diversity

Article

Diversity of Useful Mexican Legumes: Analyses of Herbarium Specimen Records

Alfonso Delgado-Salinas [1,*], Leticia Torres-Colín [1], Mario Luna-Cavazos [2] and Robert Bye [3]

[1] Departamento de Botánica, Instituto de Biología, UNAM, Av. Universidad 3000, Cd. Universitaria, Coyoacán, Ciudad de Mexico 04510, Mexico; lety@ib.unam.mx
[2] Postgrado en Botánica, Colegio de Postgraduados, Campus Montecillo, Carretera Mexico Texcoco Km 35.5, Montecillo, Texcoco 56230, Mexico; mluna@colpos.mx
[3] Laboratorio de Etnobotánica, Jardín Botánico, Instituto de Biología, UNAM, Av. Universidad 3000, Cd. Universitaria, Coyoacán, Ciudad de Mexico 04510, Mexico; bye.robert@gmail.com
* Correspondence: adelgado@ib.unam.mx

Abstract: Herbarium specimens of wild Mexican Leguminosae with ethnobotanical information are an important resource for understanding human–legume interactions. The 525 useful legume species registered in Mexico's National Herbarium (MEXU) were analyzed using a hierarchical method and represented in dendrograms. Of these, 244 species noted a single use, while 281 species reported two or more uses. Plants applied for medicinal purposes registered the greatest number of species (351 spp.), followed by those employed as animal food (205 spp.), material sources (197 spp.), environmental modifiers (139 spp.), and food and food additives (119 spp.). This study also suggests that a greater number of uses is concentrated in closely related species-rich taxa rather than in less diverse groups, and that certain uses are clustered in phylogenetically related groups. Of particular interest are multipurpose shrubs and trees managed as living fences that satisfy a variety of needs in rural areas. This diversity of legume resources used by Mexican people may be advantageous in the planning and management of conservation areas, since the diversity, ubiquity, and economic importance of some of species have promoted overuse and destruction.

Keywords: ethnobotany; use species diversity; systematics of Leguminosae (Fabaceae); life form uses; two-way cluster analysis (hierarchical method); use categories; biocultural resouces; taxonomic and genetic resources

Citation: Delgado-Salinas, A.; Torres-Colín, L.; Luna-Cavazos, M.; Bye, R. Diversity of Useful Mexican Legumes: Analyses of Herbarium Specimen Records. *Diversity* **2021**, *13*, 267. https://doi.org/10.3390/d13060267

Academic Editors: Michael Wink, Mario A. Pagnotta, Mohammad Vatanparast and Ashley N. Egan

Received: 16 March 2021
Accepted: 25 May 2021
Published: 13 June 2021

1. Introduction

The main objective of the National Herbarium (MEXU) at the Instituto de Biología, UNAM, is to curate scientific specimens of wild plants that represent the Mexican flora. These specimens enable verifiable identifications to assist botanists and professionals with botanical interests with a more complete representation of Mexican species and species from other regions of the world assembled by its exchange programs. MEXU houses approximately 1,520,000 plant specimens, of which, more than 10% represent legume collections from Mexico and other countries. The earliest type specimen at MEXU of useful legume is of *Inga jinicuil* G. Don collected almost 200 years ago by C.J.W. Schiede in 1829. Additionally, since Colonial times, various legume species were introduced in Mexican territory; while some did not flourish, others became naturalized and adopted by different native peoples. The importation of legumes continues, so that the number of useful introduced legumes is about 150 species in almost 90 genera. The oldest specimen in the herbarium of an introduced useful legume is of *Crotalaria retusa* L. collected in the state of Tamaulipas in 1898.

The information retrieved from each specimen is contingent upon the quality of the collected plant and the associated label data. The legume specimens in MEXU are the result of dedicated field collections principally in central and southern regions of Mexico, and the labels primarily reflect information about locality, vegetation, and plant attributes. Other information such as plant use and local names varied among the plant collectors and their objectives. Knowledge of plant use varies among cultures and between men and women [1]; the registry of plant uses is biased in favor of men's knowledge (rather than that of women) because plant collectors encountered men more frequently in the field.

Most legumes are important hosts to nitrogen-fixing bacteria within different types of vegetations from sea level to high-altitude forests, and their presence is directly related to the overall biological diversity and community health in maintaining and managing biodiversity in ecosystems. The Mexican Leguminosae flora currently consists of 1893 species, of which, ca. 40% are endemic; 47 new species have been described in the last decade. Family diversification in the New World indicates Mexico is the second-most diverse country in legume species (1893 spp.), after Brazil, where the family comprises c. 2800 species in more than 200 genera [2].

Because species of Leguminosae have ecologic and economic importance, useful studies with different objectives have been published throughout the world. Here, we mention some that covered all uses. For example, in Thailand (by the Karen), of the 772 native species, 77 (9.9%) are used [3]; in Nicaragua, with a total of 496 legume species, 121 (24.3%) provide some use [4]; in Southern Africa (Lesotho, South Africa and Swaziland) comprising 1620 species, a total of 704 (43.4%) are useful species [5].

Only five of the six subfamilies (Cercidoideae, Detarioideae, Dialioideae, Caesalpinioideae and Papilionoideae) in the recent classification of the Family Leguminosae or Fabaceae are represented by Mexico's native taxa [6]. A great number of them are members of Caesalpinioideae (including the important Mimosoid group) and Papilionoideae subfamilies which have proved to be useful.

Throughout culturally diverse Mexico, numerous ethnic groups have accumulated extensive knowledge of legumes, including their ecological importance; many species satisfy their daily needs and accompany their activities (Figure 1) [7]. This traditional knowledge has been reported in 3717 herbarium specimens at MEXU and almost 90 publications. The latter source generated 80 useful legume species that are not considered in this study because their taxonomic identities are pending verification (Torres-Colín et al., in prep.). The impact of wild legumes on human cultures in Mexico and throughout the world are reported in other studies [5,7–9] and references therein.

Using ethnobotanical reports based upon herbariums specimens with verified identity, this study analyzed the relationship between the plants' uses and their taxonomic hierarchical groupings. This approach attempts to answer the following questions. Do the sampling and analyses meaningfully reflect the diversity of legume uses in Mexico? Is there a relation between useful species abundance and the richness of ethnic groups in the highest biocultural state of Mexico? Are taxonomic groups correlated with different uses? Are more wild Mexican legume species used for medicines than for food, a pattern found in legume studies of other countries? How has the introduction of livestock impacted the selection and use of legumes as pasture and fodder?

Figure 1. A selection of useful Mexican legumes. (**A**) *Acaciella angustissima* (firewood and medicinal); (**B**) *Conzattia multiflora* (edible fruit); (**C**) *Crotalaria pumila* (edible and medicinal leaves); (**D**) *Erythrina americana* (edible flowers and environmental uses); (**E**) *Gliricidia sepium* (multipurpose species); (**F**) *Ebenopsis ebano* (firewood and environmental uses); (**G**) *Leucaena leucocephala* (edible seed); (**H**) *Mimosa polyantha* (firewood and materials); (**I**) *Phaseolus coccineus* (archeological and contemporary cultivated seeds); (**J**) *Prosopis laevigata* (table made in Guanajuato, Mexico); (**K**) *Senna racemosa* (medicinal

bark). Credits: (**A–E**,**H**,**K**) J. Vazquez' Slide Collection at MEXU; (**F**) D. Martínez Almaguer; (**I**) A. Delgado; (**G**,**J**) L. Torres-Colín.

2. Material and Methods

Data Scoring and Statistical Analysis

The records of useful Mexican legumes from specimens at the National Herbarium (MEXU) include a total of 25 Tribes, 115 (72.7%) out of 158 genera and 525 (27.7%) of an estimated 1893 species. No wild use records were found for species in the other legume tribes occurring in Mexico, such as Loteae and Thermopsideae (Table 1).

Table 1. Taxonomic distribution of useful native taxa amongst tribes of the five subfamilies: Cercidoideae, Detarioideae, Dialioideae, Caesalpinioideae and Papilionoideae, showing the total numbers of Mexican and their useful records. Abbreviations stand for use = useful taxa, Mx = Mexican taxa, Gen. = genera and Spp. = species. A total of 115 genera (72.7%) and 525 species (27.7%) are reported useful at the National Herbarium (MEXU).

Subfamily	Tribe	useGen.	MxGen.	%taxa	useSpp.	MxSpp.	%taxa
Cercidoideae	Cercidieae	2	3	66	7	35	20
Detarioideae	Amherstieae	1	1	100	1	3	33
Detarioideae	Detarieae	2	2	100	2	2	100
Dialioideae	Dialiineae	1	2	50	1	2	50
Caesalpinioideae	Acacieae	4	4	100	40	86	46
Caesalpinioideae	Caesalpinieae	12	15	80	22	74	29
Caesalpinioideae	Cassieae	3	3	100	38	85	44
Caesalpinioideae	Ingeae	16	17	94	72	155	46
Caesalpinioideae	Mimoseae	9	12	75	70	165	42
Papilionoideae	Amorpheae	4	7	57	32	197	16
Papilionoideae	Brongniartieae	2	2	100	7	66	10
Papilionoideae	Crotalarieae	1	1	100	13	23	56
Papilionoideae	Dalbergieae	13	14	92	38	117	32
Papilionoideae	Desmodieae	1	3	33	23	98	23
Papilionoideae	Galegeae	1	3	33	2	99	2
Papilionoideae	Genisteae	1	2	50	6	83	7
Papilionoideae	Indigofereae	1	1	100	9	34	26
Papilionoideae	Millettieae	3	5	60	35	139	25
Papilionoideae	Phaseoleae	20	29	69	74	250	29
Papilionoideae	Psoraleeae	2	4	50	2	10	20
Papilionoideae	Robinieae	6	9	66	18	51	35
Papilionoideae	Sesbanieae	1	1	100	1	5	20
Papilionoideae	Sophoreae	7	9	77	10	43	23
Papilionoideae	Swartzieae	1	2	50	1	6	16
Papilionoideae	Trifolieae	1	1	100	1	18	5
Papilionoideae	Loteae	0	2	0	0	32	0
Papilionoideae	Thermopsideae	0	2	0	0	3	0
Papilionoideae	Vicieae	0	2	0	0	12	0

Only ten of the fourteen use categories (food for humans, environmental uses, materials, fuels, medicines, animal food, food additives, social uses, vertebrate, and non-vertebrate poisons) proposed in Cook's classification [9] were registered and analyzed in this study. The other four uses (bee plants, invertebrate food, cosmetic and perfumery plants, and gene resources) are not included in this study due to a lack of records, although some of their uses are briefly discussed. A list of all scientific names and their Acronyms used in this study could be consulted in Supplementary Materials (Table S1).

