A Journal of Plants, People, and Applied Research
Ethnobotany Research & Applications

Survey of Medicinal Plants in the Main US Herbaria

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Abstract

Plant identification has been waning during the recent expansive study of medicinal plants. This has been particularly true among manufacturers of products being marketed for natural heath care sectors. In an attempt to understanding to why basic plant identification is lacking, an inventory of the main US herbaria was completed in 2002. The inventory included plants that are commonly in use for medicinal purposes and those considered as adulterants. The results identify the plants found in each herbarium collection, access to the collections, and future plans of the herbaria for virtual (computer based) access to the collections. Recommendations are made for usage of virtual herbaria and expanded usage of traditional herbaria for identification of plants used in health care.

Introduction

The number of dietary supplement products available to U.S. consumers now numbers in the thousands, and new products and new ingredients are continuously entering the marketplace (Blumenthal 1999). Manufacturers are responsible for assuring that the contents of a product are accurately represented on the label. Failure to meet this standard means that the product is adulterated and/or misbranded and subject to enforcement action by the Food and Drug Administration.

"FDA has tools at its disposal to take enforcement actions against dietary supplements found to have safety, labeling, or other violations of the FD&C Act, as amended by DSHEA" This statement was made on March 25, 1999, by Food and Drug Administration Commissioner Jane E. Henney, M.D., before the House Committee on Government Reform. Despite this, many of the more serious recorded cases of human poisoning associated with natural products have been caused by misidentification of plant species (Betz *et al*. 2002, Huxtable 1990). An historical problem in the botanical industry has been the relative unavailability of well-characterized, authentic plant material for the purpose of comparison with incoming raw material (Cardellina 2001, 2002). The problem has been made worse by an increase in the number of companies trading in crude plant materials.

Institutional herbarium collections were established hundreds of years ago as official libraries of specimens used in commerce. Thus, the species epithet, *officinalis*, *officinarum*, etc. references their status as official species in commerce, especially for medicinal purposes. Herbaria are repositories of enormous collections of authenticated plant material and home to unparalleled expertise in plant taxonomy and nomenclature. Unfortunately, they are relatively few in number, place restrictions on access to the physical collections, and are generally arranged in a manner that limits utility of the collections to non-specialists (collections cataloged and/or stored according to taxonomic systems not understood by non-taxonomists, and lacking a unifying standard for cataloging). Distance from major herbaria, rigid restrictions on access, and technical systems for arranging collections mean that these in-

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Ethnobotany Research & Applications 2:101-110(2004)

valuable resources are functionally unavailable to those who might benefit from routine access to the information that they represent. One potential approach to providing access to collections without endangering the specimens would be to generate digital images of the herbarium sheets and to make these images available electronically.

Survey of U.S. Herbaria

In order to learn more about the situation, a survey of economically important plants within United States herbarium collections was performed between November 2002 and April 2003. The goals of the survey were to:

- compile an inventory of voucher specimens of selected economically important plants,
- review access policies to herbarium collections, and
- investigate the feasibility of making images of plant specimens available to businesses, clinical researchers, and regulatory bodies.

The following is the summary of this survey. The report includes the criteria for choosing the plants used in the survey, the herbaria visited, the listing of the plants collections, and current virtual herbarium programs.

Institutions

Fourteen herbaria were chosen because of their collection sizes (Table 1) and proximity to major centers of commerce and therefore industry. Annual listings of manufacturers, and botanical materials distributors in Whole Foods, Nutraceuticals World, and Virgo's Insider magazines were used to survey the locations of natural products industry businesses. Two institutions (Botanical Research Institute of Texas, Delaware State University) have explicit goals of encouraging public access and visitation by lay botanists. The Delaware State University facility is unique in that it is open to the public, is the largest herbarium at a historically black University, and cooperates with federal, state and private institutions.

