Journal of Ethnopharmacology 135 (2011) 476–487

Contents lists available at ScienceDirect

Journal of Ethnopharmacology

journal homepage: www.elsevier.com/locate/jethpharm

Cross-cultural comparison of three medicinal floras and implications for bioprospecting strategies

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ARTICLE INFO

Article history:
Received 18 November 2010
Received in revised form 18 February 2011
Accepted 22 March 2011
Available online 30 March 2011

Keywords:
Binomial analysis
Bioprospecting
Cape of South Africa
Cross-cultural ethnomedicine
Nepal
New Zealand
Regression analysis

ABSTRACT

Ethnopharmacological relevance: One of the major drawbacks of using ethnomedicinal data to direct testing of plants which may find pharmaceutical use is that certain plants without bioactivity might be traditionally used. An accepted way of highlighting bioactive plants is to compare usage in different cultures. This approach infers that presumed independent discovery by different cultures provides evidence for bioactivity. Although several studies have made cross-cultural comparisons, they focussed on closely related cultures, where common patterns might be the result of common cultural traditions. The aim of this study was to compare three independent ethnomedicinal floras for which similarities can be more robustly interpreted as independent discoveries, and therefore likely to be indication for efficacy.
Materials and methods: Data from the literature were compiled about the ethnomedicinal floras for three groups of cultures (Nepal, New Zealand and the Cape of South Africa), selected to minimise historical cultural exchange. Ethnomedicinal applications were divided in 13 categories of use. Regression and binomial analyses were performed at the family level to highlight ethnomedicinal "hot" families. General and condition-specific analyses were carried out. Results from the three regions were compared.
Results: Several "hot" families (Anacardiaceae, Asteraceae, Convolvulaceae, Clusiaceae, Cucurbitaceae, Euphorbiaceae, Geraniaceae, Lamiaceae, Malvaceae, Rubiaceae, Sapindaceae, Sapotaceae and Solanaceae) were recovered in common in the general analyses. Several families were also found in common under different categories of use.
Conclusions: Although profound differences are found in the three ethnomedicinal floras, common patterns in ethnomedicinal usage are observed in widely disparate areas of the world with substantially different cultural traditions. As these similarities are likely to stem from independent discoveries, they strongly suggest that underlying bioactivity might be the reason for this convergent usage. The global distribution of prominent usage of families used in common obtained by this study and the wider literature is strong evidence that these families display exceptional potential for discovery of previously overlooked or new medicinal plants and should be placed in high priority in bioscreening studies and conservation schemes.

1. Introduction

Bioprospecting is the screening of organisms for novel natural products beneficial to human or animal health, or with applications in industrial sectors such as pest control. Ethnomedicine and ethnopharmacognosy have assisted bioprospecting in several cases; one survey showed that 80% of 122 plant-derived chemical products used in medicine are used congruently to their ethnomedicinal application and in many cases investigations for compounds from plants have been stimulated by knowledge of ethnomedicinal use (Fabricant and Farnsworth, 2001). Clarkson et al. (2004) screened a number of plant species used in ethnomedicine for malaria and showed that selection of plants based on traditional knowledge is effective in this case. Furthermore, Wright et al. (2007) in their review found evidence of bioactivity of many plants used as diuretics in ethnomedicine. With less than 15–20% of plant species screened to date, the potential for discovery of new drugs from plants based on ethnomedicinal knowledge is immense (Soejarto et al., 2005). However, reports have shown that even if ethnomedicine-directed screening schemes are expected to lead to high success rates, these have not been realised by recent bioprospecting efforts (Firn, 2003). Indeed, in studies that screen

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doi:10.1016/j.jep.2011.03.044

plants used in ethnomedicine to test their efficacy against specific conditions, it is common that, despite some successful hits, no activity is found (Martínez et al., 1996; Perumal Samy et al., 1998; Sokmen et al., 1999; Essawi and Srour, 2000; Ali et al., 2001) and it may be assumed that negative results are underrepresented in the literature. As funds and time are limited, the effectiveness of such schemes needs to be maximised and one way to achieve this is to employ more specific and validated criteria to identify ethnomedicinal species that are likely to possess biological activity.

In order to maximise effectiveness, ethnobotanists have sought techniques to highlight plants that are more prominently used than others. For example, persistence of use over time (Keung and Vallee, 1998; Dev, 1999; Grover et al., 2002) and frequency of use (Ankli et al., 1999; Dhar et al., 2000; Di Stasi et al., 2002) are highlighted in many studies. Different measures of cultural importance of a plant in ethnomedicine have been employed in order to underline plants that are more likely to be efficacious, including the "relative cultural importance" index (Prance et al., 1987; Phillips and Gentry, 1993a, 1993b), the "informant consensus" (Trotter and Logan, 1986), the "cultural significance index" and various others. Agreement in use and cultural importance can be sought within cultural groups (Heinrich et al., 1998; Gazzaneo et al., 2005; Teklehaymanot and Giday, 2007) or between them (Heinrich et al., 1998; Leporatti and Ivancheva, 2003; Jain, 2004; Leporatti and Ghedira, 2009). All these approaches assume that a consistent pattern of usage of a plant within or between cultural groups is more likely to be found for plants with a scientifically demonstrable biological effectiveness. Using intracultural significance as a proxy for biological activity has increased positive hits in bioscreening schemes (Johns et al., 1995; Canales et al., 2005; Uprety et al., 2010), however not with absolute success rates. Comparing plants used by different cultures and seek common patterns might prove more effective (Heinrich et al., 1998; Bletter, 2007). If plants have been selected independently more than once, the case for their efficacy can be made stronger.

Several studies have performed intercultural comparisons of ethnomedicinal floras in this context and have found common patterns. However, one of the difficulties with interpreting informant agreement as evidence of activity is that the meaning of plants may be transmitted between cultures, resulting in consensus in use despite a lack of biological activity. There is, indeed, evidence that horizontal cultural exchange can lead to common ethnomedicinal uses and, therefore, shared usage might not indicate independent discovery. This might be true especially in relatively close cultures, or ones with recent cultural exchange. For example, Pieroni and Giusti (2008) compared the ethnomedicinal flora of a recently migrated group of Croatians in a multicultural region in Croatia with those of cultures that were older migrants in the area and with traditional Italian systems. Their findings showed that even recently migrated ethnic groups in that region, after being exposed to the new flora, adopted ethnomedicinal systems similar to those of their new neighbours. Reyes-Garcia et al. (2003) found similarities between the ethnofloras of Tsimane' Amerindians from 59 villages in the Bolivian Amazon. These similarities were not correlated with socio-demographic or ecological differences and were attributed to cultural transmission between the ethnic groups. Finally, Balemie and Kebebew (2006) compared the local ethnobotanical systems of three ethnic groups from two districts in Ethiopia, where they found parallel use mostly within the same biogeographic region rather than within cultural groups, suggesting that groups with more frequent cultural exchange share more ethnomedicinal traits.

