LOS BOSQUES DE PINOS PIÑONEROS EN MEXICO

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SUMMARY

FOREWORD

Due to the great diversity of environmental conditions that characterize the territory of the Mexican Republic, its plant cover assumes the form of a very complete mosaic. The knowledge that we have so far about the vegetation of this country is basically due to a large number of regional studies, carried out with methods and criteria that are not completely concordant, but that as a whole allow us to visualize a synthetic image of a certain approximation.

Even though the need for regional research in different parts of Mexico cannot be denied yet, there is no doubt that the time is ripe and the demand for information requires the use of other angles of attack to decipher the synecological problems of this mosaic.

One of the most promising techniques in this sense is the detailed studies, or monographs, of each biotic community in all the areas where it is present or at least along a large segment of its distribution area. In our environment the approach is still unfamiliar and rather novel, but it is essential to precisely define the correlations between vegetation and its environment and above all to establish the ecological determinism of biocenosis.

It is in this context that we should warmly welcome the work of Marie-Françoise Robert-Passini, who has decided to devote her efforts, her enthusiasm and, why not acknowledge it, a good part of her life to the study of the forests of *Pinus cembroides*. This is her second major contribution to the subject in question, in which not only a large amount of data but also the results of various types of analysis stand out.

Recently, Dr. Passini has informed me that she does not consider the research she had undertaken to be concluded and that she will do her best to continue the research on Mexican pine forests. I have no doubt that these intentions will become a reality and that thanks to her tireless work we will have a basic and exhaustive body of knowledge about these forests in the not too distant future.

Mexico City, February 1981
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INTRODUCTION

The ecosystems of Mexico are very varied, because the country is located between 15 and 32 degrees north latitude, being bounded by two bodies of water: the Pacific Ocean and the Gulf of Mexico, and by the ruggedness of its relief. Two mountain ranges aligned in a general NW-SE direction, the Western and Eastern Sierras Madres constitute the main elements of the relief. The Sierra Madre Occidental, with an average altitude of 2 000 to 2 500 metres, reaches 3 000 m. This mountain system is composed of volcanic rocks, formed at the beginning of the Tertiary era. The Sierra Madre Oriental extends from Texas to Chiapas and reaches an altitude of 3 650 meters at Cerro Potosi, Nuevo Leon, but in San Luis Potosi, it does not exceed 1 600 meters. It is of sedimentary origin and emerged during the course of the laramid orogeny. The folds, which follow a general N-WS-SE direction, are oriented westward in the Monterrey-Saltillo region.

The Sierras Madres border the Central Highlands, which continues through the grasslands of Texas and New Mexico. Its altitude increases from 1,500 to 2,100 meters in a north-south direction; geologically, the southwest of the Mexican Altiplano is integrated into the Sierra Madre Occidental and the northeast into the Sierra Madre Oriental. To the south of the Neovolcanic Axis, some mountainous massifs extend from the Sierra Madre Oriental; the most outstanding are the Sierra Madre del Sur and the Sierra Madre de Chiapas.

The peninsula of Baja California is mountainous, to the north it presents some massifs of plutonic rocks continuations of the great Californian batholiths; the center is volcanic. At the southern end the plutonic rocks reappear in the Sierra de la Laguna.

The great lines of the relief determine the distribution of the vegetation. The humid plains of the Gulf of Mexico are occupied by evergreen rainforest (Rzedowski, 1978). The coastal plains of the Pacific Ocean, drier than the preceding ones, are covered by thorn forest to the north of 23° north latitude, and by sub-deciduous forest to the south. The deciduous forest occupies large areas on the slopes of the Pacific, the Sierras Madre Occidental, the South and Chiapas. The Sierras Madre Occidental and Oriental, the mountainous massifs of northern Baja California and the Sierra de la Laguna are covered by coniferous and oak forests. Finally, the Central Altiplano and the Baja California peninsula are occupied by xerophytic scrub. To the west of the Altiplano, a continuous strip of grassland separates xerophytic scrub from coniferous forest.

Coniferous forests constitute the majority of Mexico's forests, totaling approximately 38 million hectares (Madrigal, unpublished), and are represented by ten genera: *Pinus, Abies, Cupressus, Picea, Pseudotsuga, Juniperus, Taxodium, Libocedrus, Taxus and Podocarpus*. The genus *Pinus* is the most important because of the surface it occupies and its economic value. Currently forty-two species of pines are known in Mexico, among these are cited: *Pinus arizonica*, *Pinus chihuahuana, Pinus cooperi,* *Pinus engelmanii* and *Pinus cembroides* in the north of Mexico; *Pinus montezumae*, *Pinus pseudostrobus* and *Pinus patula* in the center and south of Mexico. The above species are found at altitudes ranging from 400 meters (*Pinus oocarpa*) to 4 000 meters (*Pinus hartwegii*). Some species are very sought after for the quality of their wood (*Pinus ayacahuite*, *Pinus patula*) and others produce large quantities of resin (*Pinus teocote*, *Pinus oocarpa*). The seeds of *Pinus cembroides* are edible and commercial.

Pinus cembroides is considered a species of little interest, since it lacks profitability. However, it constitutes woody formations often located between xerophytic formations and pine forests in humid regions. It grows on thin soils and plays an important role in the protection of ecosystems. As it is very resistant, it is suitable for the reforestation of severely eroded areas (some trials are currently being carried out near Saltillo, Coahuila). It should be added that *Pinus cembroides* formations are found in the areas of large indigenous migrations.

The information is presented in such a way that in the initial part reference is made to the main variations of *Pinus cembroides*, continuing in the subsequent chapters with the relationships between vegetation and environment, distribution, bioclimate, altitudinal limits and the dynamics of the formations of this species.

CHAPTER I

SYSTEMATIC OF THE PINES OF THE *CEMBROIDES* GROUP

I. 1. BACKGROUND TO THE CEMBROIDES ENGELM SUBSECTION

In 1880, Engelmann published a review of the genus *Pinus*. In the section *Pinaster* Parlatore (pine in both dorsal sides), he distinguished the subsection *cembroides* Engelmann, and grouped it in a set of short cone and thin-scaled pines. He also indicated that these pines have wide seeds and isolated leaves, or grouped in 2, 3, 4 or 5. These are *Pinus parryana* Engelm, *Pinus cembroides* Zuccarini, *Pinus edulis* Engelm, *Pinus monophylla* (Torr. and Frem.) Engelmann found that the number of resin channels of the leaves of *Pinus monophylla* is very variable, observed from 3 to 14. Therefore the leaves and fruits of these species are closely related. Engelmann proposed to combine the four species of the *cembroides* subsection into one.