Access

All herbaria visited had similar policies about who can enter and view the collections. There is a general open door policy for all taxonomists, visiting scientists, and scholars. However, if the person requesting access to the collections cannot demonstrate that their goals are legitimate for scientific advancement and that thy have the ability to navigate through the collections unassisted, then their request may be denied. Individuals focused on commercial

Table 1. List of Institutions (Herbarium Code per *Index Herbariourm* 1990. sciweb.nybg.org/science2/IndexHerbariorum.asp)

Code	Herbarium	Collection Size
A	Arnold Arboretum, Harvard University	3.35 million*
BRIT	Botanical Research Institute of Texas	1.75 million
CAS	California Academy of Sciences	1.8 million
CHIC	Chicago Botanical Garden	12,000
DOV	Delaware State University	130,000
ECON	Economic Plant collections Harvard University	3.35 million*
F	Field Museum of Natural History	2.7 million
GH	Grey Herbarium Harvard University	3.35 million*
JEPS	Jepson Herbarium at the University of California Berkeley	2.0 million
LA	University of California Los Angeles	180,000
MICH	University of Michigan, Ann Arbor	1.7 million
MO	Missouri Botanical Garden	5.3 million
NA	United States National Arboretum USDA/ARS	630,000 (many cultivated species)
NY	New York Botanical Garden	7.0 million
RSA	Rancho Santa Ana Botanic Garden	1.0 million
US	Smithsonian Institution	4.7 million

use are not encouraged particularly if there is concern that their access could involve ecologically detrimental activities. BRIT is one herbarium with explicit policies that demonstrate these positions. On its web site (www.BRIT.org) BRIT declares a business use policy. Access for commercial purposes requires the user to pay a fee for the facility's staff time. BRIT also has a policy that requires a collaborating financial agreement for use requiring extended time periods. Regardless of the purpose of a visit, it is highly advisable to call ahead to arrange a visit.

Plants

Plants were chosen based on economic importance because of their common use in products, and potential public health consequences if improperly identified. Plants were chosen by reviewing McGuffin *et al*. (2000), the *Nutrition Business Journal* top 20 herbs (Rea 2002), *Whole Foods Magazine* 8th Annual Herbal Products Sales Survey (Richman & Pier-Hocking 2002), and commercially important genera I found to be confusing in their taxonomy or nomenclature, (e.g. *Smilax*, *Plantago*, *Dioscorea*, *Symphytum*). Species with safety concern, (e.g. *Ephedra Aristolochia*) were chosen from AHPA's *Manual of Adulteration* (AHPA n.d.) and current projects of Botanical Liaisons LLC Botanical Reference and Identity assays service with Food and Drug Administration / Center for Food Safety and Nutrition (CFSAN), University of Mississippi, and National Institutes of Health / Office of Drug Services. The list was limited to 20 economic species and 20 possible adulterants as a manageable number (Table 2).

The herbarium collections of the institutions visited were organized by taxonomic system or alphabetically by family. The system used by one institution was not necessarily transferable to another. For that reason, it was important to meet with the curator and often the assistant curator to become acquainted with the system. Most large herbaria, as most of those visited, are arranged on some modified version of Engler & Prantl's system of classification (Engler & Prantl 1887-1909). Many other herbaria use alphabetical organizational systems or taxonomic systems

Table 2. Plants surveyed, (Family acronyms from Weber 1982).

Family	Plant
Apiaceae, API	*Ligusticum porteri* J.M. Coult & Rose
Araliaceae, ARL	*Eleutherococcus senticosus* Maxim.
	Panax ginseng C. A. Mey
Arecaceae, ARE	*Serenoa repens* (W.Bartram) Small
Aristolochiaceae, ARS	*Aristolochia contorta* Bunge, *A. fangchi* Y.C. Wu ex L.D. Chow & Hwang, *A. manshuriensis*, Kom., *A. mollis* Dunn
Asteraceae, AST	*Arnica montana* L. , *A. cordifiolia* Hook.
	Echinacea angustofolia DC., *E. purpurea* Moench, *E. pallida* Nutt
	Matricaria recutita L.
	Silybum marianum (L.) Gaertn
	Stevia rebaudiana Bertoni
	Tanacetum parthenium Sch. Bip.
Boraginaceae, BOR	*Symphytum officinale* L., *Symphytum Xuplandicum* Nym.
Caprifoliaceae, CPR	*Viburnum opulus* L., *V. prunifolium* L.
Clusiaceae, CLU	*Hypericum perforatum* L.
Dioscoraceae, DSC	*Dioscorea villosa* L., *D. quaternata* (Walter) J.F. Gmel.
Ephedraceae, EPH	*Ephedra sinica* Stapf., and other *Ephedra* spp
Ericaceae, ERI	*Vaccinium macrocarpon* Ait
	Vaccinium myrtillus L.
Fabaceae, FAB	*Astragalus membranaceus* Bunge
Ginkgoaceae, GNK	*Ginkgo biloba* L.
Lamiaceae, LAM	*Coleus forskohlii* (Willd.) Briq.
	Scutellaria lateriflora L.
Lardizabalaceae, LAR	*Akebia trifoliate* Koidz.

