A Regression Analysis of Q'eqchi' Maya Medicinal Plants from Southern Belize[1]

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Treyvaud Amiguet, Virginie, John Thor Arnason *(Department of Biology, University of Ottawa, 150 Louis Pasteur, P.O. Box 450, Station A, Ottawa, Ontario, K1N 6N5, Canada; Arnason phone: 613-562-5262; fax: 613-562-5765),* **Pedro Maquin, Victor Cal** *(Belize Indigenous Training Institute, Punta Gorda, Toledo District, Belize),* **Pablo Sáchez-Vindas, and Luis Poveda Alvarez** *(Herbario Juvenal, Universidad Nacional, Heredia, Costa Rica).* A Regression Analysis of Q'eqchi' Maya Medicinal Plants from Southern Belize. *Economic Botany* 60(1):24–38, 2006. *A previous study provided a general quantitative analysis of 169 collected medicinal plants used by the Q'eqchi' Maya healers of southern Belize. This paper is focused on a statistical analysis of this ethnobotanical information using the method developed by Moerman (1991). The residual values obtained from the regression analysis of the Q'eqchi' medicinal plant species versus the species listed in the checklist of the vascular plants of Belize (Balick, Nee, and Atha, 2001) placed the Piperaceae, the Rubiaceae, and the Asteraceae in the first three ranks, and the Poaceae, the Cyperaceae, and the Orchidaceae in the last three ranks. The results were compared with three northern temperate regions (Kashmir, Korea, and North America) and three southern neotropical regions (Chiapas, Ecuador, and Veracruz). The coefficients of correlation between the checklist of vascular plants of Belize and the other six floras showed, as expected, high values for regions with similar climatic type. Thus, high correlations were determined between the tropical vegetation of Belize and those of Chiapas, Ecuador, and Veracruz. The coefficients were lower with the three temperate floras but still quite high. The same analysis was done with the medicinal plants only and led to much lower coefficients, but once again, the higher results were obtained for Chiapas and Veracruz. In this case, the last rank for Ecuador demonstrated that the selection of plants in traditional medicine by the indigenous people is a complex phenomenon which depends not only on the composition of the flora but also on culture-specific factors.*

Analyse par Regression des Plantes Médicinales des Mayas Q'eqchi' du Sud du Belize. *Une précédente étude a fourni une analyse quantitative générale de 169 plantes médicinales utilisées par les guérisseurs Maya Q'eqchi' du sud du Belize. Ce document se concentre sur l'analyse statistique des informations ethnobotaniques selon la méthode développée par Moerman (1991). Les valeurs résiduelles obtenues à partir des analyses de régression des plantes médicinales Q'eqchi' vis-à-vis des espèces mentionnées dans la liste des plantes vasculaires du Belize (Balick, Nee, et Atha, 2001) ont placé les Piperacées, les Rubiacées et les Asteracées aux trois premières places, et les Poacées, les Cyperacées et les Orchidacées aux trois dernières places. Les résultats ont été comparés avec ceux de trois régions tempérées du nord (Cachemire, Corée, et Amérique du Nord) et de trois régions néotropicales du sud (Chiapas, Équateur, et Veracruz). Les coefficients de corrélation entre les plantes listées dans le manuel des plantes vasculaires du Belize et les six autres flores ont montré comme attendu de hautes valeurs pour les régions possédant un type climatique similaire. Ainsi, une haute corrélation a été démontrée entre la végétation tropicale du Belize et celles du Chiapas, de l'Équateur, et du Veracruz. Les coefficients étaient plus bas avec les trois régions tempérées mais tout de même passablement élevés. La même analyse a été effectuée avec les plantes médicinales et a mené à des coefficients beaucoup plus bas, mais encore une fois, les résultats les plus élevés ont été obtenus pour le Chiapas et le Veracruz. Dans ce cas, la dernière posi-*

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tion de l'Équateur a souligné que la sélection des plantes par les indigènes dans la médecine traditionnelle est un phénomène complexe qui dépend non seulement de la composition de la flore mais aussi de facteurs spécifiques à la culture.

Key Words: Medicinal plants, Belize, Q'eqchi' Maya, regression analysis, residual values.

The Q'eqchi' Maya of southern Belize have maintained a highly traditional way of life characterized by use of the Q'eqchi' language, oral transmission of traditional knowledge, and food production by "milpa" agriculture. Their villages are located in remote foothills of the Maya Mountains, which are sparsely populated. The close relationship between Q'eqchi' and the surrounding semi-evergreen rainforests, which provide timber, food, and medicinal plants, remains strong. Traditional healers in the Q'eqchi' villages use a large number of medicinal plants obtained from the surrounding primary and secondary rainforests.

According to a previous general quantitative analysis of the data (Treyvaud Amiguet et al. 2005), the high degree of consensus among the Q'eqchi' healers in the use of plants species, as well as in diseases treated, suggests a well-defined medicinal tradition. To provide an in-depth analysis, the regression method developed by Moerman (1991) was used to determine the relation between the first inventory of the Q'eqchi' pharmacopoeia and the recently published checklist of the vascular plants of Belize (Balick, Nee, and Atha 2001). Moerman (1991) suggested the analysis of residual values from regression of medicinal flora versus total flora to identify low use and high use of families. Previous methods using species counts or the percentage of use for each family could distort conclusions by overestimating large or small families.

This study provides the first in-depth analysis of the Q'eqchi' medicinal knowledge and highlights the most important plant families of this field collection. The Q'eqchi' medicinal plants recorded during this field work represent the majority of species commonly used by the healers who participated to the study. This attempt to analyze Q'eqchi' medicinal knowledge provides important ethnobotanical information about the commonly used medicinal plants and demonstrates the high selectivity of specific families as medicines by this indigenous people. Also presented is an intercultural comparison with the regression analysis of North America, Chiapas, Kashmir, Korea, and Ecuador (Moerman et al. 1999), as well as Veracruz (eastern Mexico) (Leonti et al. 2003).

METHODS

ETHNOBOTANICAL RESEARCH

The ethnobotanical research was undertaken in the Toledo district, southern Belize, from January to April 2001. This survey was conducted with nine healers from five different villages, and collections were made at random with groups of two healers. Healers were grouped based on their availability for the field work. Usages and preparations were recorded during the expeditions, and herbarium vouchers were collected. Finally, each species was presented to the other informants to analyze the consensus level. More details about the informants, the collection sites, and the consensus results are provided in a previous publication (Treyvaud Amiguet et al. 2005).

Approval of the project and of interview methods was obtained from the University of Ottawa ethics committee, through community meetings with the healers, and by collecting permits from the government of Belize (Minister of Natural Resources). The complete set of voucher specimens (JVR 7901 to 7920; JVR 7945 to 8101) is deposited at the Herbarium Juvenal Valerio Rodriguez (Universidad Nacional of Costa Rica); a second set was deposited at the field station in Belize but was destroyed in a hurricane in October 2001.

