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The Accuracy of Plant Identification in a Longitudinal Ethnobotanical Project in Coastal Ecuador

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Abstract

Background: Preserving traditional environmental knowledge about herbal medicine in the face of rapid environmental, economic and cultural change depends in part on the identification of traditionally used medicinal plants to their Latin binomial. When financial, legal, and/or time constraints prevent the collection of voucher specimens or the use of advanced molecular technologies, arguably the "gold standards" for plant identification, alternative methods such as photography and morphological descriptions may still be able to assist identification. There are unknowns about the relative accuracies of these different techniques. This paper compares the efficacy of several methods to correctly identify plants across five separate site visits in the province of Manabí, Ecuador.

Methods: Plants that were identified to genus-, and species-level accuracy during each of the five site visits were totaled, and the type of data (expert consultation, written, photographic, and morphological) leading to the identification noted. Percentage accuracy was calculated as the number of unambiguous identifications to Latin binomial divided by the total number of common plant names recorded for each site visit.

Results: Ninety-six common plant names were recorded across the five site visits, while each individual visit yielded information about 26-54 plants, reflecting significant overlap. In addition to interview data, site visit 4 uniquely collected additional photographic (34 plants) and morphological data (12 plants). Photographs were more effective in aiding identification to both genus (12) and species (4) than morphological data (4 genus and 0 species identifications). Percentage accuracy for the first four site visits ranged from 27-36%; site visit 5 yielded 91% accuracy, but only when considering a limited subset of the plants.

Conclusions: Photographic, and morphological data can aid identification of medicinal plant species to Latin binomial when time, money and/or collection permits are lacking, but should not be considered reliable substitutes for plant voucher specimens or advanced molecular technologies.

Keywords Traditional environmental knowledge (TEK); Latin binomial; Morphology; Plant identification

Introduction

The race is on to catalog plant use before the associated knowledge and natural resources disappear. The literature contains compelling evidence that traditional environmental knowledge (TEK) may be threatened by rapid changes in cultural [1], economic [2], and environmental conditions [3], and associated disruptions in the transmission of such knowledge across generations [4]. One type of TEK is that pertaining to herbal medicine (referred to hereafter as TEK-HM).

Efforts to catalog and preserve TEK-HM exist in numerous forms and involve a variety of community members and researchers, the latter from such diverse fields as anthropology [5,6], linguistics [7], pharmacy [8-10], health care [7-11], botany [12-14], chemistry [15], ecology [3], geography [16] and public health [7]. Some of these research efforts are community-based and are either directed by or actively involve "cultural insiders." [17].

One challenging, yet important, step of TEK-HM projects is the identification of plant specimens to their Latin binomial. Although valuable information is contained in plant common names, Latin binomials are additionally important for TEK-HM research. A reliance on common names may lead to confusion if more than one taxon is referred to by a single common name (homonymy) or if a single taxon is referred to by many different common names (synonymy) [18]. Ambiguities and inconsistencies in common names may occur within a community, among common-language communities, or among language groups [19]. Latin binomials, however, allow for unambiguous communication, which is important for clinical applications [20], informed consumption [21], and accurate communication about TEK-HM [7].

Furthermore, Latin binomials contain information about evolutionary relationships that may offer insight into ecology, biochemistry, and morphology. Plant identification in TEK-HM projects is especially difficult because researchers often encounter specimens removed from their ecological context (e.g., in markets) or as isolated plant parts (e.g., only the leaves, roots, flowers, or fruits). However, as best as possible, researchers attempt to elaborate complete voucher specimens and deposit them in local herbaria to provide tangible evidence of the research undertaken [22]. Plant identification often requires researchers to use a dichotomous key and to then confirm identification by matching the voucher specimen with others already present in herbaria. Accurately done, this approach can provide an exact match for plants collected in the field. Although generally more expensive, if sufficient material is not available to identify the plant using a key, plant identification can be carried out through laboratory-based techniques such as DNA barcoding [23] or spectrometric methods [24]. When applied correctly, the accuracy of employing a dichotomous key using voucher specimens and these laboratory methods for plant identification make them the “gold standards” or the ideal to which ethnobotanical research projects strive.