In 1909, Shaw, while studying the pines of Mexico, described the following four varieties as *Pinus cembroides* Zucc:

- Leaves in groups of 3 or 1 to 5, stomas on the dorsal and ventral sides, external resin channels: *Pinus cembroides* Zucc. s. str.
- Generally single leaves, sometimes 2: *Pinus cembroides* var. *monophylla* (Torr. and Frem.) Voss.
- Leaves harder than those of the above species, usually in groups of 2: *Pinus cembroides* var. edulis (Engelml.) Voss.
- Hard leaves in groups of 4: *Pinus cembroides* var. *parryana* (Engelm.) Voss.

Shaw considered it impossible to separate these four taxa specifically, as their cones are identical and the number of leaves changes too much in each variety.

In 1914, in his study of the genus *Pinus*, Shaw described in the *Haploxylon* Koehne section (single leaf cribovascular bundle), in the *paracembra* Koehne subsection (cone scales on both dorsal sides), a *cembroid* group of aptera seeds. This *cembroid* group of Shaw comprises three species:

- *Pinus cembroides* Zucc. is characterised by whole leaves, a caediza pod, cones with few scales, subsessile and subglobose.
- *P. pinceana* Gordon, this species differs from *P. cembroides* in that its cones have long stalks and numerous scales.
- *P. nelsonii* Shaw, differs from the two previous species in that its leaves are serrated and persistently podded.

Dallimore in 1966 adopted the latter classification.

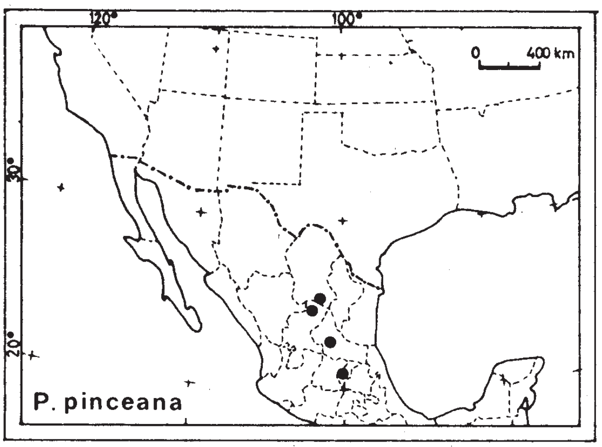


Figure 1 a. Distribution map of *Pinus pinceana*, according to Critchfield and Little (1965) modified

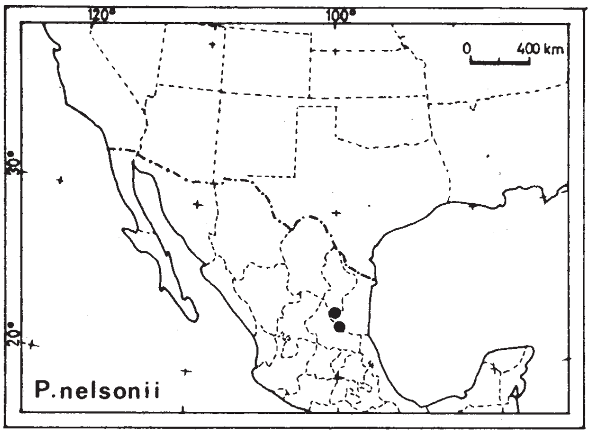


Figure 1 b. Distribution map of *Pinus nelsonii*, according to Critchfield and Little (1965) modified.

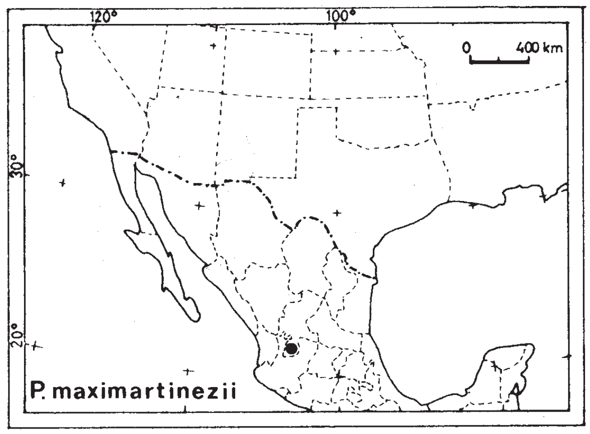


Figure 1 c. Distribution map of *Pinus maximartinezii*, according to Critchfield and Little (1965) modified.

In a study made on Mexican pines, in 1948, Martinez distinguished a section called *piñoneros*, of caediza pod; in it the scales of the cone have both dorsal and its aptera seeds are edible. These pines are:

- single-leaf (most common number)	*Pinus monophylla* Torr.
- two-leaved (most frequent number	*Pinus cembroides edulis* Voss.
- four-leaved (most common number)	*Pinus quadrifolia* Sudw.
- three-leaved (rarely 2 or 5)	
-- oblong or suboblong cones and straight leaves	*Pinus pinceana* Gord.
-- subglobose cones, generally curved leaves	*Pinus cembroides* Zucc.
-- aptera seeds	*Pinus nelsonii* Shaw

Martinez considered that *Pinus cembroides* and *Pinus edulis* could be included in the same species, without specifying the taxonomic classification that he gives to the triple nomenclature of *Pinus cembroides edulis*. This taxon differs from *P. cembroides s. str*. in that its fascicles have predominantly two leaves, thick, hard and acuminate; in Mexico it exists only in Baja California Norte. Sometimes the number of resin channels is greater than two as in *P. quadrifolia* and *P. monphylla*, which are found only in Baja California. Martínez proposed to separate *P. quadrifolia* and *P. monphylla*, without ignoring the affinities of *P. quadrifolia* and *P. edulis*.

Gaussen, in 1960, separated the pines into six sections, section VI, called Parryanoides Gaussen, is characterized by its large edible seeds. It comprises five groups of pines, one of which is the American group of aptera seeds, called cembroides, which are haplostelated pines with marginal resin channels. The Gaussen cembroides group includes *P. nelsonii, P. monophylla, P. edulis, P. cembroides, P. parryana* and *P. pinceana*.