Table 2. Plants surveyed, (Family acronyms from Weber 1982). (Continued)

Family	Plant
Liliaceae, LIL	*Allium sativum* L.
	Aloe vera L.
	Chamaelirium luteum A. Gray
Menispermaceae, MNS	*Stephania tetrandra* S.Moore
Oleaceae, OLE	*Olea europaea* L.
Onagraceae, ONA	*Oenothera biennis* L.
Piperaceae, PIP	*Piper methysticum* G. Forst.
Plantaginaceae, PTG	*Plantago arenaria* Waldst.& Kit.
Ranunculaceae, RAN	*Aconitum napellus* L.
	Actaea racemosa L., *A. pachypoda* Ell., *A. podocarpa* DC, *A. rubra* (Aiton) Willd.
	Clematis armandii Rehder & E.H.Wilson
	Hydrastis canadensis L.
Rhamnaceae, RHM	*Rhamnus purshiana* DC.
Rosaceae, ROS	*Crataegus laevigata* (Poir.) DC., *C. oxyacantha* L., *C. monogyna* Jacq.
Rubiaceae, RUB	*Morinda citrifolia* L.
Smilacaceae, SML	*Smilax aristolochiifolia* (Willd)Mill., and other *Smilax* spp
Theaceae, TEA	*Camellia sinensis* Kuntze
Valerianaceae, VAL	*Valeriana officinalis* L., and other *Valeriana* spp.
Vitaceae, VIT	*Vitis vinifera* L.

of Cronquist (1988), Thorne (1976), Dahlgren (1985), Angiosperm Phylogeny Working Group (Stevens 2001), or others. Regardless of the taxonomic system followed, each herbarium has its own interpretation of a numerical scheme for plant classification. In addition, as botany is an actively developing science, there are many taxonomic changes being made by researchers (particularly based upon new genetic data) that necessitate constant modifications in herbarium systems. However, most herbaria lack sufficient staff to regularly update the taxonomy of their collections. Some herbaria have moved away from taxonomic systems altogether and are now implementing alphabetical systems that are more easily used by lay persons.

Plant Names

Local or vernacular names are more commonly used than are scientific names in the herbal products industry. This has led to considerable confusion in the marketplace. Accepted common or usual names for plants in commerce are located in the older USP dispensatory (Wood & Osol 1943). Current scientific names can be checked at Missouri Botanical Garden's Tropicos web site www.mobot.mobot.org/W3T/Search/vast.html. The International Plant Names Index (IPNI) is a database of the names and associated basic bibliographical details found on the web site: www.ipni.org. Legally acceptable common or usual names for plants intended for use as dietary supplements in the United States are listed in the American Herbal Products Association's "Herbs of Commerce" (McGuffin *et al*. 2000).

Verification of voucher specimen accuracy was beyond the scope of this project, so the output is a simple checklist of plants of interest in each herbarium surveyed. Unfortunately, one cannot assume that all of the individual specimens within an herbarium collection have been annotated with the current taxonomic name. Herbarium staff correct them when possible, but most often this is done when a taxonomic expert is visiting or when a flora is being written or revised.

Individual herbaria specialize in different geographical regions based on the interests of the staff. The plants identified to be of interest for this project were therefore not necessarily important to individual herbaria even though the specimens were part of their collections. For that reason, careful cross-referencing was necessary to find each species of interest. Elements deemed essential were: checking to determine whether or not a particular plant family was recognized at the individual herbarium (conserved names, etc.); Whether old genera names were used and

whether or not currently accepted scientific names were used.

