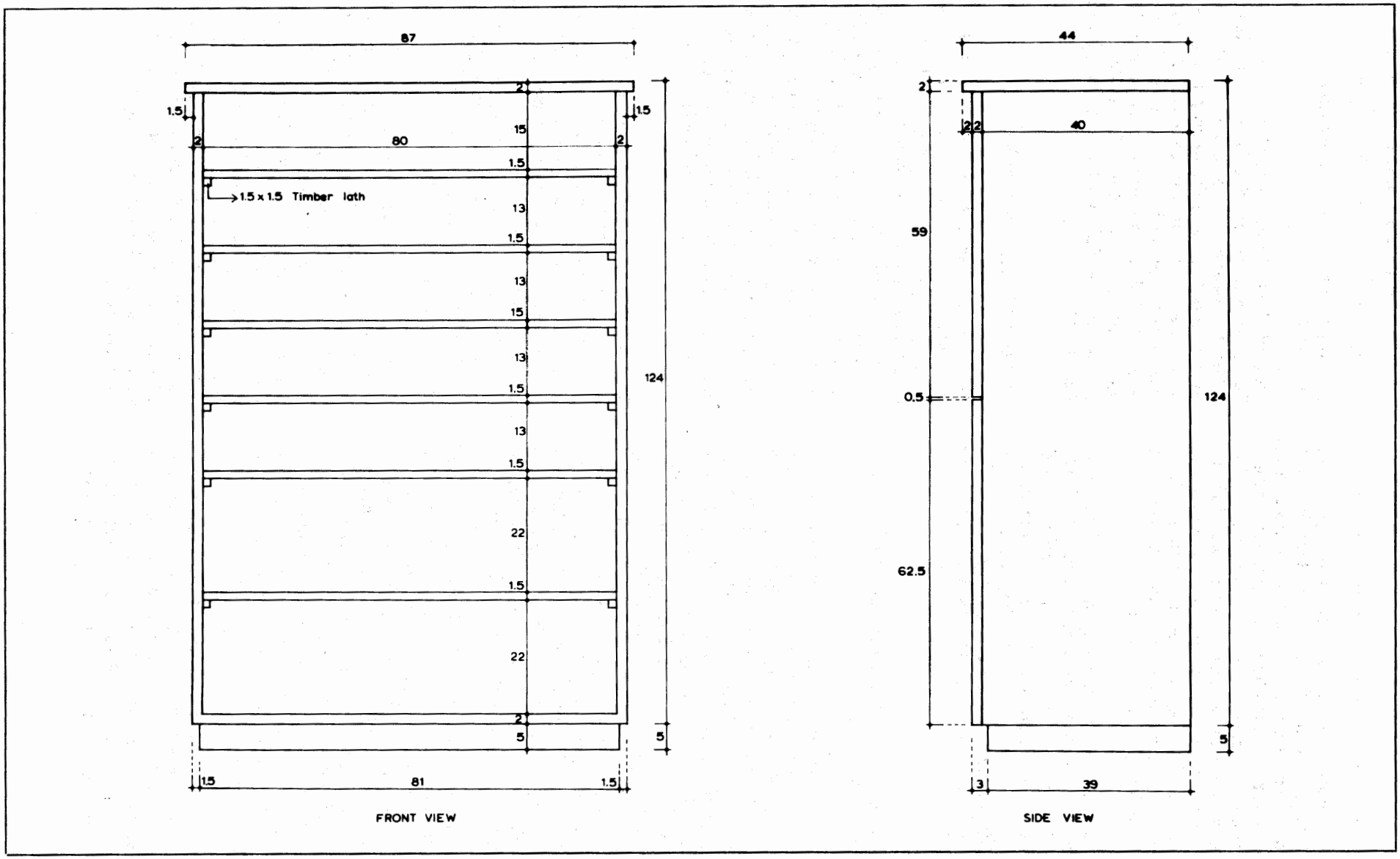

Fig. 7. Front and side view of wooden seed cabinet.