Mirov in 1967, also considered a *kembroid* group (*Pinus piñonero* or *pinyon*) consisting of seven species, to which is added in addition to the six already mentioned *Pinus culminicola* Andresen and Beaman, described in 1961.

The last complete classification of the pines is the one made by Little and Critchfield in 1969, which continues the one made by Shaw in 1914 and also extends it. In the haploxilated pines that constitute the subgenus *Strobus* Lemb, Little distinguishes two sections: *Strobus* Lemm. (with leaves in groups of five and both terminal) and *Parrya* Mayr (leaves grouped from one to five and dorsal ombus). The *Parrya* section is divided into the following three subsections: *cembroides* Engelm., *gerardianae* Loud. and *balfourianae* Engelm. The subsection *cembroides* Engelm. is characterized by including pines whose fascicles have from one to five leaves, usually whole and short (from 2 to 9 centimeters long). The seeds are large and apathetic. This subsection includes eight species of trees or shrubs from the semi-arid regions of the southwestern United States and Mexico, which are *Pinus cembroides*, *Pinus edulis, Pinus quadrifolia*, *Pinus culminicola*, *Pinus maximartinezii* Rzedowski, *Pinus pinceana* and *Pinus nelsonii*. Of these three, *Pinus maximartinezii*, *Pinus pinceana* and *Pinus nelsonii* are clearly defined and limited

Pinus cembroides Zucc., 15 meters high.
25°27'N, 100°23'W, Municipality of Arteaga (Coahuila), 2 350 m of altitude.
September 4th, 1975.

in area (Figures 1a, 1b, 1c). In contrast, the other five species are very similar. Lanner, in 1974, grouped four of them, *Pinus monophylla*, *Pinus edulis*, *Pinus cembroides* and *Pinus quadrifolia*, in "*Pinus cembroides* complex". Likewise, he proposed to add to the four mentioned species *Pinus culminicola* and *Pinus johannis* Robert, and to gather these six in the cembroides group.

Before starting the study of Mexican pine trees, the species of the cembroides group are described, with the purpose of facilitating the understanding of the kinship and complexity of the group.

I. 2. PINES OF THE CEMBROID GROUP

The number of leaves per fascicle is the most visible character and used to differentiate between the species in the group. Considering only this characteristic, the group of *Pinus cembroides* appears as a continuous evolutionary series whose ends are *Pinus monophylla* and *Pinus culminicola*. Under this hypothesis, the order of species is as follows: *Pinus monophylla*, *Pinus edulis, Pinus cembroides, Pinus johannis, Pinus quadrifolia* and finally, *Pinus culminicola*. This is the order followed in this study.

I. 2. 1. ***Pinus monophylla*** Torr. and Frem.

This species was described in 1842, from a sample taken in the Rocky Mountains. It is a small tree, 7 to 10 meters high, with a short trunk, highly branched from the base. Its fascicles are singleleaf, characteristic considered for a long time to be due to the union of two leaves. In 1935, Doak demonstrated that monophilia was due to the formation of a single leaf primordium and that it was hereditary. The leaves, 4 to 6 centimeters long, are thick, rigid and light green in color. Its cross section is circular; the stomas are numerous and the number of resiniferous channels varies from 3 to 12.

The cones are very numerous and are composed of 6 to 7 helixes of scales; the aptera seeds, "have a shell so thin and fragile that it can be easily broken with two fingers", as Little indicated in 1968. This characteristic is noted by several authors and was found in a seed lot from the United States. The shell is 0.1 to 0.3 millimeters thick. The endosperm is white; conservation of the seeds is difficult and the proven percentage of germination is low (10%). The number of cotyledons varies from 5 to 10, the average being 7.07 (calculated on 73 seeds from the United States). Seedlings are very fragile and very sensitive to excess moisture. The first year leaves, or euphils, are denticulate, a characteristic noted by Ferre in 1965. The growth of the young plant is slow, at least this was observed in Paris, France.

Pinus monophylla has been found in California, Utah, Arizona and southwestern New Mexico (United States) (Figure 2 a). In Mexico it is only known from the northern part of the state of Baja California Norte. It grows

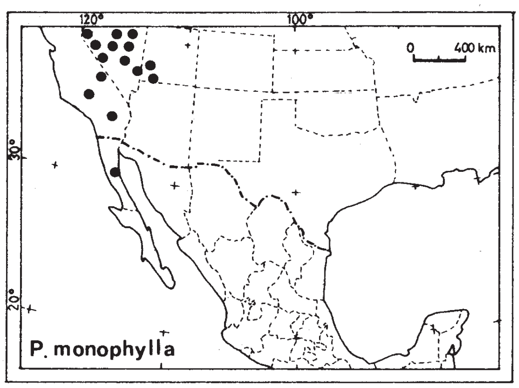


Figure 2 a. Distribution map of *Pinus monophylla*, according to Critchfield and Little (1965) modified between 1 000 and 2 200 m of altitude according to Martínez in 1948. In the State of Utah it coexists with *Pinus edulis* Engelm.

I. 2. 2. *Pinus edulis* Engelm.

Pinus edulis was described, in 1848, by Engelmann from a sample taken around Santa Fe New Mexico, collected by A. Wislizenius. It is a tree from 6 to 15 meters high with a rounded crown. Its leaves are rigid, very accumulated and whole, and are presented in pairs. The dorsal and ventral faces contain the stomas. The resiniferous channels are extensive and there are two of them. In Arizona and New Mexico, Little in 1968, described the fallax variety, which is distinguished from *Pinus edulis* var. edulis by having one rigid leaf (sometimes two) and 2 to 4 resiniferous channels. The shell of the seeds is also thin (0.3 to 0.4 millimeters).

