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<https://doi.org/10.1007/s12231-012-9215-2>

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# Species Substitution in Medicinal Roots and Possible Implications for Toxicity of Herbal Remedies in Morocco<sup>1</sup>

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**Species Substitution in Medicinal Roots and Possible Implications for Toxicity of Herbal Remedies in Morocco.** Herbal medicine is an integral part of health care in Morocco and is widely used by Moroccans. However, the efficacy and safety of traditional plant-based medicine in Morocco is threatened by insufficient knowledge about practices of adulteration and substitution. These issues are of particular importance when subterranean plant parts are employed. A combination of qualitative and quantitative methods was used to identify where and why confusion (accidental substitution) and intentional substitution occurs in root-based medicines sold in Marrakech. Additionally we examined local perceptions of the toxicological risks posed by substitution. We recorded a total of 20 species (34 unique cases) of roots for which substitution or confusion was reported by either herbalists or collectors. Substitution or confusion occurred in 54.6 % of the 33 most commonly sold medicinal roots, with herbalists reporting substitution in more species than collectors. Collectors and herbalists cited poor availability of roots (in part due to overexploitation of wild resources), high demand, high prices, and lack of knowledge as factors driving substitution and confusion. Roots for which substitution was reported were significantly more difficult for herbalists to identify. Moreover, profit was higher for roots for which intentional substitution was reported. Despite the detailed knowledge held by many herbalists and a long tradition of use of herbal medicine in Morocco, doctors and pharmacists had dismissive attitudes towards traditional medicine and expressed concern about both efficacy and safety of medicinal plant use. Given the high rates of substitution and confusion documented by this study, there is an urgent need for appropriate regulation of herbal remedies in Morocco, a conclusion embraced by herbalists and Western-trained medical practitioners alike.

يعتبر التداوي بالأعشاب جزءاً لا يتجزأ من الرعاية الصحية بالمغرب و يستعمل على نطاق واسع من طرف المغاربة؛ ملخص ومعدالك تبقى سلامة و فعالية التداوي بالأعشاب التقليدية مهددة، لعدة أسباب نذكر منها على سبيل المثال لا الحصر المعرفة لذلك تمت دراسة ويعتبر استخدام جذور الأعشاب من أهم القضايا الحساسة. غير الكافية، ممارسات الاستبدال والغش الأسباب الأساسية والمكان الذي يتم فيه الاستبدال لجذور الأعشاب الطبية التي تباع في معشبات مراكش، بالمغرب وكذلك لقد تم اعتماد مجموعة من المناهج. على التعريف بجذور الأعشاب الأكثر استعمالاً للذين هم بمثابة خبراء قدرة العشابين واستخدمت المناهج الكيفية لتسجيل تصورات العشابين وجامعي الأعشاب الكيفيتو الكمية لتوضيح الاستبدال أسباب حدوثه لقد. والأطباء و الصيادلة حول ممارسات الاستبدال، ومخاطر التسمم بسبب الاستبدال والغش و الخلط بين الأعشاب الطبية نوعاً من جذور الأعشاب التي تم فيها الاستبدال و الخلط، كما ورد على لسان العشابين و 20 تمت تسجيل ما مجموعه من 57,6% و قد تم استبدال و خلط ما نسبته. جامعياً الأعشاب، وتم التفريق بين أشكال متعددة حيث الاستبدال و الخلط محتملين إلا أن الاستغلال المفرط، و انعدام المعرفة و الخبرة، و ندرة الموارد المادية، و ارتفاع الطلب و أصلاً أشار اليه جامعي الأعشاب

<sup>1</sup> Received 9 September 2011; accepted 8 October 2012; published online 13 December 2012

*Economic Botany*, 66(4), 2012, pp. 370–382

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كان من الصعب جدا تحديد جذور الأعشاب التي ورد فيها الاستبدال و الخلطن .غلاء الأسعار كلها عوامل تقف وراء الاستبدال علاوة على ذلك، فإن سعر البيع و هامش الخطر يكون أكبر في جذور الأعشاب الطبية التي تعرضت للخلط أو طرف العشابين على الرغم من المعرفة الدقيقة لدى العشابين ، و قدم ممارستهم للطب التقليدي ، فإن الأطباء و الصيدالول لهم موقف الاستبدال ان معطى المعدلات المرتفعة للاستبدال و الخلط المقترحة معارض تجاه الطب التقليدي و أعربوا عن قلقهم حول سلامته و فعاليته من خلال هذه الدراسة، إلى جانب المخاطر المحتملة الناتجة عن ذلك و التي تهدد الصحة العمومية ،إلا انه، مع ذلك، كان من الملاحظ أن كل من العشابين و الأطباء فشلوا في التعبير عن قلقهم حول التسمم؛ في حين أنهم عبروا عن اهتمامهم بالتقنين

**Key Words:** Confusion, adulteration, identification, herbalists, collectors, doctors, pharmacists, markets, NTFP, Morocco.

