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No consensus in "traditional" medicine - Medicinal plants and their uses in the markets of Bogotá (Colombia), La Paz/El Alto (Bolivia) and Trujillo/Chiclayo (Perú)

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Local markets are an important source of medicinal plants in Bolivia, Colombia and Peru, and detailed information on larger markets in the countries has become available over the last decades. However, little comparative research reports on the pharmacopoeiae sold and the use-diversity between the markets of different countries. The present study provides a detailed comparison of medicinal plant markets in Bolivia, Peru and Colombia, hypothesizing that the species composition, and medicinal applications, should show similarities, based in the common colonial roots of medicinal plant use in the region. In this study, we encountered that both species composition and uses of species did show much larger differences across the evaluated countries than expected. Even in case of introduced species, we did hardly find any coincidence between the markets of the three countries. This might be explained by the great differences in the origin of populations, the floristic diversity, and the very distinct plant use knowledge and preferences of migrant populations in the respective cities that are transferred to the markets through customer demand. Our study clearly indicated that studies in single markets cannot give an in-depth overview on the plant supply across related regions.

Keywords: Medicinal plants, Markets, Bolivia, Colombia, Peru, Globalization
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Very little comparative information is available about which plants are sold in medicinal plant markets, under which vernacular name at any given time, for which indication, and which dosage information, and what kind of information about side effects vendors provide to their clients. Our own studies provide a framework for Peru, Bolivia and Colombia[1-12]. Lima *et al.*[12] provided a comparative review of Amazonian markets, mostly centering in Brazil, but the results from Andean and coastal markets in the different countries have never been compared. The present study attempts to compare the available information detailed inventories of medicinal plant markets Bolivia, Peru and Colombia (Fig. 1), hypothesizing that, like in Bolivia[13] the plant and use composition of different markets would vary depending on their location and customer population, but that there would be a large overlap in species and uses as effect

Fig. 1—Studied market locations across Colombia, Bolivia, and Peru

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of the shared colonial heritage of the countries investigated.

Materials and methods

Ethnobotanical Data

The authors have collected market data in semi-structured Peru, Bolivia and Colombia since 2007, based on their own market studies cited above. The nomenclature of all species follows www.tropicos.org, under APGIII[14].The present comparison covered 24 markets in Colombia, 6 markets in Bolivia and 2 market areas in Peru.

Statistical analysis

Among markets we compared plants species reported as being used (unique Latin binomials e.g. "*Aloe vera*"), plant-uses (unique combinations of a species used for an ailment or illness, e.g. "*Aloe vera* for eye irritation"), and plant-categories (unique combinations of a species used for a category of ailments, e.g. "*Aloe vera* for sensory system").

To compare the geographic/market structure of plants and plant-uses, we extracted lists of unique and shared plants, plant-uses, and plant-categories in each market[15]. In addition to these raw counts, we also used Euclidian distance as a metric of the difference among markets.

To evaluate plant importance, we used the Logarithmic Informant Consensus index of Dudney *et al.*[16]. Here, we considered markets as 'occurrences', so for a species:

LICs = sum (ICu * ln (FCus)

Where for each use of a species ICu= (FCu - NSu) / (FCu - 1), FCu is the total reports of that use and NSu is the number of species reported for the use.

To evaluate the diversity of uses across markets, we calculated, for each plant that occurred in at least two markets, the percent of its uses that are unique to each market.

All analyses were performed using the R program package[17].

Results

Plants in the market

The highest number of species (409) occurred in the markets of Bogotá, followed by Trujillo/Chiclayo in Peru (399) and La Paz/El Alto (163). This might not be surprising, given the higher biodiversity in Peru and Colombia in comparison to Bolivia. The plant family composition of the useful flora was however similar in all countries. Fabaceae (followed by Asteraceae and Lamiaceae) was the most important useful family in Colombia, compared to Asteraceae (Fabaceae and Lamiaceae) in Bolivia and Peru. In all areas Spanish was the by far most common language used for vernacular names. Everywhere most (up to over 75%), of medicinal plant remedies were taken orally as decoctions / infusions, and another many less (around 15 %) were applied as cataplasm. Applications involved preferentially leaves (> 40 %), aerial parts of the plant (> 20 %) or the whole plant (> 10 %).