The above-mentioned techniques and methodologies can be difficult to successfully execute, especially in a community far removed from research centers and associated herbaria. One pressing challenge is the difficulty in obtaining permits to collect plant material. Although some government institutions are actively working to simplify permit procedures, the steps to obtain permits are often ambiguous, and the frustrating process may take months or years (Tulio Medina, Ministry of the Environment, Peru, and pers. comm.). In addition, complex legal frameworks have decreased the ease of accessing specimens from ex situ collections, partially because curators are afraid of disobeying laws they may not understand [25]. To circumvent this challenge, past research efforts have used numerous approaches to improve on the possibility of correct plant identification on-site. For example, some have employed digital, high-resolution photography [26].

This article discusses one community-based, multi-year project, in which the ultimate goal was to accurately identify all plants mentioned by study participants, some of which were incorporated in a community medicinal garden (described below). This project included multiple site visits by researchers with different backgrounds, each of whom employed slightly different methodologies.

Throughout the process, we explored the efficiency and effectiveness of different methodological approaches to plant identification. In this paper, we investigate the hypotheses that 1) repeated site visits, regardless of the researchers’ techniques or experience, would eventually lead to accurate plant identification, and 2) detailed morphological descriptions and high-quality photographs could assist in accurate plant identification above and beyond qualitative ethnographic research techniques.

Methods

Study site

Five separate visits by researchers of different backgrounds and levels of training took place over a four-year time period to the county of Jama, Ecuador (Table 1). The coastal county of Jama, in the province of Manabí, Ecuador, has a population of approximately 25,000, who live in rural villages and small towns. The largest urban setting is the town of Jama. Latitudinal and climatic gradients create a mixture of vegetation types, including semi-deciduous tropical forest and humid montane forest embedded within a largely agricultural landscape. We conducted this TEK-HM project in the community of Tabuga (population approximately 750) near the Lalo Loor Dry Forest Reserve, a biological station operated by the Ceiba Foundation for Tropical Conservation. The Ceiba Foundation is an advocate for sustainable community development, habitat protection, and ecological research, and, as per the community of Tabuga’s request, is working to create a living collection of local medicinal plants at the reserve’s nature center, accompanied by a written document. Their well-established relationships with people in the area and the application of our research interests to an expressed community need were important factors in our decision to pursue this research at this site [27].

Site Visit	Time period	Level of training	Discipline
1	April-May, 2011	Undergraduate	Ecology
2	January, 2013	MD, and PhD student	Medical, Botany
3	July, 2013	Undergraduates	Pharmacy
4	January, 2014	PhD student	Agroecology
5	April-May, 2014	Undergraduate	Ecology

Table 1: Personnel characteristics of the five Manabí site visits.

Site Visits

There was some variation in the research goals and techniques for the five site visits, though all collected information about common names of plants and uses of those plants, and all cross-checked this information with available printed information. None of the five projects had official collecting permits that would allow corroboration of voucher specimens with herbarium specimens, partly due to logistics and partly due to an evolution in the goals of the projects, where early priorities did not include a taxonomic focus. Details about each of the five site visits are below.

The project began with Site Visit 1 (SV1), the efforts of an undergraduate intern of the Ceiba Foundation in conjunction with community members in Tabuga. SV1 involved the location of willing community participants with knowledge of herbal medicine, and ad hoc collection of information about any and all plants described as having medicinal properties and local availability. The intern recorded common names, medicinal uses, and plant preparation. Ceiba Foundation scientists assisted in the identification of plants to Latin binomials using available taxonomic keys, ecological and herbal texts, and professional experience with the local flora.

Knowing that the preliminary work was started during SV1, Site Visit 2 (SV2) was designed to extend those findings, with the understanding that even more follow-up work would be necessary. The goals of SV2 were to begin the process of documentation of TEK-HM, to comprehensively survey the herbal medicines being used in the community, and to provide educational herbal medicine resources for the community. Semi-structured interviews were conducted with ten key informants identified by Ceiba employees who lived in the community. Informants were asked to name plants they used medicinally and describe their uses and preparations.