## Introduction

Moroccan traditional herbal medicine is well known across North Africa and around the world (Bellakhdar et al. 1982; Bellakhdar et al. 1991; Boulos 1983; Sijelmasi 1993). The Moroccan pharmacopeia is diverse, highly developed, and remains an integral part of health care in the country (Bellakhdar 1997). Although the majority of Moroccans use the publically funded Western medical system as their primary source of health care, many use traditional medicine as well (Hotchkiss et al. 1995).

Herbal marketplaces in Marrakech, the main city of southern Morocco situated at the foot of the High Atlas Mountains, are famous for the reputed efficacy of their products. Of herbal remedies sold there, 61 % are collected from the wild within Morocco (El-Hilaly et al. 2003) and 14 % are subterranean plant parts (the majority of which are roots and which will be referred to as roots henceforth) (Abbad et al. 2007). Previous research has shown that roots, seeds, bark, and resins are significantly more difficult to identify than leaves, flowers, and whole plants, and that both laypeople and traditional healers in Morocco can identify fewer root-based remedies than remedies based on other plant parts (Ouarghidi 2007). These findings led us to hypothesize that species confusion and substitution were likely in root-based remedies in Morocco. Although a vast body of research exists on Morocco's medicinal plants, the question of confusion, substitutions, and adulteration of medicinal plants remain virtually unexplored topics.

Documentation of substitution and adulteration has important implications for public health and safety. In developed countries, toxicity related to herbal medicine is increasingly reported, causing growing alarm among medical and public health officials (Farah et al. 2006; Jordan et al. 2010). Misidentification and intentional substitution (as well as herb-drug interactions) are listed as two of the most common and most important causes of

poisoning from medicinal plant use (Fennell et al. 2004; Jordan et al. 2010; Pinn 2001).

Understanding the factors driving substitution allows for this potential public health issue to be better addressed and will help bring it to the attention of health authorities in Morocco, where the Western medical system has historically ignored and marginalized traditional medicine (Bellakhdar 1989). Several complex reasons for medicinal plant substitution are reported in the literature, including economic considerations among low socioeconomic status collectors, and the scarcity of some wild plant species (Fennell et al. 2004; Hersch-Martinez 1995; Tomlinson et al. 2000). Difficulty in identifying medicinal plants is likely an important factor leading to substitution, especially for root-based remedies. Fennell et al. (2004) found that lack of knowledge and experience among traditional healers in South Africa is an important factor leading to substitution.

Many forms of substitution exist. The addition of pharmaceuticals or other chemicals is usually referred to as adulteration, and has received attention in the literature (e.g., Chan 2003; Liang et al. 2006). Plant part substitution has also been discussed, although mainly as a means of ensuring sustainable use of species at risk (Zschocke et al. 2000). Misidentification (or confusion) is commonly reported in morphologically similar species (Fennell et al. 2004; Fong 2002; Khan 2006). Finally, the substitution of one species of medicinal plant for another has also been discussed (Fennell et al. 2004; Jordan et al. 2010; Tomlinson et al. 2000).

This paper investigates substitution arising from misidentification (confusion) and intentional species substitution along the market chain, and explores where and why they occur. The names of certain species change over spatial and temporal scales and as substitution occurs; vernacular names vary among harvesters, middlemen, wholesalers, retail herbalists, consumers, and exporters. Understanding the competence of retail herbalists, who interface with consumers on

a daily basis, is important for understanding the public health implications of substitution. We test the hypothesis that the inability of herbalists to identify common medicinal roots is one factor leading to substitution. Finally we present ideas and perceptions of herbalists, pharmacists, and medical doctors regarding toxicity from medicinal roots.

## Methods

### STUDY SITE

Information was collected in three markets of Marrakech: Mellah, a wholesale marketplace; Rahba l'kdima, a retail marketplace; and the old Medina, a retail marketplace. We also collected data in seven remote collection sites located mainly in the High Atlas Mountains, as well as on the El Haouz plain. Collection sites for medicinal roots were located 80–250 km from Marrakech, with elevations ranging between 500–2,200 m.

### IDENTIFYING ROOTS AND CASES OF SUBSTITUTION

At the outset of the research project an initial list of 67 medicinal roots sold in the markets of Marrakech was compiled through interviews and free listing with 15 herbalists. During this process, the most commonly sold roots were identified based on the Smith's Saliency Index using freelifting by herbalists and Anthropac 4 (Borgatti 1996). Roots reported to be collected in Morocco were pursued through the market chain to the site of collection, and botanical voucher specimens were collected in collaboration with collectors. Herbarium vouchers were collected and identified with support from specialists of the Moroccan flora at the Institut Scientifique at Rabat (RAB), and deposited there and at the Natural History Museum of Marrakech. The few vernacular names discussed by herbalists and not identified in this process were identified from the literature (Bellakhdar 1997; Benabid 2000; Fennane et al. 2007).

