ENDEMISM IN THE MEXICAN FLORA: A COMPARATIVE STUDY IN THREE PLANT GROUPS[1]

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Abstract

Endemism values are not equivalent among the Mexican Musci, Poaceae, and Asteraceae. The number of endemic species varies from one group to the next in various types of vegetation or geographical areas, perhaps in response to age, peculiarities of their life cycle, dispersal ability, and individual response to selective pressures. In Mexico, the three major plant groups include 2373 endemic taxa among which 86 are mosses, 257 are grasses, and 2030 are composites. Cluster analysis of a similarity matrix shows relationships between neighboring states and among geographically related state groups. Along the Neovolcanic Belt there are areas of endemism in western and central Mexico, but the relationship between state pairs does not always have a geographical basis. From the standpoint of the number of endemic species per unit area, Distrito Federal is the richest area in Mexico.

Key words: Asteraceae, endemism, Mexico, Musci, Poaceae.

Although Mexico, with 1,972,544 km^2, is the fourteenth largest country in the world, it ranks third in biological diversity (Mittermeier, 1988). It harbors approximately 30,000 species of vascular plants, including more than 21,600 in about 2,500 genera of flowering plants (Rzedowski, 1993). Among these, more than 300 genera and between 50 and 60% of the species are endemic to this country (Ramamoorthy & Lorence, 1987). There are 49 Mexican species of pines, representing more than 50% of the total for the world (Styles, 1993), and 900 to 1000 fern species (Riba, 1993). The bryophytes include about 1700 species (cf. Sharp et al., 1994; Fulford & Sharp, 1990), and among them, the mosses compose about 25% of the Neotropical moss flora.

High plant diversity and the large endemic element are features that set apart the flora of Mexico. Information on the number, origin, and distribution of endemics (e.g., Rzedowski, 1978; Sharp, 1953) is still imprecise, but current data suggest their concentration in certain areas such as the Neovolcanic Belt, a mountain range bisecting the country between 19 and 20°N, and the Sierra Madre del Sur, along the southern Pacific coast, which are considered centers of endemism for many groups (Ferrusquía, 1993). Pertinent literature for vascular plants includes contributions by Rzedowski (1962, 1991a, b), in which the endemic taxa and their geographical ranges are identified.

Preliminary observations indicate that the number of Mexican endemics is associated with climate- and geography-dependent factors. Thus, for instance, in the lowland moist areas of southern Mexico the percentage of endemic vascular plant genera is the lowest in the country, while their numbers increase toward the drier (Rzedowski, 1978) and cooler areas. On the highest mountains, the extreme climate may have caused many species to become narrowly adapted to the environment of the alpine meadows and subalpine elevations. Beaman and Andresen (1966), in a survey of the vascular flora of the summit of Cerro Potosí in northern Mexico, detected 27 of 64 species (42.2%) endemic to the Sierra Madre Oriental; 13 of them were restricted to Cerro Potosí. High endemism values have been detected in the dry lands of the Tehuacán Valley (Smith, 1965) where endemism approaches 17% (Villaseñor, 1993).

The significance of these observations cannot be fully evaluated for the entire flora. The main limiting factors are the lack of complete data on the

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geographical ranges of taxa and incomplete inventories or checklists of the major groups in the Mexican flora. Although these will not be attained for many years yet, the use of an alternative strategy may still permit reasonable estimates of endemism, its distribution in Mexico, and how endemism relates to the geography of the country. In this contribution, we make floristic comparisons among taxa for which preliminary lists and geographic ranges are available. As specialists, we have produced and compiled information on the Mexican Musci, Asteraceae, and Poaceae that may serve to illustrate patterns of endemism for the entire country, or for such specific areas as the Neovolcanic Belt of central Mexico where the flora is best known.

For Mexican mosses, in addition to data in a recent flora (Sharp et al., 1994), the number and relative importance of the endemic species have been published in several contributions. In the deciduous forests of eastern Mexico eight species were once considered endemic (Delgadillo, 1979), but further study has shown virtually no endemism in these communities, as is the case of the moss flora of the Yucatan Peninsula (Delgadillo, 1984). In the dry lands of Zacatecas (Delgadillo & Cárdenas, 1987) and the Tehuacán Valley (Delgadillo & Zander, 1984), the proportion of endemics is low, but appears comparatively higher than in the tropical lowlands of southern Mexico. Only five species are recognized as endemic in Zacatecas (4.3% of the moss flora), and four in the Tehuacán Valley (7% of the moss flora). In the alpine areas there are 19 endemic species that account for 17% of the moss flora there (Delgadillo, 1971, 1987).

The studies on the Poaceae of Mexico are mostly floristic in nature, but many contain reliable data on the distribution of species in the country (e.g., Hernández X., 1959, 1964; Johnston, 1940; Miranda, 1960; Rzedowski, 1962, 1965, 1975, 1978, 1993; Sharp, 1953). A valuable discussion on grass endemism was contributed by Valdés and Cabral (1993), who indicated that a total of 272 species (30% of the grass flora) are endemic to Mexico. The Chloridoideae have the highest number of endemics, with 73 species, followed by the Panicoideae with 46, and the Pooideae with 43. According to these authors, the states with the highest numbers of endemic grasses are Jalisco, México, Veracruz, and Oaxaca. Despite the cosmopolitan nature of the Poaceae, their distribution patterns are well defined and are known to be correlated with edaphic and climatic features.