EVALUATION METHODS

Moerman (1991) developed a method using regression residuals for analyzing large quantities of data, dividing plants into subgroups of varying sorts and size. The data recorded during our study was compared to the checklist of vascular plant of Belize (Balick, Nee, and Atha 2001), which is the only available record specific to Belizean plant species. The actual number of plant species listed in this checklist is 3,426, belonging to 209 families. The Toledo district, where this study was undertaken, has the greatest species diversity of any district in Belize; a large proportion of the species in the checklist can be found there. In the present paper, the equation which describes a relationship between the number of species in the checklist of the vascular plants of Belize (CVPSPE) and the number of species used medicinally by Q'eqchi' (QMPSPE) follows:

$$\text{QMPSPE} = \text{Constant} + (\text{Coefficient} \times \text{CVPSPE}) \quad (1)$$

This method was used to analyze the set of 169 Q'eqchi' medicinal plants collected previously (Treyvaud Amiguet et al. 2005). At the time, species-area curves were not evaluated, and it is not possible to fully confirm that the collection has reached the asymptote by the method of species-area curve (Cotton 1996). However, this first quantitative analysis includes, according to the healers, the majority of Q'eqchi' medicinal species, and the results are therefore culturally significant and probably close to asymptote.

The constant and the coefficient values were determined by standard least-squares regressions (Runyon and Haber 1984) using SYSTAT software (1999). Subtracting the predicted value from the actual value gives the residual value. Families or subclasses with positive residuals are ones used more often than the regression would predict, while those with negative residuals are used less often than predicted (Moerman 1991).

Results and Discussion

Residual Analysis of Belizean Plant Families

The collection of Q'eqchi' medicinal plants analyzed consisted of 169 plants species which were classified into 67 families (Treyvaud Amiguet et al. 2005). Cronquist's classification (1968) was followed, and Fabaceae-Caesalpinioideae, Fabaceae-Mimosoideae, and Fabaceae-Papilionoideae were pooled together into Fabaceae to use the same classification as Moerman (1991) for comparative analysis. Furthermore, since the Q'eqchi' medicinal plants collected were compared with the checklist of vascular plants of Belize to provide this quantitative analysis, minor adjustments in classification were required. In our previous study, we classified the plant *Dictyoxiphium panamense* into the Tectariaceae family, but Balick, Nee, and Atha (2001) listed this plant in the Aspleniaceae. For this analysis, *D. panamense* was listed in the Aspleniaceae family, and the Tectariaceae family, which was not mentioned by the checklist, was removed. The Q'eqchi' medicinal collected plants belong now to 64 families for the purposes of the present study. The regression of Q'eqchi' medicinal plant families versus the checklist of vascular plant of Belize (Fig.1) was described by the following equation:

$$\text{QMPSPE} = 0.3416 + (0.0279 \times \text{CVPSPE}) \quad (2)$$

Appendix 1 lists the 209 Belizean plant families, the subclass to which they belong, the number of species mentioned by the checklist of vascular plant of Belize (CVPSPE), the number of species in the Q'eqchi' medicinal plants collection (QMPSPE), and their residual values. The standard deviation obtained for the 209 residuals is 1.81. There are 17 families with residual values greater than the standard deviation. The Q'eqchi' healers overuse 14 families and underuse three others. The three families with the highest residuals (used more often than predicted) are Piperaceae (pepper family), Rubiaceae (coffee family), and Asteraceae (sunflower family). The ones with the lowest residuals (used less often than predicted) are Cyperaceae (sedge family), Poaceae (grass family), and Orchidaceae (orchid family).

In a first analysis of the data (Treyvaud Amiguet et al. 2005), employing a method of classification directly based on the number of medicinal species from each plant family used by the healers, the top five families were Rubiaceae (1), Piperaceae (2), Asteraceae (3), Melastomataceae (4), Fabaceae (5) and Araceae (5). Moerman's method, which takes into consideration the sizes of the plant families, highlights the importance of small families such as Piperaceae and reduces the impact of large families which might be expected to produce more medicinal species. Rubiaceae and Asteraceae stay in the top three, but Piperaceae is now ranked first. Melastomataceae and Araceae are still into the top five, but the large Fabaceae family moved from rank five to rank 179. These results obtained from a portion of the Q'eqchi' pharmacopoeia show that medicinal plant species are not chosen at random, but have been

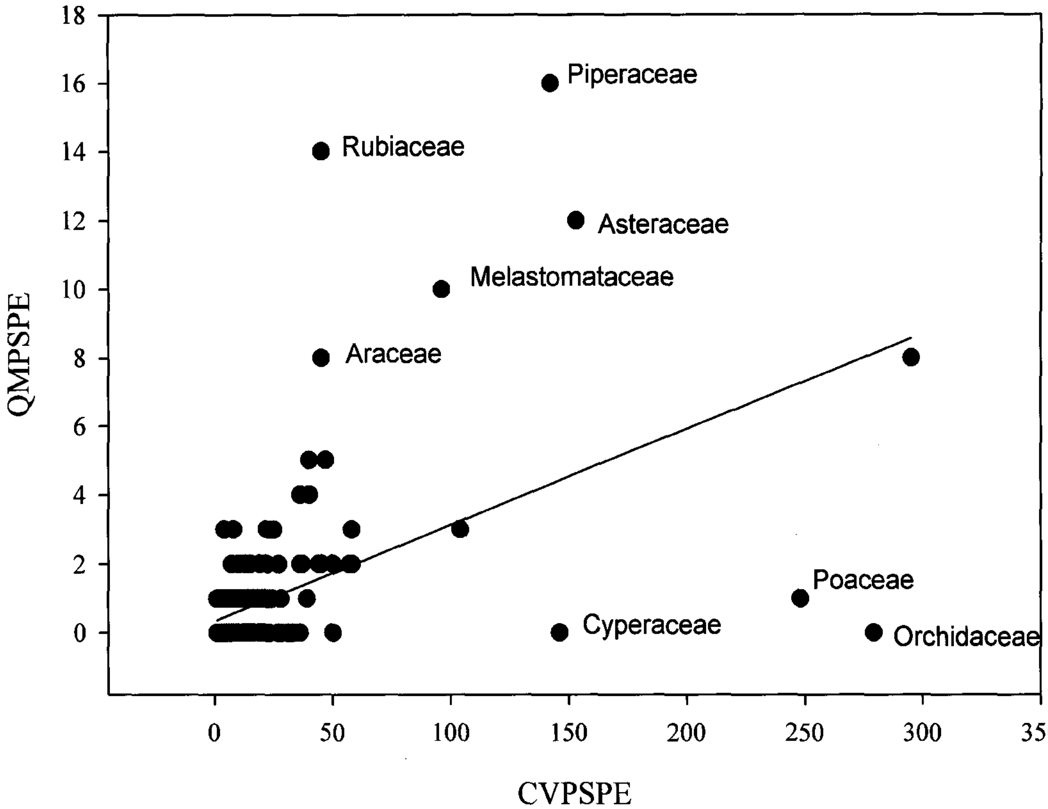

Fig. 1. Regression plot of the collected Q'eqchi' medicinal plant species (QMPSPE) versus the specie listed in the checklist of vascular plants of Belize (CVPSPE) (N=209; p-value=0; r^2 =0.26). Vertical distance between plotted points and the regression line represent residuals.

highly selected, possibly based on their biological activities as well as on culture-specific factors. Q'eqchi' medicinal plant species are selected in a distinctly nonrandom fashion.