Cases of intentional substitution and accidental substitution (confusion) were identified through participant observation, extensive participatory work, and interviews with 40 herbalists and 22 collectors (all discussion of substitution and confusion relied solely on vernacular names, and all data presented in this paper are based on what herbalists and collectors reported). Of the 40

herbalists interviewed, all were male retailers, representing different age groups, from different locations, and had been identified as willing to participate in research during our previous extensive survey of herbalists in Marrakech (Ouarghidi 2007). The 22 collectors interviewed were identified in the process of tracing roots along the supply chain. Collectors were either of Amazigh or Arab ethnicity, and most relied on small business, agriculture, and pastoralism for their primary source of livelihood. During our research numerous middlemen and traders, some of whom were also collectors, were consulted, and additional information was gathered from these exchanges. Information about why substitution and confusion of medicinal roots occurs in Morocco was also collected with the above informants through unstructured interviews and discussions.

### HERBALISTS' KNOWLEDGE

Of the 150 herbalists working in Marrakech, only 60 sell medicinal roots. We were able to interview 39 of these, or roughly two-thirds. In the interviews herbalists were shown a set of root vouchers of the 33 most commonly sold roots and asked to identify each by its vernacular name. The set of voucher roots was purchased in the market, with attention to ensuring that the material obtained did not suffer from substitution or confusion. The vouchers were packaged in clear plastic bags with coded voucher information (Fig. 1). The same set of vouchers was presented to each herbalist. In addition to the vernacular name, herbalists were asked to indicate whether the species was toxic, and in what way. Associations between herbalists' knowledge, that is, percent of roots they were able to identify compared to identification given by expert herbalists, and their years of experience and selling practices were tested statistically using correlations and t-tests. Additionally, roots for which substitution was reported were compared to roots with no substitution using t-tests and Mann-Whitney U tests.

### QUALITATIVE WORK ON TOXICITY

Qualitative work, including interviews and eight focus groups with herbalists (N=16), doctors (N=4), and pharmacists (N=4), was carried out to highlight traditional and medical-system attitudes toward, and perceptions of, traditional herbal remedies and roots, risk of toxicity, as well as the

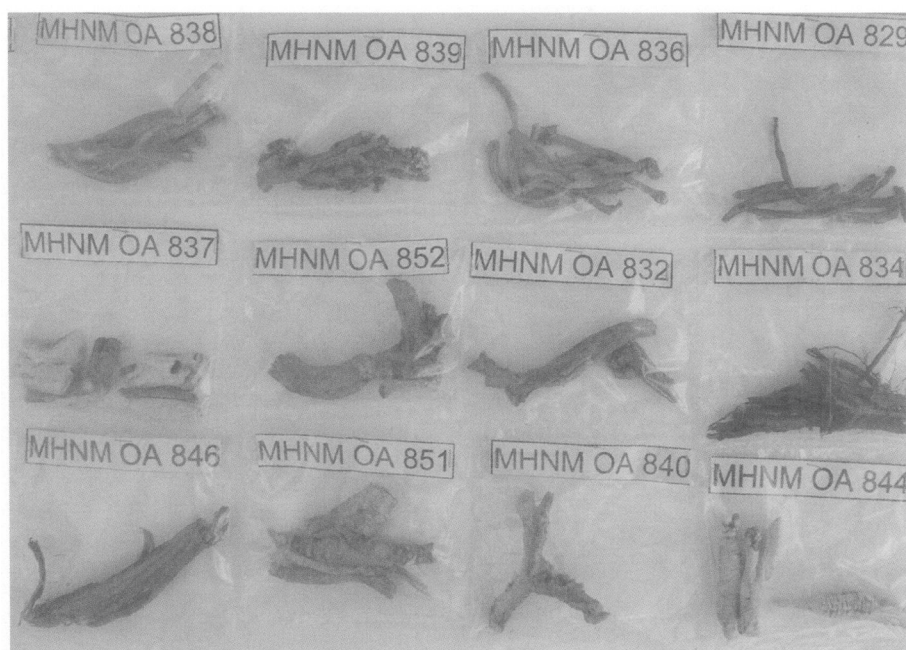


Fig. 1. A collection of some of the voucher specimens used in interviews and identification tasks with herbalists.

implications of substitution. To stimulate discussion we asked doctors, pharmacists, and herbalists questions such as: What does toxicity mean? What are different types of toxicity? What are their symptoms and causes?

## Results

### SUBSTITUTION OF MEDICINAL ROOTS

Among the 67 medicinal roots recorded as sold in the herbal markets of Marrakech, a total of 34 cases of either substitution or confusion were reported, with 20 root species reported to be involved. Herbalists reported 11 cases of confusion (accidental substitution) (Table 1) and 18 cases of intentional substitution (Table 2). Collectors reported four cases where intentional substitution occurs (Table 3) and one case where folk taxonomy under-differentiation occurs (Berlin 1973): *Deryass* (*Thapsia transtagana* Brot., MHNM465 KGh) and *Deryass* (*Thapsia villosa* L., MHNM 790 AO). Vernacular names discussed by herbalists were identified in our work with collectors. The frequency of intentional and accidental substitution reported by herbalists suggests that these happen quite frequently (Tables 1 and 2).

Of the 33 roots most commonly sold in the markets of Marrakech and used in the identifica-

tion interviews with herbalists, 15 (45.4 %) had no reports of intentional substitution or confusion by either herbalists or collectors. Intentional substitution was reported by either herbalists or collectors for 13 (39.4 %) roots, and confusion (accidental substitution) was reported for 11 (33.3 %) roots. Six roots were reported to have had both intentional and accidental substitution. Herbalists reported substitution and/or confusion in 16 (48.4 %) of the roots, while collectors identified instances of substitution and/or confusion in 5 (15.2 %) roots.