Several medicinal plants were added to the checklist for reasons other than safety or economic importance. These included *Coleus forskohlii*, *Dioscorea villosa*, *Plantago psyllium*, *Smilax* spp., *Symphytum officinale*, *S. aspera*, *S.* X *uplandicum*. Each was selected because there appears to be some confusion in the literature about their identifies. Some of the confusion appears to be taxonomic and some nomenclatural (personal communication Jim Miller & Wendy Applequist, MO).

Results

Species identified in each herbarium are reported in table 3. Herbarium abbreviations used in the table and throughout the text follow the standards of Index Herbariorum (sciweb.nybg.org/science2/IndexHerbariorum.asp) that is based at the New York Botanical Garden (NY).

MO was the only herbarium containing all of the species surveyed. Generally, those herbaria with broad Chinese collections were more likely to have most of the species surveyed.

MO, NY and DOV are focused on economic plants and therefore were very appropriate for the kinds of plants I was looking for. Many of the other herbaria have unique missions that may not fully support collections of economic plants. For instance, JEPS and RSA are focused on native plants, BRIT emphasizes the flora of North America including good economic collections, and US focuses on cultivated species.

Several herbaria included unique collections. MICH has a wonderful collection of plants used in older pharmaceuticals but these have been integrated into the regular accessions and are therefore more difficult to access as a distinct collection. US has a broad collection that includes many type specimens. GH includes the collections of Richard Schultes, father of ethnobotany, however no one at harvard has continued his work since his death in 2001. Finally, UCLA has a good collection but with the loss of its Botany Department, the herbarium has become underfunded.

Table 3. Species with reference specimens found in herbaria surveyed.

Species	Family	Herbarium
Aconitum napellus	RAN	BRIT,CAS,F,GH,JEPS,MICH,MO,NA,RSA,US,UCLA
Akebia trifoliata	LAR	BRIT,CAS,F,GH,JEPS,MO,NA,NY,RSA,US,UCLA
Arnica montana	AST	BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NY,RSA,
Arnica cordifolia	AST	BRIT,CAS,F,GH,JEPS,MICH,MO,NA,RSA,US,UCLA
Actea pachypoda	RAN	BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Actea podocarpa	RAN	BRIT,CAS,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Actea racemosa	RAN	BRIT,CAS,F,GH,JEPS,MO,NA,NY,RSA,US,UCLA
Actea rubra	RAN	BRIT,CAS,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Aloe vera	LIL	BRIT,CAS,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Allium sativum	LIL	BRIT,CAS,F,GH,JEPS,MICH,MO,NA,NY,US,UCLA
Aristolochia contorta	ARS	A,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US
Aristolochia debilis	ARS	A,GH,JEPS,MO,NA,NY
Aristolochia fangchi	ARS	MO,NY
Aristolochia manshuiriensis	ARS	A,MICH,MO,NY,US
Aristolochia mollis	ARS	CAS,JEPS,MO,NY
Astragalus membranaceus	FAB	A,CAS,JEPS,MICH,MO,NA,NY,US
Camellia sinensis	TEA	A,CAS,F,JEPS,MICH,MO,NA,NY,RSA,US
Chamaelirium luteum	LIL	BRIT,CAS,DOV,ECON,F,JEPS,MICH,MO,NA,NY,US,UCLA
Clematis armandii	RAN	CAS,JEPS,GH,MICH,MO,NA,NY,US
Coleus forskohlii	LAM	CAS,MO,NY,US,UCLA

Table 3. Species with reference specimens found in herbaria surveyed.