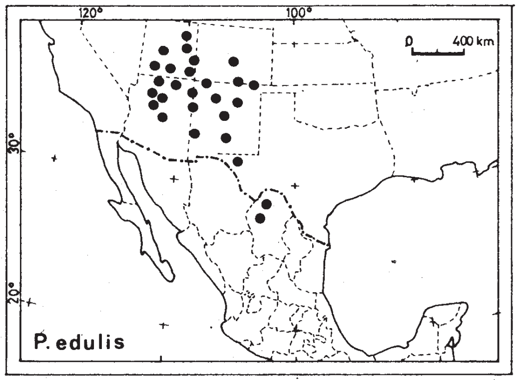


Figure 2 b. Distribution map of *Pinus edulis*, according to Critchfield and Little (1965) modified

According to Little the fallax variety is easily distinguished from Pinus monophylla, since its leaves are green, with a thickness of 1 to 1.4 millimeters while those of *Pinus monophylla* measure from 1.5 to 2 millimeters and in addition its color is green gray or pale olive green. According to the same author, the seeds of *Pinus monophylla* are easily distinguished from those of *Pinus edulis*, and even from the *fallax* variety, since they are larger than 15 to 22 millimeters long.

On the other hand, Lanner in 1972, pointed out the existence of hybrids between *Pinus edulis* and *Pinus monophylla,* which are distinguished by the presence, in the same tree, of fascicles with 1 and 2 leaves and by a variable number of resiniferous channels (from 2 to 10). It is probable that Gaussen has gathered in 1960, in his description to *Pinus edulis* and the hybrids mentioned later by Lanner, since in the leaves of *Pinus edulis* he indicates the presence of 1 to 10 resiniferous channels. It is added that the endosperm of the seeds of *Pinus edulis* is also white (observation made on a seed lot from the United States). The average number of cotyledons reaches 8.30, according to Ferre (1965).

Lanner mentioned in 1974, that the areas occupied by *Pinus monophylla* and *Pinus edulis* do not interpenetrate, but present large interfaces along which hybridizations could be possible. This author considers that *Pinus edulis* var. *fallax* is not a stable variety, but a hybrid; he bases his study on the number of leaves per fascicle and the number of resin channels, however he does not consider the character of the seed shell. Bailey (unpublished), when studying the terpenes, shares Little's opinion. This controversy indicates the close relationship between *Pinus edulis* and *Pinus monophylla*. The first species is located in the southwestern states (Figure 2b), and for Critchfield and Little (1966) it does not exist in Mexico. In 1967, Mirov enlarged the area of *Pinus edulis* in northern Coahuila on his maps, but without giving any explanation in his text. On the other hand, when the author carried out the present investigation, he found some specimens of *Pinus edulis* in the Sierra Santa Fe del Pino and in the Sierra Encantada, Coahuila. These populations are relict.

I. 2. 3. *Pinus cembroides* Zucc.

This species was described by Zuccarini from a sample without cones collected in central Mexico, which is preserved in Munich. It is a tree whose height varies from 5 to 15 meters, the fascicles are composed of 2 leaves, and sometimes 3 or 4. These are flexible, which allows to differentiate this species of *Pinus edulis*. The stomas are found on the dorsal and ventral sides of the leaves. In the cross section only two resin channels are seen. Little described in 1966, in the State of Texas, a variety of *Pinus cembroides* with two flexible leaves, whose seeds have a thin shell (0.1 to 0.4 mm thick). This is the remote variety Little. In November 1979, Bailey and Hawksworth classified *Pinus cembroides* var. *remota* as a species based on the following three reasons:

- The leaves of this taxon often have more than two resin channels.

- The scales of the pod at the base of the leaflet make a 90° angle while in the other *Pinus cembroides* species the angle is 270°.

- This taxon is found at lower altitudes than those where *Pinus cembroides* is found.

The authors do not indicate the maximum number of resin channels observed, nor the altitude at which each taxon is located. They indicate their presence in west Texas, next to the lower altitudinal limit of *Pinus cembroides*. This species and remote *Pinus* do not hybridize in this area which seems to indicate that they are different species. According to the same authors *Pinus edulis* var. *edulis* from northeastern Mexico is actually *Pinus remota*.

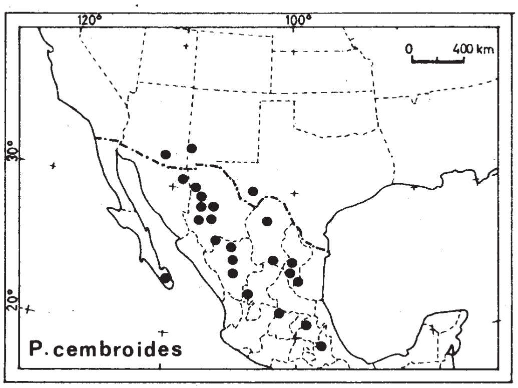


Figure 2 c. Distribution map of *Pinus cembroides*, according to Critchfield and Little (1965) modified

In Arizona, Little in 1968 described another variety of *Pinus cembroides*: *bicolor*, whose flexible leaves, in groups of three, have no stomas on the dorsal side. This one is dark green and the ventral side is white. The seeds are 8 to 13 mm long, the shell is thick (2/3 to 1 mm) and 'cannot be broken by teeth', unlike the seeds of *Pinus edulis*, *Pinus cembroides* var. *bicolor* is found from 1 620 to 2 300 meters (sometimes up to 2 600) of altitude in southwestern New Mexico, southwestern Arizona, northeastern Sonora and western Chihuahua and finally, locally in the mountains of Coahuila, Nuevo Leon, Tamaulipas, San Luis Potosi and Zacatecas. Other *Pinus cembroides* specimens have been collected without stomas on the dorsal side, in several states of the Mexican Republic. In herbariums, the bicolored character of the leaves often disappears. Thus Little concluded that the samples without stomas on the dorsal side may not belong to the bicolor variety. Bailey and Hawksworth elevated this variety to the category of species, giving it the name of *Pinus discolor*.

Pinus cembroides has a wider distribution area in Mexico than in the United States (Figure 2 c).

I. 2. 4. *Pinus johannis* M.-F. Robert

This species was described from a sample taken in Concepción del Oro, Zacatecas (Robert,1978). It is a bush of 1 to 4 meters, branched from the base, generally with more crown than height; the trunk is not well differentiated, the crown is dense and dark green. The leaves vary in number from 2 to 3 and rarely 4 (Table 1).