We found four root-based remedies in which substitution is clearly intentional among collectors. The case of *Iguendez* is particularly interesting and complicated. Collectors “cut” the more valuable *Iguendez* with approximately 40–50 % of *Tiguendizt* or *Tamzought* to increase their profit. Complex and varied systems of folk classification and nomenclature occur for these species, with many collectors and middle men in the trade intentionally referring to less valuable *Tiguendizt* or *Tamzought* as different qualities of *Iguendez* rather than by their actual name. By the time these roots reach the markets in Marrakech, they are all sold under the name *Iguende* or *a'qar qarha* (a name not used by collectors).

Table 1. MEDICINAL ROOTS WHERE CONFUSION IS OCCURRING, ACCORDING TO THE HERBALISTS OF THE MARKETS OF MARRAKECH.

Vernacular Names of Primary Roots	Scientific Names*	Vernacular Names of Confused Roots	Scientific Names*	Frequency of Confusion
Amssekhsser	<i>Ammoides pusilla</i> (Brot.) Beistr.	Ziyata	<i>Apium nodiflorum</i> (L.) Lag.	Common
Amssekhsser	<i>Ammoides pusilla</i> (Brot.) Beistr.	Deryass	<i>Thapsia villosa</i> L.	Common
Bereztem	<i>Aristolochia paucinervis</i> Pomel	Tafgha	<i>Centaurea chamaerhaponticum</i> Ball	Common
Bereztem	<i>Aristolochia paucinervis</i> Pomel	Taryala	<i>Mandragora autumnalis</i> Bertol.	Common
Deryass	<i>Thapsia villosa</i> L.	Kelkh	<i>Ferula communis</i> L.	Fairly common
Kelkh	<i>Ferula communis</i> L.	Deryass	<i>Thapsia villosa</i> L.	Fairly common
Kherchouf	<i>Cynara cardunculus</i> L.	Tasskra	<i>Echinops spinosissimus</i> Turra. ssp. <i>fontqueri</i> (Pau) Greuter	Fairly common
Serghina	<i>Corrigiola telephifolia</i> Pourr.	Tigheghcht	<i>Silene vulgaris</i> (Moench) Garcke	Common
Tafgha	<i>Centaurea chamaerhaponticum</i> Ball	Bereztem	<i>Aristolochia paucinervis</i> Pomel	Fairly common
Tafgha	<i>Centaurea chamaerhaponticum</i> Ball	Taryala	<i>Mandragora autumnalis</i> Bertol.	Fairly common
Taryala	<i>Mandragora autumnalis</i> Bertol.	Bereztem	<i>Aristolochia paucinervis</i> Pomel	Fairly common
Taryala	<i>Mandragora autumnalis</i> Bertol.	Tafgha	<i>Centaurea chamaerhaponticum</i> Ball	Fairly common
Tasskra	<i>Echinops spinosissimus</i> Turra. ssp. <i>fontqueri</i> (Pau) Greuter	Kherchouf	<i>Cynara cardunculus</i> L.	Fairly common
Tigheghcht	<i>Silene vulgaris</i> (Moench) Garcke	Serghina	<i>Corrigiola telephifolia</i> Pourr.	Common

\*Scientific names for vernacular names given by herbalists; species identified

#### FACTORS LEADING TO SUBSTITUTION

The reasons for intentional substitutions given by herbalists (Table 2) included: 1) price (where a less expensive species or variety is sold under the name of a more expensive one) for 14/18 (77.8 %) cases; 2) availability (where a different species is used when the preferred one is not available) for 13/18 (72.2 %) cases; and 3) to use up excess stock (when a root is sold under a different name because the herbalist has too much or plentiful stock and wants to use it up) in 3/18 (16.7 %) cases. The reasons given by collectors were quite similar to those of herbalists.

Most collectors denied that substitution occurs among collectors. Those who admitted to substitution cited overexploitation, lack of knowledge, and high demand as the primary reasons. Lack of experience of some herbalists and collectors was often given as a common reason for confusion (accidental substitution) as well as high rates of substitution in general.

All herbalists reported that substitution occurs in Marrakech. Most consider it a major and

complicated problem. Many believe that substitution is a new issue that has emerged for multiple reasons and now threatens to erode trust in traditional medicine and their trade. According to Marrakech herbalists, substitution and confusion occur mainly at the level of the herbalist, that is, at the site of sale rather than of collection. However, herbalists also claimed that collectors processed and dried roots in a manner intended to confuse and mislead those further down the supply chain.

Virtually all roots sold in the markets in Marrakech are dried. Herbalists noted that morphological similarity is an important factor contributing to both intentional and accidental substitution. For instance, the roots *Bereztem* (*Aristolochia paucinervis* Pomel), *Tafgha* (*Centaurea chamaerhaponticum* Ball.), and *Taryala* (*Mandragora autumnalis* Bertol.) are highly similar morphologically, especially if processed in the same manner, and are commonly confused by herbalists (Table 1).