Species	Family	Herbarium
Crataegus laevigata	ROS	A,BRIT,CAS,F,G,MICH,MO,NA RSA,US
C. oxycantha	ROS	A,BRIT,DOV,MICH,MO,NA,NY,US,UCLA
C. monogyna	ROS	A,BRIT,F,MICH,MO,NA,RSA,US
Dioscorea villosa, *D*. spp	DSC	CAS,CHIC,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Echinacea angustifolia	AST	BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,RSA,UCLA
Echinacea pallida	AST	BRIT,CHIC,DOV,F,GH,MICH,MO,NA,RSA,US
Echinacea purpurea	AST	BRIT,CHIC,DOV,F,GH,JEPS,MICH,MO,NY,NA,RSA,US
Eleutherococcus senticosus	ARL	CHIC,DOV,JEPS,MICH,MO,NY,RSA,NA,US
Ephedra sinica, *E.*spp	EPH	BRIT,CAS,F,JEPS,MICH,MO,NA, RSA,US,UCLA
Ginkgo biloba	GNK	A,BRIT,CAS,CHIC,DOV,F,GH,JEPS,MICH,MO,NA. NY.RSA,US,UCLA
Hydrastis canadensis	RAN	BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US
Hypericum perforatum	CLU	BRIT,CAS,CHIC,DOVF.GH.JEPS.MICH.MO.NA. NY.RSA,US,UCLA
Ligusticum porteri	API	A,BRIT,CAS,DOV,F,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Matricaria recutita	AST	BRIT,CAS,CHIC,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Morinda citrifolia	RUB	BRIT,CAS,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Oenethera biennis	ONA	BRIT,CAS,DOV,F,GH,JEPS,MO,NA,NY,RSA,US,UCLA
Olea europaea	OLE	A,BRIT,CAS,DOV,GH,JEPS,MO,NA,NY,RSA,US,UCLA
Panax ginseng	ARL	CAS,GH,JEPS,MO,NA,NY,US
Piper methysticum	PIP	A,BRIT,CAS,F,JEPS,MO,NA,NY,RSA,US,UCLA
Plantago afra, *P. arenaria*, *P. psylliium*[2]	PTG	BRIT,CAS,ECON,F,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Rhamnus purshiana	RHM	A,BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US
Scutellaria lateriflora	LAM	BRIT,CAS,CHIC,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US, UCLA
Serenoa repens	ARE	A,BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Silybum marianum	AST	A,BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Smilax aristolochiifolia, *S. reglei*, *S. ornata*[2]	SML	BRIT,CHIC,DOV,MO,NY,US,
Stephania tetrandra	MNS	F,GH,JEPS,MO,NA,NY,US,UCLA
Stevia rebaudiana	AST	DOV,F,GH, MO,NA,NY,
Symphytum officinale[3], *S. Xuplanidcum*[2]	BOR	BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Tanacetum parthenium	AST	BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Vaccinium myrtillus	ERI	A,BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Vaccinium macrocarpon	ERI	A,BRIT,CAS,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Valeriana officinalis, *V.* spp.	VAL	A,BRIT,CAS,DOV,F,JEPS,MICH,MO,NA,NY,RSA,US,UCLA
Viburnum opulus, *V.prunifolium*	CPR	BRIT,CAS,CHIC,DOV,F,GH,JEPS,MICH,MO,NA,NY,RSA,US,UCL A
Vitis vinifera	VIT	A,BRIT,CAS,ECON,F,JEPS,MO,NA,NY,RSA,US,UCLA

1. On loan to another herbarium, therefore not seen. 2. One of the listed species was present.
3. *Symphytum officinale* specimens are likely misidentified unless recently annotated.

Discussion

Plant Identity in Industry

Taxonomy is a human invention the general purpose of which is to create a system of classification that can be used by all who are concerned about the differences and similarities among organisms (Cronquist 1988) and be able to communicate about it. This survey is intended to expand the "all…. concerned" to those non-botanists who may need to identify relatively unfamiliar plants in their work. This includes the natural products industry, public health officials, clinical researchers, and others. Unfortunately the related sciences of taxonomy and nomenclature are not intuitive and it may take years of specialized training in botany to become truly proficient in plant identification. As a result, the science of classification has not been embraced by the herbal products industry nor by others who may need it only occasionally (clinical researchers, regulators). Introduction of a misidentified plant material into interstate commerce is illegal in the United States, but may go undetected by the manufacturer, researchers, and regulatory authorities unless an adverse public health event occurs as a result of the misidentification because of the deficiencies in training noted above (Slifman *et al*., 1998)