A dendrogram representing the use categories amongst all the recorded useful legumes was generated through a Two-way Cluster Analysis [10] by applying Jaccard coefficient and unweighted pair-grouped arithmetic average (UPGMA) method [11] using PC-ORD version 6 [12]. This analysis was based on 525 species following the 10 main use TDWG categories of Cook [9]. Each species is characterized by its use categories, presence (1), absence (2). The data matrix produces a tree on scale showing the clustering scheme (see Supplementary Materials (Figure S1)).

To determine the goodness of fit for the 525 species to clusters of use categories in the UPGMA algorithm, the relationships between the original similarity indices and cophenetic values were evaluated. Since a tree is not exactly the same as the data matrix it represents, it is necessary to know how well the tree characterizes the basic data matrix, thus, we calculate the cophenetic correlation coefficient that measures how well this tree and the resemblance matrix matches. We estimate a cophenetic correlation coefficient (CCC, [13]), by the NTSYS pc version 2.1 [14]. A new resemblance matrix was built by using the dendrogram values of the cophenetic matrix and correlated them by using a Standarized Mantel test [15], where the higher absolute value of the cophenetic correlation is, the better correspondence between the two compared matrices. Values higher than 0.8, indicate a strong correspondence and thus, a more reliable clustering [11,16].

In addition, a Two-way Cluster Analysis with the two most numerous subfamilies, Caesalpinioideae (244 spp.), and Papilionoideae (271 spp.) was produced without the species of subfamilies Cercidoideae (seven spp.), Detarioideae (three spp.), and Dialioideae (one sp.). Data for these two subfamilies were run in a Two-way Cluster Analysis and are compared with eight selected use categories; they are presented in Supplementary Materials (Figures S2 and S3).

3. Results

3.1. Mexican Representation and Biocultural Distribution of Useful Legumes at MEXU

Several central and southern Mexican states exhibit intermediate to higher frequency of useful legume herbarium reports, and amongst cultures, they share species and uses. The following states have highest number of reports are Oaxaca (522; 99%); Chiapas (391; 74%); Veracruz (319; 60.7%); Guerrero (236; 45%); Yucatán (232; 44%); Michoacán (223; 42%); and Puebla (216; 41%). Five of these seven states coincide with those reported by the National Census of INEGI [17] as having the largest share of Mexico’s indigenous populations: Oaxaca (18.3%); Veracruz (13.5%), Chiapas (13%), Puebla (9.42%), and Yucatán (8.2%). The state of Oaxaca is known for its great biodiversity [18], particularly of legume species. Oaxaca also houses the highest number of ethnic groups (17) in Mexico. In the case of legume herbarium specimens with ethnobotanical data, it also has the greatest number of reports (Figure 2). This first ranking should also consider that MEXU holds more collections of legumes from Oaxaca than any other state, due to collecting efforts (ca. 5000 numbers) by Mario Sousa and his students with the project “Legumes of Oaxaca” [19]. In contrast, the records from the northern states include only 173 (5.9%). This bias in MEXU collections with more specimens from southern states may account for greater legume diversity as well as for more ethnobotanical collections.

A total of 7479 local vernacular names (or variations) were recorded on herbarium labels for legumes; in some cases, that label listed more than one name. Most common names were in Spanish; only 4% (362 different names) of the specimens reported indigenous names. The cases where species had various names derived from native languages as well as Spanish illustrates the acculturation of ethno-taxonomic systems.

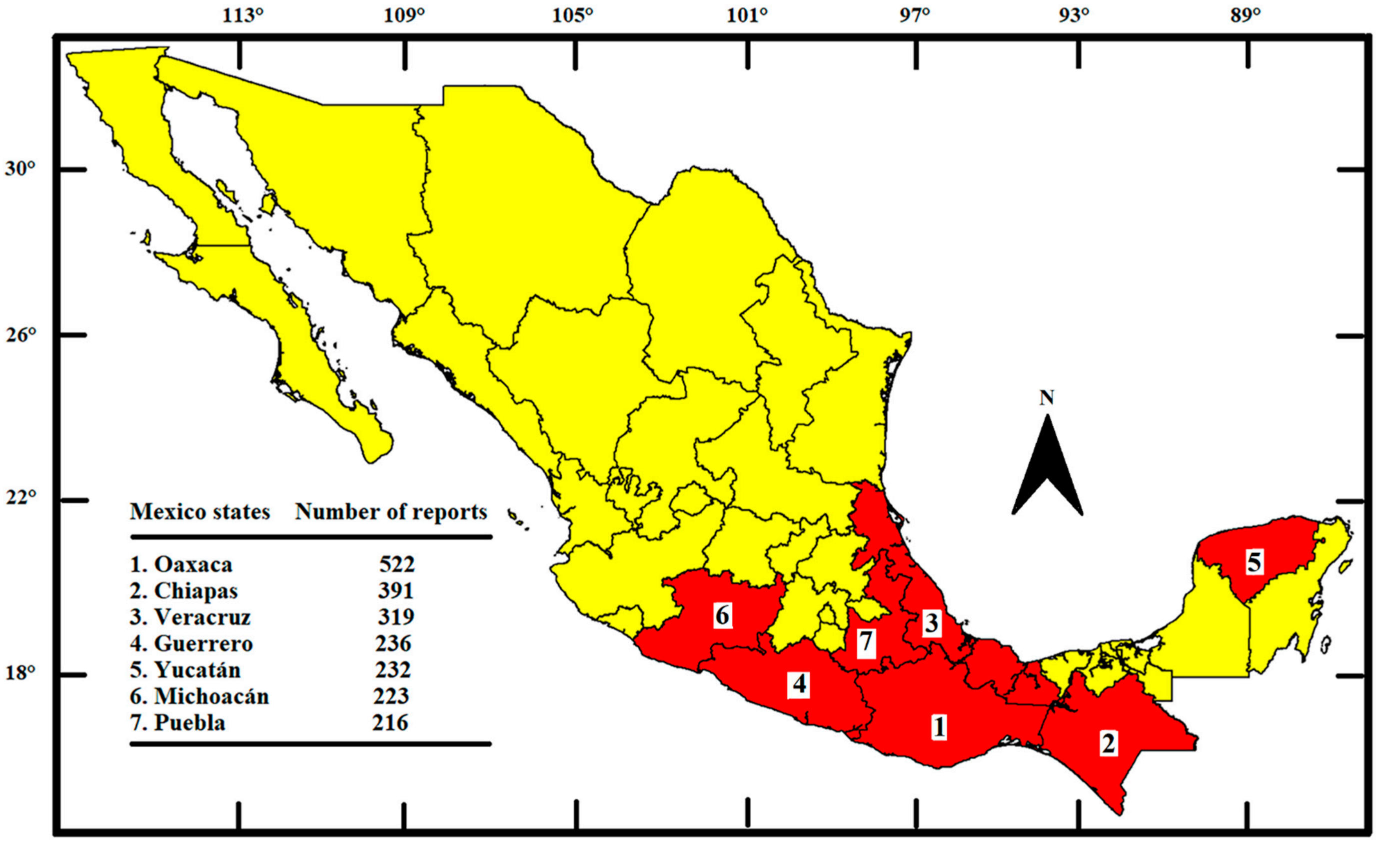

Figure 2. Map representing the Mexican states with more useful native legumes reports at MEXU.

3.2. Similarity between Use Categories

The Spearman correlation coefficient between the ten categories was elevated and significant (r = 0.80279 (NTSYS); $p < 0.001$), indicating that the calculated distances are highly correlated and show few alterations in use categories ranking (Figure 3). These results make it possible to classify distance measurements as "good", according to the classification suggested by Kruskal [20].

The clustering results depicted in the dendrogram (Figure 3) for legume use categories exhibit a clear separation of categories at the sixth-cluster level. The dendrogram separates two-groups (VERTEBRATE POISON AND NON-VERTEBRATE POISONS) from the rest of the use categories. The tree shows that MATERIALS and FUELS categories are similar as was pointed out in Cook's classification [9], where they were deliberately separated due to its "levels" classification. Similarly, the tree reveals the existence of a group conformed by FOOD and ENVIRONMENTAL uses and another that describes similarity between FUELS and MATERIALS and MEDICINE categories; these are separate from the category of ANIMAL FOOD. Furthermore, a third group is shown with the FOOD ADDITIVES and SOCIAL use categories. FOOD and FOOD ADDITIVES were separated "for the sake of clarity" since the same plant can be used as a food and as a food additive [9].

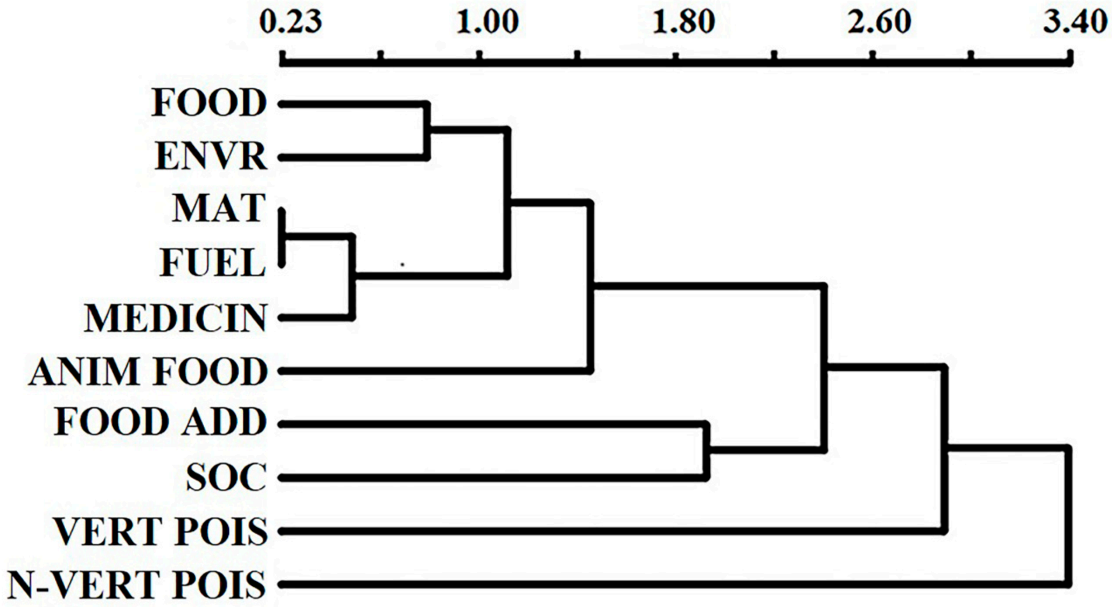

Figure 3. Dendrogram of Two-way Cluster Analysis comprising the species of the five subfamilies and 10 use categories (see Table S1 for definitions of Acronyms), correlation coefficient (r = 0.80279). The dendrogram is a graphical representation of its main matrix. The *x*-axis values are the measure of similarity or distance at which clusters join, re-ordered according to the order they were generated. Use categories stands for FOOD (Food for humans); ENVR (Environmental uses); MAT (Materials); FUEL (coal, firewood, and resins); MEDICIN (Medicines); ANIM FOOD (Animal food); FOOD ADD (Food additives); SOC (Social uses); VERT POIS (Vertebrate poison); N-VERT POIS (Non-vertebrate poison).