Three First-Ranking Families

The regression analysis placed the Piperaceae family at the first rank. Piperaceae grow mainly in the tropical areas, and many species are part of the Ayurvedic system of medicine. Atal et al. (1975) mentioned that very little work on *Piper* species had been done outside India, except with Kava (*Piper methysticum*). Chakraberty (1923) recorded plants from this family used in India as sedative and antihelminthic agents. Piperaceae are also used as a stomachic and antiperiodic in malarial fever and arthritic diseases (Dasgupta and Datta 1980). The species of Piperaceae from tropical America have the same aromaticity as those of Indian origin and have also found their way into the traditional medicine (Scott 2004). This fam ily comprises approximately five genera an 1,400 species distributed in both hemisphere with 700 species of the genus *Piper* and 600 c *Peperomia* (Joly 1977). The checklist of vascu lar plant of Belize contains 45 species whic are very widespread in the tropical rainforest: and almost one-third were present in our co lected vouchers. The Q'eqchi' healers use th Piperaceae for many ailments, but the majc usage categories are for infections, digestiv system disorders, and muscular-skeletal syster disorders. Using older methods, such as a dire count of medicinal species, the Piperaceae fan ily, which is smaller than other families, woul not be ranked in the first position, and its in portance as a medicinal family would not hav been highlighted.

The Rubiaceae and the Asteraceae are als major families in our collection, but these a larger families with three times more specie

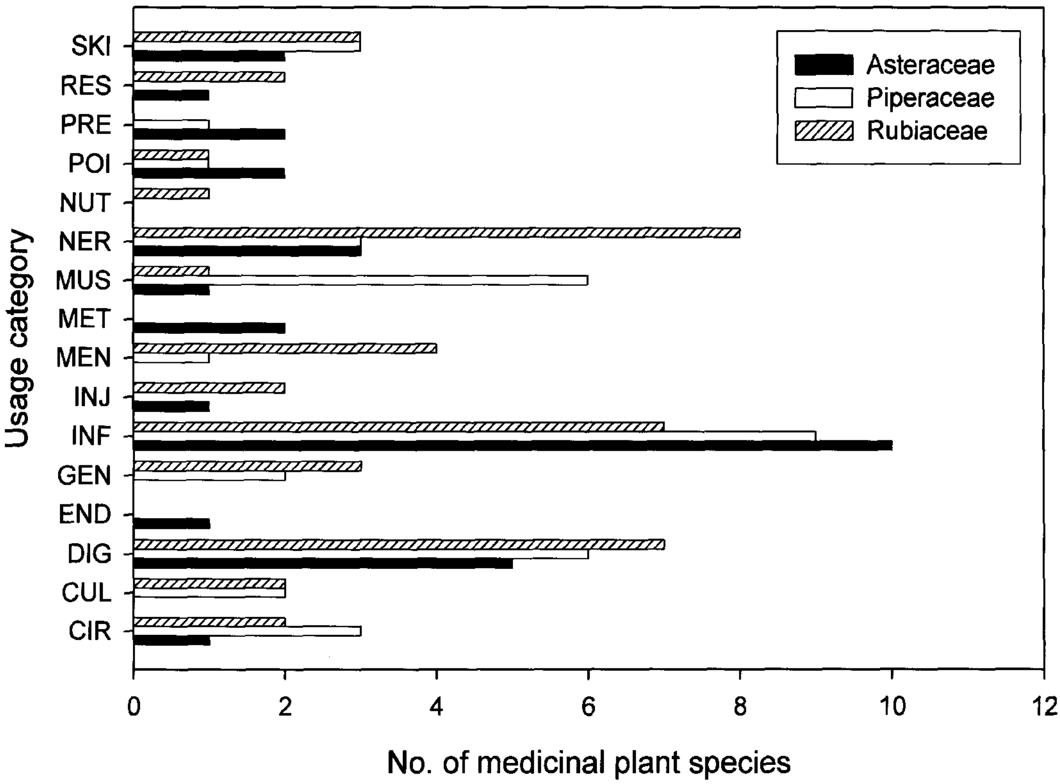

Fig. 2. Comparison of the uses among the three first-ranking families in term of usage categories. (CIR: circulatory system disorders; CUL: culture-bound symptoms; DIG: digestive system disorders; END: endocrine system disorders; GEN: genitourinary system disorder; INF: infection; INJ: injuries; MEN: mental disorders; MET: metabolic system disorders; MUS: muscular-skeletal system disorders; NER: nervous system disorders; NUT: nutritional disorders; POI: poisonings; PRE: pregnancy/birth/puerperium disorders; RES: respiratory system disorder; SKI: skin/subcutaneous cellular tissue disorders).

than the Piperaceae in Belize. The Rubiaceae are known for their content of xanthine derivatives, anthranoides, coumarines, triterpenes, triterpene saponines, proanthocyanidines, and alkaloids (Frohne and Jensen 1998). Q'eqchi' healers use this plant family principally to treat nervous system disorders, digestive system disorders, and infections.

Finally, the Asteraceae, with at least 7,000 isolated natural compounds (sesquiterpene lactones, diterpenes, phenols, or polyynes), are known for anti-inflammatory, cytotoxic, bactericidal, and fungicidal activities (Frohne and Jensen 1998). In our previous paper (Treyvaud Amiguet et al. 2005), the 69 commonly known uses recorded were sorted into 17 usage categories. This classification followed the standard for category of symptoms and ailments developed by Cook (1995). The category "culture-bound syndromes" (Simons and Hughes 1986) was used to classify folk illnesses which were not recognized by biomedical practitioners as diseases. Figure 2 shows a comparative representation of the Q'eqchi' medicinal uses for these three first-ranking families. This figure shows that the Asteraceae and the Piperaceae are mostly used to treat infections, while the Rubiaceae are used to treat nervous system disorders.

Three Last-Ranking Families

The three lowest ranking families, Cyperaceae, Poaceae, and Orchidaceae, are large unutilized families. The Cyperaceae family does not have a high biological activity, but is mentioned as used for food. Silicate, proanthocyanidins, and essential oils are the main known constituents of this family (Frohne and Jensen 1998). The large Poaceae family contains mostly grasses used for food and has few

TABLE 1. CLASSIFICATION OF THE PLANTS LISTED IN THE CHECKLIST OF VASCULAR PLANTS OF BELIZE (CVP) AND OF THE COLLECTED Q'EQCHI MEDICINAL PLANTS (QMP) INTO DIVISIONS AND SUBCLASSES. THE NUMBERS IN PARENTHESES ARE UNIDENTIFIED GENERA, BUT THE SPECIES HAVE BEEN CERTIFIED BY TAXONOMISTS TO BE UNICATES.