Living specimens were photographed when possible, and detailed taxonomic notes were taken. Interviews were audio-recorded and transcribed.

The intention of Site Visit 3 (SV3) was to corroborate accuracy of previously collected data by revisiting the informants from SV2 with the transcribed and summarized information. Of the ten original informants, seven were located and the community herbal information was reviewed and corrected; either the corrected information was reviewed orally (n=4) or as a written, corrected document (n=3).

In addition, a local herbal medicine expert in the town closest to the field site was interviewed about the common names, use, and preparation of 20 medicinal plants. Photographs were taken of specimens during this interview. Site Visit 4 (SV4) aimed to improve botanical accuracy of data from previous site visits through interviews, photographs, and morphological data collection.

Most individuals (n=9) interviewed during SV2 were re-interviewed using a semi-directed interview method. When possible, detailed photographs of the plants were taken. Detailed morphological characteristics, including flower and fruit characteristics, were recorded for plants perceived as more obscure or difficult to identify.

Site Visit 5 (SV5), as with SV1, involved a Ceiba Foundation intern working in conjunction with community members. SV5's primary goal was to create signage, with corresponding common names and Latin binomial names, for the plants in the medicinal plant garden at the Lalo Loor Dry Forest reserve. As such, a limited subset of plants was the focus of this effort. Plant uses and Latin binomial names were corroborated from past site visits through the involvement of community contacts and Ceiba Foundation biologists.

Plant identification

From December 2013, through September 2014, the plant lists resulting from each of the site visits were then analyzed by the authors of this paper in order to identify plants to a likely family, genus, or Latin binomial. This analysis used a variety of methods, including cross-referencing the common plant name with published literature on TEK-HM for Ecuador or surrounding regions, comparing likely Latin binomial with internet sources and images, and consulting other scientists with experience in tropical botany. A plant was given a Latin binomial identification only if there was no ambiguity about the Latin binomial name corresponding to its common name. In this analysis, no ambiguity resulted in three ways. First, there was no ambiguity if a plant with a given common name had no alternative identification, such as with ajo (garlic), which could distinctly only be Allium sativum. The second method for achieving a definitive identification to Latin binomial occurred when the detailed documentation of morphological characteristics with photographic and/or written description was considered adequate and unambiguous. Third, we considered there to be no ambiguity if all cross-referencing for a given common name only yielded one Latin binomial that could then be corroborated by tropical botanists familiar with the local flora.

From this analysis, a simple percentage accuracy was calculated (number of unambiguous identifications to Latin binomial divided by the total number of common names in that plant list). In some cases, there were numerous species for a given plant genus, or there was a lack of plant characteristics necessary to identify a plant beyond the plant family. These plants were recorded as identified to "genus" and "Family", respectively. Finally, for some plants, there was a lack of information to allow any accurate identification. In such cases, it was not possible to come up with a scientific name of any type.

Results

Information for 96 plants resulted from the five site visits (Table 2), though an individual site visit only yielded information for 26-54 plants (Tables 2 and 3). There was some overlap and some uniqueness between the five site visits with respect to the plants documented (Table 2). For some of these site visits, the overlap was predictable. For example, 18 plants documented in SV3 were also documented in SV2; ten of these overlapping plants occurred because a 10-plant booklet prepared from SV2 was used to guide discussions during follow-up interviews during SV3.

