CHAPTER 22

Use of herbarium specimens in ethnobotany

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INTRODUCTION

The herbarium — a collection of pressed plants mounted on paper — is central to the practice of ethnobotany, and to the use of all the other plant collections discussed in this book. Herbarium specimens both vouch for the identity of the plants being studied, and are themselves documents of plant use by people.

The accumulation of 500 years of plant collecting by botanists and travellers, herbaria are rich and underexploited sources of data about useful plants (useful in the broadest sense) and the human societies that use them. Not only do useful plants form a substantial proportion of plant species (even greater if crop wild relatives are taken into account; see Chapter 8) but they are also likely to be over-represented as specimens in herbaria, as many are widely used and thus abundant in local vegetation. Useful plants were also of particular interest to many collectors (Chapter 20). It is likely that half or more of the specimens housed in large herbaria are of plants of useful or symbolic value to humans; ethnobotany should therefore be central to the use and development of herbarium collections.

During the 20th century, herbarium botany moved away from its roots in physic gardens and applied botany, towards a focus on alpha taxonomy, the detection, description and classification of taxa. Many botanists had little interest in human relations with plants (Anderson, 1952). Perhaps not coincidentally, the late 20th century saw a crisis in natural collections, in which declines in funding coincided with a lack of confidence in the value of museum collections (Clifford et al., 1990). In response, natural history collections have encouraged more diverse uses and users of collections (Funk, 2003; Suarez & Tsutsui, 2004). The current climate is thus one in which ethnobotanists and herbaria have much to offer each other, well beyond the important field of voucher specimens.

In this chapter, I focus on special considerations related to ethnobotany: the importance of voucher specimens, and a wide-ranging exploration of the current and potential uses of herbaria for ethnobotany, expanding on coverage of this in Chapters 21 and 23. The creation, curation and management of herbaria is covered in Chapter 3.

THE IMPORTANCE OF VOUCHER SPECIMENS

Why voucher?

To properly document an ethnobotanical study, it is essential to collect quality vouchers in the form of herbarium specimens and to deposit them in a permanent collection where they will be available indefinitely to confirm the identity of the plant(s) under discussion. In some cases, the herbarium specimen itself is the only specimen collected, and it acts as a voucher for the associated ethnobotanical data contained in field notes; in other cases, the herbarium specimen also acts as a voucher for associated specimens such as woods, DNA or artefacts. In both cases, the herbarium specimen is the specimen that enables verifiable identification.

Voucher specimens perform three vital functions: they allow identifications to be made in the first instance; they allow identifications to be checked by subsequent researchers; and they allow work to be updated in the light of new taxonomic concepts. Why are these functions so important?

Most plants encountered in ethnobiological fieldwork will, of course, already have an identification in the form of a local vernacular name. In terms of the preservation of traditional knowledge and the recording of ethnotaxa, vernacular names are essential. Nevertheless, identification by of a species by botanical (Latin) name is also essential, because it also enables knowledge of the plant and its uses to be structured and understood by reference to the wider world of data about that plant: for example uses in other cultures, chemical and medicinal properties, and ecology and cultivation (Bennett & Balick, 2013). Botanical names are also, in principle, less prone to the ambiguity of vernacular names, which are often spelled in many different ways and may be used for more than one plant, as is the case for the wild and domesticated sesame species (Bedigian, 2004).

Reliable plant identification using the standard botanical tools of the flora and herbarium requires the presence of plant parts such as flowers and fruits that are often missing from ethnobotanical specimens, which may consist only of fibres or crude drugs. It is the function of the voucher specimen to provide these parts (Eisenman et al., 2012). It is sometimes assumed that accurate identifications can be made in the field, using handbooks or botanical expertise, but even well-known species can be confused with rare species that are similar in appearance. Field identifications will be uncertain for infraspecific taxa that can only be identified by morphological, chemical or DNA studies of preserved specimens. For example, the phytochemical composition of tarragon (*Artemisia dracunculus*) has been found to vary with ploidy level; similar infraspecific variation has been found in other medicinal plants (Eisenman et al., 2012).