With regard to the Asteraceae, preliminary estimates by Villaseñor (1993) include 1813 endemics out of 2861 species for 63.4% endemism in the Mexican flora; these belong in 371 genera, 67 of which are endemic to Mexico (Villaseñor et al., 1998). The number of species known from Mexico in this family was expected to rise to about 3000 and, with this, an increase in the number of endemic taxa in certain areas; Villaseñor (1993) suggested a trend toward higher endemism values in states located in the drier northern and southern areas or in the mountain region of Mexico. Unpublished data for the Valley of Tehuacán recognize at present, in addition to the taxa endemic to the country, 32 species restricted to the valley out of 358 Asteraceae for the local flora, and in Zacatecas 4 restricted taxa out of the total 488 species. The flora of Nayarit comprises 447 species of Asteraceae, 15 of which are restricted to the state (Ortíz-Bermúdez et al., 1998), while in the Yucatan Peninsula and Tabasco there are 7 restricted endemics from a flora of 252 species (Villaseñor, 1989).

Materials and Methods

A Microsoft ACCESS database containing the state distribution and the names of species of Musci, Asteraceae, and Poaceae restricted to the political limits of Mexico was compiled from bibliographic sources and support from herbarium specimens. Sharp et al. (1994) and Delgadillo et al. (1995) were the main sources for mosses. In addition to numerous monographs, information was compiled from publications such as Davidse et al. (1994), McVaugh (1983), and Valdés-Reyna and Dávila (1995) for the Poaceae, and McVaugh (1984), Rzedowski and Calderón (1995), Strother (1999), and Turner (1997), as examples, for the Asteraceae. The main herbarium sources include MEXU for the mosses, and MEXU, ENCB, IBUG, MICH, and US for the Poaceae and the Asteraceae. Specimen data were used to complement the taxon distribution.

Database information was used to compute Jaccard's Index of Similarity and a cluster analysis to determine the floristic relationships of the Mexican states. The database file information was exported to Microsoft EXCEL tables as the first step to use an NTSYSpc version 2.02 software package (Rohlf, 1998). A presence-absence OGUs (Operational Geographical Units, i.e., states) matrix served to calculate the index of similarity and to produce a similarity matrix. The UPGMA (unweighted pair-group arithmetic averages method) dendrograms (Figs. 2–4) were generated by the SAHN-clustering command in NTSYS-pc. Similar procedures were used to review the relationships of individual groups or smaller areas in Mexico, e.g., the Neovolcanic Belt states. As a whole, the present analysis concerns 2373 endemic species, including 15 subspecies and 339 varieties, in the three plant groups studied. The database and the similarity matrices are available on request from the authors.

For reference, the political subdivision of Mexico and the location of certain geomorphological features cited in the text are shown in Figure 1. The Neovolcanic Belt states discussed elsewhere in the text are Nayarit, Jalisco, Colima, Michoacán, Querétaro, Hidalgo, México, Distrito Federal, Morelos, Tlaxcala, Puebla, and Veracruz. The density values shown in Table 2 represent the computation of a simple density index of ecology textbooks, i.e., number of species per unit area.

Results

Endemism in Mexico

From our records, there are 86 endemic moss species in Mexico, 4 of which are represented by subspecific taxa. Most endemic species are known from below 2800 m, but there is a group of about 18 species known only from above 3000 m in elevation. Among the species from the higher elevations, *Astomiopsis* × *altivallis* Delgad. is conspicuous for its presumed hybrid origin between *A. amblyocalyx* C. Muell. and *A. exserta* (Bartr.) Snider; *Archidium acauloides* Schwab, a cleistocarpic species, is also of interest because it represents a form with limited dispersal ability. Because of the small number of species involved and their narrow ranges, no distinct geographical trends of state distribution are shown by the cluster analysis. However, most states along the Neovolcanic Belt are grouped together, and harbor, along with Oaxaca and Tamaulipas, more than 10 endemic taxa (Table 1). Despite the disparity in group size, the Poaceae and Asteraceae show similar behavior, i.e., they are best represented in certain adjacent states, in the Neovolcanic Belt states, and in Oaxaca. The values for all three groups seemed to confirm this trend (Table 1).