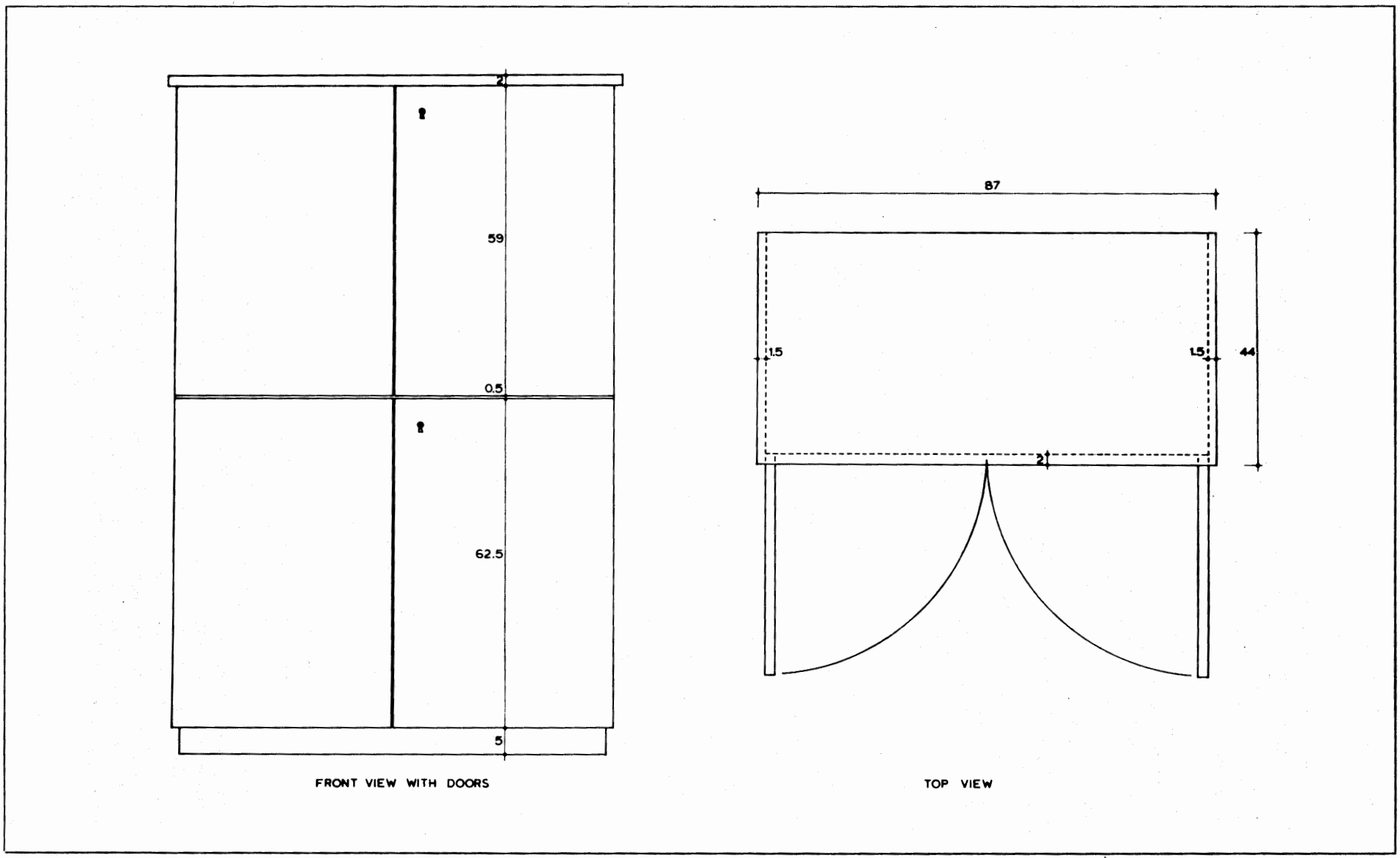

Fig. 8. Front view with doors and top view of wooden seed cabinet.