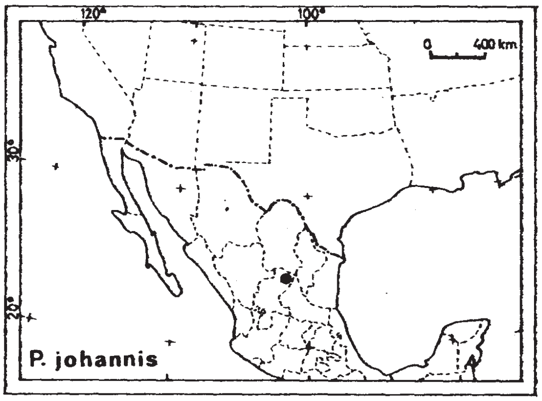
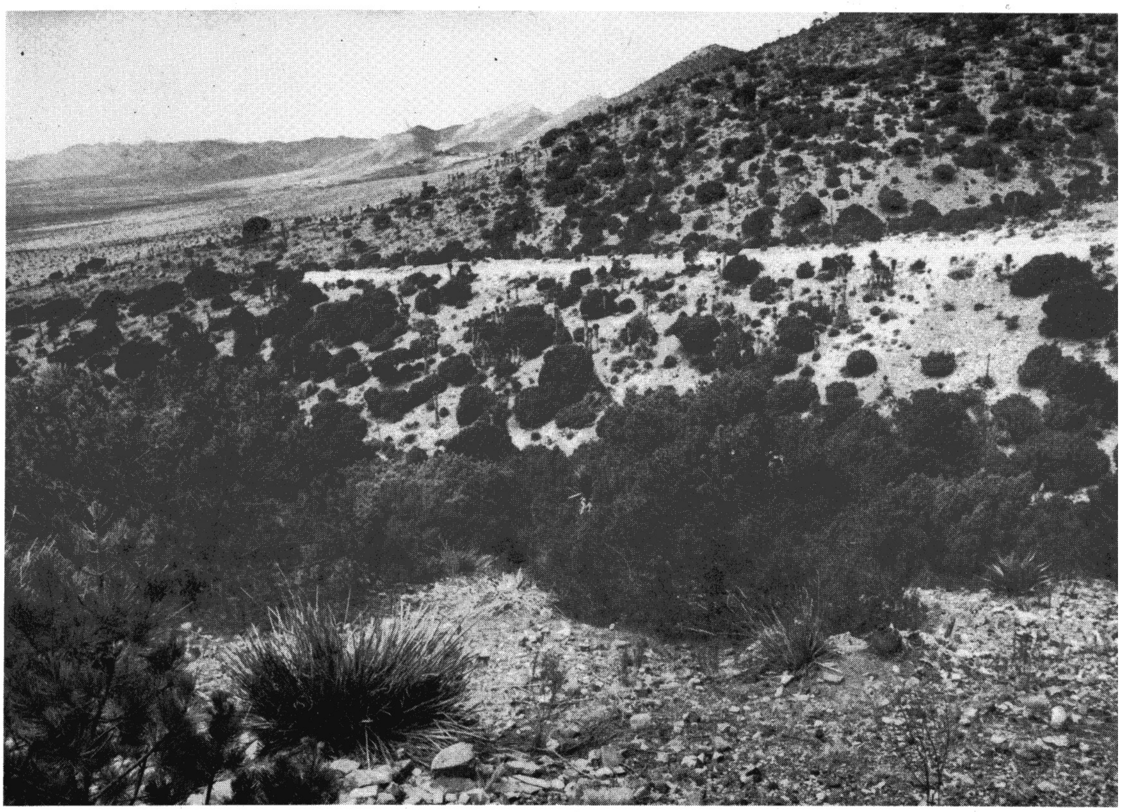


Figure 3 a. Distribution map of *Pinus johannis*.



Low formation of *Pinus johannis* with Yucca carnerosana.
Road from Concepción del Oro to Mazapil (Zacatecas), 2 500 m altitude.
February 7th, 1978.

TABLE 1. Variations in the number of leaves per fascicle* in the population of *Pinus johannis* in Puerto El Dique, Zacatecas

Number of the Tree	Number of installments examined	Percentage of issues with:		
		2 sheets	3 sheets	4 sheets
1	1 201	6.6	93.3	0.1
2	472	15.9	83.7	0.4
3	222	13	86.5	0.5
4	575	12	87.8	0.2
5	474	12.9	86.9	0.2
6	320	11.9	88.1	0
7	322	7.8	91.9	0.3
8	311	16	83.6	0.4
9	561	6.6	90.7	2.7
10	440	9.5	90.5	0
11	323	17	82.4	0.6
12	334	4.8	92.2	3
TOTAL	5 555	10,4	89	0,6

* Five branches were obtained from 1 meter above the ground in 12 randomly selected trees in the population.

The leaves are bluish green and without stomas on the dorsal side; pruinose and clear on the ventral side. but there are 3 to 8 rows of stomas on the ventral side. In the cross section two external resin channels are seen. The seeds are aptera and have a white endosperm. The embryo has 6 to 11 cotyledons; the average of these, calculated on a lot of 98 seedlings, was 8.7.

Pinus johannis shows a lot of analogy with *Pinus culminicola*, close relation with Pinus edulis and some affinities with *Pinus cembroides* s, 1.

Bailey and Hawksworth, in 1979, pointed out the existence of some shrubby *Pinus cembroides* in the Sierra Nevada de la Madera, Coahuila, and in the Sierra Madre Oriental towards the East. According to these authors, the composition in monoterpenes of the shrubs of the Sierra de la Madera is identical to the composition of *Pinus johannis*. For this reason they considered these pines as *Pinus johannis sensu lato*. In addition, *Pinus johannis* has been observed in the Sierra Madre Oriental, on the way to Miquihuana and Aramberri (Figure 3a). The endosperm is white.

According to the works of Bailey and Hawksworth, carried out in 1979, the composition in terpenes is identical in the species *Pinus johannis*, *Pinus remota* and *Pinus cembroides*.