	CVP			*QMP*		
Taxonomic Groups	Families	Genera	Species	Families	Genera	Species
Seedless plants						
I. Psilotophyta	1	1	1	0	0	0
II. Lycopodiophyta	3	4	21	1	1	2
III. Pteridophyta	17	69	234	7	9	15
Seeded plants (Spermatophyta)						
A. Gymnospermae						
I. Pinophyta	2	2	3	0	0	0
II. Cycadophyta	1	2	4	1	1	1
B. Angiospermae (Magnoliophyta)						
1. Dicotyledoneae						
i. Asteridae	28	316	757	13	33 (15)	55
ii. Caryophyllidae	11	38	79	3	4	4
iii. Dilleniidae	41	151	327	9	12	17
iv. Hamamelidae	8	26	78	1	2	2
v. Magnoliidae	14	41	129	5	7	20
vi. Rosidae	45	271	836	15	29 (4)	36
2. Monocotyledoneae						
i. Alismatidae	6	10	14	0	0	0
ii. Arecidae	4	37	91	2	4 (3)	9
iii. Commelinidae	16	130	519	6	6 (1)	7
iv. Liliidae	12	120	333	1	1	1
Total	209	1218	3426	64	109 (23)	169

medicinal uses. Silicates are the main components characteristic of the family (Frohne and Jensen 1998). Active compounds such as phenyl propanoids, flavonoids, and hydroxamic acids are found in many Poaceae species (Schulz and Weissenböck 1987; Saleh et al. 1988). These compounds are known to be active as antioxidants, antimutagenics, or anticarcinogenics, and also to have potential in the prevention for coronary heart diseases (Meltzer and Malterud 1997). However, there are no Poaceae species in the collected medicinal plants since the Q'eqchi' healers use mostly rainforest plant species as medicine.

The Orchidaceae is the second largest family on earth and the largest one in Belize. Very few of its species are used as medicine in Belize, and the Q'eqchi' healers did not mention any of them during this study, although they were collected by the healers for flower gardens during field work. The Orchidaceae family is mainly used commercially as foodstuff flavoring (vanilla) or in the perfume industry, thanks to the high flower content in aromatic compounds. Many species are rare epiphytic plants not easily accessible that makes them unlikely candidates for medicinal use.

CLASSES AND SUBCLASSES OF THE FLORA OF BELIZE

The medicinal species were classified into 1 classes and subclasses (Table 1) following th classification used by Moerman (1991) fo comparative studies. This classification wa based on the work of Conquist (1968). Th species, which are not present in Moerman' study, were classified following Thorne's classification of the Angiosperms (Thorne 2000) Table 2 presents the predicted and residual values calculated with the following regressio equation:

$$QMPSPE = 0.5034 + (0.0468 \times CVPSPE) \quad (3$$

This equation was obtained from the regression analysis of the number of species in eac class or subclass (CVPSPE) versus the numbe of them used medicinally by the Q'eqchi (QMPSPE) (Fig. 3). The residuals ranged fror

TABLE 2. RESIDUAL ANALYSIS OF THE 15 DIVISIONS AND SUBCLASSES USED TO CLASSIFY THE 64 FAMILIES OF THE Q'EQCHI' MEDICINAL PLANTS COLLECTED. NUMBERS OF PLANT SPECIES LISTED IN THE CHECKLIST OF VASCULAR PLANTS OF BELIZE (CVPSPE) AND OF THE COLLECTED Q'EQCHI' MEDICINAL PLANTS (QMPSPE) ARE PRESENTED FOR EACH CLASS OR SUBCLASS, TOGETHER WITH THE PREDICTED VALUES AND THE RESIDUALS OBTAINED FROM THE REGRESSION ANALYSIS.

Class/Subclass	CVPSPE	QMPSPE	Predicted	Residual[a]
Asteridae	757	55	35.931	19.0690
Magnoliidae	129	20	6.5406	13.4594
Arecidae	91	9	4.7622	4.2378
Pteridophyta	234	15	11.4546	3.5454
Dilleniidae	327	17	15.807	1.1930
Lycopodiophyta	21	2	1.4862	0.5138
Cycadophyta	4	1	0.6906	0.3094
Caryophyllodae	79	4	4.2006	–0.2006
Psilotophyta	1	0	0.5502	–0.5502
Pinophyta	3	0	0.6438	–0.6438
Alismatidae	14	0	1.1586	–1.1586
Hamamelidae	78	2	4.1538	–2.1538
Rosidae	836	36	39.6282	–3.6282
Liliidae	333	1	16.0878	–15.0878
Commelinidae	519	7	24.7926	–17.7926

[a] Standard deviation of the 15 residuals is 9.0283.

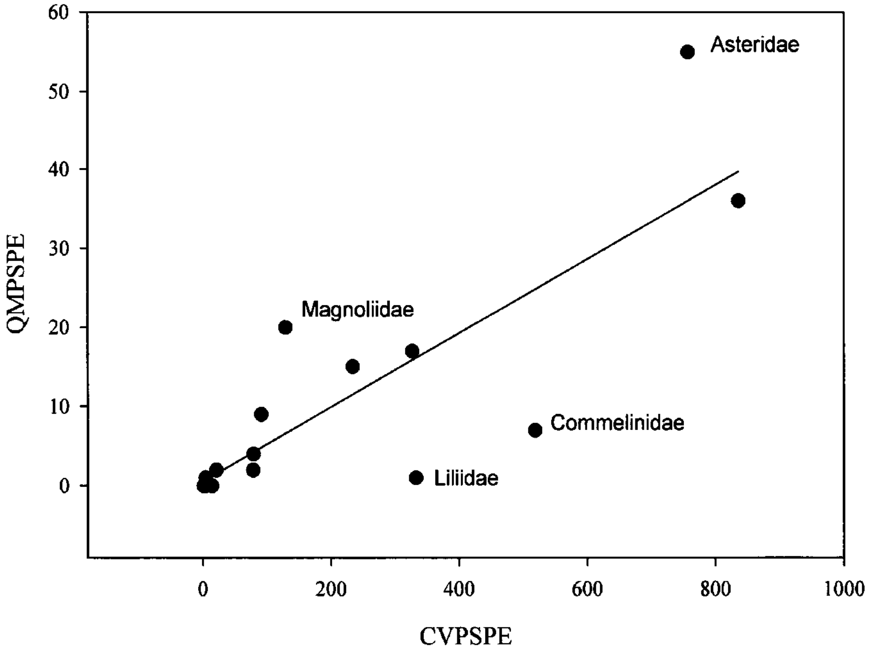

Fig. 3. Regression plot of 15 divisions and subclasses showing the medicinal Q'eqchi' species (QMPSPE) versus the species listed in the checklist of vascular plants of Belize (CVPSPE). The points plotted are the actual values of the number of species and medicinal species in each division and subclass. The residual value is represented by the vertical distance from the point to the regression line (N=15; p-value=0; r^2 =0.65). The four named points are values greater than the standard deviation of the set.