Collection of a voucher specimen is an essential step towards identification, but there is no guarantee that this specimen will always be identified correctly. Even in temperate areas with well-known floras, genera such as *Astragalus*, *Rubus* and *Salix* are difficult for experienced botanists to identify to species level. Łuczaj (2010) revisited four collections of voucher specimens made in Poland between 1874 and 1975. Even in a country with a modest flora (3,000 species) and an exceptionally good botanical infrastructure, 10% of the 465 voucher specimens examined were found to be incorrectly identified. All of the herbarium studies discussed below reported errors in 20th century re-identifications of historic herbarium specimens. Of course, in cases where voucher specimens are not collected, it is impossible to detect these errors. Nesbitt et al. (2010) found that out of 50 recent papers on nutritional analyses of wild plants, only eight cited voucher specimens or genebank or nursery accession numbers. Of 502 plants analysed in the 50 papers, 27% were identified by botanical names that were grossly outdated, or misspelt. This is a strong hint that the underlying identifications are insecure. In most cases, however, they can never be checked because there are no voucher specimens.

Changes in taxonomic concepts may lead to the redefining of plant taxa, and result in changes in the ways that plants are identified. These changes affect both taxa common in well-studied areas and those from more diverse and less explored areas, such as the wet tropics. There are many examples affecting useful plants. In Australia, large genera of trees such as *Eucalyptus* and *Acacia* have seen the identification of many new species, usually involving the splitting of an existing species into two or more species (Barker, 2008). Without a voucher specimen, it is hard to assign a wood specimen from such a species to its new taxon. In North America, *Elymus caninus* (formerly *Agropyron caninum*) is one of many species in the Triticeae tribe of the grasses that has seen extensive changes in the 20th century, sometimes being recognised as a single species, sometimes as four (Barkworth & Jacobs, 2001). In genetics, voucher specimens have enabled the reinterpretation of the results of hybridisation experiments decades after they took place, in the light of new taxonomic arrangements (Sauer, 1953; Barkworth & Jacobs, 2001). Similarly, new taxonomic work by Schmidt-Lebuhn (2008) on the aromatic genus *Minthostachys* enabled the reinterpretation of many inconsistent records of plant chemistry, use and vernacular nomenclature. Without voucher specimens, it is impossible to carry out this kind of retrospective analysis.

Voucher specimens thus enable the reproducibility of studies, a fundamental quality of science. They have another important attribute. As well as plant material, they also incorporate standard label data such as date and place of collection. As a set of georeferenced specimens that can be linked to other ethnobotanical specimens and data, they can be interrogated using new research questions and techniques. Examples of this, ranging from extraction and testing of plant chemicals to studies of over-harvesting, are presented later in this chapter.

Vouchers: current practice

Reviews of current practice show that there is wide variation between disciplines in the implementation of routine collection of voucher specimens. In the cases of nutritional analyses, natural products and molecular analyses, it is unacceptable that so few studies cite voucher specimens. The techniques of voucher collection and identification have been routine in the closely related field of ethnobotany for decades, and can easily be adopted by other disciplines. It is clear that the requirement by journals of citation of voucher specimens for plant materials in articles that they publish can be a major force in the adoption of vouchering, and this requirement should be more widely implemented.

Ethnobotany

Collection of voucher herbarium specimens is standard practice in ethnobotany. Robert Bye's seminal paper of 1986 spelt out the importance of depositing voucher specimens in recognised herbaria, where they would not only receive an initial identification but also be subject to further taxonomic scrutiny as part of the normal process of revision of herbarium holdings. The journal *Economic Botany* had already, in 1981, introduced a requirement for voucher specimens to be cited, and this is likewise compulsory for manuscripts submitted to the *Journal of Ethnopharmacology*, *Journal of Ethnobiology* and other journals within the field.

Natural products

The collection of voucher specimens is still not standard practice in this field, which is closely related to ethnobotany but usually with stronger emphasis on the commercial use of plants for medicine and other purposes (Flaster & Lassiter, 2004; Wolsko et al., 2005; Smillie & Khan, 2009; Eisenman et al., 2012). In part, this is because the supply chain is often longer, leading to a disconnection between collector and retailer.

Genetics and DNA

Regular pleas from geneticists for vouchering of plants used for chromosome counts and genetic experiments suggest that this is a long-standing problem (Sauer, 1953; Barkworth & Jacobs, 2001; Chapter 7). To this must now be added to concerns over the failure to voucher material used for molecular studies (Goldblatt et al., 1992; Pleijel et al., 2008).