A number of comparative studies have found evidence of parallel ethnobotanical use due to shared recent or more ancient cultural history via vertical transmission. Inta et al. (2008) compared the medicinal floras of two related Akha groups that migrated recently (100–120 years) around southern China and northern Thailand. The two communities carried with them their cultural traditions, which they applied in different natural environments with different floras. They maintained, nevertheless, strong cultural coherence in their ethnomedicinal floras (Inta et al., 2008). Terashima (2003) compared the names and uses of ethnotaxa for two communities of Ituri forest hunter-gatherers that were once one Pygmy ethnic group that still retain cultural similarities. He found that many taxa are used in common and their ethnomedicinal names are highly similar, although their languages are different. He hypothesised that they are relics of a common ancient Pygmy language that have been kept due to their cultural importance. Similarly, Leonti et al. (2003b) revealed notable cases of common usage between two Macro-Mayan ethnic groups in Mexico. Those two groups have been mutually isolated for approximately two millennia and use different languages. The authors claimed that the linguistic affinities of several important taxa in their ethnopharmacopoeias reveal antiquity of usage of these taxa from an ancient common culture that was inherited vertically to these two groups (Leonti et al., 2003b). Finally, Leonti et al. (2009) compared the ethnofloras of Sicily and Sardinia. They concluded that similarities might be results of common traditions, even different written versions of *De Materia Medica*. Therefore, vertical transmission of ethnomedicinal knowledge does take place, at least between closely related cultures.

Although horizontal and vertical transmission of ethnomedicinal knowledge is interesting from a historical and anthropological point of view, transmission of either kind hinders the quest for efficacious plants if symbolic plants are as likely to be transmitted as efficacious ones. However, if the cultures under study are not closely related, such common patterns are more likely to be independent discoveries. Bletter (2007) discusses this framework in detail, stating that usage of related plants for similar diseases in distant cultures are more likely to be independent discoveries of similar bioactivity in those plants against a given group of diseases. In his work he found evidence for related plants that were used in similar ways in communities in Peru and Mali. Moreover, Roersch (2010) highlights the importance of cross-cultural corroboration of medicinal usage to guide bioprospecting. In his ethnomedicinal review of *Piper umbellatum*, a species found in the Americas, Africa and Asia, he records its uses in 24 countries, stating that those with consensus across different cultures are more likely to be supported with scientific evidence and should be prioritised in pharmacological studies.

Most cross-cultural studies have investigated similarities in usage at a low taxonomic level. Comparisons at this level are usually feasible between relatively geographically close cultures that are exposed to similar floras and, hence, the same or even similar plants can be selected in traditional medicine. For example, in a comparison between the ethnofloras of Italy and Bulgaria, different congeneric species were found to be used between the two countries. The authors state that these differences are linked with the presence or absence or different abundances of different species in these regions (Leporatti and Ivancheva, 2003). Although these common patterns are interesting and can provide information on what plants are likely to be efficacious, independent discovery cannot be separated from cultural exchange in this case. This is a limitation with most studies at this level, as neighbouring cultures are likely to be related or have had recent cultural exchange.

A study by Moerman (1991) suggested a novel method of highlighting culturally important plant groups in ethnomedicinal systems. Using a regression analysis, a method was devised for highlighting those families that are richer or poorer in medicinal plants than expected by chance in a specific area, and this showed that medicinal properties are not distributed randomly across groups of plants, but different subclasses and families differ in their relative richness in medicinal plants in the North American flora (Moerman, 1991). A number of other studies applied the same method to other floras and different cultures [e.g. five holarctic floras: (Moerman et al., 1999); Popoluca, Mexico: (Leonti et al., 2003a); Southern Africa: (Douwes et al., 2008); Belize: (Amiguet et al., 2006)]. A similar method was employed by Bennett and Husby (2008) for the medicinal flora of Ecuadorian Shuar. Contingency tables were used and these showed that medicinal species were not distributed equally among taxonomic groups. Using binomial analyses the outstanding taxonomic groups in that medicinal flora were highlighted.

Such methods are appropriate for the present study for two reasons: (i) they are looking at high taxonomic groups (families, orders) instead of species, which makes the comparison more feasible for unrelated groups of cultures from distant localities and (ii) by identifying cross-cultural "hot" groups, those that are culturally important in several cultures, it is more likely that ineffective taxa are discounted.

Although some of the studies employing these methods compared their findings to those from other studies mentioning some families in common, only Moerman et al. (1999) explicitly compared "hot" ethnomedicinal groups across different regions. Their findings suggested that many locally "popular" families were popular in all four different regions that fall into the holarctic kingdom. However, the fifth region in their analysis (Ecuador), a region with dramatically different floristic composition (neotropical) when compared to the other four, shows differences in the "hot" groups. The similarities of the four holarctic ethnomedicinal floras were attributed to the presence of broadly the same families throughout these areas. There is a clear need for cross-cultural comparisons of plant use, as the gap in related literature is notable. By compiling more information on cross-cultural usage a clearer idea of which plant groups are those with higher potential in bioprospecting, both locally and globally, can undoubtedly be seen.

The main objective of this study was to perform an explicit quantitative cross-cultural analysis between geographically and culturally distant areas and to investigate whether there are common patterns in ethnomedicinal usage. To tackle this we collected ethnomedicinal information from the literature for three regions (Nepal, New Zealand and the Cape of South Africa) and performed regression and binomial analyses for each flora in order to highlight overrepresented taxa in traditional medicine ("hot" groups). The working hypothesis was that people from different cultures exposed to different floras will use similar plant groups in their ethnomedicinal floras in similar ways. Investigating common patterns at a high taxonomic level is more appropriate for such a comparison, as in this set of regions the respective floras are dramatically different. Therefore, species-level comparisons are not feasible and not many genera are found in common between the three floras and analyses were performed at the family level. Subsequently, taxa used congruently between the three regions were sought to provide evidence that such groups are efficacious, and hence suggest they should be prioritised in prospecting and conservation schemes. By selecting distantly related cultures, we aimed to minimise the possibility that any common patterns are due to cultural exchange or shared cultural history.

1.1. Regions of study

Nepal is a country located in the Himalayas and its area is estimated at 147,200 km^2. The flora of Nepal includes components of the western Himalaya and the eastern Himalaya, as well as the Tibetan Plateau, the lowland plains (Terai) from the Gangetic plains of India and further into Indochina (www.floraofnepal.org) (Royal Botanic Gardens Edinburgh, 2010). The size of the flora is estimated at around 6000–6600 species of flowering plants, distributed across 1577 genera and 230 families (Press et al., 2000) with 246 species (∼4%) endemic to Nepal (Shrestha and Joshi, 1996). The population of the country is equally diverse, comprising 61 ethnic groups mainly of Tibetan and Indian origin speaking 75 languages (Shrestha and Singh, 1992; Manandhar, 2002).

New Zealand composes an archipelago with three main islands (North Island, South Island and Stewart Island) southeast of Australia in the southern Pacific Ocean, forming an area of about 268,680 km^2. The size of the flora exceeds 4000 species belonging to 1140 genera and 191 families (Wilton and Breitwieser, 2000). One of the flora's characteristics is high endemicity (47.5%, 1900 species). Furthermore, less than half of the species (1900 in 440 genera) are autochthonous. Native people (Māori) are of Polynesian origin and were isolated since they settled in New Zealand around 1300 A.D. (Wilmshurst et al., 2008) until the 18th century, when New Zealand was colonized by Europeans (Mein-Smith, 2005). The isolation of the Māoris has allowed for a largely independent ethnopharmacopoeia and, although local ethnomedicine will have undoubtedly been influenced by the advent of Europeans, the pre-colonial ethnomedicinal flora is well documented.

The Cape of South Africa is an area of about 90,000 km^2 located at the southeastern tip of Africa. The flora comprises more than 9000 plant species, with about 70% endemics distributed in 944 genera (16% of which are endemic) and 147 families (Goldblatt and Manning, 2002). The population of the Cape of South Africa (provinces of Western and Eastern Cape) is comprised of various ethnic groups. According to the South African Census 2001, Africans (from the black ethnic groups Nguni, Sotho, Shangaan-Tsonga and Venda) compose the majority of the population (62%), followed by Coloureds of mixed origins (27%), white groups of Afrikaans and British descent (10.5%) and Asian South Africans (0.5%) (http://www.statssa.gov.za/census01/html/default.asp) (Statistics South Africa, 2010). Traditional medical practices are used by around 27 million South Africans (Mander, 1998) and as the medical doctor to population ratio is 1:17,400 in South Africa (Pretorius et al., 1993) traditional medicine is particularly important.