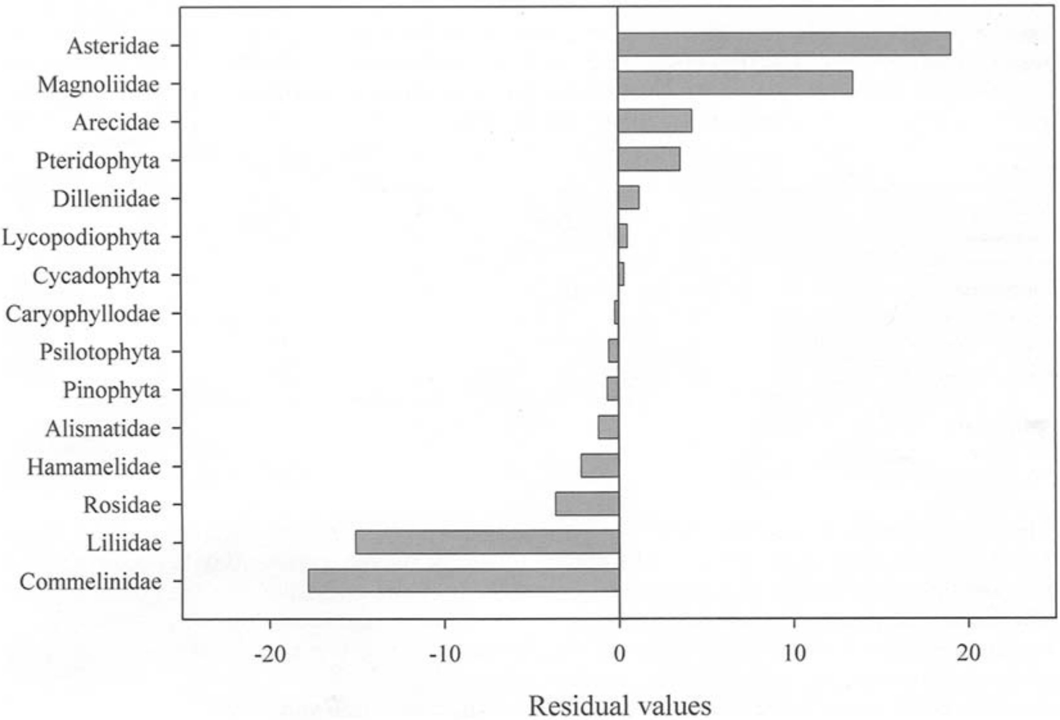

Fig. 4. Regression residuals of the 15 divisions and subclasses.

19.1 to −17.8 (Fig. 4), with a standard deviation of 9. Four values exceeded the standard deviation, two positively (Asteridae and Magnoliidae) and two negatively (Liliidae and Commelinidae). These results are consistent with those previously obtained for families, as the subclass Asteridae contains the second- and third-ranking families, Rubiaceae and Asteraceae, whereas the first-ranking family Piperaceae belongs to the Magnoliidae. In the same way, the two last ranking subclasses, Liliidae and Commelinidae, contain the last-ranking families Cyperaceae Poaceae, and Orchidaceae.

Comparative Analysis with Six Floras Previously Studied

Table 3 and Table 4 show a comparative analysis with the Veracruz (Mexico) pharmacopoeia studied by Leonti et al. (2003) and the pharmacopoeias of North America, Chiapas

Table 3. The three first- and the three last-ranking families of the Q'eqchi' medicinal plants collection (Toledo district) and the six floras used for comparative analysis.

Family rank	Toledo	Veracruz[1]	Chiapas[2]	Kashmir[2]	North America[2]	Korea[2]	Ecuador[2]
First							
1	Piperaceae	Asteraceae	Asteraceae	Asteraceae	Asteraceae	Asteraceae	Araceae
2	Rubiaceae	Piperaceae	Lamiaceae	Euphorbiaceae	Apiaceae	Lamiaceae	Fabaceae
3	Asteraceae	Fabaceae	Solanaceae	Ranunculaceae	Ericaceae	Ranunculaceae	Bignoniaceae
Last							
1	Orchidaceae	Orchidaceae	Poaceae	Poaceae	Poaceae	Cyperaceae	Orchidaceae
2	Poaceae	Poaceae	Orchidaceae	Urticaceae	Cyperaceae	Poaceae	Moraceae
3	Cyperaceae	Rubiaceae	Cyperaceae	Anacardiaceae	Fabaceae	Orchidaceae	Lauraceae

[1] Leonti et al. 2003
[2] Moerman et al. 1999

TABLE 4. SELECTED RESULTS OF THE REGRESSION ANALYSIS OF THE ANGIOSPERM FAMILIES. THE THREE FIRST- AND THE THREE LAST-RANKING PLANT FAMILIES USED BY THE Q'EQCHI' HEALERS (TOLEDO DISTRICT) ARE PRESENTED WITH A COMPARISON TO THE PUBLISHED DATA OF THE SIX OTHER AREAS. WE USED THE TERMINOLOGY "NOT AVALAIBLE" (N.A.) FOR PIPERACEAE IN KASHMIR, BECAUSE THERE IS NO SPECIES OF THIS FAMILY MENTIONED AS MEDICINAL SPECIES.

Family	Toledo	Veracruz[1]	Chiapas[2]	Kashmir[2]	North America[2]	Korea[2]	Ecuador[2]
Piperaceae	1	2	105	N.A.	237	89	27
Rubiaceae	2	172	82	9	250	65	109
Asteraceae	3	1	1	1	1	3	45
Cyperaceae	207	171	142	94	254	136	102
Poaceae	208	173	144	100	255	135	51
Orchidaceae	209	174	143	100	245	134	118
Total families	209	174	144	100	255	136	118

[1] Leonti et al. 2003
[2] Moerman et al. 1999

(Mexico), Ecuador, Korea, and Kashmir presented by Moerman et al. (1999). The three first- and three last-ranking families of the Q'eqchi' medicinal plant collected are listed with the families placed at the same ranks in the other studies (Table 3), and those six families were then presented in Table 4 with their particular ranks in the compared data. In all cases, only the families of angiosperms are taken into consideration. As Moerman et al. (1999) mentioned in their article, there are many interesting medicinal gymnosperms, but data for them were not available for all the regions.