3.3. Similarity between Species Based on the Use Categories

The 525 species, 244 species with a single use (46.4%) and 281 species with two or more uses, here denoted as multipurpose (53.5%), are represented by a hierarchical method that produce the resulting graph that shows how group of species and use categories relate to each other. Two clusters (G1 and G2) that comprise 15 subgroups formed at each partition level is illustrated in the graphical representation of the main matrix, according to the resulting order in both dendrograms, which can be seen in Supplementary Materials (Figure S1).

Group 1 [1Acaang—5Lonbal] comprising 515 species, divided in eight sub-groups (G1.1—G1.15), and Group 2 [G2.1—G2.2, 1Leupue—5Dersec] containing 10 species, which have been divided into two sub-groups.

G1.1—G1.4 [1Acaang—1Spicac] comprising 85 multipurpose of 281 species and 82 single-use Animal Food of 244 species.

G1.1—[1Acaang—5Dallep] 16 species (3%), mostly multipurpose shrubs and trees, are popularly employed as Materials for building houses, craftmanship and manufacture of household utensils, as well as providing dyes, gums, and resins. Additionally, it includes some species occurring mostly in the central and south eastern states, used especially as pasture herbaceous vines, *Centrosema plumieri*, *Macroptilium atropurpureum* and *M. longepeduncultum*, or as fodder shrubby plants such as the multipurpose *Acaciella angustissima* and *Dalbergia glabra*. Additionally, *Bauhinia ungulata*, *Dalea leporina*, *Senna uniflora* and *Vachellia pringlei* are used as Medicine plants, to treat skin problems and digestive and respiratory disorders. In addition, the endemic genus, and species, *Heteroflorum sclerocarpum* used for Materials and Animal Food. G1.2—[1Calcal—5Phamac] this multipurpose subgroup with 28 (6%) species is characterized principally by being composed of medicinal and forage plants. *Desmodium neomexicanum*, four species of *Dalea*, *Bauhinia deserti* and species of *Crotalaria* and *Phaseolus*, are widely used for food. Two of the more widely cultivated species of beans *Phaseolus vulgaris* and *P. lunatus* have also been used in

Medicine and Animal Food. G1.3—[1Chacha—5Lupunc] this is the largest of the 15 subgroups comprising 90 species (17%) (60 Papilionoideae and 30 Caesalpinioideae), of which 82 species are only use for Animal Food. A multipurpose subgroup of species (6%) is characterized by principally being medicine and forage plants, including 11 species of *Mimosa*, 10 of *Desmodium*, seven of *Dalea*, and four of *Lupinus* species are used for Animal Food. Additionally, *Eriosema grandiflorum* and *Tephrosia lanata* stand out here as providers of Non-Vertebrate Poison. Genera such as *Desmanthus, Desmodium, Eysenhardtia, Mimosa, Senegalia* and *Vachellia* contribute with 37% of endemic species. G1.4—[1Albtom—1Spicac] 33 multipurpose species (6%), mostly Mimosoids, provide their branches for fuelwood and foliage for fodder. Fourteen species that also supply FOOD as *Leucaena macrophylla, L. pallida, Lysiloma divaricatum, Mariosousa coulteri, Pithecellobium oblongum* and *Prosopis glandulosa*. Ten percent, with species such as *Brongniartia intermedia, Havardia pallens, Mimosa depauperata, M. polyantha, Poincianella eriostachys* and *Senna wislizeni* are utilized as ornamentals and/or as "cercas vivas" or living fences [21]. In addition, the ecological and economically important "palo fierro", *Olneya tesota* used in north western Mexico for wood carvings [22]. The endemic genus and species, *Calliandropsis nervosa* is used for Fuels and Animal Food.

G1.5—[1Acapai—5Dglome] 37 species (7%), mostly trees and shrubs with largely Environmental and Material uses, are grown in rural areas on pasture and rangelands or as shade trees and as ornamental plants planted on streets, parks, as well as home gardens. In home gardens, 4% of them are also used for Food, thus promoting a more integral exploitation of domestic space. *Calliandra hirsuta* and *Lonchocarpus acuminatus* are also used as Food Additives. *Inga jinicuil*, *I. oerstediana*, and *Dalbergia glomerata* also provide Food.

G1.6—G1.7—[1Calgra—5Erayme] is composed of 81 multipurpose species with Food, Environmental, Materials, and Animal Food uses.

G1.6—[1Calgra—5Lonlon] these 53 multipurpose species (10%) include members of the Papilionoideae (20 spp.), Caesalpinioideae (28 spp.), and subfamily Cercidoideae (five spp.). Twenty species (25%) provide five or more uses, such as *Bauhinia divaricata*, *Schnella herrerae*, *Gliricidia sepium*, *Leucaena leucocephala*, *L. lanceolata, Prosopis juliflora* and *P. laevigata*, *Senna atomaria* and *S. racemosa*, and *Vachellia farnesiana*, *V. pennatula*, and *V. campechiana*, *Mimosa aculeaticarpa*, *Choroleucon mangense*, *Pithecellobium oblongum*, *P. lanceolatum*, and the commonly known and widely distributed "guámuchil" tree, *P. dulce*. The "parota" or "guanacaste" tree, *Enterolobium cyclocarpum*, *Tara cacalaco*, *Diphysa floribunda*, and *Calliandra houstoniana* are also ornamental plants, living fences and shade trees; as well as some served also for medicines in many rural regions, such as the multipurpose *Mimosa aculeaticarpa*, *Vachellia pennatula* and *V. farnesiana* established in this group, have also been reported as phyto-stabilization species on mine tailings in Sonora state [21]. The multipurpose *Gliricidia sepium* (seven uses) stands out, being broadly represented in tropical agrosilvipastoral systems in south eastern México, a common component of "cercas vivas" and introduced in different countries and tropical regions of the world by propagating from branch cuttings [23,24]. In the northern and central regions of Mexico, species of *Prosopis* or "mezquites" prosper and multiply, creating highly established standings called "mezquitales". *Prosopis juliflora* and *P. laevigata* provide extensive Animal Food. Important to mention is the case of *Lonchocarpus longistylus* that provides Environmental, Material, and Medicine use, as well that with its bark the Mayans prepared "balché", a sacred ceremonial drink (Social Use). *Coursetia glandulosa* in the northwest of Mexico provides its bark, stems, and leaves for Environmental, Animal Food and Medicine use. In Cercidoideae, *Schnella herrerae* provide Environmental, Materials, Fuels, Medicine, and Animal Food. Several species of *Bauhinia* outstand in this group, *Bauhinia divaricata* provide Food, Environmental, Materials, Fuels, Medicine and Animal Food. Other species of *Bauhinia* such as *B. jenningsii* give Food, Environmental, Materials, and Medicine; *B. pauletia* Environmental, Medicine, and Animal Food; *B. rubeleruziana* Environmental, Medicine, and Animal Food uses, and *B. ungulata* Materials, Medicine, and Animal Food uses. Additionally, the multipurpose climbing vine, *Rhynchosia pyramidalis* that provide five uses, and seven species of *Senna* have Medicine use. G1.7—[1Conmul—5Eryame] 26 species (5%), mostly trees of subfamily Caesalpinioideae and species of *Erythrina* (i.e., *Erythrina americana* with five uses), are grown in rural areas on pasture and rangelands as living fences, for fodder and pasture improvement. This agrosilvipastoral group of trees in Chiapas, Tabasco, and Veracruz states, with species of *Dalbergia*, *Erythrina*, *Inga, Leucaena*, *Lonchocarpus* and *Pithecellobium*, among others, have proved to be locally important as multipurpose plants [25,26], and some grown as ornamental plants. In home gardens, 4% of them are also used for FOOD, bringing a more integral use. Two species of *Senna* have Medicine use. *Crotalaria cajanifolia* and *Phaseolus coccineus* besides important Food providers give Environmental, Medicine, and Animal Food. The endemic genus and species, *Conzattia multiflora* provide Environmental and Food use.

G1.8—[(1Lenmel—5Lupmex)] comprising three Environmental species, two of them provide SOCIAL uses. *Lennea melanocarpa*, *Lonchocarpus sericeus* and *Lupinus mexicanus* have been reported to be used as decorations for "Día de Muertos", in central and western portions of Mexico.

G1.9—G1.10—G1.11—[1Calcalo—5Lonhid] comprising 54 multipurpose and 75 single-use species, mostly for Medicine use.

G1.9—[1Calcalo—5Nisbra] 80 species (15%), Papilionoideae (56 spp.) and Caesalpinioideae (24 spp.), that provide Medicine use, occurring throughout different regions of Mexico. Various genera, such as *Chamaecrista* (five spp.), *Crotalaria* (four spp.), *Dalea* (three spp.), *Desmodium* (10 spp.), *Eriosema* (two spp.); *Eysenhardtia* (three spp.), *Indigofera* (six spp.), *Machaerium* (four spp.), *Mimosa* (13 spp.) and *Senna* (four spp.), coincidentally have been reported in the treatment of kidney and urinary problems, respiratory and digestive disorders as well as skin infections. G1.10—[1Epolys—5Piscar] 47 species (9%), Papilionoideae (22 spp.) and Caesalpinioideae (25 spp.) share with the members of latter subgroup the attribute of being employed as Medicine; a good number of them are multipurpose trees that allow a maximum usage also providing wood for construction, charcoal, and their foliage for fodder. However, these multipurpose important species such as *Andira galeottiana, Diphysa suberosa, Eysenhardtia polystachya, Lonchocarpus hermannii*, *Lysiloma microphyllum*, *L. tergeminum* and *Mimosa galeottii* have a mid to southern-range distribution in the country. *Andira galeottiana*, *Lonchocarpus hermannii*, and *Piscidia carthaginensis* besides providing Materials and Medicine are also use as Vertebrate Poison. In this group the popular "tepezcohuite", *Mimosa tenuiflora* for skin care and two species of *Dalea* and five species of *Senna* that have Medicine use.