	SV1			SV2			SV3			SV4			SV5		
Common name	*	G	S	*	G	S	*	G	S	*	G	S	*	G	S
Agua del carmen										*					
Ajenjo										*			*		X
Ají													*		X
Ajo				*		X	*		X				*		X
Albahaca	*		X				*						*		X
Albahaca de mentha	*	X											*	X	
Altamara				*											
Altamisa				*		X	*								
Amanza toro										*			*		X
Ardor				*											
Ayahuasca										*		X	*		X
Badeilla										*	X				

Begonia	*	X													
Berro	*		X	*											
Biblia				*						*					
Café													*		X
Calagualla							*								
Campana										*	X				
Caña agria										*					
Cedrón				*	X										
Chala	*			*						*					
Chanca piedra				*		X									
Chilinche										*					
Cigarillo				*		X									
Congona	*									*	X		*		X
Cordoncillo	*	X		*		X									
Corrimiento	*	X								*			*		X
Doña Juana										*					
Dulcamara										*	X		*		X
Emori	*	X													
Escancel	*		X	*			*			*		X	*		X
Espanto	*			*						*	X		*	X	
Geranio				*	X					*			*	X	
Gualanga	*									*	X				
Guayaba							*	X		*	X		*		X
Hierba buena				*		X							*		X
Hierba chivo				*		X	*		X	*		X	*		X
Hierba luisa	*		X	*		X	*		X	*		X	*		X
Hierba mora										*	X		*		X
Higo				*											
Huaco	*	X													
Jengibre	*	X		*	X					*	X		*	X	
Jorra	*									*	X				
Lechuga				*		X									
Limón	*	X		*		X				*		X	*		X
Limoncillo				*		X									
Llanten				*	X		*	X		*	X		*	X	
Malacapa				*						*					

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Mango				*		X									
Manzanilla				*		X	*		X	*		X			
Mate	*		X	*						*		X			
Matico				*		X									
Menta silvestre	*	X								*					
Milton							*								
Monte	*	X													
Muyuyu	*		X							*		X	*		X
Nacerera										*					
Noni	*		X							*		X			
Oreganita	*		X												
Oregano	*			*		X				*			*		X
Oreganón	*		X	*	X		*	X		*	X		*		X
Ortiga				*		X				*	X				
Paico	*		X	*		X	*		X	*		X	*		X
Palo santo													*		X
Papaya				*		X							*		X
Pegador										*					
Pestaña				*											
Piña de monte	*	X													
Piñuella	*	X													
Piñon				*						*		X			
Plátano													*		X
Poleo				*											
Pomón										*	X				
Rábano										*		X			
Romedillo							*								
Ruda castilla	*	X		*		X	*		X	*		X	*		X
Ruda clavellina										*			*		X
Ruda de gallinaso	*			*			*			*			*	X	
Ruda de muerto							*								
Sábila	*		X	*	X		*	X					*		X
San Juanito	*														
Santa María				*									*		X*
Santa Maria del bosque	*		X							*	X				
Suelda consuelda				*											

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Tamarindo										*		X			
Tiatina	*		X				*			*		X	*		X
Tilo				*		X	*		X	*		X	*		X
Tres puntas							*								
Uña de gato										*	X				
Uvilla				*	X										
Valeriana	*	X		*	X					*	X		*		X
Verbena	*	X		*			*			*					
Verde laya															
Zapallo										*					
Zaragoza	*		X	*			*			*					
Zorrilla	*						*			*					

Table 2: Compilation of plants, alphabetical by most accepted common name spelling, from five site visits (SV1-SV5), and identifications to genus (G) and species (S). The symbol * indicates the plant was documented during that site visit.

Table 3 lists, for each site visit, the number of plants documented and respective identifications. The percent accuracy, calculated by dividing the number of plants identified to species by the total number of plants documented during that site visit, is also listed. The percent accuracy varied slightly between SV1-SV4. Site visit 5 had a much higher accuracy (91%), although, as analyzed in the discussion, this research effort was conducted on a limited subset of plants, namely those that were planted in the Ceiba Foundation medicinal plant garden and ones for which Latin binomial names were likely known.