Market comparison

An extremely large number of species was found in only a single market in Colombia, compared to many more species found in 2-3 markets in Bolivia or 2 markets in Peru (Fig. 2). The high proportion of unique plants in the markets of Bogotá did not show any relations to geography or market size. Two countries shared 10 % of species and 23 % of genera, while three countries shared 4 % of species and 10 % of genera. There was much more differentiation among plant-use combinations: two countries shared 6 % of species-uses and 12 % of genus-uses, and three countries shared only 1 % species-uses and 2 % genus-uses (Fig. 3). Only few species were shared among the markets of the three countries. Of the 36 shared species encountered in Bolivian, Colombian, and Peruvian markets, 25 were introduced in all three countries, and only 9 were widespread (between at least 6/24 markets in Colombia, 3/6 markets in Bolivia and 2/2 markets in Peru) in every country. Thirteen species were widespread in two countries,

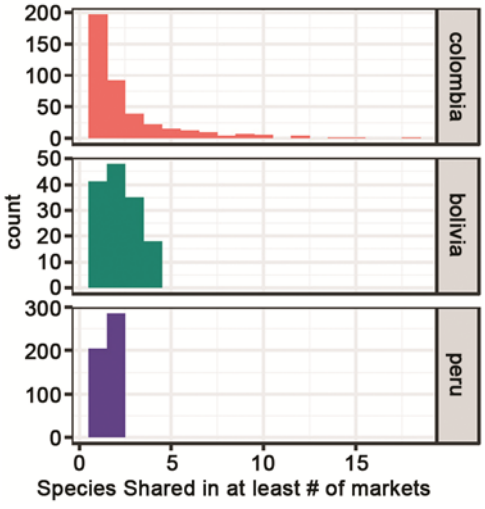

Fig. 2—Count of species shared and number of markets they are shared within across Colombia, Bolivia, and Peru

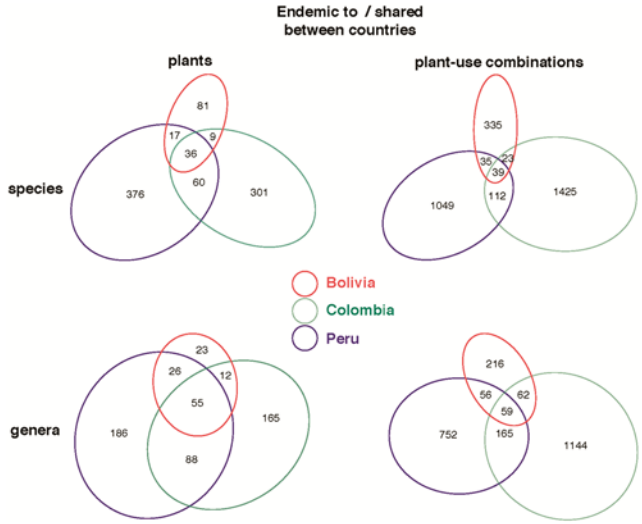

Fig. 3—Plant species, plant genera, species-use combinations, and genus-use combinations endemic to or shared among Peru, Bolivia and Colombia

13 in one country, and 1 (*Chenopodium quinoa*) was rarely found in all three countries (Table 1). Not surprisingly, while generally low, Informant Consensus (IC) was highest for introduced species (Table 1).

Peruvian markets were distant outliers. In the comparison of all countries, even the eleven most widespread plant species occurred in relatively few markets. Although there was some overlap, markets were clearly differentiated by country. Mean pair wise distance between markets was similar for Bolivia and Colombia, except in Uses, which differed much more widely in Bolivian markets (Fig. 4).

Discussion

In Bolivia and Peru, the small markets contained much less species than the main markets[4,8,13]. In contrast, in Colombia this difference did not occur. In contrast to the similarities in family composition, parts

Table 1—Regionally important species and uses. The number of uses categories shared in all three countries out of the total use categories reported across all countries are shown, and use categories indicated as: A – Digestive system, B – Infections and infestations, C – Urinary system, D – Cultural illnesses, E – Nervous system and mental health, F – Skin and subcutaneous system, G – Pregnancy, partum and puerperium, H – Respiratory system, I – Blood and circulatory system. p = species present in a country, w = species widely used. Species in bold are introduced.