2. Materials and methods

2.1. Selection of regions and floras

The selected areas were chosen to represent distantly related cultures, as well as dissimilar floras. Culture and human population phylogenies (Bateman et al., 1990; Long et al., 1990) were used to select distantly related human groups. These studies recover three major clades: the African, the North Eurasian, and the Southeast Asia (Fig. 1). One region was selected from each clade respectively: Cape of South Africa, Nepal, and New Zealand.

Furthermore, the floras of these regions are also notably different, as they belong to three different floristic kingdoms (Takhtajan et al., 1986): the South African kingdom for the Cape of South Africa (Cape region), the Holarctic kingdom for Nepal (elements from Eastern-Asiatic and Irano-Turanian regions), and the Antarctic kingdom for New Zealand (Neozeylandic region).

2.2. Data collection and organisation

The complete list of species from the flora of Nepal was compiled from Press et al. (2000) and the updated online version of this volume (www.floraofnepal.org) (Royal Botanic Gardens Edinburgh, 2010). The list of genera for the flora of New Zealand was assembled from the online version of the flora (http://floraseries.landcareresearch.co.nz/pages/index.aspx) (Landcare Research, 2010a). Finally, the list of genera for the flora of the

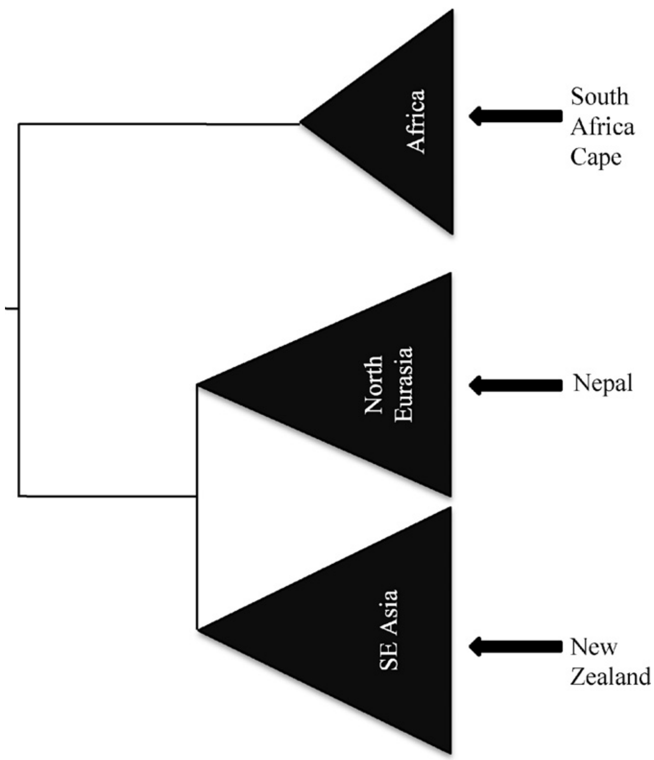

Fig. 1. Summary of phylogenies of human cultures and human populations from published studies that recover three major clades of human groups. One culture and its respective flora were selected from each of these three clades.

Cape of South Africa was compiled from Goldblatt and Manning (2000). Genera were subsequently organised into families. The delimitation of families followed the classification of APG III.

Data for the medicinal uses were gathered from (Riley, 1997) and (Brooker et al., 1981; Brooker et al., 1989) and the *Ngā Tipu Whakaoranga database* (http://maoriplantuse.landcareresearch.co.nz) (Landcare Research, 2010b) for New Zealand, (Manandhar, 2002) and (Suwal, 1993) for Nepal and (Neuwinger, 2000) and (Van Wyk et al., 1997) and the Survey of Economic Plants for Arid and Semi-Arid Lands (http://www.kew.org/ceb/sepasal/) (Royal Botanic Gardens Kew, 2010) for the Cape of South Africa. For each species we recorded its ethnomedicinal uses by the indigenous people.

Medical conditions were grouped into 13 categories. Although similar classifications are often used in similar studies (Moerman, 1991; Leonti et al., 2003a) there is no consistent classification of conditions. However, we tried to adhere to previous groupings. The conditions we used were the following: Cardiovascular problems/Blood purity, Dentistry/Stomatology, Gastro-Intestinal conditions, General, Gynaecology/Fertility, Neurological conditions, Ophthalmology, Musculo-skeletal conditions, Skin conditions, Other, Oto-rhino-laryngology, Respiratory/Pulmonary ailments, and Urinary conditions.

2.3. Regression analyses

2.3.1. General regression analyses

General regression analyses were performed at the family level. Following Moerman's (Moerman, 1991) rationale, this is a way of highlighting groups that are overrepresented or underrepresented in a medicinal flora. Those with extreme positive values are used more frequently and those with extreme negative values are used less frequently than expected from the model. Here we are focussing on the overrepresented families. Outliers were identified using the interquartile range (IQR) of the distribution of *r* values. Positive outliers are those with *r* values 1.5 times the IQR or more above from the third quartile ($Q_3 + 1.5 \times \text{IQR}$).

2.3.2. Condition-specific secondary regression analyses

Condition-specific regression analyses were performed to highlight "hot" families for each category of use in each area. Two types of regression analyses were conducted per category per area. Both took into account only the families with at least one recorded use for the category under consideration.

In the first type the total number of species per family versus the number of species used for the specific category was plotted in order to answer the question: How important is the family in the ethnopharmacopoeia for the category under consideration?

In the second type the number of medicinal species per family versus the number of species used for the specific category was plotted to answer the question: How specific is medicinal usage of the family for the category under consideration?

"Condition-specific hot families" were considered to be those that are recovered in both these secondary analyses under each category of use. This way important families for each category of use can be identified using two criteria: (i) that the family is used more than expected for the category under consideration and (ii) that the use for this category is predominant within the family. All regression analyses were carried out in Microsoft Excel 2007.

2.4. Binomial analyses

Further to regression analyses, we conducted binomial analyses as described by Bennett and Husby (2008). This method, although not as widely applied as regression analysis, has the same rationale, but with different underlying assumptions: to highlight those families that depart from a uniform model of proportion of medicinal plants in a given flora. Binomial analyses were carried out in Microsoft Excel 2007, as described in Bennett and Husby (2008).

2.5. Similarities between total and medicinal floras

To assess the overall similarities between the floras the Pearson correlation coefficient between all possible pairs of (i) the total and (ii) the medicinal floras was calculated, as in previous similar studies (Moerman et al., 1999; Leonti et al., 2003a). The range of the metric is from minus one, denoting opposite trends in the two floras, to one, denoting identical trends. For pair-wise comparisons of the total floras, the calculation of the coefficient took into account the number of species in each family in the two floras. When a family was present in one flora and not in the other, the number of species was set to zero in the second one. However, for the medicinal floras the calculation of the coefficient was based on the residual values from the general regression analysis and therefore only the families present in both regions were taken into account (Moerman et al., 1999).

3. Results

3.1. Overview of ethnopharmacopoeias

The size and taxonomic distribution of the medicinal flora of each region is given in Table 1. Nepal has the richest ethnomedicinal flora in terms of species number (982 species) and percentage of generic and family coverage. In all three cases the local ethnopharmacopoeias are taxonomically broad, covering more than half the families present in the local floras.