After the removal of gymnosperms from the Belize data, a new regression analysis of angiosperm families gave this equation:

$$QMPSPE = 0.3485 + (0.0274 \times CVPSPE) \quad (4)$$

The new residual values were used to determine the pairwise correlations between the data recorded in Belize and the plant families of the six other regions. Table 5 presents the Pearson correlation coefficients (r) and the Bonferroni probabilities (p) obtained with SYSTAT (1999), as well as the numbers of plant families taken into consideration (n) for each analysis. The results show a very high similarity between the plant families of Belize and the ones of Chiapas ($r = 0.928$) and Veracruz ($r = 0.914$) (Table 5). This is not surprising, since Chiapas and Veracruz are located in the southern Mexico and are two areas neighboring Belize. The climates and floras are thus very similar. The next country with a strong relationship of 0.795 with Belize is Ecuador, which also has a neotropical vegetation. Kashmir, North America, and Korea come next with correlations between 0.5 and 0.7. It is not surprising that the coefficients of relationship are lower than the other close countries, but the coefficients are still quite high.

The correlation values with the plant families used as medicines are much lower than those obtained with the total indexed angiosperm families (Table 5). However, the highest correlation coefficients are once again between Belize (Q'eqchi') and Chiapas (Tzotzil) ($r = 0.489$) and Belize (Q'eqchi') and Veracruz (Popoluca) ($r = 0.480$). Leonti et al. (2003) obtained a high correlation between these two Mexican regions (Chiapas and Veracruz) and explained this close relationship by the similarity of their floras and also the fact that they are members of the Macro-Mayan language stock and are culturally related. The Q'eqchi' group also has a similar flora and a common cultural past with these two populations.

The results are variable with the other four populations. In fact, Kashmir ($r = 0.441$) is in the third position, followed by Korea ($r = 0.386$), North America ($r = 0.290$), and Ecuador ($r = 0.243$). Once again, the low relationship with the Ecuador pharmacopoeia shows the same pattern presented by Leonti et al (2003). The indexed plant families of Belize and Ecuador gave a coefficient of 0.795, which would predict a correlation of their pharmacopoeias of about 0.42. This expected value was calculated using the coefficient ratio of the Chiapas region (1.897) which showed a higher

TABLE 5. PEARSON CORRELATION COEFFICIENTS (R) AND BONFERRONI PROBABILITIES (P) CALCULATED FOR THE INDEXED ANGIOSPERM FAMILIES AND THE FAMILIES USED AS MEDICINES. THIS ANALYSIS IS A PAIRWISE COMPARISON OF THE BELIZE DATA AND EACH OF THE SIX OTHER AREAS. THE NUMBERS OF PLANT FAMILIES (N) TAKEN INTO CONSIDERATION FOR EACH ANALYSIS ARE ALSO PRESENTED.

	Belize vs.					
	Veracruz[1]	Chiapas[2]	Kashmir[2]	North America[2]	Korea[2]	Ecuador[2]
Indexed Angiosperm Families						
r =	0.914	0.928	0.695	0.667	0.586	0.795
p <	0.001	0.001	0.001	0.001	0.001	0.001
n =	202	208	202	272	219	190
Medicinal Families						
r =	0.480	0.489	0.441	0.290	0.386	0.243
p <	0.001	0.001	0.001	0.001	0.001	0.010
n =	152	120	82	168	101	112

[1] Leonti et al. 2003
[2] Moerman et al. 1999

relationship with the Belize. This ratio was obtained by dividing the flora coefficient (r = 0.928) by the pharmacopoeia coefficient (r = 0.489). In fact, the actual Ecuador coefficient of 0.243 means that the relatedness of their flora is not the only influencing factor. As mentioned by Leonti et al. (1999), knowledge of medicinal species may have been transmitted via migrating peoples and, by the time people reached the tropical regions of Ecuador, where the floristics were dramatically different, they had to develop a new range of ethnobotanical knowledge. Furthermore, the selection of plant species as medicines depends also on culture-bound factors. The coefficient of pharmacopoeia is also low with North America, but in this case the results could be explained by the fact that the Q'eqchi' healers principally use plants collected in tropical rainforests.

CONCLUSION

The previous quantitative analysis of the Q'eqchi' medicinal plants (Treyvaud Amiguet et al. 2005) showed the major plant families used by the healers. The first three families were Rubiaceae, Piperaceae, and Asteraceae. This regression analysis gave a slightly different result as the size of the family is taken into consideration. Then the large family of Rubiaceae dropped to the second rank, while the medium-sized family of Piperaceae became first. The most important difference of rank was observed for the large Fabaceae family, which moved from the fifth position to position 179.

Since 14 families of the collection are overused and three underused, this confirms the strong Q'eqchi' medicinal knowledge which has selected the plants based on their availabilities, on their biological activities, and on cultural factors. As the previous publication (Treyvaud Amiguet et al. 2005) and this in-depth analysis were the first attempts to highlight the importance of the Q'eqchi' medicinal knowledge and their well-defined traditions, further collections could slightly modify the profile of the plant families ranking list. However, according to the healers, the medicinal plants presented in this first field collection were the most important species of their pharmacopoeia. Based on the above results, further field collections are planned to analyze the ethnopharmacological use of the Piperaceae family by the Q'eqchi' in more detail.

The high utilization of and consensus for these plants as medicines is explained by the fact that the Q'eqchi', like other Maya groups have lived for thousands of years in Mesoamerica, and their cosmocentric worldview has led to a sophisticated and complex relationship with the natural world.

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APPENDIX 1: REGRESSION ANALYSIS OF THE 209 BELIZEAN FAMILIES. THE NUMBER OF SPECIES FOR EACH FAMILY MENTIONED IN THE CHECKLIST OF VASCULAR PLANTS OF BELIZE (CVPSPE) AND IN THE COLLECTED Q'EQCHI' MEDICINAL PLANTS (QMPSPE), PRESENTED WITH RESIDUAL VALUES