Species	Colombia	Bolivia	Peru	Widespread in # countries	Shared uses / total uses
Mentha spicata L.	w	w	w	3	2/11: A, B
Equisetum bogotense Kunth.	w	w	w	3	2/11: C, A
Ruta graveolens L.	w	w	w	3	2/12: D, E
Aloe vera (L.) Burm. f.	w	w	w	3	2/13: A, F
Taraxacum officinale Wigg.	w	w	w	3	1/11: A
Cynara cardunculus L.	w	w	w	3	1/11: A
Foeniculum vulgare Mill.	w	w	w	3	1/12: G
Eucalyptus globulus Labill.	w	w	w	3	1/13: H
Artemisia absinthium L.	w	w	w	3	1/15: D
Melissa officinalis L.	**w**	p	**w**	2	2/5: E, I
Rosmarinus officinalis L.	p	**w**	**w**	2	5/15: E, I, D, H, A
Croton lechleri Müll. Arg.	p	**w**	**w**	2	2/6: F, A
Cymbopogon citratus (DC.) Stapf	**w**	p	**w**	2	3/12: E, A, H
Allium sativum L.	**w**	p	**w**	2	2/11: D, H
Mentha x *piperita* L.	**w**	p	**w**	2	1/8: A
Borago officinalis L.	**w**	p	**w**	2	1/9: H
Opuntia ficus-indica (L.) Mill.	p	**w**	**w**	2	1/9: C
Equisetum giganteum L.	p	**w**	**w**	2	1/10: C
Spartium junceum L.	p	**w**	**w**	2	0/8
Ficus carica L.	p	**w**	**w**	2	0/10
Schinus molle L.	p	**w**	**w**	2	0/12
Sambucus peruviana Kunth	**w**	p	**w**	2	0/14
Phyllanthus niruri L.	p	p	**w**	1	2/7: C, A
Peumus boldus Molina	p	p	**w**	1	2/12: A, C
Plantago major L.	p	p	**w**	1	2/12: A, C

(Contd.)

Table 1—Regionally important species and uses. The number of uses categories shared in all three countries out of the total use categories reported across all countries are shown, and use categories indicated as: A – Digestive system, B – Infections and infestations, C – Urinary system, D – Cultural illnesses, E – Nervous system and mental health, F – Skin and subcutaneous system, G – Pregnancy, partum and puerperium, H – Respiratory system, I – Blood and circulatory system. p = species present in a country, w = species widely used. Species in bold are introduced. (Contd.)

Species	Colombia	Bolivia	Peru	Widespread in # countries	Shared uses / total uses
Malva parviflora L.	p	p	**w**	1	0/6
Brassica rapa L.	p	**w**	p	1	0/8
Erythroxylum coca Lam.	p	p	**w**	1	0/8
Urtica urens L.	**w**	p	p	1	0/11
Chenopodium quinoa Willd.	p	p	p	0	0/7