Genetic resources

The importance of herbarium voucher specimens for documenting and assuring the identity of germplasm has clearly been well-understood since the early 20th century, and is stressed (with practical instructions) in current handbooks on germplasm collection (Miller & Nyberg, 1995; Way, 2003: 187–191). If a genebank does not have its own herbarium, voucher specimens can be deposited elsewhere.

The plant exploration programme of the Office of Foreign Seed and Plant Introduction, US Department of Agriculture was established in 1898. A high proportion of its collections were and are grown on and vouchered in the USDA's Economic Botany Herbarium, today known as the National Arboretum Herbarium. Collections continue to be grown and vouchered by this herbarium and it remains the official depository for documented specimens of USDA plant introductions, including food, drug, forage, industrial and forest plants. Similarly the N. I. Vavilov Institute of Plant Industry, established in 1923, has a herbarium of voucher specimens for its genebank holdings. Such herbaria are very rich in cultivated plants, which are often neglected in other herbaria.

Taxonomy

Citation of voucher specimens for new plant taxa — known as type specimens —was recommended in the Rochester Code of 1892, and was widely practiced. Nevertheless, it did not become a mandatory part of the *International Code of Botanical Nomenclature* until 1958. The necessity of type specimens is widely understood, and they have been the initial focus of most herbarium digitisation projects (Chavan et al., 2010).

Ethnomycology

Preservation of fungal voucher specimens has been urged since the 1970s, but is still not standard practice (Ammirati, 1979). The form of the voucher specimen needs careful consideration, according to the part of the fungus being studied, and whether or not a live culture is preserved (Agerer et al., 2000). Where a live culture is not preserved, the collection locality is particularly important as it will enable re-collection of living material.

Wood anatomy

Citation of wood specimens, for work involving their anatomy, chemistry or DNA, has long been well-established (Chapter 9). Wood specimens are usually cited by the *Index Xylariorum* code of the holding institution and the accession number allocated by that institution. However, 50 years ago, Stern and Chambers (1960) argued that citations of wood specimens should also include the collector and collector number, and the location of the voucher herbarium specimen (if there is one). It is important to be able to find the original wood specimen, but this does not itself allow an independent identification of the taxon. Barker (2008) reports that citation of herbarium voucher specimens is still not standard practice in wood research, and gives many examples of Australian trees with changed taxonomic status, including the merging and splitting of species, that can only be resolved through voucher herbarium specimens. Citation of herbarium specimens is more important than ever for woods, as wood research moves beyond the easily recognisable commercial species that were the focus of research in the 20th century to encompass non-industrial woody plants that are harder to recognise.

Nutrition

Nesbitt et al. (2010) found that out of 50 recent papers on nutritional analyses of wild plants, only one cited voucher specimens; a further seven papers cited genebank or nursery accession numbers (good practice, but not sufficient as such material may be incorrectly identified). A recent manual on the documentation of traditional foods only advises collection of herbarium specimens for hard-to-identify taxa (Kuhnlein et al., 2006), but such taxa can be difficult to separate from easy-to-identify taxa in the field.

HERBARIUM SPECIMENS AS ETHNOBOTANICAL DATA

A brief history

The earliest herbaria were formed in Italy in the 16th century, and were in the form of pressed plants mounted on sheets of paper, which were bound into books. Binding specimens into books remained standard practice until the 18th century; for example, the herbarium of Sir Hans Sloane (1660–1753), now housed at the Natural History Museum in London, comprises 260 bound volumes, made up of specimens received from many collectors. From the mid-18th century onwards, perhaps reflecting the influence of Linnaeus's new classifications, herbarium sheets were kept loose so that they could be shelved in taxonomic order. Increasingly, herbaria were housed in institutions rather than the homes of wealthy collectors such as Sloane and Sir Joseph Banks (Figure 1).

As with all museum collections, understanding the history of herbaria is crucial to their effective use. A herbarium is, on the one hand, an accumulation of collections created by individuals in specific times and places for particular purposes, and on the other hand, an aggregate of these collections. Its specimens thus encompass a far greater geographical and chronological range than any one researcher can achieve (Drew, 2011). There are therefore two approaches to using herbaria for ethnobotanical research. One is to home in on a discrete collection from a particular time and place within the whole; for example a surviving volume of 170 specimens collected by the herbalist Ferrante Imperato (1525–1621) in Italy, or the 17th century herbarium collected by Hendrik Meyer in Suriname before

Figure 1. The herbarium belonging to Sir Joseph Banks, at his house in central London. Sepia painting by Francis Boott, 1820. © NATURAL NISTORY MUSEUM, LONDON.