With respect to the Poaceae, a total of 257 endemic species—including 12 subspecies and varieties—out of 950 grasses, have been registered for Mexico (Tables 1, 3) for 27% endemism. Some species, such as *Festuca hintoniana* Alexeev, are known only from one or a few localities, while others are exclusively known from the type locality, as is the case of *Schaffnerella gracilis* (Benth.) Nash. By contrast, many endemic species, including *Bouteloua scorpioides* Lag., *Muhlenbergia gigantea* (Fourn.) Hitchc., *M. firma* Beal, *Bothriochloa hirtifolia* (J. Presl) Henrard, *Panicum decolorans* Kunth, and *Urochloa meziana* (Hitchc.) Morrone & Zuloaga, are widespread in Mexico. Except for Tabasco, there are endemic grasses known from every Mexican state, mostly distributed at intermediate elevations (ca. 1500–2800 m). The highest number of endemic species is found in Jalisco, México, and Michoacán, with 55 or more species, but the states of Chiapas, Chihuahua, Durango, Guanajuato, Nuevo León, Oaxaca, Puebla, San Luis Potosí, and Veracruz have between 32 and 49 endemic species. In contrast, Baja California, Campeche, Quintana Roo, Tlaxcala, and Yucatán have less than 10 endemic species. In contrast to the results reported by Valdés and Cabral (1993), the present study includes species with a strictly Mexican range only. If the grasses restricted to the southwestern United States (California, Arizona, New Mexico, and Texas) and Mexico were included, the number of endemic species would increase to about 300, with the highest number of them occurring in the semiarid habitats and the alpine grasslands. Endemic Poaceae are present in low numbers in the states of Campeche and Quintana Roo, and are unknown from Tabasco.

The flora of Mexico includes about 3003 Asteraceae; 1972 of them, or 65.7%, are endemic to the country. However, for the analysis, 2030 species, subspecies, and varieties of endemic Asteraceae were accepted, i.e., incorporating 58 taxa not fully documented and increasing the percentage to 67.6 (Table 3). The endemic taxa include 10 subspecies and 328 varieties. The known altitudinal interval for the Mexican Asteraceae places many of the endemic taxa in the intermediate elevations (ca. 1500–2800 m), and their individual ranges are frequently broader than those of mosses and grasses. Some species of Asteraceae have narrow ranges that depend on the presence of special habitats, e.g., *Geissolepis suaedifolia* B. L. Rob. or *Stephanodoria tomentella* (B. L. Rob.) Greene that are endemic to gypsophilous grasslands in San Luis Potosí; other species, such as *Psacalium peltatum* (Kunth) Cass., whose range extends from Chihuahua and Durango south to Puebla and Oaxaca, demonstrate a comparatively broad distribution in Mexico. In terms of the states, those with the largest number of endemic species are Jalisco, México, Michoacán, Oaxaca, and Durango, with 385 to 526 species in each state. A second group, formed by Guerrero and Puebla, contains between 317 and 365 species (Table 1).

Cluster analysis of similarity data for the Asteraceae indicates that many Mexican states are related to their neighbors; the overall analysis for all three groups (Fig. 2) clearly shows this trend at the