Herbalists expressed concern that the death of key local experts was leading to degradation of knowledge. One highly respected collector and

Table 2. MEDICINAL ROOTS WHERE INTENTIONAL SUBSTITUTION IS OCCURRING, ACCORDING TO THE HERBALISTS OF THE MARKETS OF MARRAKECH.

Vernacular Names of Primary Roots	Scientific Names*	Vernacular Names of Substituted Roots	Scientific Names* of Substituted Roots	Frequency of Substitution	Reasons for Substitution
Amssekhsser	<i>Ammoides pusilla</i> (Brot.) Beistr.	Ziyata	<i>Apium nodiflorum</i> (L.) Lag.	Common	High-priced, not available in the market
Amssekhsser	<i>Ammoides pusilla</i> (Brot.) Beistr.	Deryass	<i>Thapsia villosa</i> L.	Common	High-priced, not available in the market
Bessbess	<i>Foeniculum vulgare</i> Mill.	Dergue	<i>Opuntia ficus-indica</i> (L.) Mill.	Rare	Substitute is cheaper and occasionally used, not available in the market
Boughlam	<i>Spergularia marginata</i> (DC.) Kitt.	Serghina	<i>Corrigiola telephiiifolia</i> Pourr.	Fairly common	High-priced, not available in the market
Bouzfour	<i>Ammoides pusilla</i> (Brot.) Beistr.	Amssekhsser	<i>Ammoides pusilla</i> (Brot.) Beistr.	Common	High-priced, not available in the market
Deryass	<i>Thapsia villosa</i> L.	Kelkh	<i>Ferula communis</i> L.	Fairly common	Not available in the market
Fijel	<i>Ruta montana</i> Mill.	Bessbess	<i>Foeniculum vulgare</i> Mill.	Rare	High-priced
Fijel	<i>Ruta montana</i> Mill.	Dardar	<i>Fraxinus excelsior</i> L.	Rare	High-priced
Fijel	<i>Ruta montana</i> Mill.	R'tam	<i>Retama raetam</i> (Forssk.) Webb.	Rare	High-priced
Fnina	<i>Not identified</i>	Ouden helouf	<i>Pulicaria odora</i> Rchb.	Rare	High-priced, not available in the market
Foua	<i>Rubia peregrina</i> L.	Dbagh	<i>Quercus ilex</i> L. ssp. <i>rotundifolia</i> (Lam.) T. Morais	Common	High-priced
Kelkh	<i>Ferula communis</i> L.	Deryass	<i>Thapsia villosa</i> L.	Fairly common	Not available in the market
Nidkhir	<i>Not identified</i>	Njeem	<i>Cynodon dactylon</i> (L.) Pers.	Fairly common	High-priced, not available in the market
Serghina	<i>Corrigiola telephiiifolia</i> Pourr.	Tigheghcht	<i>Silene vulgaris</i> (Moench) Garcke	Common	Not available in the market
Swak raayan	<i>Scrophularia canina</i> L.	Awedmi	<i>Armeria</i> cf. <i>alliacea</i> (Cav.) Hoffmanns. & Link, or <i>Meum athamanticum</i> Jacq.	Common	High-priced, not available in the market
Tasskra	<i>Echinops spinosissimus</i> Turra. ssp. <i>fontqueri</i> (Pau) Greuter	Harmel	<i>Peganum harmala</i> L.	Rare	Substitute is cheaper and occasionally used

TABLE 2. (CONTINUED).

Vernacular Names of Primary Roots	Scientific Names*	Vernacular Names of Substituted Roots	Scientific Names* of Substituted Roots	Frequency of Substitution	Reasons for Substitution
Tigheghcht	<i>Silene vulgaris</i> (Moench) Garcke	Serghina	<i>Corrigiola telephifolia</i> Pourr.	Common	Occasionally used, not available in the market
Tiguendizt	<i>Anacyclus pyrethrum</i> (L.) Lag.	Awedmi	<i>Armeria cf. alliacea</i> (Cav.) Hoffmanns. & Link, or <i>Meum athamanticum</i> Jacq.	Common	High-priced, not available in the market

\*Scientific names for vernacular names given by herbalists identified

middle-man had recently passed away, and his death was noted as a potential problem by many herbalists who relied on him as a source of information and to confirm the identity of questionable roots. Another collector who had supplied two medicinal roots, *Fouilia* and *Fnina*, had recently died, and *Fnina* was no longer available in the markets (and thus not identified in our study). Accordingly, herbalists had started selling an alternative to *Fnina*.

Herbalists repeatedly lamented that their decreasing ability to get advice from experts was leading to problems with identification of roots and their correct use, errors in prescription, and adverse outcomes in terms of both patient health and herbalists' reputations. They reported that limited knowledge of herb toxicity has led to cases of poisoning. Some herbalists remembered one herbalist who confused *Bereztem* (*A. paucinervis*) and *Tafgha* (*Centaurea chamaerhaponticum* Ball) and mistakenly gave *Bereztem* to a woman who developed a serious ulcer after a number of months. Most experienced herbalists specifically blamed inexperienced counterparts. Some inexperienced herbalists acknowledged their own inability to distinguish morphologically similar roots, and as a result they stocked and sold only a limited number of root-based remedies.