The three medicinal floras demonstrate similarities in the main categories of conditions they are used to treat. More specifically, as

Table 1
Overview of the ethnomedicinal floras of Nepal, New Zealand, and the Cape of South Africa.

	Number of medicinal species	% of total flora	Number of medicinal genera	% of total flora	Number of medicinal families	% of total flora
Nepal	982	17.1	626	39.8	160	71.1
New Zealand	165	8.3	115	26.2	65	56.4
Cape of South Africa	323	3.6	214	22.7	89	60.5

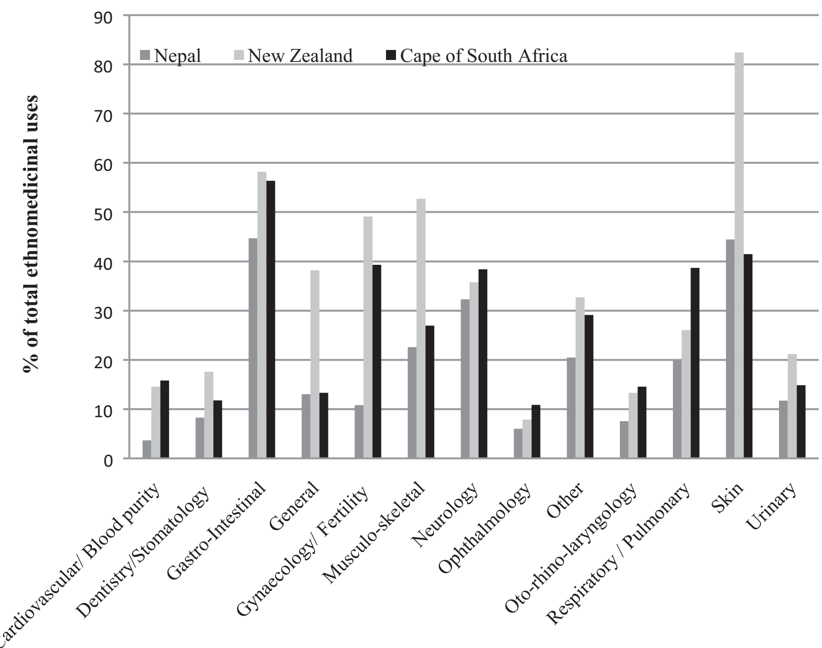

Fig. 2. Percentage of total ethnomedicinal uses per category of use in the ethnopharmacopoeias of Nepal, New Zealand and the Cape of South Africa.

shown in Fig. 2, in all three regions Skin conditions and Gastro-Intestinal conditions are the most common conditions treated. These include treatments for wounds and skin diseases, diarrhoea, stomach disorders, and intestinal parasites. Although these categories prevail in all three floras, there are underlying differences. For example, the most commonly used Gastro-Intestinal remedies in Nepal are for diarrhoea/dysentery, in New Zealand they are against intestinal parasites, while in the Cape of South Africa stomach disorders and diarrhoea/dysentery treatments are the most common ones. Dentistry/Stomatology and Ophthalmology remedies are among the least commonly encountered in all three areas (Fig. 2).

3.2. Similarities between the floras

The similarities of the total and the medicinal floras at the family level are given in Table 2. The values recovered for the total floras are higher than those for the medicinal floras. Nepal and New Zealand demonstrate the highest similarity in their total and medicinal floras. Lower levels of similarity were recovered in the other two pair-wise comparisons (Table 2). A paired Student's t-test between the means of the similarity values of the total and the medicinal floras was performed to test the null hypothesis (H_0) that the similarity of the total floras is not significantly higher than the similarity of the medicinal floras. The results ($p = 0.012$) reject the H_0, so in these three regions the total floras are significantly more similar than the medicinal ones.

3.3. Regression and binomial analyses at regional level

Regression analyses across all families from the three areas obtained different models for each region. The equation parameters and the graphs for all three areas are shown in Fig. 3. Based on the residual values for families from these regression analyses we highlighted those that were positive outliers ("hot" families) per area, as shown in Table 3. Nepal has the largest number of positive outliers (24 families, 12.2%), followed by The Cape of South Africa (13 families, 8.8%) and New Zealand (7 families, 6%). The top five families were as follows: Fabaceae, Lamiaceae, Asteraceae, Euphorbiaceae and Rubiaceae in Nepal, Myrtaceae, Podocarpaceae, Geraniaceae, Malvaceae and Asteraceae in New Zealand, Asteraceae, Poaceae, Solanaceae, Malvaceae and Lamiaceae in the Cape of South Africa. Eight families were positive outliers in at least two of the three regions. These are: Anacardiaceae, Asteraceae, Convolvulaceae, Geraniaceae, Lamiaceae, Malvaceae, Rubiaceae and Solanaceae (Table 3).

Table 2
Similarities between the total and medicinal floras of Nepal, New Zealand, and the Cape of South Africa at the family level, calculated with the Pearson correlation coefficient. Values in cells: similarities of total floras (left), similarities of respective medicinal floras (right).

	Cape of South Africa		Nepal		New Zealand
Cape of South Africa	1.00				
Nepal	0.58, $p = 0.000$	0.13, $p = 0.682$	1.00		
New Zealand	0.44, $p = 0.000$	0.18, $p = 0.108$	0.72, $p = 0.000$	0.35, $p = 0.001$	1.00

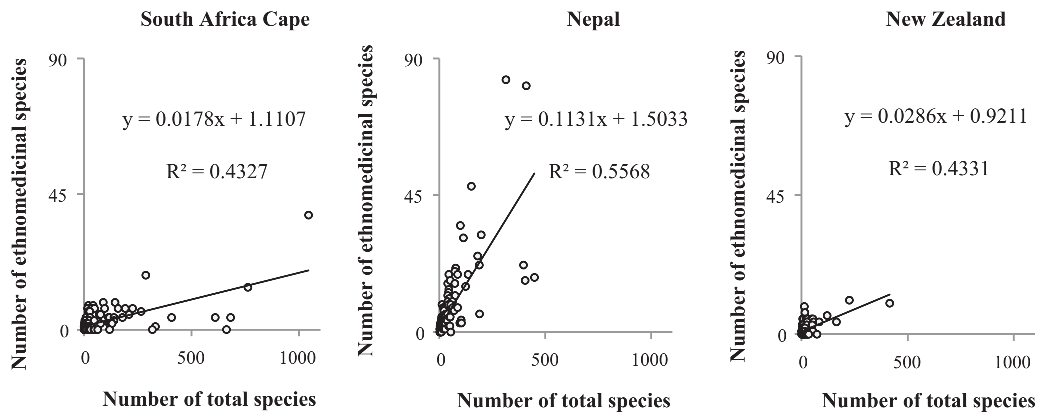

Fig. 3. Regression plots at the family level for the Cape of South Africa (left), Nepal (centre), and New Zealand (right) with equation details for each region.

The results from the binomial analyses are given in Appendix A. There were 20 families that had statistically more medicinal species than the total flora in Nepal (8.7% of the total families), 45 for the South African Cape (30.6%) and 16 for New Zealand (8.6%). Nine families have more species than expected in at least two of the tree regions: Clusiaceae, Cucurbitaceae, Euphorbiaceae, Lamiaceae, Malvaceae, Rubiaceae, Sapindaceae, Sapotaceae and Solanaceae (Appendix A). The comparison of overrepresented families recovered from regression and binomial analyses is shown in Table 3.