G1.11—[1Mimpig—5Lonhid] two species, *Lonchocarpus hidalgensis* used for MEDICINE, and *Mimosa pigra* provide Fuels, Medicine and Animal Food. Both species are also use, as Vertebrate Poison.

G1.12—[1Zaplam—5Tepmul] representing four species used for Non-Vertebrate Poison, and two of them also for Medicine.

The species *Zapoteca lambertiana*, *Harpalyce formosa*, *Brongniartia podalyrioides*, and *Tephrosia multifolia*, which have been reported in Morelos, Oaxaca, and Veracruz states, with insecticidal properties for the control of corn plagues, as well use as lice poison. The latter two species are also use as Medicine.

G1.13—G1.14—[1Desbic—5Ramstr] comprising 20 multipurpose and 19 single-use, mainly Food species.

G1.13—[1Desbic—5Phagla] 19 species (4%), of Food legumes, such as *Crotalaria, Desmanthus, Inga* (five species), *Leucaena*, *Phaseolus* (wild, feral and cultivate individuals), *Pithecellobium* and *Zygia*. One relevant edible and high-nutritional species, with underground fruit and nutritious seeds is *Amphicarpaea bracteata*, that occurs in forests and is grown also in "milpas" in the north of Puebla state [27]. G1.14—[1Leutri—5Ramstr] comprising 20 species (4%) of four subfamilies (Detarioideae (one sp.), Dialoideae (one sp.), Caesalpinioideae (six spp.) and Papilionoideae (12 spp.) that all provide Food. Two subgroups are established comprising species that are used for Fuels, Materials (45%), and Medicine purposes (e.g., *Dialium guianense*, Dialoideae), and, additionally, recorded for

Medicine use is the endemic genus and species, *Hymenaea courbaril* (Detarioideae), *Pithecellobium hymenaeifolium, Ramirezella strobilophora, Senna fruticosa* and *S. papillosa*.

G1.15—[1Acateq—5Lonbal] 55 species (11%), comprising 35 species that only provide MATERIALS and 20 multipurpose species with Environmental, Materials, Fuels, Food, Vertebrate and Non-Vertebrate Poison uses.

A total of 55 species of which 24 species are Caesalpinioideae, 29 are Papilionoideae and two are Detarioideae, consisting of trees that provide high quality durable wood for house construction, furniture, carpentry, and carving or for making tool handles. Two species outstand in this subgroup due to their colourful and aromatic oily wood, *Dalbergia congestiflora* and the endemic genus and species, *Peltogyne mexicana* (Detarioideae). Other species that apart of providing strong and durable wood for their timber, for construction and for cooking are used as shade for crops and as ornamentals. Bark of some species of *Lonchocarpus* such as *L. guatemalensis*, *L. hintonii* and *L. pittieri* commonly called "Palo de Arco" are popularly used for hoop cheese containers. In addition, *Lonchocarpus balsensis* is also used for Non-Vertebrate Poison and *Lennea modesta* as Vertebrate Poison. The endemic genus and species, *Hesperalbizia occidentalis* provides Fuels and Materials.

Group G2 is represented by 10 species (2%), in two subgroups, G2.1—[1Leupue—1Mardol] comprising six species of Mimosoids, five used only as Fuels in regions of southern Mexico, and *Mariosousa dolichostachya* that it is also used for Vertebrate Poison. G2.2—[1Vacsta—5Dersec] comprising four species used as Vertebrate Poison, of which one *Dermatophyllum secundiflorum* also provides Environmental use.

3.4. Assessement of Use Values in Sufamilies Cercidoideae, Detarioideae, and Dialioideae

The wild species of subfamilies Cercidoideae (seven spp.), Detarioideae (three spp.), and Dialioideae (one sp.) stand out by providing Medicine; the subsequent order of uses including those for Materials, Environmental and Animal Food. It should be mention that in Cercidoideae six of seven species are multipurpose, and that in Detarioideae, the "palo morado" *Peltogyne mexicana* (G1.15) stands out as an endemic to the state of Guerrero, with red-purple wood, that is widely employed for construction and handcrafting [28]. Another highly exploited material (G1.14) is the "guapinol", *Hymenaea courbaril*, which provides timber for construction, firewood and charcoal and extraction of resins for ceremonies, and medicinal uses, occurring mostly in humid forests of coastal and mid-lands of north central and southern Mexico, and *Dialium guianense*, the only species of Dialioideae is mostly use for Medicine, Materials and Food. Their species and use categories are display in the following Table 2.

Table 2. Values of use categories and total percent of Cercidioideae (7 spp.), Detarioideae (3 spp.), Dialoideae (1 sp.), excluding Caesalpinioideae and Papilionoideae. Categories values are based on Figure S1 (Supplementary Materials). * 100% woody plants.

Use Categories	Cercidioideae *	Detarioideae *	Dialoideae *	Total (%)
FOOD	2	1	1	4 (12%)
ENVIRONMENTAL	5	0	0	5 (15.5%)
MATERIALS	3	2	1	6 (18%)
MEDICINES	7	2	1	10 (30%)
ANIMAL FOOD	6	0	0	5 (15.5%)
FUELS	2	0	0	2 (6%)
FOOD ADDITIVES	0	0	0	0
SOCIAL	0	0	0	0

3.5. Analyses of Useful Species of Caesalpinioideae and Papilionoideae

To examine the differences among the useful Mexican species of Caesalpinioideae and Papilionoideae, eight use categories were analyzed separately. Data matrix with species groupings based on dendrograms of species and use categories are displayed in Supplementary Materials (Figures S2 and S3, respectively).

The Spearman correlation coefficient in the analysis among the eight categories for Caesalpiniodeae species was significant (r = 0.76391), indicating that the calculated distances are mid to highly correlated and show few alterations in use categories ranking (Figure 4A). In the Papilionoideae analysis, the Spearman correlation coefficient between the eight categories was elevated and significant (r = 0.88120), indicating that the calculated distances are highly correlated and show few alterations in use categories ranking (Figure 4B). Both analyses results make it possible to classify distance measurements as "good", according to the classification suggested by Kruskal [20].

All three resulting graphical representations product of their own matrices and reordered accordingly to use categories appear to be related to each other, where more similar use categories linked first while more dissimilar use categories are separated a greater distance (Figures 3 and 4A,B). The dendrograms display in both the analysis of all subfamilies data as well as that of Caesalpinioideae matches (1) in their clustering pattern with respect to similarity and dissimilarity of use categories and (2) with the same use categories are closer to each other; however, the distances of hierarchical clusters are different in x-axis of the two diagrams (Figure 4A,B). In contrast in the Papilionoideae dendrogram, the hierarchical clusters clustered differently, where materials and medicine categories are more similar and are established closer (Figure 4B). Additionally, in herbaceous Papilionoideae (40%), animal food of single-use species accounts for greater diversity along with materials and medicine categories than in the Caeslpinioideae.

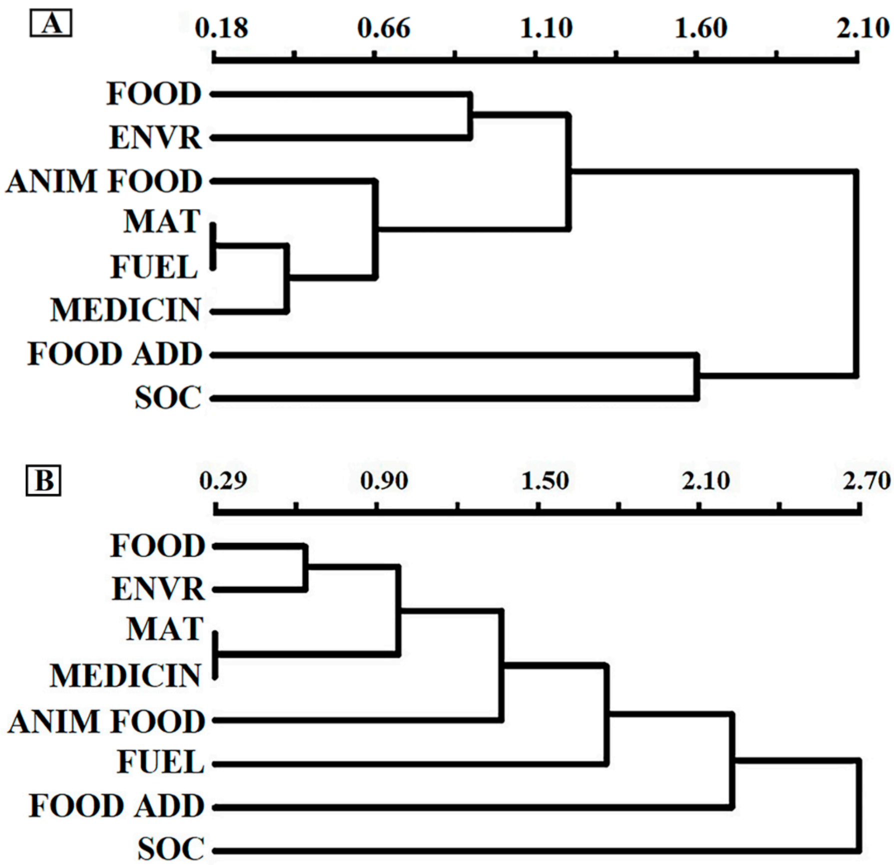

Figure 4. Two dendrograms from two-way cluster analyses. (**A**) Caesalpinioideae and eight use categories, correlation coefficient (r = 0.76391). (**B**) Papilionoideae and eight use categories, correlation coefficient (r = 0.88120). Each dendrogram is a graphical representation of its main matrix. The *x*-axis values are the measure of similarity or distance at which clusters join, re-ordered according to the order in produced. For use category abbreviations, see the caption of Figure 3.

To test similarity patterns, abundance and diversity of single-use or multipurpose species of both Caesalpinioideae and Papilionoideae species for each category of use, the percentage of the total of each single-use and multipurpose use species were recorded and are included in Tables 3 and 4.

Table 3. Values of eight selected use categories of Caesalpinioideae, calculated percent of a total of 244 species. Categories values are based on Figure S2 (Supplementary Materials). * ca. 95% woody plants. Matrix correlation: r = 0.76391.