1687 (De Natale & Cellinese, 2009; van Andel et al., 2012b). In both cases, significant detective work was required to identify the original collector. The other, and most common, approach is to treat the whole herbarium as an assemblage of data points, allowing research into both geographical and temporal changes in the occurrence of particular species. Herbaria cannot, however, be treated as random samples of nature, and a critical approach to understanding data is required, as demonstrated by the following case studies.

Ecology and conservation

One of the major challenges facing ethnobotany is detecting and quantifying overharvesting of wild resources. Several attributes of herbarium specimens can be used as proxies for harvesting pressure, including the abundance of specimens (as plants are over-collected they become rarer, and less likely to be encountered by botanists), plant size, and plant maturity (larger and more mature plants are more likely to be harvested, leading to a decrease in size). Of course, a wide range of other factors also affects these attributes, but several studies have made effective use of comparisons of harvested and non-harvested species in order to identify factors specific to harvesting. A study of 915 herbarium specimens of American ginseng (*Panax quinquefolius*) found a decrease in nine of eleven size-related traits, such as root length and leaf width, occurring from 1900 onwards (McGraw, 2001). Plants from northern parts of the USA did not exhibit this decline, suggesting that the cause is more likely to be related to localised effects such as over-harvesting. Living plants of *Saussurea laniceps* were also found to be smaller in more intensively harvested locations today (Law & Salick, 2005). As larger plants are preferred by harvesters, and the plant is harvested just before the seeds mature, there is a strong selection against large plants.

A further study compared the number of ginseng specimens in 85 herbaria to the number of specimens of four closely related species that are not commercially harvested (Case et al., 2007). After allowing for preferential collection of ginseng by some botanists, the proportion of ginseng specimens significantly decreased in most regions over the past 150 years. In a similar study, Applequist et al. (2007) found a decline in the number of collections of *Echinacea purpurea* relative to those of the less-collected *E. pallida* var. *pallida*, which was interpreted as evidence of over-harvesting of *E. purpurea*.

Geographical distribution can also give insights into plant systematics, as in the case of medicinal rhubarb (*Rheum*) species in China where overlapping distributions suggest that three species may in fact be one (Wang et al., 2010).

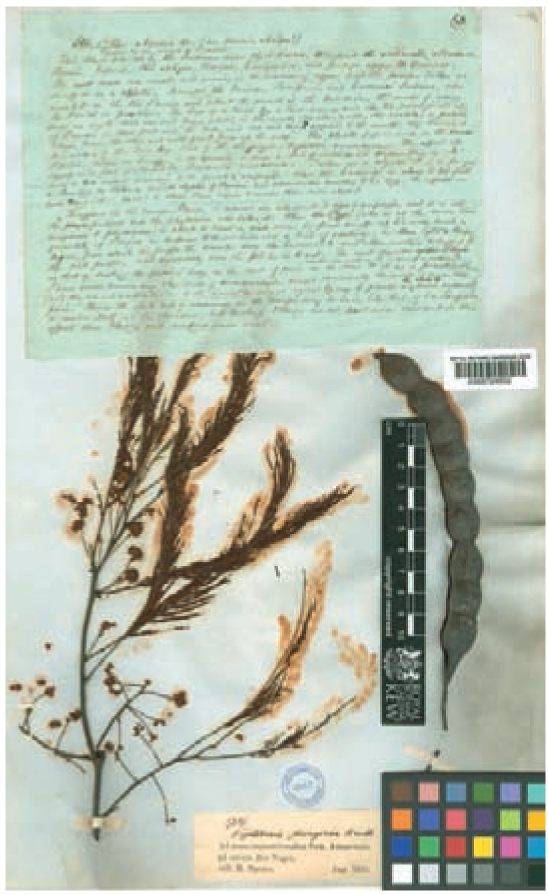
Uses

In the past, herbarium specimens sometimes doubled as ethnobotanical specimens, as in the case of Sir Hans Sloane's herbarium specimen of the Jamaican lace-bark tree (*Lagetta lagetto*) housed in the Natural History Museum in London, to which is attached a piece of lace made from the inner bark of the tree (Figure 2; Brennan et al., 2013). However, this is unusual (and not standard practice today); instead, when present, ethnobotanical information is often conveyed by written information on the herbarium sheet (Figure 3), as well as in associated specimens (ethnobotanical, biochemical, wood etc.) for which the herbarium specimen is a voucher.