Other reasons for substitution provided by many herbalists included decreased availability of some medicinal herbs in wholesale markets and in the wild. This situation also contributed to rising prices. Herbalists considered these factors as important reasons for intentional substitution. For example, *Tiguendizt* (*Anacyclus pyrethrum* [L.]

Lag.) has reached 700 Moroccan dirham (approximately USD 100) per kg due to high demand, huge increases in export, and its reported efficacy for a wide range of ailments. Many consumers are no longer willing or able to pay for the high-quality or (pure) *Tiguendizt* and accept lower-quality substitutes, usually *Awedmi* (*Meum athamanticum* Jacq.), at lower prices, sometimes knowingly.

#### HERBALISTS' KNOWLEDGE AND ABILITY TO IDENTIFY MEDICAL ROOTS

Of the 39 herbalists who completed the identification task/interview, the mean percent of root specimens correctly identified was 68.3 %  $\pm$  22.2 %. The first quartile identified less than 54.4 %, and the third quartile identified 75.8 % or more. There were strong positive correlations between the number of roots identified and the following: 1) the herbalists' expertise (number of years in practice) ( $r=0.581$ ,  $p<0.001$ ); 2) the number of the most common root specimens reportedly stocked in the shop ( $r=0.720$ ,  $p<0.001$ ); and 3) The number of root specimens the herbalist reported selling ( $r=0.820$ ,  $p<0.001$ ). There was also a positive correlation between the percent of the roots that herbalists reported as toxic and the percent of the roots they were able to identify ( $r=0.519$ ,  $p<0.001$ ). Figure 2 shows differences in expertise, percent of items stocked, and percent sold between the upper and lower 50 % of herbalists, based on their ability to identify roots.

We compared roots for which intentional substitution was reported by either herbalists or

Table 3. MEDICINAL ROOTS WHERE INTENTIONAL SUBSTITUTION IS OCCURRING, ACCORDING TO COLLECTORS.

Vernacular Names of Primary Roots	Vernacular Names of Substituted Roots		Voucher of Substituted Roots	Family	Notes
	Scientific Names of Primary Roots	Scientific Names of Substituted Roots			
Aansla	<i>Drimys maritima</i> (L.) Stearn	<i>Ornithogalum narbonense</i> L.	MHNM 882 AO	Hyacinthaceae	Species not very similar. Substitution by collectors intentional.
Awedmi	<i>Armeria cf. alliacea</i> (Cav.) Hoffmanns. & Link	<i>Merum athamanticum</i> Jacq.	MHNM 802 AO	Plumbaginaceae	Species from different families, not very similar. Substitution by collectors intentional.
Iguendez	<i>Anacyclus pyrethrum</i> var. <i>pyrethrum</i> (L.) Link	<i>Anacyclus pyrethrum</i> var. <i>depressus</i> (Ball) Maire	MHNM 864 AO MHNM 865 AO MHNM 872 AO MHNM 875 AO	Asteraceae	Two varieties morphologically very similar. Collectors clearly differentiate each vernacular name and match vernacular names to their corresponding species and variety. Despite similarity this is not "under-differentiated" but intentional substitution by collectors.
Iguendez	<i>Anacyclus pyrethrum</i> var. <i>pyrethrum</i> (L.) Link	<i>Catananche caerulea</i> L.	MHNM 864 AO MHNM 865 AO MHNM 872 AO MHNM 875 AO	Asteraceae	Two varieties that are morphologically very similar and from different genus. Collectors clearly differentiate each vernacular name and match vernacular names to their corresponding species and variety. Despite similarity this is not "under-differentiated" but intentional substitution by collectors.

TABLE 3. (CONTINUED).

Vernacular Names of Primary Roots	Scientific Names of Primary Roots	Voucher of Primary Roots	Vernacular Names of Substituted Roots	Scientific Names of Substituted Roots	Voucher of Substituted Roots	Family	Notes
Tasserghint	<i>Corrigiola telephifolia</i> Pourr.	MHNM 867 AO MHNM 879 AO	Tasserghint	<i>Petrorhagia illyrica</i> (Ard.) P.W.Ball & Heywood	MHNM 866 AO	Caryophyllaceae	Species from different families, not very similar. Substitution by collectors intentional.

collectors to those with no reported substitution (Fig. 3). Roots where intentional substitution occurred were identified by a lower percentage of herbalists and were stocked and sold by a lower percentage of herbalists. Price gained from sale (difference between wholesale and retail price) was more than two times higher for roots for which substitution was reported (Mann-Whitney U test,  $p < 0.01$ ).

#### TOXICITY

Risk of poisoning or toxicity from traditional herbal remedies is perceived differently by different medical practitioners in Marrakech and Morocco. As noted by Bellakhdar (1989), the Western medical system in Morocco has a long history of rejecting and marginalizing traditional medicine. Antagonistic attitudes between traditional healers and Western medical practitioners remain strong today; patients likely do not report use of traditional medicine to Western medical practitioners for fear of negative reactions. Accordingly, doctors, pharmacists, and scientists alike expressed strong concerns about toxicity from traditional medicine. Herbalists argue that Western medical practitioners blame them as a group for cases of herb-related poisonings, without consideration of the fact that not all herbalists have the same level of expertise, and that some cases of poisoning may be due to allergic reactions or herb-drug interactions.