Caesalpinioideae *			
97 spp. Single—Use (40%)		147 spp. Multipurpose (60%)	
Use Categories	**Total Species, (%)**	**Total Species, (%)**	**Total**
FOOD	17 (7)	51 (21)	68
ENVIRONMENTAL	12 (5)	65 (26.6)	77
MATERIALS	15 (6.1)	91 (37.4)	106
MEDICINES	20 (8.1)	91 (37.2)	111
ANIMAL FOOD	28 (11.4)	67 (27.4)	95
FUELS	5 (2)	84 (34.4)	89
FOOD ADDITIVES	0	3 (1.2)	3
SOCIAL	0	6 (2.4)	6

Table 4. Values of eight selected use categories of Papilionoideae, calculated percent of a total of 271 species. Categories values are based on Figure S3 (Supplementary Materials). * ca. 60% woody plants. Matrix correlation: r = 0.88120.

Papilionoideae *			
154 spp. Single—Use (57%)		117 spp. Multipurpose (43%)	
Use Categories	**Total Species, (%)**	**Total Species, (%)**	**Total**
FOOD	7 (2.5)	35 (13)	42
ENVIRONMENTAL	11 (4)	46 (17)	57
MATERIALS	19 (7)	66 (24.3)	85
MEDICINES	58 (21.4)	72 (26.5)	130
ANIMAL FOOD	56 (20.6)	49 (18)	105
FUELS	2 (0.7)	22 (8.11)	24
FOOD ADDITIVES	0	6 (2.2)	6
SOCIAL	1 (0.3)	8 (3)	9

Despite the difference of size between the two subfamilies and their use categories, both groups show a relevant number of multipurpose use species (261 species); however, it is also important to note that single-use species include 253 species. The number and percentage of species share in highly similar use is registered (Tables 3 and 4). Additionally, an overall comparison of percentage values on single-use and multipurpose species of six selected used categories between these two subfamilies is given in Figure 5.

Taxa of six Caesalpinioideae tribes, Acacieae (13 spp.), Cassieae (six spp.), Caesalpinieae (five spp.), Ingeae (18 spp.), and Mimoseae (13 spp.) are the most diverse in their uses, the most notables being the multipurpose *Acaciella angustissima* and species of *Vachellia* in the Acacieae. Twenty species of *Senna* in Cassieae are prominently characterized by their medicinal properties. Species of tribe Caesalpinieae contribute not only by their ornamental assets but are important components of timber, dyes, and fuels. The tribe Mimoseae with their widely used genera, outstands for species of *Leucaena*, *Mimosa* and *Prosopis*, that provide multipurpose uses to different regions and cultural groups, and some of them have been introduced pantropically, even to the point of being regard as environmental dangerous weeds (i.e., *Leucaena leucocephala*). In tribe Ingeae, species of *Albizia*, *Calliandra*, *Enterolobium*, *Havardia*, *Inga*, and *Pithecellobium*, mostly big trees that not only supply shade, but also furnish hard and durable woods, barks for leather tanning, and some species (i.e., *Enterolobium*, *Inga*, and *Pithecellobium*) are important food providers.

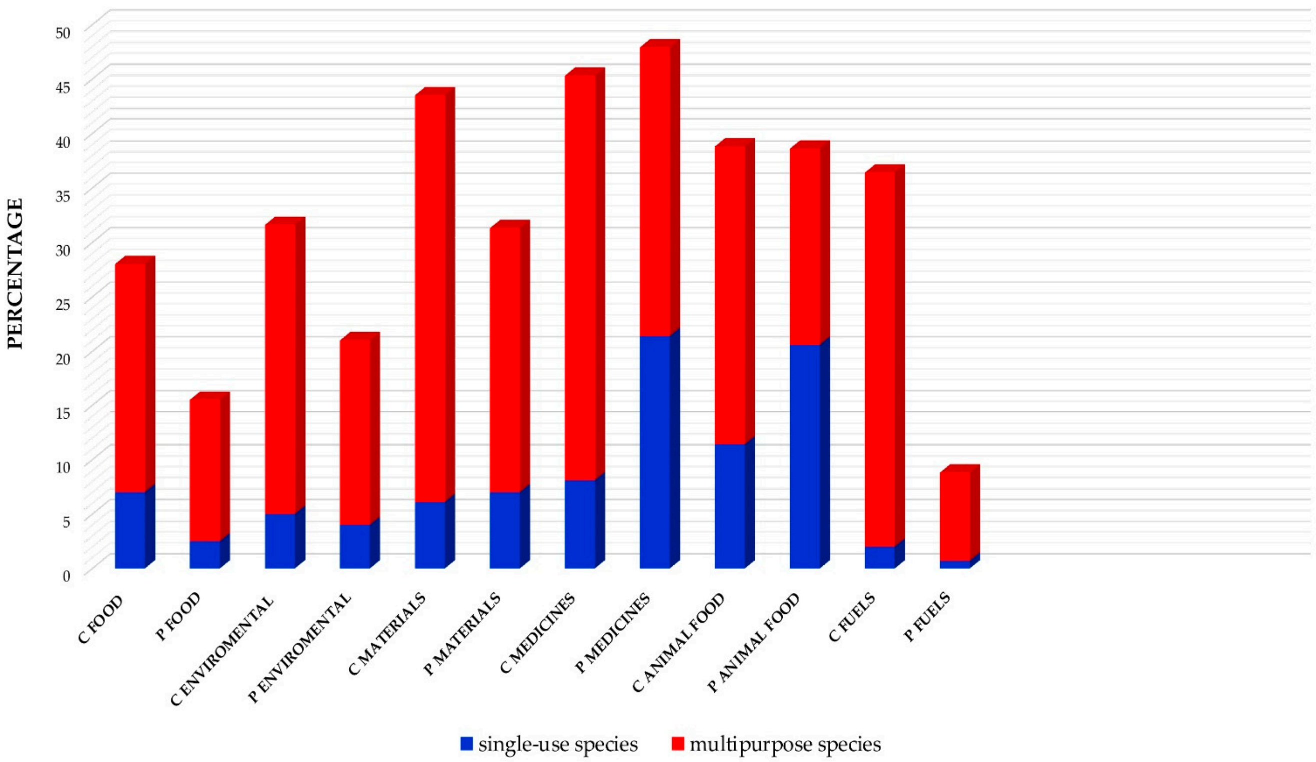

Figure 5. Comparison of percentage values of eight selected categories in Caesalpinioideae (C) and Papilionoideae (P). Categories percent values correspond to Tables 3 and 4, that are based on Supplementary Materials (Figures S2 and S3).

The distance coefficients displayed in Papilionoideae assume a minimum value of 0.29 between materials and medicine categories, that grouped species of most tribes. The tribes Swartzieae and Sophoreae species provide timber for construction, whereas fruits of Crotalarieae species are sometimes used as rattles. In tribe Amorpheae, species of *Dalea* provide medicine, animal food and branches for broom handles and/or brooms; species of *Eysenhardtia* give medicine, animal food and their timbers are used for construction and wooden posts. The tribe Dalbergieae includes species that their timber is used for construction and for house walls, horse whips, traditional instruments such as marimbas, house fences and barnyards, as well as for handicrafts. In tribe Indigofereae, several species are medicine and *Indigofera spicata* leaves are used for dye extraction. In Millettieae, wood species are used for building houses and fences. Some members of tribe Phaseoleae provide timber for construction, extraction of dyes, traditional bark masks, and used for toys; additionally, flowers are edible in species of *Erythrina* and their colorful seeds are use in handicrafts as beads for necklaces and bracelets. The flowers of *Phaseolus coccineus* are food for barn yard animals such as domesticated turkeys in the state of San Luis Potosí. In Robinieae, timber is used for construction of palm shelters or "palapas", hair soap substitutes and for wood carvings. Barks of trees of some members of all tribes have importance in ethnomedicine as has been reported for Mexico [29]; this pattern is reported also for South African plants of this tribe [30].

In Figure 5, we show the percent values of the six highly diverse categories that confirms the diversity of both diversified subfamilies, despite different sample sizes, where the importance of multipurpose species with higher percentage values outstands those of single-use species.

Single-use Papilionoideae species are an important source of medicines and animal food (11%), whereas in Caesalpinioideae, only 4 to 5% of the species contribute with these uses. In contrast for multipurpose species, the Caesalpinioideae exceed in medicinal, animal food and materials, as well that there shrubs and trees are useful fuel, contrasting with species of Papilionoideae (4.4%). The latter could be explained by the fact that several species of Caesalpinioideae are more accessible and, thus, have a high demand; this is in contrast with some Papilionideae trees species, which are characterized by fine-quality wood and are an impotant source as materials, of which Caesalpinioideae species (13.3%) also excel.

The ANIMAL FOOD category is where the pattern of importance of this use is maintained for legumes in general, as has been reported in previous works. However, the number of species is twice as high for Papilionoideae, with a greater diversity of herbaceous species. In this category, the contribution is contrary to single-use species, whereas Caesalpinioideae provide 27.4% and Papilionoideae only 18%.

MEDICINE USE category shows that the greatest number of species and the largest number of reports. These two subfamilies stand out in the use of species in Mexico's traditional medicine, and this importance is congruent with what has been reported for other countries [31]. Table 4 and Figure 5 show that it is twice as high for Papilionoideae (multipurpose) species, may be as consequence of their diversity of chemical compounds.

FOOD USE category shows that the subfamily Papilionoideae would be expected to contribute a greater number of species, as over time, many of its species have been given greater interest for human food [32,33]; however, this work reveals that subfamily Caesalpinioideae contributes with the largest number of species for this category, where species of *Desmanthus, Inga, Leucaena* and *Pithecellobium* excel. Nevertheless, in Papilionoideae, species of *Phaseolus* have been for domesticated thousands of years and are an important food-protein resource in Mexico. Cultivate plants of *P. vulgaris* are one of the most widely consumed pulses throughout the world [34] and references therein.

MATERIALS USE category species are mostly trees, where Caesalpiniodeae has greater number of species, and percentage values are higher with respect to the total species in Papilionoideae. The Caesalpinioideae (15 spp.) highlights the genus *Mimosa*, whereas in Papilionoideae (19 spp.) contribute with wood for the construction of houses, furniture, tools, musical instruments, including species of *Dalbergia, Diphysa, Lonchocarpus,* and *Platymiscium.*

ENVIRONMENTAL contribution values by both subfamilies are similar, although higher in Caesalpinioideae species with mostly ornamental trees or primary components of living fences.