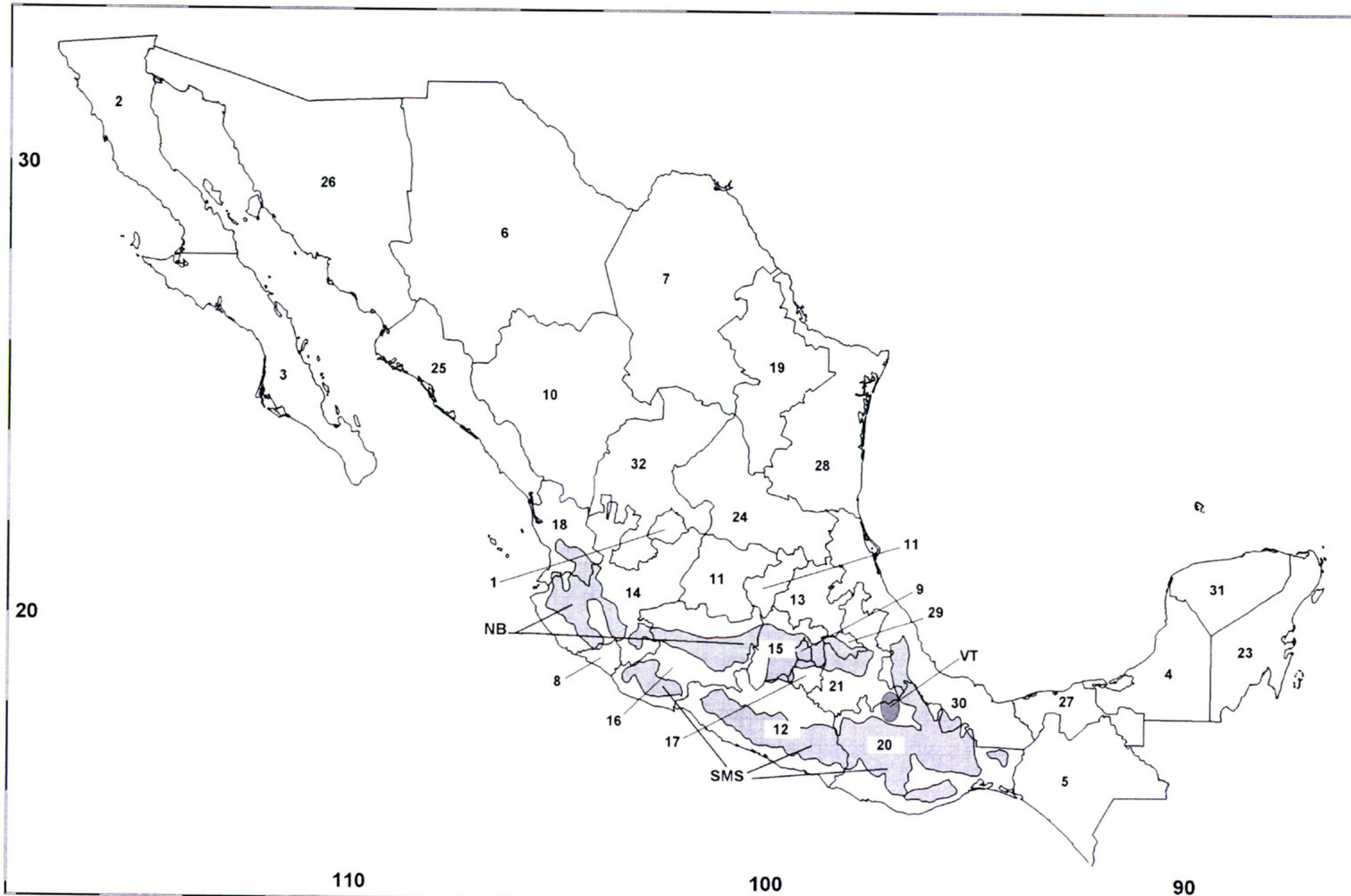

Figure 1. Political subdivision of Mexico. 1 = Aguascalientes (Ags), 2 = Baja California (BC), 3 = Baja California Sur (BCS), 4 = Campeche (Camp), 5 = Chiapas (Chis), 6 = Chihuahua (Chih), 7 = Coahuila (Coah), 8 = Colima (Col), 9 = Distrito Federal (DF), 10 = Durango (Dgo), 11 = Guanajuato (Gto), 12 = Guerrero (Gro), 13 = Hidalgo (Hgo), 14 = Jalisco (Jal), 15 = México (Mex), 16 = Michoacán (Mich), 17 = Morelos (Mor), 18 = Nayarit (Nay), 19 = Nuevo León (NL), 20 = Oaxaca (Oax), 21 = Puebla (Pue), 22 = Querétaro (Qro), 23 = Quintana Roo (QR), 24 = San Luis Potosí (SLP), 25 = Sinaloa (Sin), 26 = Sonora (Son), 27 = Tabasco (Tab), 28 = Tamaulipas (Tamps), 29 = Tlaxcala (Tlax), 30 = Veracruz (Ver), 31 = Yucatán (Yuc), 32 = Zacatecas (Zac), NB = Neovolcanic Belt, SMS = Sierra Madre del Sur, VT = Tehuacán Valley.

Table 1. Number of endemic taxa per state for each major plant group investigated in Mexico. Number of species endemic to a state are given in parentheses; Neovolcanic Belt states are shown in **bold.**

State	Musci	Asteraceae	Poaceae	Σ
Aguascalientes	0 (0)	154 (0)	19 (0)	173 (0)
Baja California	1 (0)	140 (32)	5 (2)	146 (34)
Baja California Sur	1 (0)	103 (48)	12 (4)	116 (52)
Campeche	0 (0)	4 (0)	5 (0)	9 (0)
Chiapas	6 (3)	135 (37)	38 (6)	179 (46)
Chihuahua	2 (0)	275 (58)	44 (8)	321 (66)
Coahuila	1 (1)	223 (46)	41 (10)	265 (57)
Colima	**0 (0)**	**113 (10)**	**20 (6)**	**133 (16)**
Distrito Federal	**12 (3)**	**180 (1)**	**25 (0)**	**217 (4)**
Durango	4 (1)	385 (59)	48 (1)	437 (61)
Guanajuato	0 (0)	213 (2)	38 (0)	251 (2)
Guerrero	2 (1)	365 (54)	29 (0)	396 (55)
Hidalgo	**10 (0)**	**271 (15)**	**28 (0)**	**309 (15)**
Jalisco	**10 (3)**	**526 (64)**	**80 (15)**	**616 (12)**
México	**21 (2)**	**391 (15)**	**67 (7)**	**479 (24)**
Michoacán	**17 (1)**	**460 (25)**	**55 (4)**	**532 (30)**
Morelos	**6 (0)**	**230 (5)**	**22 (0)**	**258 (5)**
Nayarit	**7 (2)**	**277 (15)**	**27 (5)**	**311 (22)**
Nuevo León	4 (2)	257 (41)	32 (4)	293 (47)
Oaxaca	17 (5)	473 (115)	40 (3)	530 (123)
Puebla	**23 (3)**	**317 (13)**	**49 (1)**	**389 (17)**
Querétaro	**1 (0)**	**218 (6)**	**18 (0)**	**237 (6)**
Quintana Roo	0 (0)	6 (0)	2 (0)	8 (0)
San Luis Potosí	8 (1)	249 (23)	48 (5)	305 (29)
Sinaloa	1 (1)	224 (25)	21 (1)	246 (27)
Sonora	1 (0)	160 (27)	23 (0)	184 (27)
Tabasco	0 (0)	6 (0)	0 (0)	6 (0)
Tamaulipas	11 (2)	166 (16)	24 (2)	201 (20)
Tlaxcala	**5 (0)**	**119 (0)**	**9 (0)**	**133 (0)**
Veracruz	**25 (3)**	**271 (21)**	**38 (6)**	**334 (30)**
Yucatán	1 (0)	9 (2)	8 (0)	18 (2)
Zacatecas	5 (0)	208 (5)	22 (1)	235 (6)
TOTAL	86 (34)	2030 (780)	257 (91)	2373 (905)