The system used for storing test-tubes at the British Institute of Archaeology in Ankara, designed by Gordon Hillman in the 1970s, is described at greater length as it requires some carpentry.

We use standard test-tubes with a flared rim (this makes tipping seeds in and out easier), 105 mm high with a diameter of 12.5 mm. The tubes are stoppered with cotton wool. Larger seeds are kept in a separate series of larger tubes, H 160 mm, D 16 mm. The tubes are stored upright in depressions drilled into solid wood blocks. Blocks hold 48 standard tubes, or 24 large tubes. Our wooden cabinets each hold 55 racks of standard tubes (total 2640) and 26 racks of large tubes (624). The wooden racks can be conveniently slid in and out and can be easily rearranged when extra racks are inserted. The wooden blocks are very stable. The end of each rack bears a label giving the family(ies) (with Flora of Turkey number) in the rack. A cheaper alternative to wooden racks would be expanded polystyrene racks, of the kind used for holding specimen tubes. However, these hold too many test-tubes for easy use, and will eventually disintegrate. Another possibility is the kind of open lattice test-tube metal rack used in laboratories. Joy McCorriston has found these to have the advantage of allowing scanning of tube contents at a glance, with no need to remove tubes until a closer examination is desired. They are perhaps less stable and easy to handle than solid wooden blocks, but would certainly be worth a trial.

The seed cabinet is illustrated and drawn in Figs. 7 and 8; also shown are the standard rack (Fig. 9) and the large-tube rack (Fig. 10). Although the Ankara cabinets have locks with keys, it would be preferable to use non-locking catches—keys are all too easily lost. A ready-made metal cabinet could be used if economy is important, but a specially made wooden cabinet will be comfortable to use.

We do not keep the racks full of tubes, so as to allow further accessions to be easily added. Care is needed when a tube of seeds is taken out of a rack for study. Although the Flora of Turkey number on its label ensures it can be returned to the right spot, it is easier simply to mark the appropriate depression by putting a brush or pencil in it. Taking seeds out of more than one tube at the same time is best avoided, as it introduces the risk of returning the seeds from the Petri dish to the wrong tube.

An ingenious storage system is described by Christian de Vartavan (1988). Specimen tubes fit into longitudinal slots that are cut into cork tiles. Although easily carried, I suspect that fitting the tubes in and out of their slots could be more fiddly than simply placing a tube into a wooden rack. I also wonder how well this system would work with stoppered test-tubes rather than specimen tubes (which are too small for holding an adequate number of seeds for many species). However de Vartavan's system would be suitable for collections where ease of carrying is a major consideration, and is very cheap.

Some older collections are kept in small 'cells' mounted on slides. This system has the advantage of allowing very quick browsing, but is laborious to prepare, and does not allow the seeds to be handled. Where such a collection already exists it can be very useful and should be maintained, but I would not recommend starting one from scratch.

Very large seeds and fruits

These are best kept in rectangular transparent polystyrene boxes, stored in drawers. A variety of sizes should be kept available so as to ensure the most economical use of space.

Cereal ears

Typical cereal ears tend to get stuck in test-tubes, and in any case they will not hold the minimum 3–4 ears that should be to hand from each collection. The most satisfactory solution is, again, transparent plastic polystyrene boxes with lift-off lids. We use two sizes, as described above (p. 31): small—mainly for loose spikelets and grain—and large-for intact ears.

We also have a back-up collection of ears stored in tall paper-bags (as recommended for collecting), arranged inside a plastic-lined wooden crate. Each bag contains around 10–30 ears, and these have proved very useful for large-scale studies of variation, and also for the provision of intact ears if all those in a box have been dissected.

Wood and charcoal specimens

In Ankara we have followed the practice of the Institute of Archaeology, London, by using enamelled steel cabinets containing transparent plastic drawers; these are widely sold in hardware stores for storing small items.