FUELS in Caesalpinioideae out numbers those of Papilionoideae, highlighting genera that are selected for their availability and competing alternative sources, such as *Mimosa* and *Vachellia,* of which firewood and coal are obtained. Contrasting with Papilionoideae species which are more selected for their high-quality woods. Caesalpinioideae provide a larger number of trees (34.4%), from which they obtain firewood and coal, contrasting with Papilionoideae with very few trees used as fuels (8.11%).

4. Discussion

Wiersema and León [35] have reported 17,568 useful plants in the world where the greatest number of species provided environmental uses (6631), followed by medicines (2997), materials (2758) and food (1725). They estimated that Mexico has 1822 useful plant species (10% of the total number). If the latter abundance of useful Mexican plant species is considered, our results point that approximately 30% of them are native useful legumes. Recently, Clement et al. [36] have recorded in Mexico ca. 6000 wild useful species; of these, Leguminosae is the most species-rich family, with (699 spp.; 10.8%); the order of importance of the use categories are medicinal (3478 spp.; 53.5%), edible (1810 spp.; 27.9%), fodder (1637 spp.; 25.2%), construction (1224 spp.; 18.8%) and fuel (883 spp.; 13.6%). If the latter report represents the actual diversity of useful Mexican legumes, our study based upon verified specimens in the National Herbarium (MEXU) records shows 75% of these legume species.

4.1. Diversity of Species and Their Systematics

The diversity of genera and categories of use do not exhibit a correlation between genera with species numbers and uses; as well as other genera display agreement between species numbers and their uses.

Mexican legume useful taxa recorded on five of six taxonomic Leguminosae subfamilies belong to 25 taxonomic tribes, one each in Dialoideae and Cercidoideae, three in Detarioideae, five in Caesalpinioideae, and 16 in Papilionoideae. Outstanding diverse useful tribes comprise 42.6% of the species in Caesalpinioideae are Ingeae (72 spp.), Mimoseae (70 spp.), Acacieae (40 spp.) and Cassieae (38 spp.). In Papilionoideae with 34% of the species included in tribes Phaseoleae (74 spp.), Dalbergieae (38 spp.), Milletieae (35 spp.) and Amorpheae (32 spp.) (Table 1). High diversity, therefore, at this level category, appears to be related to their diverse useful values, at least in these Tribes.

In genera of Caesalpinioideae, 12 of 19 are more diverse. Genera such as *Mimosa* with ca. 100 species include 35 spp. that are useful; *Senna* with 63 species have 27 with some use, and *Inga* presents 16 useful species of a total of 39. Contrasting with *Lysiloma* that has eight species and seven have some use.

In genera of Papilionoideae, nine are the most diverse (accounting for more than 50% of the species) are not necessarily the most used. Only 25 of the 83 species of *Lonchocarpus* are known to be used, as well as 17 of the 132 species of *Dalea* are reported as useful. However, in the genus *Piscidia* three of the four species are employed. The expectation that higher species richness and greater number of useful species per genus is necessary a rule.

The fact that commonly target most diverse groups could show cultural transmission, but also that some taxa could reflect independent discovery due to continuous screening and selection. Phylogenetic signals could be another type of evidence in these screening of plant uses, where the chemical constituents are trace and several phylogenetic related species have been selected [37,38]. Dowes et al. [39] show that the diversity of legume chemical constituents is an important factor in the selection of medicines. Van Wyk [5] complements this by arguing that these compounds are also important in other uses and applications.

In this study, an examination of several legume genera containing useful species displays some uses that are significantly grouped on phylogenetic related groups, which carry similar chemical compounds (e.g., secondary metabolites in tribe Milletieae), or others that are used not only for their diversity and distinctiveness, and evidenced phylogenetic signal as happens in species of *Senna* (tribe Cassieae), which can be easily identify for their flowers, and medicinal use. The Cassieae (Caesalpinioideae) in this study is represented by three genera *Cassia*, *Chamaecrista* and *Senna*. *Cassia* includes two species that provide mainly Environmental use; *Chamaecrista* with nine species, four of which have a Medicine use, and *Senna* represented in Mexico with a total of 63 species, of which 27 species have been register providing different uses, 23 are common Medicine in different regions. *Senna* species produce a multitude of chemical constituents, with bioactivity secondary metabolites that have medical applications in different regions of the world [40]. Trying to find out if there is a phylogenetic signal of these *Senna* use species, and following Marazzi et al. [41], our species established in different phylogenetic groups. Van Wyk [5] listed one species of medicinal *Cassia*; 6 species of *Chamaecrista*, provide medicines; 15 species of *Senna*, of which, 11 are medicinal.

The so-called "cercas vivas" (or living fences) that are established throughout Mexico are house fences or pasture barriers composed of multipurpose useful shrubs and trees, where legumes are one of the principal components. Some of these legume species (i.e., *Erythrina* species and *Gliricida saepium*) are easy to cultivate from root suckers or stem cuttings and can withstand regular pruning. They are conveniently grown not only to provide food, materials, fuel, forage, ornament, and some provide bees with food, but also as cover, shelter and to the improvement of soils, their diversity of useful parts and chemical constituents creates a useful landscape mosaic. In this study, shrubs, and trees multipurpose species with five to seven uses are found in sub-groups (G1.1—G1.4), and (G1.6—G1.7).

4.2. Growth Forms: Importance of Woody Plants

This greater estimate of legume reports in this study correspond to the higher number of multipurpose legume species (281 species), mostly shrubs and trees of all subfamilies, that occur from dry to humid environments, in some places their number cover large extensions of the landscape (Tables 2–4). Single-use species (244 species), some being herbaceous such as in Papilionoideae (ca. 40%), are highly appreciated throughout the country, sometimes occurring in cultivate plots, home patios, pastures or roadsides.

4.3. Relevant Medicine Use

Legumes have always been known as providers of local medicinal plants due to their diverse chemical components [42,43]. Souza and Hawkins [44] of the Brazilian legumes compiled 1400 use reports, of which 319 (22.7%) species are cited with medicinal uses. Van Wyk [5] registered for the southern Africa region 704 useful legume species and, of these, 291 (41.3%) are medicinal. This study registered 78 single-use and 174 multipurpose plants, with a total of 252 (48%) plant species that provide medicine use, a few widely used, many of them for the first time registered (i.e., 10 species of *Dalea*) and others pertaining to the same taxonomical tribes, and even to the same genus (i.e., *Chamaecrista*, *Senna, Vachellia, Desmodium, Indigofera*) as the ones reported in the above studies; this revealed a strong awareness and agreement amongst different human groups through the world of their diverse chemical compounds and medicinal properties by selection and experimentation throughout time, contributing to their well-being [45].

However, some legumes that produce compounds with pharmaceutical properties are also employed for their toxic effects. Vertebrate poison can be made using the following species: *Mariosousa dolichostachya* and *Vachellia x standleyi* (Acacieae), and *Mimosa pigra* (Mimoseae). *Andira inermis* and *A. galeottiana* (Dalbergieae); *Astragalus mollissimus* (Galegeae), *Lonchocarpus hermannii, L. hidalgensis*, *Piscidia carthagenensis* and *Tephrosia crassifolia* (Millettieae); *Rhynchosia pyramidalis* (Phaseoleae); *Gliricidia sepium* and *Lennea modesta* (Robinieae) and *Dermatophyllum secundiflorum* (Sophoreae). Non-vertebrate poison used species: *Zapoteca lambertiana* (Ingeae); *Eriosema grandiflorum* (Phaseoleae); *Harpalyce formosa* and *Brongniartia podalyrioides* (Brongniartieae); *Lonchocarpus balsensis*, *Tephrosia multifolia* and *T. lanata* (Millettieae).

Overall, the holistic benefits of the above cited plants should be candidates for pharmacological investigation. However, it is important to note that medical research has reported only limited health benefits derived from legumes.

4.4. Food and Domestication

The importance of many useful Leguminosae can influence many levels in the food chain and, in this study, 114 species provide edible plant parts; roots as in wild *Macroptilium gibbosifolium*, and cultivars of *Pachyrhizus erosus*; cooked leaves and flowers of *Crotalaria longirostrata*; fruits and seeds of multiple wild and cultivated legumes. At times of short food supply, these plants are harvested widely. Some have been brought closer and are important food resources [45]. Some others have been domesticated and have a major agricultural importance (e.g., *Phaseolus* species) [46].

4.5. Animal Food for Livestock

Forty percent of the species have been reported as providers of a single use, being a source of ANIMAL FOOD. This study proves the enormous knowledge that different cultures have of plants, and as food providers for native animals. Eighty-four native forage legumes species (28 Caesalpinioideae and 56 Papilionioideae), plus 206 multipurpose ones pertaining to all subfamilies, are a food source for domesticated animals. This knowledge gave them with a selection of pasture, browse and cover plants for recently imported livestock and barn-yard animals in different habitats and seasons, proving that this recognition and selective process was by no means limited to plants also introduced by the Spaniards. Only recently have *Lupinus* species (in G1.3) been considered as potential forage plants [47]. Amazingly, Mexico still imports non-native legumes and other plants to feed its livestock.

4.6. Other Important Cook's Use Categories

4.6.1. Gene Sources

Domesticated legume species or legumes that provide local food when crops are immature or failed, have potential as a high protein crop. Such as the large, fleshy, tuberous roots of "jicama" *Pachyrhizus erosus*, that are eaten raw and provide an important source of water, and proteins in southern regions. One of the most economically important cultivate plant in Mexico and the World is the common bean, *Phaseolus vulgaris* L. Favorable genetic traits from its wild counterparts in Mexico are genetic resources for this crop [46].

4.6.2. Bee Plants

Legumes floral resources (pollen and nectar) of different genera such as *Gliricidia*, *Lonchocarpus* and *Senna*, provide food to bees not only enhancing pollination and plants yield with this [48], but also providing honey, bees wax, and pollen as a regular food, and as part of religious ceremonies and medical resource. Moreover, these resources have turned out to be economically important products for western and south eastern Mexican cultural groups [49].

4.6.3. Invertebrate Food

Legumes consumed by invertebrates—such as "Xamues", leaf-footed bugs (*Thasus gigas* Burm) of Family Coreidae that eat from several legumes such as *Vachellia farnesiana* and *Prosopis juliflora*—can be useful to humans and are used to prepare a sauce in Hidalgo state [50].

4.7. Threatened or Endangered Species

The diversity, ubiquity, and economic importance of some of these species have promoted overuse and destruction; consequently, governmental regulations and actions by scientists have been implemented.