regional level. Aguascalientes, Zacatecas, Guanajuato, Querétaro, Hidalgo, and San Luis Potosí form the first block of neighboring states that share numerous endemic taxa. The states in the peninsulas of Baja California and Yucatan stay together in the endemism dendrogram (Fig. 2) as do groups of states in northeastern (Coahuila, Nuevo León, and Tamaulipas), northwestern (Chihuahua and Durango), and central Mexico (Distrito Federal, Tlaxcala, Puebla, Veracruz, Guerrero, México, Michoacán, and Morelos). The position of certain states does not conform to geographical vicinity as, for instance, in the case of Oaxaca, which is closer to Morelos and Michoacán than to Puebla and Guerrero, which limit it to the north and west; the endemic flora of Chiapas remotely links that state to the rest of the country. The data set for mosses and grasses modifies the value of the similarity coefficient and the relative position of many states in the dendrogram (Fig. 3). Such states as Aguascalientes, Guanajuato, San Luis Potosí, Zacatecas, Chihuahua, and Durango from the first block in Figure 2 have a different pairing arrangement in Figure 3. Also, individual analyses for mosses and grasses fail to produce reliable dendrograms, as indicated by the lack of similarity among neighboring states, perhaps induced by the low number of records and, in mosses, by the absence of endemic records for about six states.

The number of endemic taxa in the overall analysis seems indirectly related to the size of each state; thus, for instance, Aguascalientes, Colima, and Tlaxcala are among the smallest states in Mexico and have some of the lower numbers (Table 1). By contrast, the low numbers exhibited by the states of the Yucatan Peninsula (Campeche, Yuca-

Table 2. Endemism along the Neovolcanic Belt of Mexico. The second column gives the number of species restricted to a state in parentheses; the last column shows the corresponding density index also in parentheses. Density = Number of endemics/surface area × 100.

State	No. endemics	Surface (km^2)	Density
Colima	133 (16)	5,191	2.56 (0.31)
Jalisco	616 (12)	80,836	0.76 (0.01)
Nayarit	311 (22)	26,979	1.15 (0.08)
Distrito Federal	217 (4)	1,479	14.67 (0.27)
Tlaxcala	133 (0)	4,016	3.31 (0)
Hidalgo	309 (15)	20,813	1.48 (0.07)
Querétaro	237 (6)	11,449	2.07 (0.05)
México	479 (24)	21,355	2.24 (0.11)
Michoacán	532 (30)	59,928	0.89 (0.05)
Morelos	258 (5)	4,950	5.21 (0.10)
Puebla	389 (17)	33,902	1.15 (0.05)
Veracruz	334 (30)	71,699	0.47 (0.04)

tán, and Quintana Roo) may not be dependent on their surface area as each one has between 38,000 and 50,000 km^2. On the other hand, the similarity and relationship among states along the Neovolcanic Belt (Table 1, Fig. 2) suggest areas of endemism that require further analysis.

ENDEMISM ALONG THE NEOVOLCANIC BELT

Mosses represent an important element in the flora of the Neovolcanic Belt. The Belt occupies portions of the states of Colima, Jalisco, Nayarit, Distrito Federal, Tlaxcala, Hidalgo, Querétaro, México, Michoacán, Morelos, Puebla, and Veracruz, thus extending the width of the country (Fig. 1). About 728 moss species are known from this area. By virtue of this number, the states along the Belt may be considered bryologically diverse, for they include about 74% of the mosses known from Mexico. The Belt states are easily accessible, and their collecting record is better than that of other Mexican states. The percentage of endemism, with about 62 shared endemic moss species in the Belt (8.5%), is nearly as high as that for moss flora of the entire country (8.8%), as shown in Table 3. A distinction must be made between "shared" and "restricted" endemics; in this contribution the former refers to species distributed in two or more states while the latter are known from a single state.

The Asteraceae are represented by 1640 species and infraspecific taxa along the Belt, or nearly 55% of the Mexican Asteraceae. About 1095 of them are endemic to Mexico and 190 are restricted to a single Neovolcanic Belt state (Table 3); the percentage of endemism nationwide (67.6%) is nearly the same as that for the Belt (66.8%). By contrast, there are 222 species of Poaceae (23% of all Mexican grasses) along the Belt states, 162 of which are shared with other states (73% of the Neovolcanic Belt Poaceae), and 44 of them restricted to this mountain range (Table 3). The Neovolcanic Belt may be considered an area of high diversity (4935 in these plant groups) and high endemism (1319 endemics, including 251 narrow endemics, Table 3) and might be recognized, by these criteria, as a separate floristic province. Rzedowski (1978) treated it as part of the Southern Ranges province (see Fig. 1).