I. 2. 5. ***Pinus quadrifolia*** **Parl.**

The leaves of this pine tree appear in fascicles of four. It was described in the

19th century in Baja California and is only observed in that state and in California, USA, along the Mexican border (Figure 3 b). It can reach up to 25 meters in height. Lanner in 1974 considered it a hybrid of a 5-leaf pine, also discovered in Baja California and called *Pinus juarezensis* Lanner and *Pinus monophylla*. This statement constitutes an interesting hypothesis that confirms the complexity of the keloid series. The author was not able

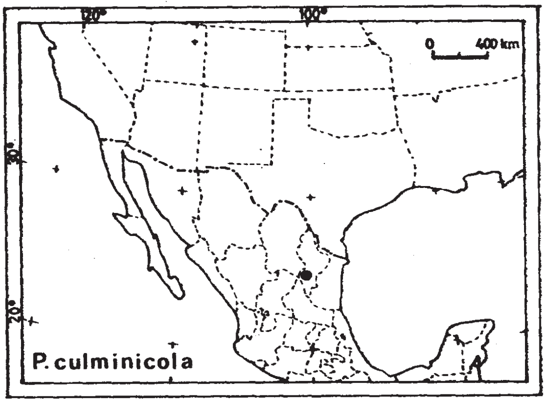


Figure 3 c. Distribution map of *Pinus culminicola,* according to Critchfield and Little (1965) modified

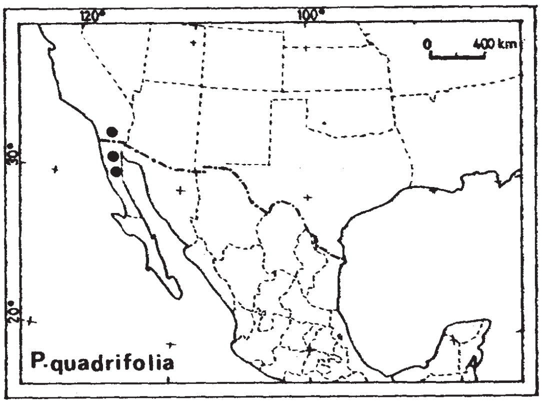


Figure 3 b. Distribution map of *Pinus quadrifolia*, according to Critchfield and Little (1965) modified

to observe *Pinus quadrifolia* and *Pinus juarezensis* in their natural environment, and no researcher mentions the characteristics of the seeds or seedlings. The National Institute of Forestry Research of Mexico, now the National Institute of Forestry and Agricultural Research (INIFAP), provided a seed lot of *Pinus quadrifolia*. The endosperm is white.

I. 2. 6. *Pinus culminicola* Andresen and Beaman

The last pine of the *cembroides* group, has 5 leaves per fascicle and was described in 1961. Its area is very reduced (Figure 3 c). This tree lives in higher places than *Pinus cembroides*, and is very low in height. Its leaves are thin; the dorsal side has no stomata, is blue-green while the ventral side is light green. In a cross section only one resin channel per leaf is observed. The cones are sessile and small. Some observations were made in the population of Cerro Potosí, Nuevo León, where the type was described, and in individuals from Sierra de la Marta, Coahuila as Riskind in 1975. In these two populations there were numerous very resinous cones; the seeds were frequently empty and small, 4 to 6 millimeters long. The endosperm, white and resinous, has a less pleasant taste than that of *Pinus cembroides*. Sowing in Paris yielded 23 seedlings; the number of cotyledons varied from 8 to 11, with an average of 9.23. The seedlings are robust, the euphils have entire edges. In this species the characterization is faster than in *Pinus edulis* and *Pinus monophylla*, since from the second year 80% of the seedlings present fascicles with five leaves.

Therefore, the two extremes of the keloid group are well defined and are *Pinus monophylla* and *Pinus culminicola*. Their respective characters are described in Table 2. The study of *Pinus monophylla* and *Pinus culminicola* will not be extended, nor will the information on *Pinus quadrifolia* and *Pinus juarezensis*, the work on which has not yet been completed.

In the course of the floristic and ecological observations made in the forests of *Pinus cembroides* s.l., a great variability in this species has been noted (for example, the number of leaves per fascicle varies from 2 to 4 in the same individual). On the other hand, when visiting the markets it was noticed that the shelled seeds (pine nuts) are pink. In addition, it was observed that whatever the dominant number of leaves per fascicle of the seed-producing tree, these are of the same color. Thus, it became clear that *Pinus cembroides* s. str. has pink seeds due to phenolic compounds.

TABLE 2. Comparison of *Pinus monophylla* and *Pinus culminicola*

	Pinus monophylla	*Pinus culminicola*
Sheets		
number	1	5
section	circular letter	triangular
stomas	numerous, regularly distributed	back side only
resin channels	2 a 12	1
Cones	subglobose, sessile	subglobose, sessile
Seeds		
long	11 to 18 millimetres	4 to 6 millimeters
shell	thin	thick
endosperm	White	White
Number of cotyledons	5 a 10	8 a 11
Euphils	serrated edge	entire edge

The following study will deal with *Pinus edulis* s.l. and *P. cembroides* s.l. and their variations in Mexico.

I. 3. P*INUS EDULIS* s.l. AND ITS VARIATIONS IN MEXICO

I. 3. 1. Pines of Santa Catarina, Nuevo León

The pines of the municipality of Santa Catarina, Nuevo Leon (highway from Monterrey to Saltillo), thrive from an altitude of 1,000 meters at the foot of the eastern arc of the Sierra Madre Oriental (Figure 4a).

Their unique appearance is very similar to that of junipers. Its height is less than 4 metres, and it is very branched. The leaves are presented in fascicles of 2, 3 or 1 (Table 3). They are dark green, more rigid than those of *P. cembroides*. The dorsal and ventral faces have stomas. The cross section of the solitary leaves is triangular, without any similarity to those of *P. monophylla*.

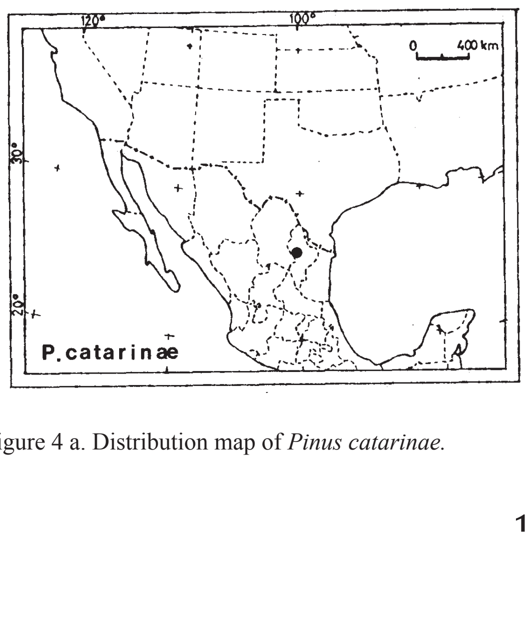


Figure 4 a. Distribution map of *Pinus catarinae.*

The peduncle of the female cones is curved, which is not observed in *Pinus* *edulis* or *P. cembroides*. Mature cones have a short peduncle; they are subglobose and very similar to those of *P. edulis* and *P. cembroides,* although more resinous. The few seeds found in 1974 had a white endosperm and thick shell.