3.4. Regression analyses per category of use

The results of secondary regression analyses are shown in Appendix B. In general, different families are used for the same category of condition in different floras (Appendix B). It requires only 37 families for Nepal (23% of the medicinal flora, 16% of the total flora), 12 for New Zealand (18% of the medicinal and 6% of the total flora) and 22 for the Cape of South Africa (25% and 15% of the medicinal and total flora, respectively) to cover all the "hot" fam-

Table 3
Positive outliers as recovered from regression analyses of the ethnomedicinal floras of Nepal, South Africa Cape, and New Zealand. "Regression" columns: Numbers show the ranking of the family in each ethnomedicinal flora, starting from the one with the largest residual value as recovered from regression analyses. Numbers followed by '*' indicate that the family was recovered as a positive outlier in the respective ethnomedicinal flora. "Binomial" columns: '*' denotes that the family has statistically more medicinal species than expected in the flora, '–' denotes that the family does not have statistically more medicinal species than expected as recovered from binomial analyses. Families with n.p. in both columns are not present in the local flora and those in bold were recovered as positive outliers in regression analyses for at least two areas.

Family	Nepal		South Africa Cape		New Zealand	
	Regression	Binomial	Regression	Binomial	Regression	Binomial
Amaryllidaceae	–	–	13*	–	–	–
Anacardiaceae	24*	–	12*	*	33	–
Apocynaceae	8*	*	32	–	44	–
Araliaceae	85	–	39	*	7*	–
Asparagaceae	109	–	8*	*	n.p.	n.p.
Asteraceae	3*	–	1*	–	5*	–
Caryophyllaceae	188	–	135	–	6*	*
Celastraceae	58	–	11*	*	65	–
Clusiaceae	18*	*	29	*	n.p.	n.p.
Combretaceae	14*	*	n.p.	n.p.	n.p.	n.p.
Convolvulaceae	21*	–	10*	*	28	–
Cucurbitaceae	15*	*	23	*	68	–
Ebeneaceae	171	–	6*	*	n.p.	n.p.
Euphorbiaceae	4*	*	17	–	20	*
Fabaceae	1*	*	81	–	32	–
Geraniaceae	27	–	7*	–	3*	*
Lamiaceae	2*	*	5*	–	26	–
Lythraceae	19*	*	91	–	n.p.	n.p.
Malvaceae	9*	*	4*	*	4*	*
Melastomataceae	20*	*	n.p.	n.p.	n.p.	n.p.
Moraceae	6*	*	123	–	50	–
Myrtaceae	45	–	110	–	1*	*
Oleaceae	23*	–	43	*	98	–
Poaceae	197	–	2*	*	116	–
Podocarpaceae	138	–	n.p.	n.p.	2*	*
Polygonaceae	12*	–	42	*	27	–
Rosaceae	17*	–	126	–	11	–
Rubiaceae	5*	*	9*	–	10	–
Rutaceae	11*	*	47	–	52	–
Solanaceae	10*	*	3*	*	22	*
Symplocaceae	24*	*	n.p.	n.p.	n.p.	n.p.
Urticaceae	16*	–	127	–	62	–
Verbenaceae	7*	*	114	–	83	–
Vitaceae	22*	–	21	*	n.p.	n.p.
Zingiberaceae	13*	*	n.p.	n.p.	n.p.	n.p.

ilies for all the conditions. In all three cases, breaking down plant use per category of use recovers more families than in the general regressions.

Despite the differences in the three local ethnopharmacopoeias, we detected common use of some families for the same category in different regions. The common families in at least two of the three areas that were recovered under specific categories of use are the following: Cardiovascular: Asteraceae, Dentistry/Stomatology: Rutaceae and Solanaceae, Skin: Asteraceae, Geraniaceae, Lamiaceae, Malvaceae and Solanaceae, Gastro-intestinal: Rosaceae, Asteraceae and Lamiaceae, Gynaecology/Fertility: Solanaceae, Neurology: Asteraceae, Lamiaceae and Solanaceae, Musculo-skeletal: Asteraceae, Lamiaceae and Solanaceae, Other: Apocynaceae, Asteraceae and Solanaceae, Oto-rhino-laryngology: Caryophyllaceae (Appendix B).

4. Discussion

4.1. Similarities of ethnomedicinal systems

Our results show that the three ethnomedicinal systems under study are largely different, as shown by the low similarity values of the medicinal floras and the different "hot" families used both overall and for specific conditions in the three regions. Furthermore, the similarities between the medicinal floras were lower than in other studies (Moerman et al., 1999; Leonti et al., 2003a; Amiguet et al., 2006). This is an expected result, as regions with distinct floras and cultures were selected in order to ensure that floristic similarity and cultural contact are minimised as determinants of any common patterns that may occur.

Comparative ethnomedicine predicts that if people had selected largely similar plant groups in their ethnomedicinal floras, then higher similarities in the medicinal than in the total floras would be observed (Bletter, 2007). However, this study shows that the similarity values of the medicinal floras are significantly lower than those of the total floras. This negative correlation has been recovered in previous studies (Moerman et al., 1999; Leonti et al., 2003a). The intuitive interpretation of this is that the three traditional medicinal systems are governed by different criteria and principles. However, given the striking differences in the three floras, this might not be the case. Even when a family is present in two or three distinct geographical regions, it usually has substantially different compositions in those regions. People might be using the same criteria to discover efficacious plants, but since the family compositions are so different, family membership might not be a good proxy for shared efficacy. However, many common patterns in family usage were recovered across the three regions for the regression analyses. Given the aforementioned differences, this study suggests that such similarities are highly informative with regard to efficacy of certain families.

4.2. Cross-cultural patterns from general regression and binomial analyses

By performing a cross-cultural quantitative comparison of three independent and, as shown, largely different ethnomedicinal systems, common patterns in medicinal plant use were recovered that can, in turn, be taken into account in bioscreening schemes. The importance of performing such comparisons between distant cultures lies in being able to highlight common patterns from independent discoveries that can make the case for the efficacy of certain taxa stronger (Heinrich et al., 1998; Bletter, 2007; Roersch, 2010).

These results add information to the literature regarding outstanding ethnomedicinal plant groups in other geographical regions by reporting the families that are overrepresented in the ethnopharmacopoeias of Nepal, New Zealand and the Cape of South Africa (Table 3). The fact that the ethnomedicinal systems under study show little overall similarity increases the significance of any common patterns between them. Indeed, this investigation recovered culturally important families that are used in common. Listed here are those families that were recovered as positive outliers in the regression analyses of at least two of the three regions under study: Anacardiaceae, Asteraceae, Convolvulaceae, Geraniaceae, Lamiaceae, Malvaceae, Rubiaceae and Solanaceae (Table 3). Respectively, the families that stood out in the ethnopharmacopoeias in at least two regions from binomial analyses are: Clusiaceae, Cucurbitaceae, Euphorbiaceae, Lamiaceae, Malvaceae, Rubiaceae, Sapindaceae, Sapotaceae and Solanaceae (Appendix A). Four of these families (Lamiaceae, Malvaceae, Rubiaceae and Solanaceae) were recovered from both analyses (Table 3), demonstrating that the two analyses yield relatively similar results. The different assumptions of the two methods are discussed in Bennett and Husby (2008), who also note that there is agreement between the results of the two methods.