The dendrogram in Figure 4 shows the overall relationship of endemism among the states along the Neovolcanic Belt with a general trend in a west-east direction. Jalisco and Nayarit, on the western coast, are very similar to each other, with about 240 shared endemic taxa; the states of México and Michoacán also share numerous taxa (300) and together constitute a separate area of endemism, despite the geographical vicinity with states on the western coast. Colima and Tlaxcala have the lowest endemism numbers along the Belt (Table 2), and this is attributed in part to their small surface area. The latter state, however, is floristically more similar to Distrito Federal (Fig. 4) than to Puebla or Veracruz that surround it. Otherwise, the close flo-

Table 3. Number of endemic species and percentage of endemics among Musci, Asteraceae, and Poaceae in Mexico and in the Neovolcanic Belt.

	Musci	Asteraceae	Poaceae	Total
Mexican species	982	3003	950	4935
Mexican endemics	86	2030	257	2373
Percentage in Mexico	**8.8**	**67.6**	**27**	**48**
Neovolcanic Belt species	728	1640	222	2590
Percentage from total	**74.1**	**54.6**	**23.4**	**52.5**
Shared endemics in Belt states	62	1095	162	1319
Percentage in Belt states	**8.5**	**66.8**	**73.0**	**50.9**
Restricted to one Belt state	17	190	44	251

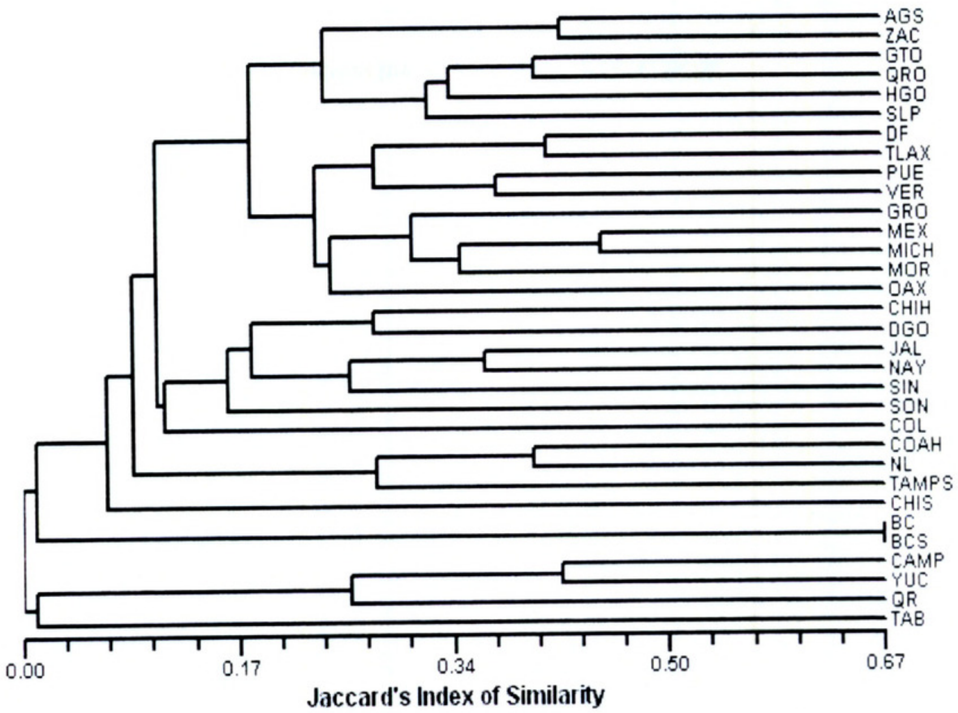

Figure 2. UPGMA dendrogram of the floristic relationships among Mexican states as illustrated by endemic Asteraceae, Poaceae, and Musci.

ristic relationship between members of most state pairs (Fig. 4) may be due to their geographical proximity.

As with the overall analysis, species endemism is only indirectly dependent on size of the area along the Neovolcanic Belt. Geologic history, topographic differences, and climatic regimes may provide better explanations for the number of endemics in a given area. By these measures, the states of Jalisco, Michoacán, and México may be