Such annotated herbarium specimens were very much working collections for the original collectors. The 313 heavily annotated specimens of North American medicinal plants collected by Dr Gideon Lincecum for his personal herbarium between 1835 and 1852 would have been an important educational resource for a physician such as Lincecum who had no formal training (Birch, 2009). Detailed study of the composition of such a herbarium gives valuable insights both into Lincecum's

LEFT **Figure 2.** Herbarium specimen of Jamaican lace-bark (*Lagetta lagetto*), collected by Sir Hans Sloane in 1687–88. Note the piece of processed inner bark on the left-hand side of the specimen. © NATURAL HISTORY MUSEUM, LONDON.

BELOW **Figure 3.** Herbarium specimen of paricá (*Anadenanthera peregrina*), collected by Richard Spruce near the Rio Negro, Brazil (No. 1786; barcode K000724602). A lengthy note on the plant's medicinal uses is attached. Spruce's ethnobotanical work and this specimen are discussed by Schultes (1983). © ROYAL BOTANIC GARDENS, KEW.



own practice, with its strong links to Native American medical traditions, and into Native American practices in a period predating most written records, most of which date from late 19th century ethnobotanical recording. In addition to the ethnobotanical notations, the medical purpose of the overall assemblage meant that the whole suite of taxa could be understood as a proxy for the materia medica known to and used by Lincecum. If specimens had been studied in isolation, without attention to their history, their medicinal function would not have been fully understood.

The Hermann Herbarium, collected in Suriname by Hendrik Meyer, before 1687, is another example of a herbarium — in this case of 51 specimens — which is almost entirely comprised of useful plants. Again, extensive historical and botanical research has enabled the time and place of collection to be specified (van Andel et al., 2012b). DNA analysis was used to identify an incomplete Malvaceae specimen to species, *Pachira* *aquatica*. The herbarium is the earliest collection of plant specimens for the Guianas region, and the vernacular names (in the Carib Indian language) and uses recorded on specimens demonstrate considerable continuity in plant use from the 17th century to the present. Of particular interest are two specimens of crops, okra (*Abelmoschus esculentus*) and sesame (Figure 4), the first physical evidence of the cultivation of African crops in Suriname, occurring 30 years after the first African slaves were imported (van Andel et al., 2012a, 2012b).

Figure 4. Herbarium specimen of a wild sesame (*Sesamum radiatum*) from the Hermann Herbarium, Leiden. Collected before 1687 in Suriname and with okra the first record of an African crop in that country. The annotations give the vernacular name as Bowangala, very similar to the current day Arawak name boangila, and give the uses (translated from Dutch to English): 'Carries white flowers, that in form resemble Hyosciamum. Pressed seeds give rise to a sweet, painkilling oil.' (van Andel et al., 2012a).

The Libyan ethnobotanical collection formed by the Italian agronomist Alessandro Trotter, and now housed at the University Federico II in Naples, is a reminder that many historic herbarium specimens were collected in the context of colonisation. Italy conquered the Ottoman province of Libya in the 1911–1912 Italo-Turkish War. Trotter made several expeditions to Libya between 1912 and 1924. In his herbarium of 2,300 specimens, about 80 are annotated with use data; there are a further 87 packets of drugs collected in markets (De Natale & Pollio, 2012). These represent a rare record of early 20th century plant uses from the region. Edward Palmer formed a similar ethnobotanical collection in Mexico; his market and herbarium specimens have been studied by Robert Bye (1979).

Two methodological aspects stand out in the three studies mentioned above: the importance of situating herbarium specimens in their original context through historical research, and the prevalence of incorrect identifications, both by the original collector and in subsequent studies. Not only does this reinforce the point that without the existence of herbarium specimens these incorrect identifications could not be detected, but it is also a reminder that voucher identifications need to be rechecked by subsequent users of specimens. It is also notable that all three herbaria survived as separate collections: the Hermann Herbarium as a bound volume, the Lincecum herbarium in the hands of his descendants, and the Trotter herbarium in a special wooden cupboard. This is counter to standard practice adopted since the 19th century, which is to integrate all herbarium specimens into a general sequence. Such a system makes the herbarium far more convenient to botanists, as all plant material of one taxon can be consulted in one place, but necessarily obscures the place of individual specimens as components of original collections. As herbaria are more completely databased, it will be possible to recreate original collection groupings virtually, enabling similar studies to be carried out more widely.