Fortunately, individuals involved in industrial quality assurance or in identification of plants for clinical research or regulatory enforcement purposes will not need to determine *de novo* to which of the several hundred thousand taxa of plants a particular material on a loading dock or in a bottle belongs. In a well established system the original materials will have been identified prior to the production research. From a practical point of view, it can be just as valuable to demonstrate that the shipment is not the expected species as to show that it is. In such a case, the identity of the "wrong" species is unimportant, it will simply be rejected. A prime reason for undertaking this study was to see how well lay-persons who need to identify plants can use these tools to assist them in quality control or in regulatory settings. Unfortunately, most of the companies doing business in the natural products industry are very small businesses (Anonymous 2003), and even a small reference collection would impose a large storage and upkeep burden if the company dealt in a large number of plant species.

Virtual Herbarium Projects

In order to make their herbarium collections accessible to international collaborators, the taxonomic community has begun to create virtual herbaria. These consist of electronic images of herbarium specimens that are made available on the internet. Visual access to images of herbarium sheets is intended to decrease the costs of shipping specimens and to increase the speed of taxonomic research. At present, these on-line programs have minimal impact on the herbal products industry and the lay botanist. The initial goals of these programs have largely been to provide images of "type specimens." The New York Botanical Garden herbarium defines a 'type' as a "specimen selected to serve as a reference point when a plant species is first named." As a result, these specimens are extremely important to botanists who are attempting to determine the correct application of a name. They are usually specially curated in herbaria because of their critical roles as starting points in taxonomic descriptions. The University of California at Berkeley's Jepson herbarium includes in its definition of type "that it is important to realize that the type specimen is not necessarily more "typical" than is any other specimen, any more than one person can be considered more "typical" than everybody else. In fact, there are numerous examples of decidedly "atypical" type specimens, collected at the margin of the species' range (where it was most likely to be first encountered)" (JEPS 2003).

Making images of type specimens available on-line permits immediate access for everyone, therefore minimizing expense and handling of these archival records. CHIC, F, MO, NA, NY, US, are all working on this priority and are close to meeting their goals. Those herbaria that did not have virtual herbaria do not expect to have them in the future either. Their charters and goals do not dictate the need to develop such a tool. These herbaria are usually geared to local botanists,

In general each data entry and image costs about $3 to produce and make available on-line. The cost seems to be about the same whether using high or low-level technology imaging systems. This cost was confirmed by NY and F virtual herbarium staff.

The following are summaries of pertinent projects in progress at the institutions visited for this survey:

Field Museum of Natural History, Herbarium

F is using a commercially available scanner to acquire digital images of specimens from its collections. An interesting feature of this project is the use of the scanner in an upside-down configuration to preserve the specimens. The program is very different than most of the others in that it is a collaboration with the Chicago Botanic Garden and the Morton Arboretum and focuses on the endangered plants of the counties that surround Chicago. The program is called v plants (www.vplants.org). A searchable database has been developed that delivers a tabular taxon summary that includes:

- the location from which the specimen was acquired (U.S. State, County),
- the collection date
- name of the primary collector
- the name of the herbarium at which the physical specimen resides

In addition, the table provides links to scanned images. Images may be viewed in JPEG or MrSid format. Other virtual projects worth mentioning are the work of Field Museum's Environmental and Conservation Program (www.fmnh.org/plantguides/). The first is a micro herbarium book and is intended for use by botanists to compare plants from various regions. The second is a series of Rapid Color Guides: photos of plants that can be used for quick ID in the field. Robin Foster has also created guides for specific cultural groups that provide photos of textiles and other items made from economic plants. These photos are linked to herbarium sheets. Finally there are photos of Neotropical plants.

University of California Berkeley, Jepson Herbarium

JEPS initiated a virtual herbarium program earlier than other herbaria. It is called the Specimen Management System for California Herbaria (SMASCH). This program was funded in 1992 by the National Science Foundation (NSF) for the development of a database of textual data and images of specimens that document the distribution and classification of the plants of California. It is available at http://www.mip.berkeley.edu/www_apps/smasch/. The SMASCH project has created a computerized database of the label information from ~340000 California vascular plant specimens in the University of California and Jepson Herbaria (UC and JEPS). Human data entry specialists who transcribed the information directly from the specimen sheets did data entry. Images of a subset of the specimens in the database (~30000) were also collected. They are on display on the site.