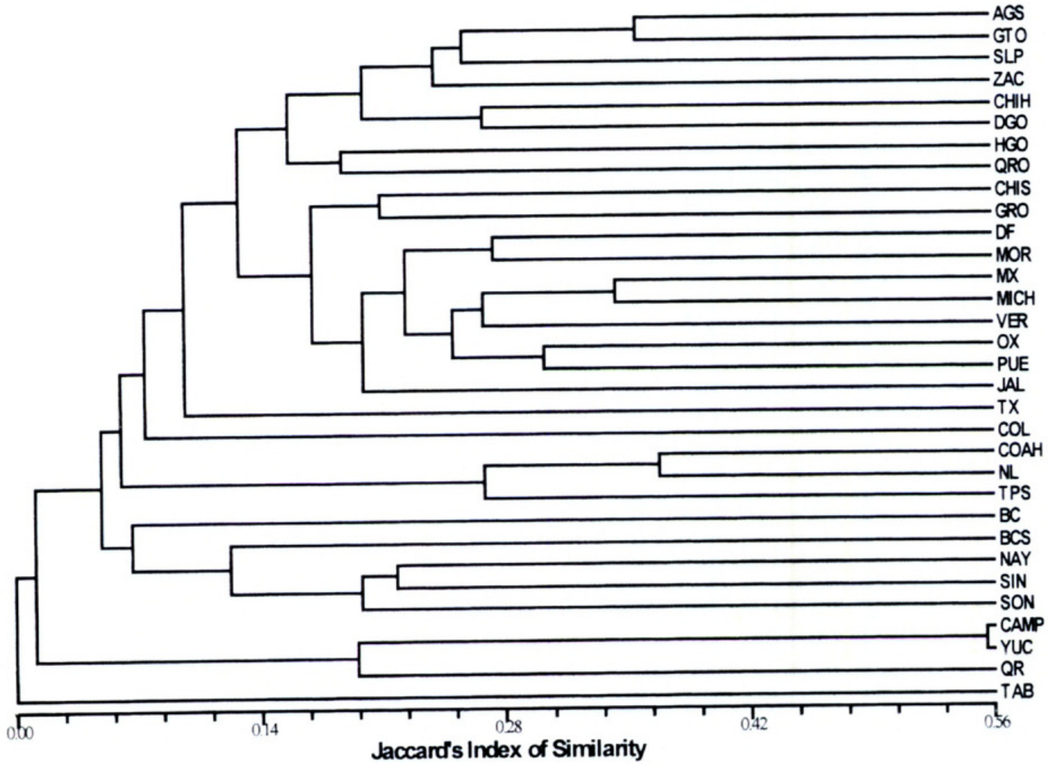

Figure 3. UPGMA dendrogram of the floristic relationships among Mexican states as illustrated by endemic Poaceae and Musci.

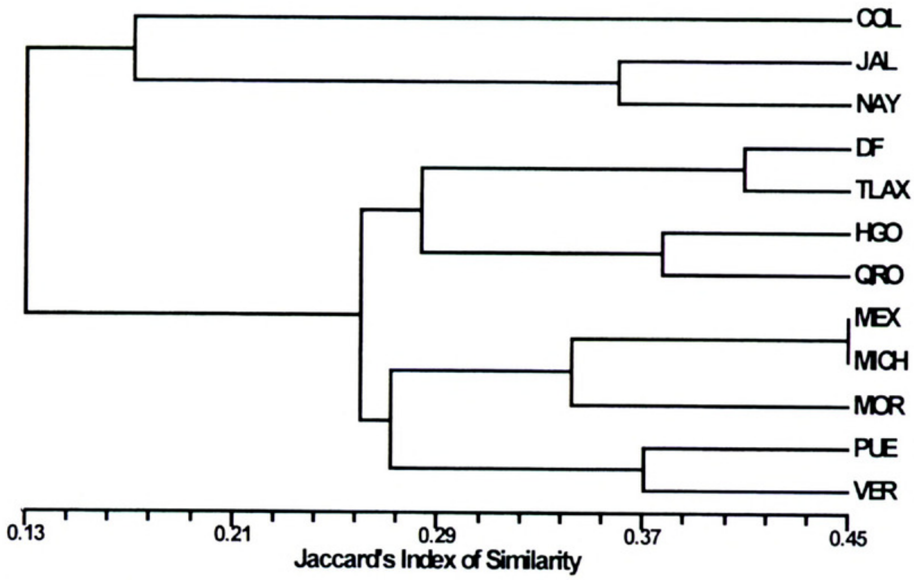

Figure 4. UPGMA dendrogram of the floristic relationships of the states along the Neovolcanic Belt of Mexico as illustrated by endemic Asteraceae, Poaceae, and Musci.

considered the most important areas of endemism along the Neovolcanic Belt. Together these states constitute the largest portion of the Belt, and most endemic taxa in the three major groups are represented in one or the other states. Nevertheless, the computation of the number of endemic taxa per 100 km^2 indicates that Distrito Federal (with a density index of 14.67), Morelos (5.21), and Tlaxcala (3.31, see Table 2) are, by far, the most important areas of endemism in the Belt. A more accurate measure of the relative importance of each state may be obtained by determining the size of the range of endemic taxa and their numbers per unit area. In this study, the density index calculated for the endemic species restricted to each Belt state (Table 2) is not meaningful because their general range size is unknown.

Discussion

The use of a similarity coefficient and cluster analysis has shown that the floristic relationships of states may be established with certain degree of accuracy. The resolution of the analysis, however, depends on the amount of field or herbarium information and an adequate taxonomic background. The input of data from other major plant groups should assist in refining the scheme of relationships among such states, particularly among those that show little similarity with their neighbors. In this contribution, the unusual position of a state may indicate areas of endemism or lack of distributional data, but other explanations may be sought in regional peculiarities or in the biological traits of the plant groups.

The study of endemism by resorting to assemblages of species from widely different plant groups may be advantageous because the combined study of patterns may be a measure of the response of the entire flora to environmental factors that operate over broad geographical areas. The obvious disadvantage of this approach is that the taxa under investigation differ in size, evolutionary history, and biological attributes and, thus, in their response to selective pressures. For these reasons, it could not be assumed that endemism values in mosses would be similar to those of Asteraceae or Poaceae in the same region. Each taxon, by virtue of a differing life cycle or ecological preferences, does not operate under the same selective pressures and, in fact, has differing responses. The dependency on running water for fertilization in mosses contributes to their minor representation in desert areas. Nevertheless, the low number of moss endemics in other habitats may be due to relatively rapid spread of taxa following speciation. Mosses are usually considered to be slow-evolving organisms, but the effect of somatic mutations on evolution and their rates of spread in local populations are unknown. From the standpoint of the life cycle, there are theoretical considerations by which at least some populations may undergo rapid evolutionary change. For instance, if polyploids are produced by diplospory or apospory, or if a somatic mutation is retained in an otherwise haploid organism, with the aid of asexual reproduction these processes may yield an independent and distinct taxon from one generation to the next. Rapid speciation, however, may not be the rule; new taxa may appear by slow evolutionary change and disperse gradually.