Some of the families recovered here have been highlighted as prominent families in similar studies in other areas: Anacardiaceae, Asteraceae, Convolvulaceae, Malvaceae, Rubiaceae and Solanaceae in southern Africa (Douwes et al., 2008), Asteraceae, Lamiaceae, Anacardiaceae and Malvaceae in Veracruz, Mexico (Leonti et al., 2003a), Asteraceae, Lamiaceae and Solanaceae in North America (Moerman, 1991), Asteraceae and Lamiaceae in Korea (Moerman et al., 1999), Asteraceae, Lamiaceae, Malvaceae and Solanaceae in Kashmir (Moerman et al., 1999), Asteraceae, Lamiaceae, Solanaceae in Chiapas, Mexico and Malvaceae in Ecuador (Moerman et al., 1999), Asteraceae and Rubiaceae in Belize (Amiguet et al., 2006) and Lamiaceae in Ecuadorian Shuar (Bennett and Husby, 2008). Although the common use of the above families highlights their high cultural importance in different cultures and would suggest that they be prioritised in bioscreening schemes (Douwes et al., 2008), as Bletter (2007) pointed out such common patterns are of particular importance if similar plant groups are used to treat similar conditions. This was investigated with the category of use specific regression analyses.

4.3. Category of use "hot" families

Four main points can be made from the results of the category of use specific regressions. First, the difference of the three ethnopharmacopoeias is also reflected in the little overlap in families used for the same condition. In very few cases do families that appear important in one flora, appear as such in another for the same category (Appendix B).

Second, some "hot" families overall in each area are resolved as "hot" in several categories (for example, Asteraceae, Lamiaceae, Solanaceae in Nepal, Myrtaceae and Plantaginaceae in New Zealand and Asteraceae, Solanaceae, Ebenaceae in the Cape of South Africa), revealing the use of some families as generalists in local ethnomedicinal floras because as they have a wide range of applications.

Third, there was no obvious relationship between similarity of the total or the medicinal flora and parallel plant use. Indeed, the majority of cases of plant families in common are observed between Nepal and the Cape of South Africa (Appendix B), two regions with the lowest similarity in medicinal floras. Conversely, between the two regions with high similarity in total and medicinal floras (Nepal and New Zealand) we observed very few cases where the same family is used for the same condition.

Last, out of the nine families showing category-specific common usage (Apocynaceae, Asteraceae, Caryophyllaceae, Geraniaceae, Lamiaceae, Malvaceae, Rosaceae, Rutaceae and Solanaceae), five are

Table 4
Presentation and discussion of the most important ethnomedicinal families used in parallel in the ethnopharmacopoeias of Nepal, the Cape of South Africa and New Zealand.

Family	Discussion
Anacardiaceae	Used heavily in Nepal and the Cape of South Africa. Stand out in Nepal for gynaecological/fertility and skin treatments.
Apocynaceae	Ranked eighth in Nepal and lower in New Zealand and the Cape of South Africa. Outlier in category "Other" in Nepal and the Cape of South Africa. Uses in both regions include snakebites and scorpion stings, as well as veterinary applications. In Nepal, Apocynaceae are also important for gynaecological/fertility, gastro-intestinal, musculo-skeletal and skin treatments.
Asteraceae	Ranked third in Nepal, first in the Cape of South Africa, and fifth in New Zealand, which makes it overall the most valuable ethnomedicinal family in this study, although not highlighted in any region in the binomial analyses. Among the most important ethnomedicinal families in the literature (Moerman et al., 1999; Leonti et al., 2003a; Amiguet et al., 2006). Prominent use in the category of skin treatments in all three regions, cardiovascular/blood purity, gastro-intestinal, neurology, musculo-skeletal and other in Nepal and the South African Cape, dentistry/stomatology, general, gynaecology/fertility, oto-rhino-laryngology in the Cape and ophthalmology and urinary in Nepal.
Caryophyllaceae	Outlier in New Zealand and were ranked lower in the other two regions. Important for oto-rhino-laryngological remedies in both New Zealand and Nepal and musculo-skeletal and skin categories in New Zealand.
Clusiaceae	Important family in Nepal and the Cape of South Africa, but does not stand out for any category of use.
Convolvulaceae	Although it stands out in Nepal and the Cape of South Africa, the family does not stand out in any category of use in any of the three regions.
Cucurbitaceae	Important in Nepal and the Cape of South Africa. Prominent in cardiovascular/blood purity, gastro-intestinal and urinary treatments in Nepal and other in the Cape of South Africa.
Euphorbiaceae	The family has more than expected medicinal species in Nepal and New Zealand. It stands out in cardiovascular/blood purity, gastro-intestinal, general, gynaecology/fertility, musculo-skeletal, other, oto-rhino-laryngology and skin treatments in Nepal.
Geraniaceae	Positive outliers in New Zealand and the Cape of South Africa and they are ranked high in Nepal as well. Family uses stand out in skin treatments in New Zealand and the Cape of South Africa, as well as in gastro-intestinal and respiratory/pulmonary disorders in the Cape.
Lamiaceae	Very important medicinal family in Nepal and the Cape of South Africa. Particular value for gastro-intestinal, neurology, musculo-skeletal and skin remedies in Nepal and the South African Cape, oto-rhino-laryngology and gynaecology/fertility in Nepal and in general, respiratory-pulmonary and other remedies in the Cape of South Africa. Low ranking of the family in New Zealand possibly due to its relative small size; only five species in New Zealand (two used medicinally) compared to 150 in Nepal and 43 in the Cape.
Malvaceae	Malvaceae are the second of only two families used heavily in all three areas, along with Asteraceae. Although Malvaceae are important for gastro-intestinal, respiratory/pulmonary and gynaecological/fertility treatments in Nepal, their only common usage was found for skin treatments in Nepal and the Cape of South Africa.
Rosaceae	Outlier in Nepal only. High value for several treatments in all three areas. Parallel usage for gastro-intestinal disorders in both Nepal and New Zealand, but also stood out in cardiovascular/blood purity in Nepal, dentistry/stomatology in the Cape of South Africa and neurology in New Zealand.
Rubiaceae	Heavily used in Nepal and the Cape of South Africa, but also an important family in New Zealand, ranked 10th. An outlier in New Zealand for ophthalmological problems.
Rutaceae	Stands out in Nepal, especially in the categories of dentistry/stomatology, gastro-intestinal and neurology, but they also stand out in many categories in the Cape of South Africa (cardiovascular/blood purity, dentistry/stomatology, musculo-skeletal, oto-rhino-laryngology, other). The only common usage between the two regions is in dentistry/stomatology related remedies.
Sapindaceae	Important family in the Cape of South Africa and New Zealand. Stands out for its uses in cardiovascular/blood purity, other, oto-rhino-laryngology conditions in the Cape of South Africa, however it is also an outlier for skin problems in Nepal.
Sapotaceae	More medicinal species than expected in Nepal and the Cape of South Africa. Prominent use for cardiovascular/blood purity conditions in Nepal.
Solanaceae	A very important family in Nepal and the Cape of South Africa. The family with the most hits in common usage for the same category in this study. Used in Nepal and the Cape of South Africa for treatments in the categories of dentistry/stomatology, neurology, gynaecology/fertility, musculo-skeletal, skin and other. Also prominently used in oto-rhino-langology and urinary in Nepal and gasto-intestinal in the Cape. As in the case of Lamiaceae, Solanaceae are not an important element of the local flora of New Zealand, represented by only three species, compared to 50 and 21 species in Nepal and the Cape, respectively.

families that are positive outliers in the overall medicinal floras of at least two of the three regions.

4.4. Discussion of "hot" families

We revealed 13 families that are heavily used in at least two out of three regions under study. These regions are very distant geographically and culturally, with substantially different floras and ethnomedicinal systems, as we showed. Given their cultural divergence and long-term mutual isolation in the past, we are claiming that this common usage is a result of independent discovery. These families are Anacardiaceae, Asteraceae, Convolvulaceae, Clusiaceae, Cucurbitaceae, Euphorbiaceae, Geraniaceae, Lamiaceae, Malvaceae, Rubiaceae, Sapindaceae, Sapotaceae and Solanaceae (Table 3, Appendix A). Additionally, we recovered another four families that were used in parallel for specific categories of use (Apocynaceae, Caryophyllaceae, Rosaceae and Rutaceae). Based on our findings, we consider these 17 families to be the most promising for successful hits in bioscreening studies. A brief discussion for each of these families is given in Table 4.