Site visit #	# Plants	Type of data[1]	# Only identified to Genus	# Identified to species	Accuracy of Latin Binomial(%)
1	39	Expert	15	14	36
2	47	Expert;Written	9	16	34
3	26	Expert	3	7	27
4	54	Expert; Written;Morph	17	16	29
5	34	Expert; Written	6	31	91
Overall	96	Expert; Written;Morph	21	51	53

Table 3: Plants documented and respective identifications for each site visit and for the project as a whole, with percent accuracy of identification to *Genus species*

1. Types of data used to identify plants:

Expert: Consultation with tropical botanists familiar with the local Ecuadorian flora

Written: Reputable primary or secondary sources of local plants, including internet sources

Morph: Detailed documentation of morphological characteristics with photographic and/or written description considered adequate by taxonomists

Site visit 4 used methods unique from the others: detailed documentation of morphological characteristics (plant form, leaf and/or flower characteristics) with photographic (macro photographs of flowers, when possible) or written descriptions. In this case, there were photographs for 34 plants and morphological descriptions for 12 plants.

Table 4 shows the tendency of the photographs or morphological descriptions to have aided in identification to Latin binomial. Detailed photography aided in the identification of 12 plants to genus and four plants to species, whereas the morphological details aided in the identification of four plants to genus and zero to species.

Method	Total plants on which the method was used	Of total plants, number unambiguously identified through other methods	Of total plants, number whose identification to genus was aided by the given method	Of total plants, number whose identification to species was aided by the given method
Detailed photographs. Including floral macro-photographs when possible	34	7	12	4
Detailed morphological descriptions	12	2	4	0

Table 4: The effectiveness of detailed photographic or morphological details in leading to an accurate identification in Site Visit 4 (SV4).

Overall, gleaning information from Table 2, of the 96 plants listed by common name during the five site visits, 51 (53%) of the plants were identified to their Latin binomial (Table 3). An additional 21 plants were identified to Genus when the five site visits were analyzed as a whole (Table 3).

Discussion

The results of our research did not support our initial hypotheses that 1) repeated site visits, regardless of the researchers' techniques or experience, would eventually lead to accurate plant identification, and 2) written morphological descriptions and high-quality photographs could assist in accurate plant identification above and beyond qualitative ethnographic research techniques.

In addition, a "hidden agenda" of sorts was the hope that there was some taxonomic alternative to the two "gold standards", voucher specimens (labor intensive, requiring permits), or DNA barcoding (expensive, requiring a laboratory). We can simply summarize our findings by stating that repeated site visits without collection permits or consistent access to full plant specimens did not lead to an evolution toward great accuracy, nor did one attempt at using photography or a morphological description of a subset of the plants. All site visits, regardless of methodology or researcher training hovered around 30-40% accuracy, minus the spuriously high percentage of the SV5 (a calculation based on a limited subset of the plants).

Overall, the five TEK-HM site visits had varying levels of success in identifying the plants species from common names to Latin binomial (Table 3). Even SV5, arguably the culmination of the four years of fieldwork, only led to the definitive identification of 31 plant species. Although this was 91% of the 34 plants detailed in the sign-making project for the medicinal plant garden, it was still just 32% (31/96 plants) in the context of the combined plant list from all five site visits. Predictably, given the pleas from taxonomists, a TEK-HM project that is not grounded in voucher specimens and corresponding herbaria identification, or, more recently, DNA barcoding or spectrophotometry, is unlikely to yield a high percentage of plants unequivocally identified to Latin binomial, even with the cross-referencing, photography, and morphological description approaches of this investigation.

It is interesting to view the results from this project as a whole in comparison to the gold standard methods alluded to above. If we assume that exact plant matches were to occur with the correct application of herbarium-matched voucher plant specimens or laboratory methods, then the overall 53% accuracy using mixed methodology (expert consultation, written cross referencing, photography, morphological descriptions) falls far short of the ideal.