Doctors and pharmacists conceptualized toxicity differently than herbalists. Herbalists defined toxicity based on the route of exposure and provided lists of symptoms, whereas doctors and pharmacists defined it as a pathology caused by a foreign organism or compound. The route of ingestion is a central concept in the herbalists' perception of medicinal-herb-related toxicity. They noted that toxicity could occur when remedies meant for external use were ingested. Remedies in which this was reported to be a potential risk included *Tigheghcht* (*Silene vulgaris* [Moench] Garcke), *Addad* (*Chamaeleon gummifer* [L.] Cass.), *Amssekhsser* (*Ammoides pusilla* [Brot.] Breistr.), and *Deryass* (*Thapsia villosa* L.). Inhalation of other remedies was reported to also have toxic potential, especially with extended use. The inhalation of the powder from *Addad* (*C. gummifer*) and *Taryala* (*M. autumnalis*) during the preparation of remedies was reported to cause eventual toxicity, with symptoms such as

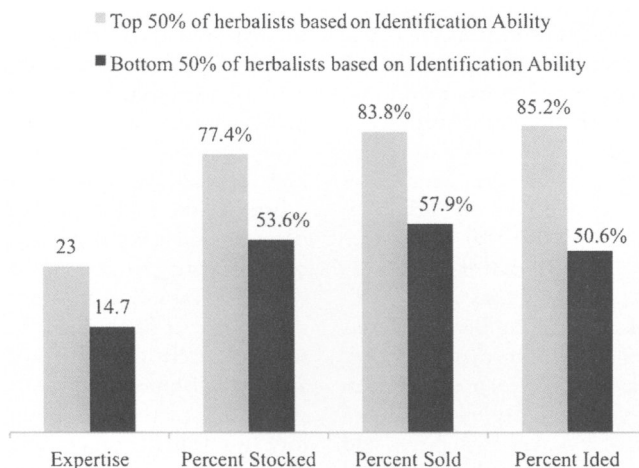


Fig. 2. Potential criteria influencing the ability of herbalists to identify medicinal roots.

dryness of the nasal mucosa, migraine, and vision problems.

Although herbalists did not use scientific terms, they demonstrated complex understanding of pharmacology when discussing herb-herb interactions. In focus group discussions herbalists agreed that inappropriate or unbalanced mixtures of herbs could lead to toxicity. Those with advanced knowledge were able to list herbs that were incompatible when taken together. Expert herbalists known for their competency reported that herbalists without sufficient knowledge may unknowingly use rotten herbs, misidentify remedies, and frequently prescribe the wrong dose. They noted that toxicity is dose-dependent and that the strength of a given remedy is not always consistent across specimens. Again demonstrating in-depth understanding, they noted that different

remedies cause toxicity after different periods of use.

Interestingly, of the 33 most commonly sold medicinal roots investigated in our above work, roots where substitution or confusion was reported were also reported as toxic by a greater percentage of herbalists (24.5 %) than roots where none was reported (12.0 %).

### Discussion and Conclusions

The findings presented herein suggest that substitution and confusion are pervasive and frequent in herbal medicines sold in Marrakech, with implications for biodiversity conservation and public health and safety. Morphological identification of medicinal roots is difficult. A recent study of Marrakech root products using DNA barcoding has shown up to 20 % to be

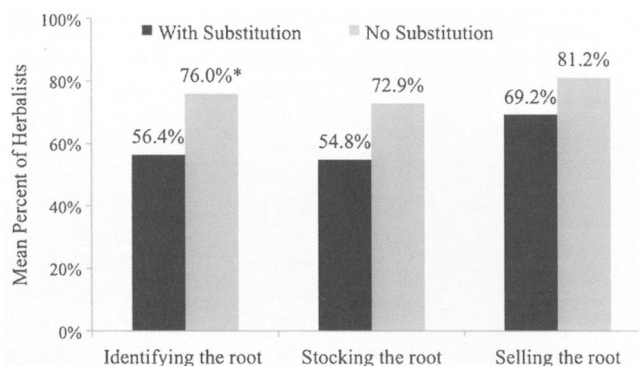


Fig. 3. Comparison of roots where intentional substitution occurs to roots where no intentional substitution occurs (according to either herbalists or collectors), based on percentage of herbalists correctly identifying them, stocking them, and selling them. (\*Statistically significantly different,  $p < 0.05$  in a student's t-test, other differences not statistically significant).

different species than those recorded in the herbal pharmacopoeia (Kool et al. 2012). Of the 67 medicinal roots commercialized in Marrakech, we recorded 34 cases of either substitution or confusion (with 20 root species involved), a rate that seems high compared to the handful of herbal substitution cases reported by other research (cf. Fennell et al. 2004). All health-care practitioners in Morocco should be alert to substitution and of its potential risks.