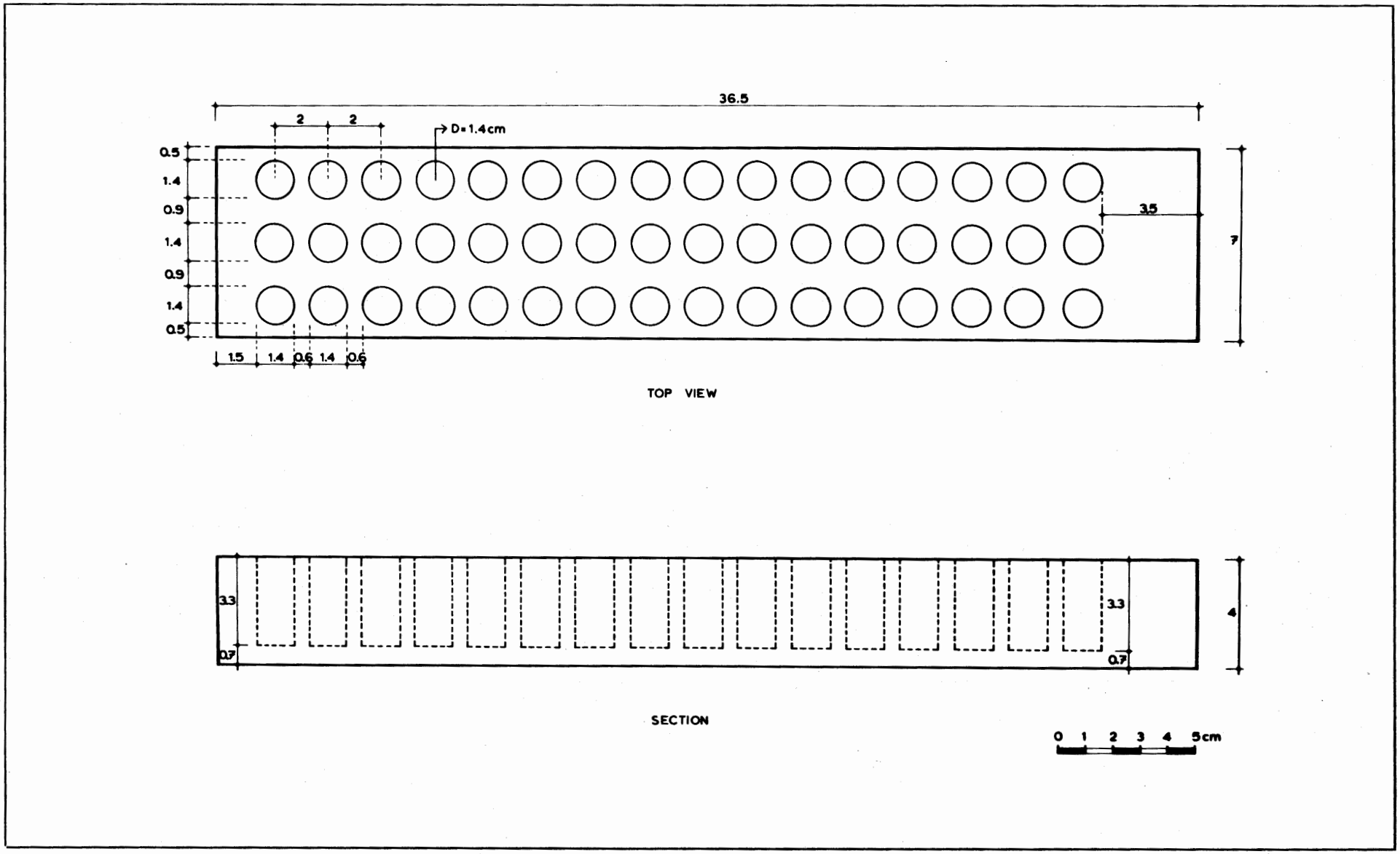

Fig. 9. Top view and section of rack for standard test-tubes.