Our results, in retrospect, should come as no surprise. Researchers in the fields of botany and ethnobotany have long emphasized the importance of voucher specimens for optimal scientific rigor [7,22,28]. Clearly, as our results show, there are no shortcuts to accurate plant identification: not with repeated site visits, nor with a diverse researcher team. It goes without saying that a focused, taxonomically-oriented research agenda, allowing ample time to procure collecting permits, the deposition of plant specimens in a local herbarium, and support for follow up identification efforts, would have significantly improved the rate of successful identification of the plants in this project [25,27]. The difficulties in establishing such a comprehensive project are worth enduring, as exemplified by the alternative (these results). The community of Tabuga and the Ceiba Foundation are on board with a future goal of obtaining appropriate permits to enable collection of voucher specimens and confirmation of identity in a local herbarium.

Some lessons from this project may have applicability for future TEK-HM work. The relative ineffectiveness in retroactively using morphological characteristics for plant identification speaks to the complexity of plant dichotomous keys and the difficulty in predicting, without a key in hand, which characteristics will turn out to be the crucial details at branch points. Having the relevant keys in the field would certainly be a step in the right direction, although transporting such texts (even in electronic form) is not always a viable option. Photographs were slightly more useful than morphological descriptions because they allowed for the possibility to cross reference and compare with abundant internet resources and scientific papers including high-quality photographs.

With an eye toward a broader view of herbal medicine use, these results parallel challenges with plant identification in clinical medicine [20]. Some TEK-HM studies have attempted to definitively identify plants, realizing the clinical importance of traditional plant use in the context of pharmaceutical co-use or other medical interventions [29,30]. The dynamic nature of plant use only increases the challenge of and need for more accurate communication about plants and plant names. For example, when immigrants arrive in new places with their plants, their plant use may change and it may or may not be communicated with their health care provider [30-32]. The accurate identification of plants and then a substantive discussion about their use in the clinical environment would do much to foster the safe and effective application of herbal medicines and the continuance of TEK-HM.

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References

1. Benz BF, Cevallos EJ, Santana MF, Rosales AJ, Graf MS (2000) Losing knowledge about plant use in the Sierra de Manantlan Biosphere Reserve, Mexico. Economic Botany 54(2): 183-191.
2. Reyes-García V, Vadez V, Huanca T, Leonard WR, McDade T (2006) Economic development and local ecological knowledge: a deadlock? quantitative research from a native Amazonian society. Human Ecology 35(3): 371-377.
3. Salick J, Fang Z, Byg A (2009) Eastern Himalayan alpine plant ecology, Tibetan ethnobotany, and climate change. Global Environmental Change 19(2): 147-155.
4. Turner NJ, Ignace MB, Ignace R (2000) Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia. Ecological Applications 10(5): 1275-1287.