TABLE 3. Frequency of leaves per fascicle, in percentage, in the formation of Casa Blanca, Nuevo León, at an altitude of 1 100 meters.

Tree number	Number of leaves			Number of brochures counted
	1	2	3	
1	2.5	95	2.5	200
2	0	94.5	5.5	200
3	1.5	77.5	21	200
4	0	99	1	200
5	2.5	91	6.5	200
6	0	99	1	100
7	0.5	96	3.5	200
8	0	100	0	200
9	1	93	6	200
10	1	93.5	5.5	1 700
TOTAL	1 %	94 %	5 %	3 400

These pines can be seen to the south, in the direction of Galeana, Nuevo León, on the inner slopes of the east-west oriented mountain ranges, up to 1 500 meters of altitude. They rarely reach 6 meters in height.
Samples of fascicules were taken at 1 400 meters of altitude, observing that those of 2 leaves are dominant (Table 5).

TABLE 4. Frequency of resin channels, in percent, in the Casa Blanca formation at 1 100 meters of altitude.

Tree number	Number of channels			Number of leaves studied
	2	3	4	
1	10	55	35	20
2	10.5	79	10.5	20
3	30	65	5	20
4	10	70	20	20
5	25	60	15	20
6	50	50	0	20
7	0	100	0	20
8	20	70	10	20
TOTAL	18	69.5	12.5	160

The analysis of the data in Table 5 allows us to consider tree number 3 as a hybrid between the 2-leafed, low-leafed pine (Table 2) and the 3-leafed *P. cembroides,* which grows further south in the same mountain range. Sampling shows that at an altitude of 1500 m the numbers of resin channels vary from 2 to 5, with an average of 3 (Table 4).

TABLE 5. Frequency of leaves per fascicle, in percent, in a pine formation in the municipality of Santa Catarina, N. L., at 1 400 m altitude

Number of trees	Number of leaves		Number of fascicles counted
	2	3	
1	98.75	1.25	200
2	99.5	0.5	200
3	65.7	34.3	100
4	100	0	100
5	99.2	0.8	100
6	100	0	100
7	100	0	100
8	98.2	1.8	120
TOTAL	97	3	1 020

These pines grow in a xerophytic region where the average annual rainfall does not exceed 270 millimeters and the average annual temperature varies from 17 to 18°C (data from Ramos Arizpe, Coahuila, at 1 399 meters of altitude). At 1 100 meters of altitude, in this community exist *Yucca thompsoniana*, *Fouquieria splendens*, *Larrea tridentata*, *Berberis trifoliata*, *Agave striata*, *Agave lecheguilla*, *Bouteloua curtipendula* and *Bouteloua hirsuta*, (among other species in superior altitudes, until 1 500 meters become more important the following species: *Sophora secundiflora*, *Rhus microphylla*, *Nolina sp*. and numerous gramineous.

From the sudden cones and the seeds it can be deduced that the pines of Santa Catarina belong to the cembroid group. Their hard leaves and white endosperm make them similar to *Pinus edulis*, species with which they have in common the predominance of 2 leaves per fascicle. However, they are distinguished from *P. edulis* var. *edulis* by their low height and the number of resin channels (more than two). As for *P. edulis* var. *fallax* Little, it was found that it has more than 2 resiniferous channels, it has fascicles of only one leaf, rarely two, a fact that does not occur with the pines of Santa Catarina (Table 5).

Bailey and Wendt in 1979, stated without argument, that the population of pine trees located at an altitude of 1 000 to 1 100 metres between Monterrey and Saltillo is made up of *P. remota*. It is recognised that this population represents the shortest Mexican pine trees in size ("New pinyon records for northern Mexico"), but the identification of these authors is not accepted. The same authors briefly describe *P. remota*. If the description of *P. cembroides* var. *remota* Little is accepted as valid, it should be considered as a tree 3 to 9 meters high, with a wide and rounded crown. The pines of Santa Catarina are dwarfs, as they hardly reach 6 meters in height. However, the fructification is achieved even in specimens smaller than 2 meters high. Two factors that sometimes cause non-hereditary dwarfism are the low altitude, and the action of the winds, but in this case they are insignificant. Therefore, the character of dwarfism should be considered as characteristic of the pines of Santa Catarina. On the other hand, Bailey and Hawksworth pointed out that *P. remota* is sometimes confused with *P. edulis* in northeastern Mexico; however, the latter look very different from Santa Catarina pines.

For a better understanding of the Cembroides group in Mexico, the pines of Santa Catarina will be considered as belonging to a new taxon. It is proposed to give them the name of *Pinus catarinae*, name of the municipality where this population is located.

Pinus catarinae M.-F. Robert-Passini, *sp. nov*.
Diagnosis: Arbol ramoso de 6 metros de altura. Hojas rigidas y aciculadas pero rara vez conjuntas; presentan estomas en las caras dorsal y ventral conos pedunculados y curvos de 3 a 8 milímetros de largo. Semilla teguncutada, de color blanco.
Tipo: ROBERT 10 011, Casa Blanca, Municipio de Santa Catarina Nuevo León. (25° 39' 30" N, 100° 42' 40" 0), pie de monte pedregoso-calcáreo, con una formación de *Agave filifera* (figura), altitud de 1 140 metros 10.02. 1978 (holotipo, P; isotipo, MPU, TLJ, ENCE, INIF, ANSM).
Se trata de un arbusto de 1 a 6 metros de altura, ramificado desde la base, generalmente con mas copa que altura y de corona densa; su tronco no está bien definido. Su corteza es grisácea y sus ramas presentan color gris. Tiene 2 ó 3 hojas coriáceas y aciculares de 2.5 a 5 centímetros de largo; su color es verde grisáceo en ambas caras. Su borde es entero. Se observan 4 ó 5 hileras de estomas en la cara ventral y de 3 a 4 hileras en la cara dorsal. Los conos femeninos son de color claro, miden de 4 a 8 milímetros de largo y de 4 a 8 de ancho, presentan un pedúnculo de 5 a 10 milímetros de largo. Sobre las escamas se observa un muero.
Los conos, pequeños, son muy dehiscentes. Las escamas, en número inferior a 30, tienen una apófisis romboidal. Las carenas laterales están bien marcadas. El ombligo dorsal es ligeramente cóncavo y no tiene muero.
Las semillas ápteras son pequeñas y su tegumento externo mide de 0.2 a 0.5 milímetros de espesor. El endospermo es blanco y comestible.