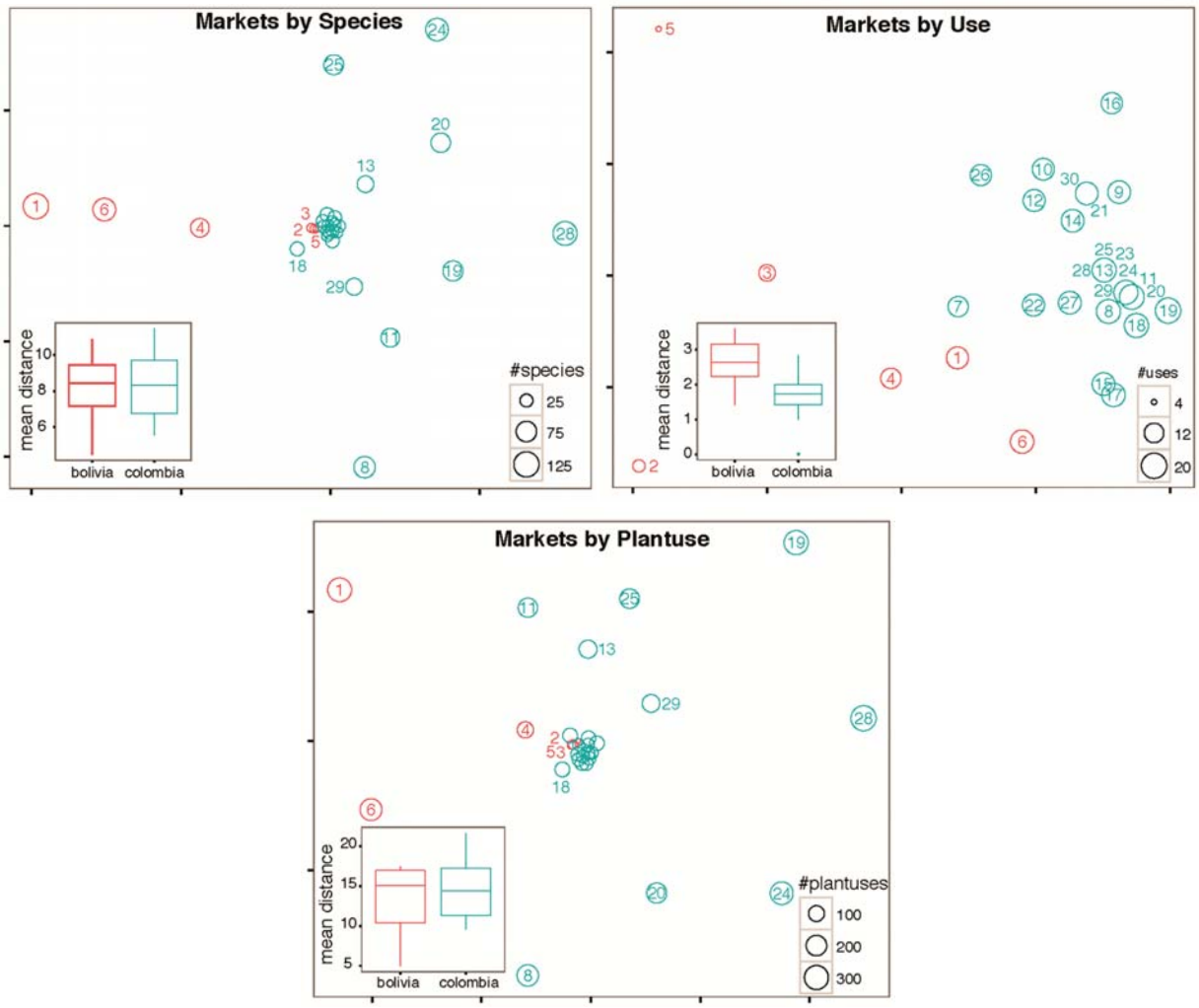

Fig. 4—Ordination of Bolivian and Colombian markets in plant-space, use-space, and plant-use space. Peru markets are distant outliers and not shown here

used, and mode of preparation, the species composition and plant-uses divergence in the markets of Bogotá was however astonishingly high. Markets in Bogotá had very large numbers of unique plants, even compared to Bolivia[13], and the difference between the plants individual markets reported was not explained by geographical factors (by 9 geographical zones: p = 0.37; by 15 localities: p = 0.41) nor size (by number of species reported: p = 0.22).This was completely on contrast to our initial hypothesis that markets in Andean countries like Bolivia, Colombia and Peru would have large similarities in species composition and uses, especially based on colonial heritage.

Conclusion

The present study indicated very large differences in species composition and use diversity of medicinal plants in the markets studied in Bolivia, Colombia and Peru. This difference even covered introduced species. Our hypothesis that colonial heritage would have influenced medicinal plant use was clearly proved wrong. The species composition and species-use patterns in the markets were clearly more a result of the great differences in the origin of populations in La Paz/El Alto, Trujillo/Chiclayo, and Bogotá, and the floristic diversity in the respective countries, and the very distinct plant use knowledge and preferences of the local populations, that were transferred to the markets through customer demand. Our study clearly indicates that studies in single markets cannot give any in-depth overview on the plant supply and use within the region.

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Author contributions

RWB and NYPZ designed the study; CR conducted the fieldwork, RHE conducted the main statistical analysis; RBU, NYPZ, CMand RHE analyzed the data and wrote the manuscript; all authors read, corrected and approved the manuscript.

Competing financial interests

The authors declare that they have no competing financial interest.

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