5. Girón LM, Freire V, Alonzo A, Cáceres A (1991) Ethnobotanical survey of the medicinal flora used by the Caribs of Guatemala. Journal of Ethnopharmacology, 34(2-3): 173-187.
6. Merlin MD (2003) Archaeological evidence for the tradition of psychoactive plant use in the old world. Economic Botany 57(3): 295-323.
7. Balick MJ, Cox PA. (1996) Plants, people, and culture: the science of ethnobotany. Scientific American Library, New York.
8. Michel J, Duarte RE, Bolton JL, Huang Y, Caceres A, et al. (2007) Medical potential of plants used by the Q'eqchi Maya of Livingston, Guatemala for the treatment of women's health complaints. Journal of Ethnopharmacology 114(1): 92-101.
9. Andrade-Cetto A (2009) Ethnobotanical study of the medicinal plants from Tlanchinol, Hidalgo, México. Journal of Ethnopharmacology 122(1): 163-171.
10. De la Cruz de MG, Malpartida SB, Santiago HB, Jullian V, Bourdy G (2014) Hot and cold: medicinal plant uses in Quechua speaking communities in the high Andes (Callejón de Huaylas, Ancash, Perú). Journal of Ethnopharmacology 155(2): 1093-117.
11. Cáceres A, López B, González S, Berger I, Tada I, Maki J (1998) Plants used in Guatemala for the treatment of protozoal infections. I. Screening of activity to bacteria, fungi and American trypanosomes of 13 native plants. Journal of Ethnopharmacology 62(3): 195-202.
12. Schultes RE (1969) Hallucinogens of plant origin. Science 163(3864): 245-254.
13. Meyer RS, Bamshad M, Fuller DQ, Litt A. (2014). Comparing medicinal uses of eggplant and related Solanaceae in China, India, and the Philippines suggests the independent development of uses, cultural diffusion, and recent species substitutions. Economic Botany 68(2): 137–152.
14. Vandebroek I, Balick MJ. (2014). Lime for chest congestion, bitter orange for diabetes: foods as medicines in the Dominican community in New York City. Economic Botany, 68(2): 177–189.
15. Heitzman ME, Neto CC, Winiarz E, Vaisberg AJ, Hammond GB (2005) Ethnobotany, phytochemistry and pharmacology of Uncaria (Rubiaceae). Phytochemistry 66(1): 5-29.
16. Corlett JL, Dean EA, Grivetti LE (2003) Hmong gardens: botanical diversity in an urban setting. Economic Botany 57(3): 365-379.
17. McClatchey W (2007) Two Ethnobotanists. Ethnobotany Research & Applications 5: 95-96.
18. Soleri D, Worthington M, Aragón-Cuevas F, Smith SE, Gepts P (2013) Farmers' varietal identification in a reference sample of local Phaseolus species in the Sierra Juárez, Oaxaca, Mexico. Economic Botany 67(4): 283-298.
19. Emshwiller E (2006) Evolution and conservation of clonally propagated crops. In TJ Motley, N Zerega, HB Cross [eds.] Darwin's harvest: new approaches to the origins, evolution, and conservation of crops, 308–332. Columbia University Press New York.
20. Kiefer D, Tellez-Girón P, Bradbury J (2014) A pilot study of herbal medicine use in a Midwest Latino population. Wisconsin Medical Journal 113(2): 64-71.
21. Cimino M (2010) Ensuring the specific identity and quality of herbal products by the power of DNA. HerbalGram 86: 50-57.
22. Nguyen MLT (2005) Cultivated plant collections from market places. Ethnobotany Research & Applications 3: 5-16.
23. Chase MW, Fay MF (2009) Barcoding of plants and fungi. Science 325(5941): 682-683.
24. Durgante FVM, Higuchi N, Almeida A, Vicentini A (2013) Species spectral signature: discriminating closely related plant species in the Amazon with near-infrared leaf-spectroscopy. Forest Ecology and Management 291(C): 240-248.
25. Galluzzi G, López Noriega I (2014) Conservation and use of genetic resources of underutilized crops in the Americas: a continental analysis. Sustainability 6: 980-1017.
26. Thomas E, Vandebroek I, Van Damme P (2007) What works in the field? A comparison of different interviewing methods in ethnobotany with special reference to the use of photographs. Economic Botany 61(4): 376-384.
27. Engels JMM, Dempewolf H, Henson-Apollonio V (2010) Ethical considerations in agro-biodiversity research, collecting, and use. Journal of Agricultural and Environmental Ethics 24(2): 107-126.
28. Bye RA, Linares E (1983) The role of plants found in Mexican markets and their importance in ethnobotanical studies. Journal of Ethnobiology 3(1): 1-13.
29. Ceuterick M, Vandebroek I, Torry B, Pieroni A (2008) Cross-cultural adaptation in urban ethnobotany: the Colombian folk pharmacopoeia in London. Journal of Ethnopharmacology 120: 342-359.
30. Vandebroek I, Balick MJ, Ososki A (2010) The importance of botellas and other plant mixtures in Dominican traditional medicine. Journal of Ethnopharmacoly 128(1): 20-41.
31. Mehta DH, Gardiner PM, Phillips RS, McCarthy EP (2008) Herbal and dietary supplement disclosure to health care providers by individuals with chronic conditions. Journal of Alternative and Complementary Medicine 14: 1263-1269.
32. Kuo GM, Hawley ST, Weiss LT, Balkrishnan R, Volk RJ (2004) Factors associated with herbal use among urban multiethnic primary care patients: a cross-sectional survey. BMC Comp Alt Med 2(4): 18.