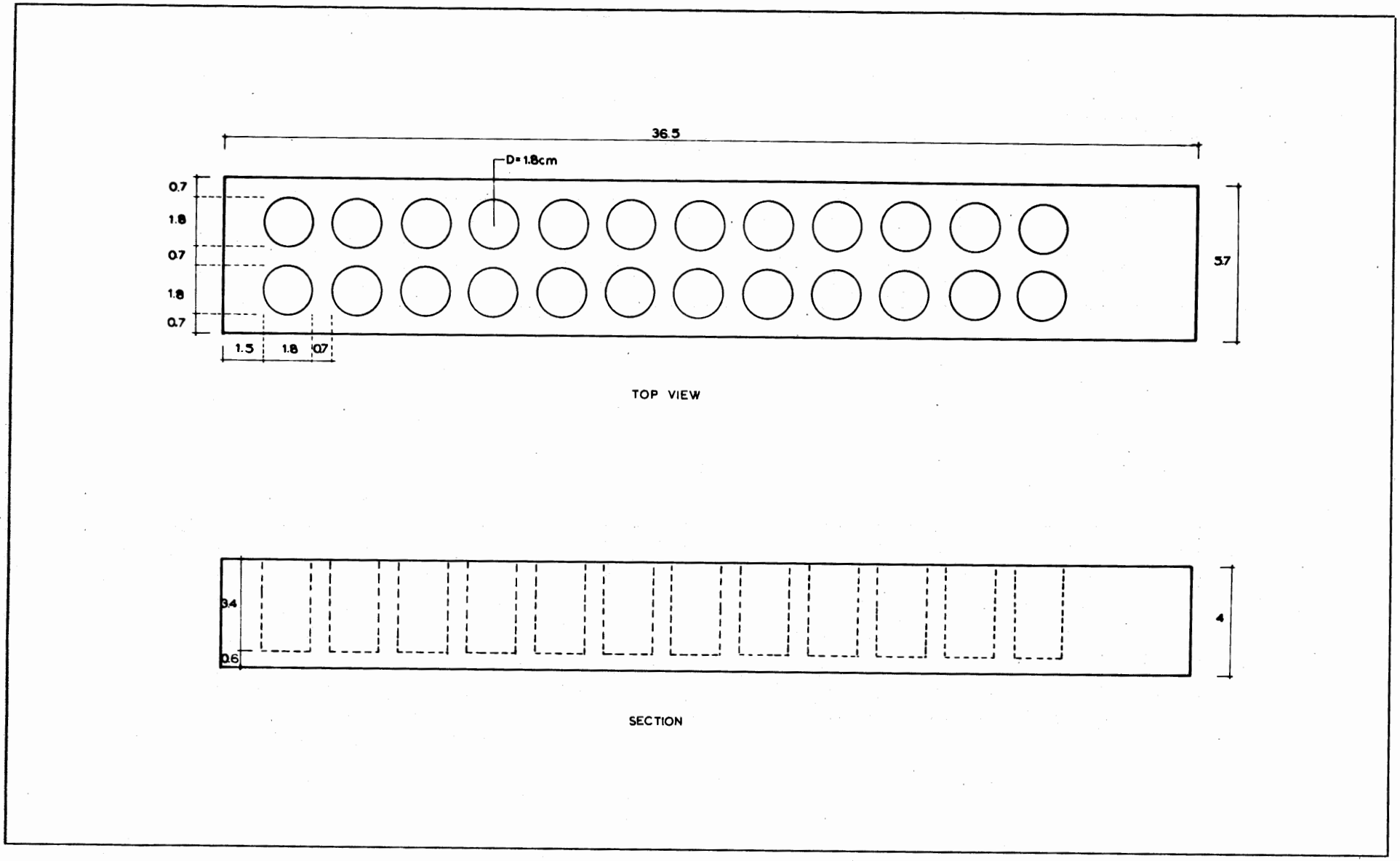

Fig. 10. Top view and section of rack for large test-tubes.