According to the "Norma Oficial Mexicana-NOM 059" [51], modified in 2018, a total of 29 legume species, of which 15 species are *Dalbergia*, are endangered. In this study, 15 useful species are recorded, one species of Detarioideae, two species of Caesalpiniodieae, and twelve of Papilionoideae. *Dalbergia congestiflora* (G1.15), *Erythrina coralloides* (G1.6), *Enterolobium schomburgkii* (G1.6), *Hesperalbizia occidentalis* (G1.15), and *Peltogyne mexicana* (G1.15) have been listed in the **A** category ("Amenazada", a vulnerable species according to IUCN 2009). *Dalbergia congestiflora*, *Dalbergia granadillo*, *Dalbergia palo-escrito* (G1.5), *Dalbergia tucurensis* (G1.10), *Ormosia isthmensis* (G1.10), *Ormosia macrocalyx* (G1.15), *Platymycium lasiocarpum* (G1.15), and *Vatairea lundelli* (G1.10) have been listed in the **P** category ("Peligro de extinción", species in danger of extinction or critically endangered, IUCN

[52]. *Dalbergia glomerata* (G1.5) and *Olneya tesota* (G1.4) have been listed in the **Pr** category ("Protección especial", species with less risk, IUCN [53]). Although these species are established in different clusters, all have in common provide Materials, and valuable high-quality wood that are gathered from woodlands. A recent indiscriminate exploitation of the fine wood provided by *Dalbergia* species has brought a national effort for their conservation [54]. Several wild species of *Phaseolus* have recently being included in the IUCN Red List of threatened species [55].

5. Conclusions

Legumes have fulfilled human needs because of their usefulness in addition to their ecosystem services.

Mexican legume diversity offers the people of this culturally diverse country many useful benefits. The present revision shows at least a 5-fold increase in the number of species with useful attributes in herbarium records, without taking into account ca. 100 reported in publications. Furthermore, there is an overall increase in the extent of information regarding those species that what was given in these publications. A total of 525 legumes species (in 115 genera) had 3717 use reports. A high diversity of plant uses was revealed for single-use and multipurpose species that were not restricted to any particular taxonomic group. In total, 525 legumes species with one to seven uses were recorded at MEXU; of these, 26% are endemic. Plants with medicinal uses had the most reports with 351 species (66.8%), followed by those employed for animal food with 205 species (39%), materials source with 197 species (37.5%), environmental uses with 139 species (26.5%), food and food additives with 119 species (22.6%), fuels with 114 species (21.7%), poisons with 21 species (4%), and social uses with 15 species (2.8%).

Herbarium specimens with ethnobotanical information allow the taxonomic verification of species of biocultural important resources. The correct nomenclatural identity permits further reliable investigation to attend unanswered questions for future legume research.

Supplementary Materials: The following are available at online at www.mdpi.com/1424-2818/13/6/267/s1**.** Table S1: Taxa and Acronyms used in two-way cluster analyses. Please consider that the following group of genera share the first three letters in their acronyms (Calliandra and Calliandropsis—1CAL; Entada and Enterolobium—1ENT; Pithecellobium and Pityrocarpa—1PIT; Senegalia and Senna—1SEN; Dalbergia and Dalea—5DAL; Leptolobium and Leptospron—5LEP; Machaerium and Macroptilium—5MAC; Marina and Mariosousa—5MAR). Figure S1: Cluster data set of a Two-way cluster analysis of Mexican useful legumes; the dendrograms based on UPGMA analysis of uses amongst native legume species with distance graph, showing relationships among 525 taxa and their one to ten uses (correlation coefficient r = 0.80279). Species acronyms are listed in Supplementary Materials, where initial numbers refer to Fabaceae subfamilies [3] 1: Caesalpinioideae, 2: Cercidioideae, 3: Detarioideae, 4: Dialioideae and 5: Papilionoideae. Types of uses following Cook [9], Categories [9], FOOD (Food for humans); ENVR (Environmental uses); MAT (Materials); FUEL (coal, firewood, and resins); MEDICIN (Medicines); ANIM FOOD (Animal food); FOOD ADD (Food additives); SOC (Social uses); VERT POIS (Vertebrate poison); N-VERT POIS (Non-vertebrate poison). Numbers in colors indicate the clades and their use category. Figure S2: Cluster data set of a Two-way cluster analysis of Mexican useful Caesalpinioideae; the dendrogram based on UPGMA analysis of uses amongst native Caesalpinioideae species with distance graph, showing relationships among 243 taxa and their one to eight uses (correlation coefficient: r = 0.76391). Categories of uses following Cook [9], FOOD (Food for humans); ENVR (Environmental uses); MAT (Materials); FUEL (coal, firewood, and resins); MEDICIN (Medicines); ANIM FOOD (Animal food); FOOD ADD (Food additives); SOC (Social uses); VERT POIS (Vertebrate poison); N-VERT POIS (Non-vertebrate poison). Cercidioideae (7 spp.), Detarioideae (3 spp.), and Dialioideae (one sp.) were excluded from this analysis. Different colors for clusters or groups and subgroups characterize species and prevailing use categories. Figure S3: Cluster data matrix recovered from a Two-way cluster analysis of Mexican useful Papilionoideae; the dendrogram, based on UPGMA analysis of uses amongst species depicted in a distance graph, shows relationships among 268 species and their one to eight uses (correlation coefficient: r = 0.88120). Categories of uses following Cook [9], FOOD (Food for humans); ENVR (Environmental uses); MAT (Materials); FUEL (coal, firewood, and resins); MEDICIN

(Medicines); ANIM FOOD (Animal food); FOOD ADD (Food additives); SOC (Social uses). Different color for groups and subgroups characterized species and prevailing use categories.

Author Contributions: A.D.-S., L.T.-C., M.L.-C. and R.B. designed the study; M.L.-C. conducted the statistical analyses. All authors contributed to writing the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This study was supported by the Instituto de Biología (IBUNAM) and Colegio de Postgraduados.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data without the collaborators interviewed are available upon request to the first author.

Acknowledgments: We wish to thank the fieldwork of many collectors, curators and the assistance of the Academic Staff of the National Herbarium of Mexico (MEXU; http://www.ib.unam.mx/botanica/herbario/, 12/11/2020): L. Calvillo-Canadell, M.R. García Peña, V. Juárez Jaimes, M. Olvera García, G. Ortiz Calderón, A. Ramírez Roa, A. Reyes García, E. Martínez Salas, and R. Torres Colín (IBUNAM). Additionally, we thank F. Basurto-Peña (JB-IBUNAM) for providing his support with publications, Julio Cesar Montero Castro for his help with the elaboration of figures, and Diana Martínez Almaguer for her photographs. We appreciate the use of the images from the collection of Vazquez' slide collection of (MEXU). We also thank Cecilia Xie, Assistant Editor, and three reviewers for critical review of the manuscript and helpful suggestions. This study especially honored the value of Mario Sousa, whose involvement as Head of MEXU herbarium promoting field collection and international exchange programs, as well as his legume knowledge, was the foundation of this and other studies; among these, we are grateful for the impulse and direction of José Carmen Soto, who provided legume specimens with cultural information that was assessed in this paper. You all played a major role in obtaining our results.

Conflicts of interest: The authors declare that they have no competing interests.

References

1. Voeks, R.A. Are Women Reservoirs of Traditional Plant Knowledge? Gender, Ethnobotany, and Globalization in Northeast Brazil. *Singap. J. Trop. Geogr.* **2007**, *28*, 7–20, doi:10.1111/j.1467-9493.2006.00273.x.
2. Brazilian Flora (in construction). Rio de Janeiro Botanical Garden. Available online: http://floradobrasil.jbrj.gov.br/ (15/02/2020).
3. Sutjaritjai, N.; Wangpakapattanawong, P.; Balslev, H.; Inta, A. Traditional Uses of Leguminosae among the Karen in Thailand. *Plants* **2019**, 1–20, doi:10.3390/plants8120600.
4. Grijalva, A. *Flora útil Etnobotánica de Nicaragua*; 1st ed.; Marena: Managua, Nicaragua, 2006.; pp. 100–112.
5. Van Wyk, B.-E. The Diversity and Multiple Uses of Southern African Legumes. *Aust. Syst. Bot.* **2019**, *32*, 519–546, doi.org/10.1071/SB19028.
6. LPWG. Phylogeny and Classification of the Leguminosae. *Taxon* **2017**, *66*, 44–77.
7. Casas, A.; Valiente-Banuet, A.; Viveros, J.L.; Caballero, J.; Cortes, L.; Dávila, P.; Lira, R.; Rodríguez I. Plant Resources of the Tehuacán-Cuicatlán Valley, Mexico. *Econ. Botany* **2000**, *55*, 129–166.
8. Lewis, G.; Schrire, B.; Mackinder, B.; Lock, M. *Legumes of the World*; Royal Botanic Gardens: Kew, UK, 2005.
9. Cook, F.E.M. *Economic Botany Data Collection Standard;* Royal Botanic Gardens: Kew, UK, 1995.
10. Peck, J.E. *Multivariate Analysis for Community Ecologists: Step-by-Step Using PC-ORD*; MjM Software Design: Gleneden Beach, OR, USA, 2010.
11. Sneath, P.H.A.; Sokal, R.R. *Numerical Taxonomy, the Principles and Practice of Numerical Classification;* Freeman: San Francisco, CA, USA, 1973.
12. McCune, B.; Mefford, M.J. *Multivariate Analysis of Ecological Data;* PC-ORD v. 6. MjM Software Design: Gleneden Beach, OR, USA, 2011.
13. Sokal, R.R.; Rohlf, F.J. The Comparison of Dendrograms by Objective Methods. *Taxon* **1962**, *11*, 33–40.
14. Rohlf, F.J. *NTSYS-pc, Numerical Taxonomy and Multivariate Analysis System*, Version 2.1. Exeter Software; Applied Biostatistics Inc.: New York, NY, USA, 2000.
15. Mantel, N.A. The Detection of Disease Clustering and a Generalized Regression Approach. *Cancer Res.* **1967**, *27*, 209–220.
16. Balzarini, M.G.; González L.; Tablada, M.; Casanoves, F.; Di Rienzo J.A; Robledo, C.W. *InfoStat, Manual del Usuario versión 2008;* Editorial Brujas: Córdoba, Argentina, 2008.
17. Instituto Nacional de Estadística y Geografía. INEGI. Available online: https://www.inegi.org.mx/ (23/11/2020).