A typical catalog entry (for *Scutellaria californica*) is presented here (see www.mip.berkeley.edu/www_apps/smasch/smasch_accession.html):

- Accession Detail Results
- Accession JEPS104353
- Determination *Scutellaria californica* A. Gray
- Collector Lowell Ahart
- Collection Number 10207
- Collection Date 5/22/2003
- County Shasta
- Habitat Foothill Woodland. Normal size plants on dry soil, around rocks, north rim of creek.
- Elevation 850 ft.
- Latitude 40.4167
- Longitude -122.0669
- Township/Section 30N02W
- Other data included Location description, popula tion biology, and flower de scription.

Note that some details are not cited in order to protect the habitat and species authors. Data entry for new California accessions is ongoing. Online access to current activities in California plant taxonomy is available at the Jepson Interchange www.ucjeps.berkeley.edu/interchange. The interchange incorporates links from each taxon report page to CalPhotos and to other resources pertinent to California plants..

Jepson's site is easy to use and has several interactive programs for mapping locations of plants within California. In addition to the information content, the web site provides a field for input from investigators as a means of keeping the maps updated. An interactive key for botanical identification is provided at: www.ucjeps.berkeley.edu/keys/. The key uses Multiple-Entry Key Algorithm (MEKA), to enable rapid plant identification. However, when examining the site for this survey, I could not find any actual herbarium sheet images.

Missouri Botanical Garden, Herbarium

The Missouri Botanical Garden home page (www.mobot.org) provides a number of programmatic links, particularly to its herbarium, MO. An image gallery is available at www.ridgwaydb.mobot.org/m obot/imls/. It is arranged alphabetically by plant family. At inception, the project had two goals: to digitize the existing slide collections of Garden botanists Alwyn Gentry, Thomas Croat, and Peter Goldblatt (10-12,000 images); and to make and digitize slides of type specimens taken as part of this project (10,000 to 12,000 images). The stated intent of the project is to provide a centralized source of plant images that will serve botanical researchers, as well as individuals who need to correctly identified plant images linked to authoritative information.

MO has compiled digital images of about 200,000 (33%) of its type collections and is adding some 20,000 more images annually. Images are acquired using a scanning back camera and MrSID program that allows the user to zoom in on any portion of an image by pointing and clicking on it. The camera requires a special room and lighting and a full time staff member. Each specimen takes 2.5 minutes to scan. In addition to plant specimens, staff are scanning rare books and representative specimens for other projects.

When an image is selected from the MO web site an indication is given whether or not a photo or type specimen image is available. Since voucher images use the MrSid program the user may zoom in on an area if necessary to observe diagnostic characters. Unlike images provided at the Field Museum of Natural History and New York Botanical Garden sites, magnified images are available immediately available and do not require the user to downloading the Windows only MrSID plugin. In addition to these features, some plant listings provide hyperlinks to images available at other institutions that maintain digital image collections.

MO hosts the w3TROPICOS web site that provides up-to-date information on nomenclature of vascular plants and bryophytes. In addition, chromosome counts, digital plant images, and specimen lists, field photographs, and maps of geographic distribution. Below is a sample listing from the database for *Scutellaria californica* collection information:

- Location: United States, California, Butte
- Vicinity: Cherry Hill
- Elevation: 5000 ft
- Coordinates:
- Collector(s): M.S. Taylor
- Collection number: 1729
- Collection date: 19 July 1978
- Herbaria: MO
- Specimen data: Corolla white.