Rank	Family	CVPSPE	QMPSPE	Residual [a]
1	Piperaceae (Magnoliidae)	45	14	12.4029
2	Rubiaceae (Asteridae)	142	16	11.6966
3	Asteraceae (Asteridae)	153	12	7.3897
4	Melastomataceae (Rosidae)	96	10	6.9800
5	Araceae (Arecidae)	45	8	6.4029
6	Adiantaceae (Pteridophyta)	40	5	3.5424
7	Acanthaceae (Asteridae)	47	5	3.3471
8	Apocynaceae (Asteridae)	36	4	2.6540
9	Begoniaceae (Dilleniidae)	4	3	2.5468
10	Verbenaceae (Asteridae)	40	4	2.5424
11	Menispermaceae (Magnoliidae)	8	3	2.4352
12	Passifloraceae (Dilleniidae)	22	3	2.0446
13	Aspleniaceae (Pteridophyta)	58	4	2.0402
14	Cucurbitaceae (Dilleniidae)	25	3	1.9609
15	Vitaceae (Rosidae)	7	2	1.4631
16	Cactaceae (Caryophyllidae)	10	2	1.3794
17	Gesnariaceae (Asteridae)	13	2	1.2957
18	Schizaeaceae (Pteridophyta)	13	2	1.2957
19	Gentianaceae (Asteridae)	15	2	1.2399
20	Commelinaceae (Commelinidae)	19	2	1.1283
21	Myrsinaceae (Dilleniidae)	22	2	1.0446
22	Lamiaceae (Asteridae)	27	2	0.9051
23	Moraceae (Hamamelidae)	36	2	0.6540
24	Caryophyllaceae (Caryophyllidae)	1	1	0.6305
25	Haemodoraceae (Commelinidae)	1	1	0.6305
26	Sapindaceae (Rosidae)	37	2	0.6261
27	Marattiaceae (Pteridophyta)	2	1	0.6026
28	Monimiaceae (Magnoliidae)	2	1	0.6026
29	Campanulaceae (Asteridae)	4	1	0.5468
30	Costaceae (Commelinidae)	4	1	0.5468
31	Zamiaceae (Cycadophyta)	4	1	0.5468
32	Zingiberaceae (Commelinidae)	4	1	0.5468
33	Apiaceae (Rosidae)	5	1	0.5189
34	Araliaceae (Rosidae)	5	1	0.5189
35	Davalliaceae (Pteridophyta)	5	1	0.5189
36	Rhamnaceae (Rosidae)	6	1	0.4910
37	Burseraceae (Rosidae)	7	1	0.4631
38	Marcgraviaceae (Dilleniidae)	7	1	0.4631
39	Loganiaceae (Asteridae)	8	1	0.4352
40	Malvaceae (Dilleniidae)	44	2	0.4308
41	Chrysobalanaceae (Rosidae)	9	1	0.4073
42	Combretaceae (Rosidae)	9	1	0.4073
43	Dilleniaceae (Dilleniidae)	9	1	0.4073
44	Bignoniaceae (Asteridae)	45	2	0.4029
45	Aristolochiaceae (Magnoliidae)	10	1	0.3794
46	Celastraceae (Rosidae)	11	1	0.3515
47	Marantaceae (Commelinidae)	11	1	0.3515
48	Dioscoriaceae (Liliidae)	12	1	0.3236
49	Selaginellaceae (Lycopodiophyta)	13	1	0.2957
50	Tiliaceae (Dilleniidae)	14	1	0.2678
51	Convolvulaceae (Asteridae)	50	2	0.2634
52	Polygalaceae (Rosidae)	16	1	0.2120
53	Annonaceae (Magnoliidae)	18	1	0.1562

APPENDIX 1: *CONTINUED*

Rank	Family	CVPSPE	QMPSPE	Residual [a]
54	Rutaceae (Rosidae)	20	1	0.1004
55	Thelypteridaceae (Pteridophyta)	21	1	0.0725
56	Solanaceae (Asteridae)	57	2	0.0681
57	Clusiaceae (Dilleniidae)	22	1	0.0446
58	Myrtaceae (Rosidae)	58	2	0.0402
59	Amaranthaceae (Caryophyllidae)	24	1	-0.0112
60	Polypodiaceae (Pteridophyta)	28	1	-0.1228
61	Euphorbiaceae (Rosidae)	104	3	-0.2432
62	Actinidiaceae (Dilleniidae)	1	0	-0.3695
63	Alstroemeriaceae (Liliidae)	1	0	-0.3695
64	Balanophoraceae (Rosidae)	1	0	-0.3695
65	Bataceae (Dilleniidae)	1	0	-0.3695
66	Brunelliaceae (Rosidae)	1	0	-0.3695
67	Buddlejaceae (Asteridae)	1	0	-0.3695
68	Buxaceae (Rosidae)	1	0	-0.3695
69	Ceratophyllaceae (Magnoliidae)	1	0	-0.3695
70	Chloranthaceae (Magnoliidae)	1	0	-0.3695
71	Cistaceae (Dilleniidae)	1	0	-0.3695
72	Crassulaceae (Rosidae)	1	0	-0.3695
73	Droseraceae (Dilleniidae)	1	0	-0.3695
74	Hamamelidaceae (Hamamelidae)	1	0	-0.3695
75	Isoetaceae (Lycopodiophyta)	1	0	-0.3695
76	Juncaceae (Commelinidae)	1	0	-0.3695
77	Lacistemataceae (Dilleniidae)	1	0	-0.3695
78	Lecythidaceae (Dilleniidae)	1	0	-0.3695
79	Loasaceae (Dilleniidae)	1	0	-0.3695
80	Lophosoriaceae (Pteridophyta)	1	0	-0.3695
81	Magnoliaceae (Magnoliidae)	1	0	-0.3695
82	Martyniaceae (Asteridae)	1	0	-0.3695
83	Mayacaceae (Commelinidae)	1	0	-0.3695
84	Menyanthaceae (Asteridae)	1	0	-0.3695
85	Metaxyaceae (Pteridophyta)	1	0	-0.3695
86	Monotropaceae (Dilleniidae)	1	0	-0.3695
87	Musaceae (Commelinidae)	1	0	-0.3695
88	Myricaceae (Hamamelidae)	1	0	-0.3695
89	Najadaceae (Alismatidae)	1	0	-0.3695
90	Pedaliaceae (Asteridae)	1	0	-0.3695
91	Plantaginaceae (Asteridae)	1	0	-0.3695
92	Plumbaginaceae (Caryophyllidae)	1	0	-0.3695
93	Podocarpaceae (Pinophyta)	1	0	-0.3695
94	Polemoniaceae (Asteridae)	1	0	-0.3695
95	Proteaceae (Rosidae)	1	0	-0.3695
96	Psilotaceae (Psilotophyta)	1	0	-0.3695
97	Quiinaceae (Dilleniidae)	1	0	-0.3695
98	Rafflesiaceae (Rosidae)	1	0	-0.3695
99	Salicaceae (Dilleniidae)	1	0	-0.3695
100	Sphenocleaceae (Asteridae)	1	0	-0.3695
101	Staphyleaceae (Rosidae)	1	0	-0.3695
102	Styracaceae (Dilleniidae)	1	0	-0.3695
103	Surianaceae (Rosidae)	1	0	-0.3695
104	Symplocaceae (Dilleniidae)	1	0	-0.3695
105	Tovariaceae (Dilleniidae)	1	0	-0.3695
106	Triuridaceae (Alismatidae)	1	0	-0.3695
107	Trigoniaceae (Rosidae)	1	0	-0.3695
108	Typhaceae (Commelinidae)	1	0	-0.3695