18. Monroy Gamboa, A.G.; Sánchez-Cordero, V.; Briones-Salas, M.; Lira-Saade, R.; Maass Moreno, J.M. Representatividad de los Tipos de Vegetación en Distintas Iniciativas de Conservación en Oaxaca, México. *Bosque* **2015**, *36*, 199–210, doi:10.4067/S0717-92002015000200006.
19. Sousa, S.M.; Medina L., R.; Andrade M., G.; Rico A., M.L. Leguminosas. In *Biodiversidad de Oaxaca*; García-Mendoza, A.J., Ordoñez, M.J., Briones-Salas, M., Eds.; Instituto de Biología, Universidad Nacional Autónoma de México: México City, México; Fondo Oaxaqueño para la Conservación de la Naturaleza and World Wildlife Fund: Mexico City, México, 2004; pp. 249–269.
20. Kruskal, J.B. Nonmetric Multidimensional Scaling: A Numerical Method. *Psychometrika* **1964**, *29*, 115–129.
21. Avendaño Reyes, S.; Acosta Rosado, I. Plantas Utilizadas como Cercas Vivas en el Estado de Veracruz. *Madera Bosques* **2000**, *6*, 55–71.
22. Hubbard, T. *Natural History of the Desert Ironwood Tree (Olneya tesota). A Synopsis of Published Literature*; Desert Museum Organization: Tucson, AZ, USA, 2015.
23. Mendez, M.O.; Maier, R.M. Phytostabilization of Mine Tailings in Arid and Semiarid Environments—An Emerging Remediation Technology. *Environ. Health Perspect.* **2008**, *116*, 278–283, doi:10.1289/ehp.10608.
24. Lavin, M.; Sousa S.M. Phylogenetic Systematics and Biogeography of the Tribe Robinieae (Leguminosae). *Syst. Bot. Monogr.* **1995**, *45*, 1–165.
25. Nashed-Toral, J.; Valdivieso-Pérez, A.; Aguilar-Jiménez, R.; Cámara-Cordova, J. Grande-Cano, D. Silvopastoral Systems with Traditional Management in Southeastern Mexico: A Prototype of Livestock Agroforestry for Cleaner Production. *J. Clean. Prod.* **2013**, *57*, 266–279.
26. Peacock, C. *Improving Goat Production in the Tropics: A Manual for Development Workers*; Oxfam: Oxford, UK. 1996.
27. Basurto-Peña, F.; Villalobos, G.; Martínez, M.A.; Sotelo, A.; Gil, L.; Delgado Salinas, A. Use and Nutritive Value of Talet Beans, *Amphicarpaea bracteata* (L.) Fern. (Fabaceae: Phaseoleae) as Human Food in Puebla, México. *Econ. Bot.* **1999**, *53*, 427–434.
28. Sotuyo, S. El Palo Morado (*Peltogyne mexicana*), una Leguminosa Maderable con Futuro Incierto y Parientes Lejanos. *Rev. Digit. Univ.* **2014**, *15*, http://www.revista.unam.mx/vol.15/num4/art28/index.html. ISSN=1607-6079.
29. Hastings, R.B. Medicinal Legumes of Mexico: Fabaceae, Papilionoideae, Part One. *Econ. Botany* **1990**, *44*, 336–348, doi:10.1007/BF03183915.
30. Grace, O.M.; Prendergast, H.D.V.; Van Staden, J.; Jäger, A-K. The Status of Bark in South African Health Care. *South Afr. J. Bot.* **2002**, *68*, 21–30.
31. Catarino, S.; Duarte M.C.; Costa, E.; García-Carrero, P.; Romeiras, M.M. Conservation and Sustainable Use of the Medicinal Leguminosae Plants from Angola. *Peer J.* **2019**, 7, e6736, doi:10.7717/peerj.6736.
32. Duke, J.A. *Handbook of Legume of Economic Importance*; Plenum Press: New York, NY, USA, 1992; p. 345.
33. Graham, P.H.; Vance, C.P. Legumes: Importance and Constraints to Greater Use. *Plant Physiol.* **2003**, *131*, 872–877.
34. Bitocchi, E.; Rau, D.; Bellucci, E.; Rodriguez, M.; Murgia, M.L.; Gioia, T.; Santo, D.; Nanni, L.; Attene, G.; Papa, R. Beans (*Phaseolus* ssp.) as a Model for Understanding Crop Evolution. *Front. Plant Sci.* **2017**, *8*, 722, doi:10.3389/fpls.2017.00722, ISSN=1664-462X.
35. Wiersema, J.H.; León, B. *World Economic Plants: A Standard Reference;* 2nd ed.; CRC Press: Boca Ratón, FL, USA, 2016.
36. Clement, C.R.; Casas, A.; Parra-Rondinel, F.A.; Levis, C.; Peroni, N.; Hanazaki, N.; Cortés-Zárraga, L.; Rangel-Landa, S.; Alves, R.P.; Ferreira, M.J.; et al. Disentangling Domestication from Food Production Systems in the Neotropics. *Quaternary* **2021**, *4*, 4, doi:10.3390/quat4010004.
37. Saslis-Lagoudakis, C.H., Savolainen, V.; Williamson, E.M.; Forest, F.; Wagstaff, S.J.; Baral, S.R.; Watson, M.F.; Pendry, C.A.; Hawkins, J.A. Phylogenies Reveal Predictive Power of Traditional Medicine in Bioprospecting. *Proc. Natl. Acad. Sci. USA* **2012**, *109*, 15835–15840.
38. Souza, E.N.F.; Williamson, E.M.; Hawkins, J.A. Which Plants Used in Ethnomedicine are Characterized? Phylogenetic Patterns in Traditional Use Related to Research Effort. *Front. Plant Sci.* **2018**, *9*, 834.
39. Dowes, E.; Crouch, N.R.; Edwards, T.J.; Mulholland, D.A. Regression Analyses of Southern African Ethnomedicinal Plants: Informing the Targeted Selection of Bioprospecting and Pharmacological Screening Subjects. *J. Ethnopharamacology* **2008**, *119*, 356–364, doi:10.1016/j.jep.2008.07.040.
40. Selegato, D.M.; Monteiro, A.F.; Vieira, N.C.; Cardoso, P.; Pavani, V.D.; Bolzani, V.S.; Castro-Gamboa, I. Update: Biological and Chemical Aspects of *Senna spectabilis*. *J. Braz. Chem. Soc.* **2017**, *28*, 415–426, doi:10.21577/0103-5053.20160322.
41. Marazzi, B.; Endress, P.K.; Queiroz de, L.P.; Conti, E. Phylogenetic Relationships within *Senna* (Leguminosae, Cassiinae) Based on Three Chloroplast DNA Regions: Patterns in the Evolution of Floral Symmetry and Extrafloral Nectaries. *Am. J. Bot.* **2006**, *93*, 288–303.
42. Southon, I.W.; Bisby, F.A.; Buckingham, J.; Harborne, J.B. Eds. *Phytochemical Dictionary of the Leguminosae*; Chapman & Hall: London, UK, 1994.
43. Moerman, D.E. Native North American Food and Medicinal Plants: Epistemological Considerations. In *Plants for Food and Medicine*; Prendergast, H.D.V., Etkin, N.L., Harris, D.R., Houghton, P.J., Eds.; Royal Botanic Gardens: Kew, UK, 1998; pp. 69–74.
44. Souza, E.N.F.; Hawkins, J.A. Comparison of Herbarium Label Data and Published Medicinal Use: Herbaria as an Underutilized Source of Ethnobotanical Information. *Econ. Bot.* **2017**, *71*, 1–12, doi:10.1007/s12231-017-9367-1.
45. Wink, M. Evolution of Secondary Metabolites in Legumes (Fabaceae). *South Afr. J. Bot.* **2013**, *89*, 164–175.
46. Acosta-Gallegos, J.A.; Kelly, J.D.; Gepts, P. Prebreeding In Common Bean And Use Of Genetic Diversity From Wild Germplasm. *Crop Sci.* **2017**, 47, S44–S59, doi:10.2135/cropsci2007.04.0008IPBS.

47. Zamora-Natera, J.F.; Rodríguez-Macías, R.; Salcedo-Pérez, E.; García-López, P.; Barrientos-Ramírez, L.; Vargas-Radillo, J.; Soto-Velasco C.; Ruiz-López M.A. Forage Potential of Three Wild Species of Genus *Lupinus* (Leguminosae) from Mexico. *Legume Res. Int. J.* **2020**, *43*, 93–98.
48. Suso, M.J.; Bebeli, P.J.; Christmann, S.; Mateus, C.; Negri, V.; Pinheiro de Carvalho, M.A.A.; Torricelli, R.; Veloso, M.M. Enhancing Legume Ecosystem Services through an Understanding of Plant-pollinator Interplay. *Front. Plant Sci.* **2016**, *7*, 333.
49. Villanueva-Gutiérrez, R., Roubik, D.W.; Colli-Ucán, W.; Tuz-Novelo, M. The Value of Plants for the Mayan Stingless honeybee *Melipona beecheii* (Apidae: Meliponini): A Pollen-based Study in the Yucatán Peninsula, Mexico. In *Pot-Pollen in Stingless Bee Melittology*. Vit, P., Pedro, S.R.M., Roubik D.W., Eds.; Springer: Cham, Switzerland, 2018.
50. Ramos-Elorduy, J. Threatened Edible Insects in Hidalgo, Mexico and Some Measures to Preserve Them. *J. Ethnobiol. Ethnomedicine* **2006**, *2*, 51, doi:10.1186/1746-4269-2-51.
51. Norma Oficial Mexicana NOM-059-Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) México. Available online: https://dof.gob.mx/nota_detalle_popup.php?codigo=5173091 (20/11/2010).
52. Red List of Threatened Species, IUCN. Version 2009. IUCN. International Union for Conservation of Nature. Available online: https://www.iucnredlist.org (23/ 03/2021).
53. Barstow, M. *Olneya tesota*. The IUCN Red List of Threatened Species 2018. Available online: https://dx.doi.org/10.2305/IUCN.UK.2018-2.RLTS.T62026716A62026718.en. (15/03/2021).
54. Cervantes, A.; Linares, J.; Quintero, E. An Updated Checklist of the Mexican Species of *Dalbergia* (Leguminosae) to Aid in Its Conservation Efforts. *Rev. Mex. Biodivers.* **2019**, *90*, e902528.
55. Delgado-Salinas, A., Alejandre-Iturbide, G., Azurdia, C. Wild Species of *Phaseolus*. The IUCN Red List of Threatened Species. https://dx.doi.org/10.2305/ IUCN.UK.2019-3.RLTS.T71777142A71777145.en. (20/12/2019).