In contrast to these studies, which focus on single collections, another approach is to study large herbaria as a whole. The formal application of this technique was pioneered in the 1960s by Siri von Reis Altschul, through the systematic survey of herbarium specimens in the Harvard University Herbaria and the New York Botanical Garden (Altschul, 1967, 1968, 1970, 1973; von Reis 1962; von Reis & Lipp, 1982). This work set out with the aim of finding plants 'valuable to modern medical science' and was sponsored both by the National Institute of Mental Health and pharmaceutical companies. As the aim was to find new uses, those already documented in Uphof's *Dictionary of Economic Plants*, or obvious from the botanical name of the plant, were not recorded. Vernacular names that implied medicinal or food use were recorded, and it is important to note that names (which are recorded by botanists far more often than uses) can embody significant use information. The impact of this work is unclear; it would be interesting to carry out a similar survey, focusing on a region with a well-documented ethnoflora, to see to what extent herbarium specimens do add new information, or indeed can be used as a proxy for field work, particularly for diachronic studies where old data sets may not be available. Such an approach would benefit from the recording of *all* data relating to uses.

A concrete example of the value of label data is a study of the genus *Clitoria*, where significant data on poison and dye properties was obtained from herbarium specimens (Fantz, 1991); herbarium data have also been used in similar reviews of Cucurbitaceae in Mexico (Lira & Caballero, 2002) and *Plectranthus* in Africa (Lukhoba et al., 2006). Data on herbarium specimens were integrated with data from ethnobotanical literature to compare plant use in 40 communities in Ecuador (de la Torre et al., 2012). The potential of herbarium specimens as a source of vernacular names is indicated by the 1,200 Xhosa plant names found on voucher specimens collected by the Bantu Cancer Research Registry in South Africa from 1963 to 1980 (Dold & Cocks, 1999).

Destructive sampling

As we have seen, much ethnobotanical information can be obtained from looking at herbarium specimens and their label data. Herbarium specimens are also a useful source for analyses that require plant material. They are often reliably identified (and can be easily verified against other specimens shelved nearby), and usually bear the date and location of collection. A comprehensive range of species will be present, enabling wide-ranging research without time-consuming and expensive travel. The disadvantages are two-fold: first, chemical and genetic material does not survive as well, or as predictably, as in extracts from living material; second, each sampling from a herbarium specimen is a form of damage that may reduce the utility of the specimen to future researchers. New techniques have led to greater numbers of requests for samples from herbarium specimens, but at the same time have reduced the quantity of material needed for each genetic or chemical analysis.

Plant chemistry

Herbarium specimens of plants and fungi have been used as a source of raw material for chemical analysis since the 1960s, both for chemotaxonomy and for natural products research (Farnsworth, 1966; Phillipson & Hemingway, 1975; Phillipson, 1982; Paterson & Hawksworth, 1985). Experiments with plant material of known age has resulted in successful extraction of plant compounds from specimens collected as long ago as 1893. Furthermore, leaf extracts of *Combretum erythrophyllum* dating to 1909 retained their antibacterial activity, pointing to the use of herbarium material for preliminary screening for activity, as well as for the identification of chemicals (Eloff, 1999). Alkaloids are well-documented as surviving for long periods of time (Phillipson, 1982: 2443); examples include mescaline identified in peyote effigies from Texas, radiocarbon dated to about 6,000 years old (El-Seedi et al., 2005) and the identification of harmine, one of the active ingredients of the hallucinogenic plant *Banisteriopsis caapi* in 1969 in stems collected in the Amazon by Richard Spruce in 1852 (Schultes et al., 1969; Figure 5). Even volatile chemicals such as essential oils can be detected in old material. In a reminder that analytical techniques can be simple, Gyllenhaal et al. (1990) taste-tested small squares of leaf from herbarium specimens of 110 species of *Stevia* to see if any shared the sweetness of *Stevia rebaudiana*.