APPENDIX 1: *CONTINUED*

Rank	Family	CVPSPE	QMPSPE	Residual [a]
109	Vochysiaceae (Rosidae)	1	0	-0.3695
110	Zygophyllaceae (Rosidae)	1	0	-0.3695
111	Anthericaceae (Liliidae)	2	0	-0.3974
112	Basellaceae (Caryophyllidae)	2	0	-0.3974
113	Bixaceae (Dilleniidae)	2	0	-0.3974
114	Cabombaceae (Magnoliidae)	2	0	-0.3974
115	Cannaceae (Commelinidae)	2	0	-0.3974
116	Caricaceae (Dilleniidae)	2	0	-0.3974
117	Casuarinaceae (Hamamelidae)	2	0	-0.3974
118	Chenopodiaceae (Caryophyllidae)	2	0	-0.3974
119	Clethraceae (Dilleniidae)	2	0	-0.3974
120	Cuscutaceae (Asteridae)	2	0	-0.3974
121	Cyrillaceae (Dilleniidae)	2	0	-0.3974
122	Dichapetalaceae (Rosidae)	2	0	-0.3974
123	Hydrocharitaceae (Alismatidae)	2	0	-0.3974
124	Hydrophyllaceae (Asteridae)	2	0	-0.3974
125	Lemnaceae (Arecidae)	2	0	-0.3974
128	Ophioglossaceae (Pteridophyta)	2	0	-0.3974
126	Papaveraceae (Magnoliidae)	2	0	-0.3974
127	Pinaceae (Pinophyta)	2	0	-0.3974
129	Portulacaceae (Caryophyllidae)	2	0	-0.3974
130	Primulaceae (Dilleniidae)	2	0	-0.3974
131	Ranunculaceae (Magnoliidae)	2	0	-0.3974
132	Rhizophoraceae (Rosidae)	2	0	-0.3974
133	Rosaceae (Rosidae)	2	0	-0.3974
134	Salviniaceae (Pteridophyta)	2	0	-0.3974
135	Valerianaceae (Asteridae)	2	0	-0.3974
136	Aizoaceae (Caryophyllidae)	3	0	-0.4253
137	Alismataceae (Alismatidae)	3	0	-0.4253
138	Aquifoliaceae (Rosidae)	3	0	-0.4253
139	Brassicaceae (Dilleniidae)	3	0	-0.4253
140	Cymodoceaceae (Alismatidae)	3	0	-0.4253
141	Dracaenaceae (Liliidae)	3	0	-0.4253
142	Gleicheniaceae (Pteridophyta)	3	0	-0.4253
143	Hypoxidaceae (Liliidae)	3	0	-0.4253
144	Icacinaceae (Rosidae)	3	0	-0.4253
145	Myristacaceae (Magnoliidae)	3	0	-0.4253
146	Nymphaeaceae (Magnoliidae)	3	0	-0.4253
147	Olacaceae (Rosidae)	3	0	-0.4253
148	Oleaceae (Asteridae)	3	0	-0.4253
149	Oxalidaceae (Rosidae)	3	0	-0.4253
150	Pontederiaceae (Liliidae)	3	0	-0.4253
151	Theaceae (Dilleniidae)	3	0	-0.4253
152	Arecaceae (Arecidae)	39	1	-0.4297
153	Cecropiaceae (Hamamelidae)	4	0	-0.4532
154	Connaraceae (Rosidae)	4	0	-0.4532
155	Ebenaceae (Dilleniidae)	4	0	-0.4532
156	Elaeocarpaceae (Dilleniidae)	4	0	-0.4532
157	Erythroxylaceae (Rosidae)	4	0	-0.4532
158	Potamogetonaceae (Alismatidae)	4	0	-0.4532
159	Simaroubaceae (Rosidae)	4	0	-0.4532
160	Amaryllidaceae (Liliidae)	5	0	-0.4811
161	Cyclanthaceae (Arecidae)	5	0	-0.4811
162	Hippocrateaceae (Rosidae)	5	0	-0.4811
163	Iridaceae (Liliidae)	5	0	-0.4811

APPENDIX 1: *CONTINUED*

Rank	Family	CVPSPE	QMPSPE	Residual [a]
164	Ochnaceae (Dilleniidae)	5	0	-0.4811
165	Phytolaccaceae (Caryophyllidae)	5	0	-0.4811
166	Theophrastaceae (Dilleniidae)	5	0	-0.4811
167	Ulmaceae (Hamamelidae)	5	0	-0.4811
168	Agavaceae (Liliidae)	6	0	-0.5090
169	Burmanniaceae (Liliidae)	6	0	-0.5090
170	Podostemaceae (Rosidae)	6	0	-0.5090
171	Blechnaceae (Pteridophyta)	7	0	-0.5369
172	Ericaceae (Dilleniidae)	7	0	-0.5369
173	Lycopodiaceae (Lycopodiophyta)	7	0	-0.5369
174	Xyridaceae (Commelinidae)	7	0	-0.5369
175	Fagaceae (Hamamelidae)	8	0	-0.5648
176	Grammitidaceae (Pteridophyta)	8	0	-0.5648
177	Smilacaceae (Liliidae)	8	0	-0.5648
178	Turneraceae (Dilleniidae)	8	0	-0.5648
179	Fabaceae (Rosidae)	295	8	-0.5721
180	Cyatheaceae (Pteridophyta)	9	0	-0.5927
181	Loranthaceae (Rosidae)	9	0	-0.5927
182	Lythraceae (Rosidae)	9	0	-0.5927
183	Anacardiaceae (Rosidae)	10	0	-0.6206
184	Bombacaceae (Dilleniidae)	10	0	-0.6206
185	Heliconiaceae (Commelinidae)	10	0	-0.6206
186	Nyctaginaceae (Caryophyllidae)	10	0	-0.6206
187	Onagraceae (Rosidae)	10	0	-0.6206
188	Viscaceae (Rosidae)	10	0	-0.6206
189	Dennstaedtiaceae (Pteridophyta)	12	0	-0.6764
190	Violaceae (Dilleniidae)	12	0	-0.6764
191	Capparaceae (Dilleniidae)	13	0	-0.7043
192	Eriocaulaceae (Commelinidae)	13	0	-0.7043
193	Meliaceae (Rosidae)	15	0	-0.7601
194	Sterculiaceae (Dilleniidae)	15	0	-0.7601
195	Lentibulariaceae (Asteridae)	16	0	-0.7880
196	Polygonaceae (Caryophyllidae)	19	0	-0.8717
197	Urticaceae (Hamamelidae)	21	0	-0.9275
198	Hymenophyllaceae (Pteridophyta)	22	0	-0.9554
199	Flacourtiaceae (Dilleniidae)	23	0	-0.9833
200	Sapotaceae (Dilleniidae)	23	0	-0.9833
201	Asclepiadaceae (Asteridae)	27	0	-1.0949
202	Scrophulariaceae (Asteridae)	28	0	-1.1228
203	Lauraceae (Magnoliidae)	31	0	-1.2065
204	Boraginaceae (Asteridae)	33	0	-1.2623
205	Malpighiaceae (Rosidae)	36	0	-1.3460
206	Bromeliaceae (Commelinidae)	50	0	-1.7366
207	Cyperaceae (Commelinidae)	146	0	-4.4150
208	Poaceae (Commelinidae)	248	1	-6.2608
209	Orchidaceae (Liliidae)	279	0	-8.1257

[a]Standard deviation of the residuals is 1.8121