Collectors and herbalists cited different reasons for substitution and confusion of medicinal roots. It was not surprising that, as the drivers of substitution and confusion, they cited overexploitation, high demand, unavailability of materials, high prices, and lack of knowledge, reasons commonly reported in previous research (Chan 2003; Fong 2002; Mati and de Boer 2011; Yu et al. 1995). Many practitioners called for regulations and processes for controlling the herbal trade. These changes could reduce the number of practitioners and increase business for certified practitioners. The confidence with which collectors and herbalists express their perceptions of the reasons behind substitution reinforces our belief that substitution is pervasive in herbal medicine in Morocco. It also underscores the extensive knowledge that many herbalists and collectors hold about the products on which their livelihoods depend.

Scarcity of material was given as a factor in substitution for 13 different medicinal roots. These roots represent a significant proportion of all the medicinal roots for which we recorded substitution and confusion, and an even higher proportion of those for which substitution was intentional. The fact that many important medicinal roots are not readily available in the markets of Marrakech suggests that the wild populations of these species may be in peril. *Tiguendizt* (*A. pyrethrum*), *Ziyata* (*Limoniastrum guyonianum*), *Boughlam* (*Spergularia marginata*), and *Serghina* (*Corrigiola telephifolia*) are harvested from the wild in the Azilal, Touama, and Rhamna regions of Morocco. These locations include many areas famous for their biodiversity and known for their ecosystem fragility (Medail and Quezel 1997). Overharvesting is especially likely to occur in medicinal plants where the bark or root is used (Ticktin 2004). There is a growing body of research indicating that medicinal plants and other non-timber forest products are too often harvested in an unsustainable manner, threatening the species, the ecosystem from which

they are obtained, and the livelihoods that local people derive from them (Roe 2008). The gravity of the issue of conservation and sustainability of medicinal roots in Morocco is clear in the case of *A. pyrethrum* var. *pyrethrum*. The scarcity and high demand for this species has led traders to substitute the root with *Anacyclus pyrethrum* var. *depressus* and *Catananche caerulea* L. Remarks by collectors suggest that the variety *A. pyrethrum* var. *pyrethrum* is overexploited in the wild. It is thus not surprising that local collectors express strong concern over the protection of the species and establishment of user rights. This species seems well placed for activities such as participatory assessment of traditional harvesting and management practices to improve sustainability and ensure conservation of this vulnerable species, as well as the fragile and biodiversity-rich ecosystem in which it grows (Ghimire et al. 2005; Ticktin and Johns 2002).

For a number of reasons, many of the medicinal roots for sale in the Marrakech markets may be of poor quality and/or adulterated with other species. Substitution and confusion by collectors and herbalists may lead to serious problems in public health. Other authors have noted the risks associated with confusion of medicinal plant species in Morocco. For example, Bellakhdar (1997) reported the risky practice of adding *Atropa belladonna* L. to a recreational herbal mixture called *M'aajoun* (to "liven up dull guests at wedding parties"). It has also been reported that *Chamaeleon gummifer* (L.) Less. has been mistaken to be *Scolymus hispanicus* L., *Cynara humilis* L., *Carlina acaulis* L., *Centaurea ornata* Willd., and *C. chamaerhaponticum*, resulting in over 50 % mortality when consumed (Skalli et al. 2002). Our research found that *C. gummifer* is sold as *Addad* in Marrakech with potential for toxic outcomes (Daniele et al. 2005). We identified many additional species where confusion may be a problem.

Pharmacologists and doctors, dismissing herbalists' knowledge and caution, expressed alarm over the risk of misidentification and misuse of medicinal roots and the potential for poisoning. The poor performance of some herbalists in the test of root identification further draws into question the adequacy of herbalists' knowledge. Even when not associated with toxic outcomes, confusion and intentional substitution can reduce efficacy of traditional medicine and thus reduce the confidence of patients. It is in the best interest of experienced

herbalists, Western medical practitioners, and public health officials to address the issues created by substitution and confusion of medicinal roots. Our work suggests that some herbalists may have enough knowledge to mitigate these risks (3 of the 40 who performed the identification task were able to correctly identify 100 % of the roots). The expertise of highly knowledgeable and experienced herbalists should be sought to develop systems to ensure efficacy and safety of herbal products sold in Morocco. Enhanced communication and integration between traditional and Western medical systems in Morocco is an important step needed to reduce the risk of adverse events from confusion, intentional substitution, or adulteration of herbal medicine, as well as herb-drug interactions. Experts from both medical systems expressed interest in the development of standards and regulations governing the sale of herbs. However, before this can be achieved there is a need for reconciliation between Western health care practitioners and herbalists to achieve better understanding of both the benefits and the risks of traditional herbal medicine.

### Acknowledgments

First we need to thank the Moroccan herbalists and collectors for their time and valuable discussions; we will never be able to repay them for their generosity. Thanks to our collaborators at the University of Uppsala and the Global Diversity Foundation, and to two anonymous reviewers whose comments helped us to make immense improvements to the manuscript. The authors are especially grateful to the Swedish Research Links (SRL) for financial support, and to the Museum of Natural History of Marrakesh (MHNM).

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