5. Conclusions

This study performed a cross-cultural comparison of the ethnomedicinal floras of Nepal, New Zealand, and the Cape of South Africa that represent three distant groups of cultures. These cultures have different ethnomedicinal systems and are exposed to different environments. Despite high dissimilarities in the ethnopharmacopoeias, common patterns were found in a number of cases. The "hot" families in each flora (defined as those that stand out in regression and binomial analyses) were identified and prominence in ethnomedicine was detected in at least two of the three regions for 13 families, namely Anacardiaceae, Asteraceae, Convolvulaceae, Clusiaceae, Cucurbitaceae, Euphorbiaceae, Geraniaceae, Lamiaceae, Malvaceae, Rubiaceae, Sapindaceae, Sapotaceae and Solanaceae (Table 3, Appendix A), the majority of which are mentioned in similar studies from other localities. Although these families are largely used in different ways in the three areas, some examples of use under the same category were found, many of which are supported by data from similar literature (Appendix A, Appendix B).

Convergent use in disparate regions of the world by distantly related cultures could be considered strongly indicative of efficacy. These families may have potential for discovery of previously overlooked or new medicinal plants and should be placed in high priority in bioscreening studies and conservation schemes. By compiling information from three regions here and comparing our results with those from other studies, we are contributing towards a synthesis of which families might prove to be the best candidates for future bioscreening schemes. As we are demonstrating here, cross-cultural patterns that were previously largely overlooked in the literature are starting to arise. Furthermore, we are providing a novel approach (secondary regressions analyses) of highlighting groups of plants that are used for a specific affliction.

Ethnobotany is the study at the interface between botany and human culture, for which dramatic changes are predicted in following years. Nowadays, we are faced with considerable extinction of plant species, with the latest figures reporting that almost one-fifth of plant species are endangered (Sampled Red List Index of Plants, Royal Botanic Gardens, Kew, UK, September 2010). At the same time, ongoing cultural homogenisation means that traditional knowledge is lost (Lee et al., 2001). In cases where this knowledge is well reported it can be preserved and serve as a resource in ethnopharmacology (Buenz et al., 2005). As Fabricant and Farnsworth (2001) state: "*With the rapid industrialization of the planet and the loss of ethnic cultures and customs, some of this information will no doubt disappear. An abundance of ethnomedical information on plant uses can be found in the scientific literature but has not yet been compiled into a usable form*". Cross-cultural ethnomedicinal analyses can be used to assign higher priorities in bioscreening and conservation strategies. In this changing world a utilitarian point of view should be adopted in order to preserve the biodiversity that can harbour the needs of medicine for future generations (Cordell and Colvard, 2005).

Traditional medicine is rich in context, and the use of plant medicines which are not bioactive may persist because of the power of the contextual and symbolic effects of intervention, for example placebo effect (Moerman and Jonas, 2002; Moerman, 2007; Lewith et al., 2009). Of course it is neither possible nor desirable to remove the influence of the placebo effect from traditional medicine as practiced around the globe. Further research to develop a more nuanced understanding of the placebo effect in relation to traditional use is a necessary part of a critical engagement with traditional knowledge. However, screening for pharmacological activity requires some tool to tease apart these contributory factors underling persisting traditional use. Methods for identifying common cross-cultural patterns are blunt tools, in comparison to the ethnobotanical approaches which might be taken to deepen our understanding of cultural and contextual impacts on efficacy, but we argue that they are more likely to permit identification of bioactive plants. Recognition of the significance of the placebo effect in traditional medicine and deeper understanding of its relation to bioactivity depends on better knowledge of bioactivity itself. Thus pharmacologically driven approaches need not drive decontextualisation of traditional knowledge, but may feed back scientific knowledge which deepens understanding and appreciation of current traditional practice.

Analyses like ours can be applied to further datasets from more regions to provide a more comprehensive synthesis of which plant groups are globally prominently used in medicine. However, they can also be applied to similar fields to answer similar questions. For example, one could perform the same analyses to highlight plant groups that are "bad" candidates for bioscreening, namely those that are underused in different areas of the world. Furthermore, other characters like toxicity or food potential can be put under the scopes of similar studies, where one could identify plant groups that are consistently perceived as toxic in different cultures, or those that are more heavily used as food, in order to avoid the former and investigate the latter for their potential in finding new food plants. Additionally, it would be interesting to identify any common underlying cultural perceptions that lead to convergent cross-cultural plant use.

The proposed conceptual framework here can be further tested and refined. There are two needs which are in conflict in any cross-cultural ethnomedicinal study. On one hand, there is the need for cultures under study to be distant in order to assume little exchange when looking for evidence of independent discovery. On the other hand, there is the need to compare plant use at the lowest taxonomic level possible, which will allow us to infer substantial correspondence in the medicinal properties between different cultures. Placing species in higher taxa, such as families, and extrapolating properties across wide taxonomic distances is not problem-free. Families differ greatly in number of species so they should not always be treated as comparable units and different members of a family with distinct chemical profiles might be present in different areas. In this study the first confounding issue was minimised by selecting three largely distant groups of cultures. The advent of molecular phylogenies in the last decades enables the development of new methodological approaches, which can overcome the limitations of traditional taxonomic approaches by measuring the "relatedness" of taxa. Such methods would provide a continuum of phylogenetic distance, rather than groupings in different families, and their application in ethnobotany seems rather promising (Bletter, 2007; Douwes et al., 2008). The subject of future work in our group is the development and application of such methods in order to bring more power to quantitative study of cross-cultural ethnomedicinal plant use.

Lastly, we would like to draw attention to an ethical consideration. We recognise that intellectual property rights of traditional knowledge must stay with the local community originating that intellectual property. Therefore, any bioscreening effort should strictly adhere to the precepts of the Convention of Biological Diversity. Furthermore, a primary goal of such schemes should be to implement any findings in order to provide healthcare for the indigenous communities where the knowledge came from (Etkin, 2001; Reyes-Garcia, 2010).

Acknowledgements

The authors would like to thank the technical staff of the Philip Lyle Building, School of Biological Sciences, University of Reading, B. Press from the Natural History Museum London, as well as M. Watson and C. Pendry from the Royal Botanic Gardens, Edinburgh, who all assisted at various stages during the study. Four anonymous reviewers and M. Heinrich provided comments that enhanced the manuscript.

Funding: This study was funded by the John Spedan Lewis Fellowship that financially supported C. Haris Saslis-Lagoudakis in his doctoral studies. The funding source did not have a role in the writing of the paper or the decision to submit the paper for publication.

Appendix A.

Families that have statistically more medicinal species than expected from a null model from binomial analyses in at least one of the floras of Nepal (NEP), the Cape of South Africa (SAC) and New Zealand (NZ). A family with '*' has statistically more medicinal species than expected, a family with '–' does not deviate from the null model, and a family with n.p. is not present in the local flora.