There is, however, complex variability, which is not yet fully understood, in the survival of compounds and their activity, which means that the analysis of dry, old material must be treated critically (Amoo et al., 2012). Treatment during collection can also affect preservation, with procedures such as the Schweinfurth Method, in which plants are preserved in alcohol before pressing, leading to loss of compounds such as flavonoids (Coradin & Giannasi, 1980). In general, phytochemical characterisation, especially for nuclear magnetic resonance (NMR), requires relatively large quantities of plant material. Taking into account this and the effects of time on secondary metabolites, herbarium material is usually used to fill gaps in sampling, or for special studies, but is not the first choice for phytochemical research.

Although leaves are most often sampled for biochemical analysis, other plant parts are present on herbarium specimens; for example, reference material of *Pinus* resin has been obtained by scraping pine cones housed at the Royal Botanic Gardens, Kew (Stacey et al., 2006).

Seeds

Herbarium specimens can be a valuable source of viable seeds. If herbarium specimens contain mature seed, and if the specimen has not been treated by microwaving (a popular treatment for pest control in the 1980s, no longer used), then seed viability will depend on the longevity attributes of that species, and the number of seeds available for germination trials. Germination tests of hard-walled orthodox seeds (seeds that survive drying) are regularly successful for seeds 100–200 years old (Bowles et al., 1993; Daws et al., 2007; Leino & Edqvist, 2010; Godefroid et al., 2011), a lifespan covering the great majority of herbarium specimens. Sampling for seed germination should be considered with caution; seeds of many species are more easily available from genebanks, and use should also be made of existing information on the germination characteristics of the species (Chapter 8). Fern spores have also been successfully germinated (Magrini et al., 2010; Magrini, 2011).

Figure 5. Ethnobotanical specimen of *Banisteriopsis caapi* (Spruce ex Griseb.) C. V. Morton (formerly *Banisteria caapi* Spruce ex Griseb.) held in the Economic Botany Collection, Royal Botanic Gardens, Kew (EBC 67428). Collected in the Amazon by Richard Spruce in 1852 and sampled for its chemistry over 100 years later (Schultes et al., 1969).

DNA

As with seeds, fresh material or material collected and rapidly dried in the field, or material from specialist storage facilities, is favoured for DNA analysis (Chapter 7). Where permissions allow, DNA samples (leaf fragments in silica gel) can be collected as a routine part of plant collection. DNA from herbarium specimens is often highly fragmented. Trials suggest that closer attention to extraction methods, and acceptance that routine use of DNA will be of relatively short fragments, will both be required (Särkinen et al, 2012). Leaf material is usually sampled, but better-quality DNA may be available from seeds, even those that are no longer viable (Walters et al., 2006). The implications of DNA sampling of herbarium specimens for herbaria are discussed by Jansen et al. (1999), Metsger (1999) and Wood et al. (1999). DNA extraction has proved successful from specimens up to 200 years old (Ames & Spooner, 2008; Andreasen et al., 2009; Lister et al., 2008, 2009, 2010), but is affected both by age and by treatment of the plant material during collection (Erkens et al., 2008; Staats et al., 2011). DNA is of particular ethnobotanical relevance to studies of crop evolution; for example, Malenica et al. (2011) were able to extract DNA from 90-year-old herbarium specimens of grapevine (*Vitis vinifera*) and show that it had an identical single sequence repeat (SSR) genotype to that of the cultivar Zinfandel.

Pollen

Herbarium sheets are routinely used as sources of pollen for reference collections. This requires some understanding of floral morphology in order to extract one or more stamens from the flower safely. Practical advice is given by Jarzen & Jarzen (2006).

CONCLUSIONS

The historical links between herbaria and ethno- or economic botany that weakened in the 20th century have been reforged. Herbarium specimens are now widely recognised as the ideal voucher specimen for most ethnobotanical research, and it is likely that the few fields (such as nutrition) that do yet fully implement best practice will soon do so. The core techniques for collecting herbarium specimens remain as straightforward and easy to learn as they were 400 years ago. Herbarium specimens are also the subject of new research questions and techniques: they act as records of use through their labels and associated data, and as biological specimens that can be measured and sampled. As herbaria are gradually databased, their usefulness will increase further. It will be easier to find voucher specimens, regardless of changes in botanical name or in location of deposition, and it will be easier to find specimens that embody ethnobotanical data. These are encouraging times for the symbiotic relationship between herbaria and ethnobotany.

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