The drawers have label holders on the front, and if separate collections of trunk wood, twigs and roots have been made, each drawer can be split up with plastic dividers to accommodate these. An alternative procedure would be to glue radial, cross and tangential sections to a jar lid interior, and then screw this into the short jar to protect the samples from dust and wear. In earlier times charcoal used to be identified by comparison to mounted slides with thin sections of modern wood. Today ancient charcoal is identified by comparison with lumps of modern charred wood, and the painstaking preparation of thin sections only necessary if uncharred wood is to be identified. For charcoal and wood specimens the same kind of label as described for seeds should, of course, be used.

Pollen

Modern pollen can be extracted from dried flowers on herbarium material, but collectors interested in collecting for pollen specimens should consult a palynologist beforehand. In general, it is helpful if insect pollinated flowers can be collected within a day of opening, as in older flowers there is a risk of insect-borne cross contamination from other species.

Phytoliths

If it is intended to extract phytoliths (silica bodies), the appropriate parts of the plants should be placed in a paper bag for extraction treatment in the laboratory (see Piperno 1988 for more details). As with seeds, voucher herbarium specimens must be collected.

Seed viability

Many seeds will retain some viability under the storage conditions of a normal seed reference collection (i.e. room temperature), and I have successfully grown a number of seeds from collections made twenty years ago. If it is particularly desired to keep seeds viable, standard procedure in genebanks is to reduce seed moisture to 4% and store in sealed containers at around –20°C. This will keep the seeds of most species viable indefinitely. A good domestic freezer is perfectly suitable. If this is not possible, then higher temperatures (–10° or –5°C) will still give reasonable protection of viability. However seed moisture must always be reduced to a low level, either by sun-drying or low heat, before freezing. Further details on these procedures are given in Dickie, Linnington and Williams (1984), Ellis, Hong and Roberts (1985), Hawkes (1987) and Holden and Williams (1984).

Using the collection

Anyone working with charred or waterlogged material will need to carry out artificial treatments on some of the reference material for comparative material. Charring of both wood and seeds is a relatively simple matter, providing a high enough temperature can be obtained. Domestic ovens [in Turkey at least] generally have a maximum temperature of 250°C, which will char seeds far too slowly (10–20 hours). Two hours at 350° in a muffle furnace is satisfactory (Ann Butler, pers. comm.); the seeds should be placed in sand. A simpler method of charring is to heat the seeds in a sand-bath with a Bunsen burner (or domestic stove) for ten minutes (Jacomet 1987, 21) or, as described by Kosina (1984, 178) over a gas burner in a layer of powdered clay, with 0.25 kg of sand on top for about three hours. Anyone interested in the effects of charring on seed size will need to carry out experiments at different temperatures, times and levels of seed moisture. Once the charred seeds have been examined, they can be placed in a gelatin capsule labelled with details of temperature and time, and returned to the seed test-tube.

Ancient waterlogged plant material can look very different to modern material, owing to the loss of the softer tissues. Techniques for replicating this effect on modern material are given by Tomlinson (1984). Material treated this way will need to be mounted on slides and stored separately. Care should be taken to ensure that the appropriate collector number is applied to mounted material.

Eight "do's" in building up a seed reference collection

1. Read one of the handbooks on plant collecting and follow its advice.

2. Always collect herbarium voucher specimens.

3. Give all accessions to the collection a unique collection number; use only one series in your collecting career.

4. Keep tidy collecting notes, in permanent black ink, on well laid out forms; ensure a photocopy of these notes is safely housed in an institution.

5. Deposit sets of duplicate herbarium specimens in at least one good herbarium, in exchange for a list of identifications.

6. Deep freeze all seed material to kill pests.

7. Split seed collections made with grants or other official funds with at least one institutional collection, so that this material is available to other scholars.

8. Use a seed storage system that is 'self-organising' and easily expanded.

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