Thus, endemic mosses should be comparatively scarce in Mexico and elsewhere. This is supported by current phytogeographic and geologic information suggesting that the moss flora of Mexico has not evolved in isolation. In addition to the examples given in the introduction, a recent study in the lowland areas of Chiapas (Delgadillo & Cárdenas, 2002) reports a single endemic species, *Pylaisiadelpha sharpii* Crum, for the Lacandon Forest and more than 130 species shared with other continental areas. The broad geographical patterns exhibited by Mexican moss species and the age and North–South orientation of mountain ranges agree with the hypothesis of rapid dispersal of newly evolved species in Mexico. The exploration of poorly known areas is not expected to produce a sharp increase in the number of endemic species, but rather the decrease in percentage endemism values as the distribution of described species is better known or as modern taxonomic evaluations result in synonymy. A few years ago, Delgadillo (1994) calculated nearly 11% moss endemism in Mexico; this contribution records only 9%, while the known number of species has increased from 943 in 1994 to about 982 in 2002.

Compared to mosses, grasses and composites represent heterozygote systems where sexual reproduction, the length of the life cycle, and dispersal retard evolutionary events. Assuming similar rates of speciation, but differences in dispersal ability and age of taxa, vascular plants would be expected to be geographically limited, genetically stable, and narrowly distributed, more so than mosses. Long-lived moss species have been documented in the fossil record (Frahm, 2000; Miller, 1984), and broad continental and intercontinental ranges are common among mosses (cf. Sharp et al., 1994). This may not be the case in vascular plants where, in addition, selection does not immediately eliminate mutant genotypes. Phenotypic expressions recognized as endemic taxa may remain for a long time in recombinant diploid populations, even under negative selective pressures. In Mexico, although the number of moss and grass species are similar, the groups differ in their proportion of endemic taxa; the explanation for this difference may be sought among the biological attributes cited above. The present study illustrates how endemism values may not be equivalent between similar taxonomic categories, but does not support such differences in the taxonomic hierarchy.

Local climates certainly act as strong selective forces for every plant group. Mosses, grasses, and composites, however, show differential responses to climate. The distribution of the first group in the drier areas of Mexico does not apparently follow obvious patterns. In fact, there are few endemic species in the desert areas of Zacatecas (e.g., *Curviramea mexicana* (Thér.) Crum and *Jaffuelibryum arsenei* (Thér.) Thér.; Delgadillo & Cárdenas, 1987), but in the alpine areas where mosses are dominant with lichens and grasses, an important endemic element appears. Rzedowski (1962, 1991a) discussed the importance of the dry areas for endemism among vascular plants. In the higher elevations these plant groups may also increase their endemic representation. High UV radiation, daily temperature fluctuation, low organic nitrogen and phosphorus in the substrate of alpine and subalpine areas seem strong selective forces for all plants, including mosses, grasses, and composites.

There are other differences that are evident in the present analysis. Degree of endemism varies among groups, and there are disparities in their altitudinal and latitudinal gradients and in the types of vegetation they occupy. Contributions by Delgadillo (1979, 1984) and Delgadillo and Zander (1984) attest to the uneven distribution of endemic mosses in the deciduous forests of eastern Mexico, in the Yucatan Peninsula, and in the Tehuacán Valley, respectively. Endemism values observed for the Asteraceae and Poaceae also indicate differences among geographical areas, even among those of similar surface area. On a national scale, these preliminary findings may be the basis for the identification of areas of high endemism and the selective forces in operation. They will also assist in unveiling the history of the flora in Mexico and its relationships to other floras in the American tropics. The Neovolcanic Belt, as an example, has been shown to be one such region where portions of the mountain range (Distrito Federal, Jalisco, México, and Michoacán) have higher endemism concentrations than the rest. However, a detailed floristic knowledge of less known or undercollected parts of the country, or even of adjacent areas in other countries, is essential to determine whether the differential distribution of endemics is not an artifact derived from historical collecting preferences.

Literature Cited

Beaman, J. H. & J. W. Andresen. 1966. The vegetation, floristics and phytogeography of the summit of Cerro Potosi, Mexico. Amer. Midl. Naturalist 75: 1–33.

Davidse, G., M. Sousa & A. Chater (editors). 1994. Poaceae. Pp. 476–484 *in* Flora Mesoamericana, Vol. 6. Alismataceae a Cyperaceae. Universidad Nacional Autónoma de México, México D.F.; Missouri Botanical Garden, St. Louis; and The Natural History Museum, London.

Delgadillo M., C. 1971. Phytogeographic studies on alpine mosses of Mexico. Bryologist 74: 331–346.