Note the location information (Coordinates) is protected in the text but not on the scanned images. [**So what is the point, if it can still be easily found in the public domain?]**

New York Botanical Garden, Herbarium

NY uses an instant capture high resolution camera for imaging. This system is capable of acquiring 40-60 images per hour and is thus considerably faster than the scanning back camera. In addition, it does not require a specialized room. NY also uses MrSID software. The Garden currently has 700,000 records in its database, including 95,000 type specimens and 85,000 digital images. NY has a larger staff devoted to this project than any of the other herbaria visited. In order to protect local plant populations from unscrupulous commercial collectors, NY is very careful to protect location data ordinarily listed on herbarium sheet labels, so localities are blurred. In addition, locations of endangered species are never listed. NY also has a strict policy about Intellectual Property Rights, so ethnobotanical labels are imaged and maintained by the researcher but are not available to the public. In addition to type specimens, NY images priority projects.

The NY web page, www.nybg.org/bsci/hcol/ is very inclusive and lists all the floras that are integral to their system. A search may be conducted by imaged specimens. Two formats on all specimens are listed in table form. When selected, the information is provided as seen below.

- Family: Aristolochiaceae
- Species: *Aristolochia bahiensis* F. González
- Image: JPEG Available
- MrSID Image: Available
- Location: Brazil. Bahia. Una. Reserva Biológica do Mico-leao (BAMA). Entrada no km 46 da Rod. BA-001 Ilhéus/Una. Coletas efetuadas no ramal que leva à Faz. Jaqueiral ca. 8 km da entrada.
- Coordinates: 15° 09’ S 39° 05’ W
- Collector: Jomar G. Jardim 809
- Co-Collectors: with S. C. Sant’Ana & J. L. Paixao
- Collection Date: 01 May 1996
- Description: Liana vegetando sobre árvores no interior da mata. Folhas discolores verdes com face inferior opaca. Flores com estrias vinosas no lado externo e amarelo vivido no seu interior. Flower.
- Habitat: Mata higrófila sul Baiana.
- Publication: Brittonia. 50: 8-10. 1998.
- Verified: W. W. Thomas. 2001.
- Other: NY Specimen ID: 566035

Smithsonian Institution, National Herbarium

US is creating digital images of type collections only. Types are scanned by family as they are loaned for special projects or requests. Images of 23,000 specimens are currently available. Individual requests for images may be made by any individual and should be directed to the Curator. The images are not available on-line. Details are available at: www.rathbun.si.edu/botany/

Next Steps

Most plants of commerce are available in the larger herbaria in the US. This may be an advantage to industry members and academics if their in-house procurement procedures require specimens to accompany collections. Preliminary comparisons can then be made to types online. However, due to variations, viewing one specimen may be misleading to the untrained eye. These acquired specimens may be sent or brought to a local herbaria for positive identification. Distances would require additional time that is often not productive in an industrial setting. Photos along with scanned images of vouchers may be more helpful as they appear more life-like than the pressed specimens.

These virtual herbarium collections provide an important service to the international academic botanical community, but are of little utility in assuring the identity and therefore the quality of raw materials used in herbal products industry. To assist the herbal products industry, a more specialized virtual herbarium needs to be established. A publicly accessible virtual herbarium geared to the needs of individuals who must identify plants, but who are not trained botanists would be ideal. A site that is useful to the non-specialist community would need to make minimal use of technical jargon while allowing viewers access to multiple images and photos of individual plant specimens. A single image of a single specimen may not adequately represent individual variability found in nature. For that reason, several individual specimens may need to be available for each species. Such a web site would require a visual glossary and an interactive, illustrated interactive key. Such a key would have to be kept as simple as possible and, because of this simplicity and limitations in the amount of information provided by two-dimensional digital images, would need to explicitly alert users when alternative identifications are possible. The interactive key

needs to train citizen scientists as amateur botanists for their specific needs familiarizing them with terms, references and techniques needed for basic plant identification. Unfortunately, scanned images of whole plant specimens are not currently available. Since industry often receives various parts of the plant this makes identification difficult. Expansion of the concept of the virtual herbarium to include photomicrographs of powdered specimens would also be useful as much of the word's commerce in medicinal plants is in the form of cut or powdered material or crude extracts.

Acknowledgements

I want to thank all the people who have assisted me; it is a long list, but in particular, the Herbarium Directors and Curators, Assistant Directors, herbaria staff, and Joseph Betz-of the NIH/ODS. Funding for this project was provided by the Office of Dietary Supplements, National Institutes of Health, Department of Health and Human Services.

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