Family	NEP	SAC	NZ	Family	NEP	SAC	NZ
Aizoaceae	–	–	*	Lythraceae	*	–	n.p.
Alliaceae	–	*	n.p.	Malvaceae	*	*	*
Anacardiaceae	–	*	–	Melastomataceae	*	n.p.	n.p.
Apocynaceae	*	–	–	Meliaceae	–	*	–
Aquifoliaceae	–	*	n.p.	Melianthaceae	n.p.	*	n.p.
Araliaceae	–	*	–	Menispermaceae	–	*	n.p.
Argophyllaceae	n.p.	n.p.	*	Moraceae	*	–	–
Asparagaceae	–	*	n.p.	Myrtaceae	–	–	*
Balsaminaceae	–	*	n.p.	Oleaceae	–	*	–
Betulaceae	*	–	n.p.	Orobanchaceae	n.p.	*	–
Caryophyllaceae	–	–	*	Pedaliaceae	*	n.p.	n.p.
Celastraceae	–	*	–	Pittosporaceae	–	*	–
Celtidaceae	n.p.	*	n.p.	Plantaginaceae	–	*	–
Clusiaceae	*	*	n.p.	Poaceae	–	*	–
Combretaceae	*	n.p.	n.p.	Podocarpaceae	–	n.p.	*
Commelinaceae	–	*	n.p.	Polygonaceae	–	*	–
Convolvulaceae	–	*	–	Ranunculaceae	–	*	–
Cornaceae	–	*	n.p.	Rhamnaceae	–	–	*
Cucurbitaceae	*	*	–	Rubiaceae	*	*	–
Cunoniaceae	n.p.	–	*	Rutaceae	*	–	–
Ebenaceae	–	*	n.p.	Salicaceae	–	*	n.p.
Elaeocarpaceae	n.p.	n.p.	*	Salvadoraceae	n.p.	*	n.p.
Euphorbiaceae	*	–	*	Sapindaceae	–	*	*
Fabaceae	*	–	–	Sapotaceae	*	*	–
Flacourtiaceae	n.p.	*	n.p.	Solanaceae	*	*	*
Geraniaceae	–	–	*	Symplocaceae	*	n.p.	n.p.
Goodeniaceae	n.p.	*	–	Typhaceae	–	*	–
Gunneraceae	n.p.	*	–	Vahliaceae	n.p.	*	n.p.
Hemerocallidaceae	–	–	*	Valerianaceae	–	*	n.p.
Hydnoraceae	n.p.	*	n.p.	Verbenaceae	*	–	–
Icacinaceae	–	*	n.p.	Viscaceae	n.p.	*	n.p.
Lamiaceae	*	*	–	Vitaceae	–	*	n.p.
Lauraceae	–	n.p.	*	Winteraceae	n.p.	n.p.	*
Loganiaceae	–	*	–	Zingiberaceae	*	n.p.	n.p.

Appendix B.

Most important families for each category of use, as recovered from secondary category of use specific regression analyses for Nepal, New Zealand and the Cape of South Africa. Families in bold were recovered as positive outliers in both secondary regression analyses (they are overrepresented in the local ethnopharmacopoeia for a category of use and demonstrate specificity of use) and families in normal only in the first secondary analyses (they are overrepresented in the local ethnopharmacopoeia for a category but do not demonstrate specificity of use).

Appendix B (*Continued*)

Category of use	Nepal	South Africa Cape	New Zealand
Cardiovascular/ blood purity	**Asteraceae, Cucurbitaceae,** Elaeocarpaceae, Ephedraceae, Euphorbiaceae, Linaceae, Nyctaginaceae, Nymphaeaceae, Oxalidaceae, Rosaceae, Sapotaceae, **Valerianaceae**	Asteraceae, **Ebenaceae**, Poaceae, **Rutaceae, Sapindaceae, Viscaceae**	**Argophyllaceae, Fabaceae**
Dentistry/ stomatology	Fabaceae, **Moraceae, Rutaceae, Solanaceae, Rutaceae, Solanaceae**	Aizoaceae, **Asteraceae, Ebenaceae**, Rosaceae, **Rutaceae**, Solanaceae	–
Gastro-intestinal	**Apiaceae, Amaranthaceae,** Apocynaceae, Asteraceae, **Cucurbitaceae,** Euphorbiaceae, **Fabaceae,** Lamiaceae, **Malvaceae,** Moraceae, **Rosaceae, Rubiaceae, Rutaceae,** Verbenaceae	Amaryllidaceae, Asteraceae, Amaryllidaceae, Ebenaceae, Geraniaceae, Lamiaceae, Poaceae, Solanaceae	**Myrtaceae, Plantaginaceae, Podocarpaceae, Rosaceae**
General	Euphorbiaceae, Fabaceae	Amaranthaceae, Asteraceae, **Cyperaceae, Lamiaceae**, Orobanchaceae	**Myrtaceae, Plantaginaceae**
Gynaecology/ fertility	**Amaranthaceae, Anacardiaceae, Apocynaceae, Euphorbiaceae, Fabaceae**, Lamiaceae, **Malvaceae, Menispermaceae, Moraceae, Nyctaginaceae, Oleaceae, Solanaceae**	Asteraceae, **Ebenaceae, Solanaceae**	**Myrtaceae, Plantaginaceae**, Podocarpaceae, Rubiaceae
Neurology	**Apiaceae**, Asteraceae, Fabaceae, **Gentianaceae, Lamiaceae**, Rubiaceae, Rutaceae, **Solanaceae, Verbenaceae, Zingiberaceae**	Asteraceae, Ebenaceae, **Lamiaceae**, Ranunculaceae, Solanaceae	Myrtaceae, **Plantaginaceae, Podocarpaceae, Rosaceae**
Ophthalmology	**Asteraceae, Berberidaceae**	–	**Ranunculaceae, Rubiaceae**
Musculo-skeletal	**Apocynaceae, Asteraceae, Euphorbiaceae, Fabaceae, Lamiaceae, Solanaceae,** Zingiberaceae	Asteraceae, Hyacinthaceae, **Lamiaceae,** Poaceae, **Rutaceae, Solanaceae**	**Caryophyllaceae**, Myrtaceae, **Plantaginaceae,** Podocarpaceae
Other	Apocynaceae, Asteraceae, **Euphorbiaceae, Fabaceae**, Moraceae, **Solanaceae, Verbenaceae**	**Apocynaceae, Asteraceae, Celastraceae, Cucurbitaceae, Ebenaceae,** Lamiaceae, **Rutaceae, Sapindaceae, Solanaceae**	Argophyllaceae, Myrtaceae, Pittosporaceae, Plantaginaceae
Oto-rhino-laryngology	Caryophyllaceae, Euphorbiaceae, **Lamiaceae, Ranunculaceae, Solanaceae**	Asteraceae, **Rutaceae, Sapindaceae**	**Caryophyllaceae**
Respiratory/ pulmonary	**Combretaceae, Fabaceae, Malvaceae, Verbenaceae, Zingiberaceae**	Amaryllidaceae, Asparagaceae, **Asteraceae,** Geraniaceae, **Lamiaceae,** Solanaceae	–

Appendix B (*Continued*)

Category of use	Nepal	South Africa Cape	New Zealand
Skin	Anacardiaceae, Apocynaceae, **Asteraceae**, Euphorbiaceae, Fabaceae, **Lamiaceae, Lythraceae, Malvaceae, Moraceae**, Rubiaceae, **Sapindaceae, Scrophulariaceae, Solanaceae, Urticaceae**, Verbenaceae	Asteraceae, Geraniaceae, Lamiaceae, **Malvaceae, Solanaceae**	Asteraceae, **Caryophyllaceae**, Geraniaceae, Myrtaceae, **Plantaginaceae, Podocarpaceae, Ranunculaceae**
Urinary	**Amaranthaceae,** Asteraceae, Cucurbitaceae, Euphorbiaceae, **Fabaceae, Menispermaceae**, Nyctaginaceae, Solanaceae, Zingiberaceae	–	Plantaginaceae

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