I. 3. 2. Pines of the North-East of the State of Coahuila

Two populations of *Pinus edulis* have been observed, one in the Sierra de Santa Fe del Pino and the other in the Sierra de la Encantada, Coahuila (Figure 4 b). Their determination was based on width, hardness and number of leaves. These populations are considered relict.
In the cross sections of the leaves there are more than two and more commonly four resiniferous channels, therefore, it is not *P. edulis* s. str. Due to this, the following hypotheses were formulated:

1. The number of resiniferous channels varies within the taxon.
2. These pines represent some hybrids between *P. monophylla* and *P. edulis*.
3. They constitute a variety that can be distinguished within the species. The hypotheses will be successively and exhaustively reviewed below:

1. The number of resin channels varies within the taxon. Little never reported such variations for *Pinus edulis* in the United States. The number of resin channels seems constant except for the fallax variety, which has 2-4 resin channels, but mostly a single leaf, which is not the case in the above-mentioned populations. Lanner in 1974, when studying the hybrids between *P. monophylla* and *Pinus edulis*, verified this characteristic

and concluded that the number of resin channels is "markedly uniform" since only 1.7% of the leaves examined showed "a number of resin channels different from the number characteristic of the species". Such is the situation found in Arizona, Colorado, New Mexico and Utah, so it is difficult to accept that it is different south of the Rio Bravo.
It should be noted that the Sierra de Santa Fe del Pino is quite close to some places studied by Lanner north of the Rio Bravo. Of course, Utah's climate is different from the climate of northwestern Coahuila. The pines of the Sierra de Santa Fe del Pino grow at altitudes of 2 000 to 2 100 meters, on soils with a black surface horizon, with a pH of 7, and reach 9 to 15 meters in height. The pines of the Cuesta La Encantada grow at 1 400 metres in soil identical to that of the Sierra de Santa Fe del Pino, but the microclimate is xerophytic. In the pines of the two seasons the average number of resin channels is four.
From Lanner's 1974 studies on the ecological conditions, it is clear that the first hypothesis cannot be accepted; since the pines of Sierra de Santa Fe del Pino and La Encantada, Coahuila do not belong to *P. edulis s*. str. Perhaps they are hybrids between *P. monophylla* and *P. edulis*.

2. These pines are hybrids between *P. monophylla* and *P. edulis*. The hybrids between *P. edulis* and *P. monophylla* described by Lanner in 1974 have 2 to 4 resin channels, but correlatively they have a high percentage of fascicles with one leaf. Thus, in the samples collected in both stations it was observed that there was a lack of fascicles with one leaf, but other samples should be made. The hypothesis of a hybrid between *P. monophylla* and *P. edulis* is only a probability. To confirm the hypothesis, sites with *P. edulis* and *P. monophylla* should be found not far from Sierra Santa Fe del Pino and Sierra de La Encantada. These two taxa are located in southwestern New Mexico, and are likely to be widespread in Mexico. Since the 17th century deforestation has been intense. The Sierra de La Encantada is hollowed out with mines, and the Sierra Santa Fe del Pino has been subject to unregulated deforestation since the land Reform. Martinez in 1948 mentioned the existence of *P. cembroides* in that area, a species that was not found.

If the absence of singleleaf is confirmed in the future by subsequent collections, this second hypothesis will be discarded.

3. These pines represent a variety of *P. edulis*.
They therefore represent a variety of *P. edulis*, which is distinguished from *P. edulis* var. *edulis* by the number of resin channels, which varies from 2 to 4. They are also distinguished from *P. edulis* var. *fallax* Little, because the number of resin channels is greater than 2, but with singleleaf fascicles, rarely two.
According to Bailey and Hawksworth (1979), *P. remota* has been confused with *P. edulis* in northwest Mexico and west

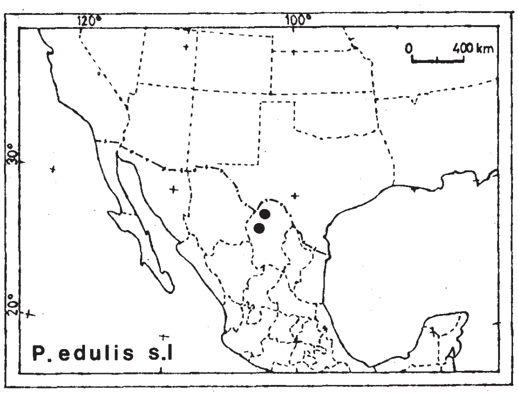


Figure 4 b. Distribution map of *Pinus edulis* s.l., according to Critchfield and Little (1965) modified

Texas, as its leaves are more leathery in these regions than in the Edwards Plain. These data allow us to suppose that *P. remota* presents fluctuations in the hardness of its leaves, which increases the difficulty of this characteristic to be used to distinguish *P. edulis* from *P. cembroides*. Although *Pinus remota* is very similar to *Pinus cembroides* with the naked eye, identification is difficult. Thus, the pines of northwestern Coahuila are taxonomically closer to *P. edulis* than to *Pinus cembroides*, making it difficult to consider them as *Pinus remota*. Furthermore, *Pinus cembroides* var. *remoto* was described by Little as a small tree, and the pines of northwest Coahuila reach a height of 9 to 15 meters.
A more complete collection will allow the characteristics of the seeds and seedlings to be clarified and the relationship with *Pinus remota* (Little) Bailey and Hawksworth and their systematic level clarified.

I. 4. PINUS CEMBROIDES s.l. IN MEXICO

The regional tours allowed us to observe the variations in the morphological characters of *Pinus cembroides*. For example the height varies from 3 to 15 meters there are also differences in size. The length of the leaves fluctuates in the same tree and on the same branch, from one year to another. This characteristic and the duration of the life of the leaves, seems to be linked to the water conditions of the environment, for this reason, it was preferred not to take it into consideration, for the present study.
Subsequently, the number of leaves, seeds and seedlings of *Pinus cembroides* were observed in Mexico.

I. 4. 1. The leaves

I. 4. 1. 1. Number of sheets per booklet

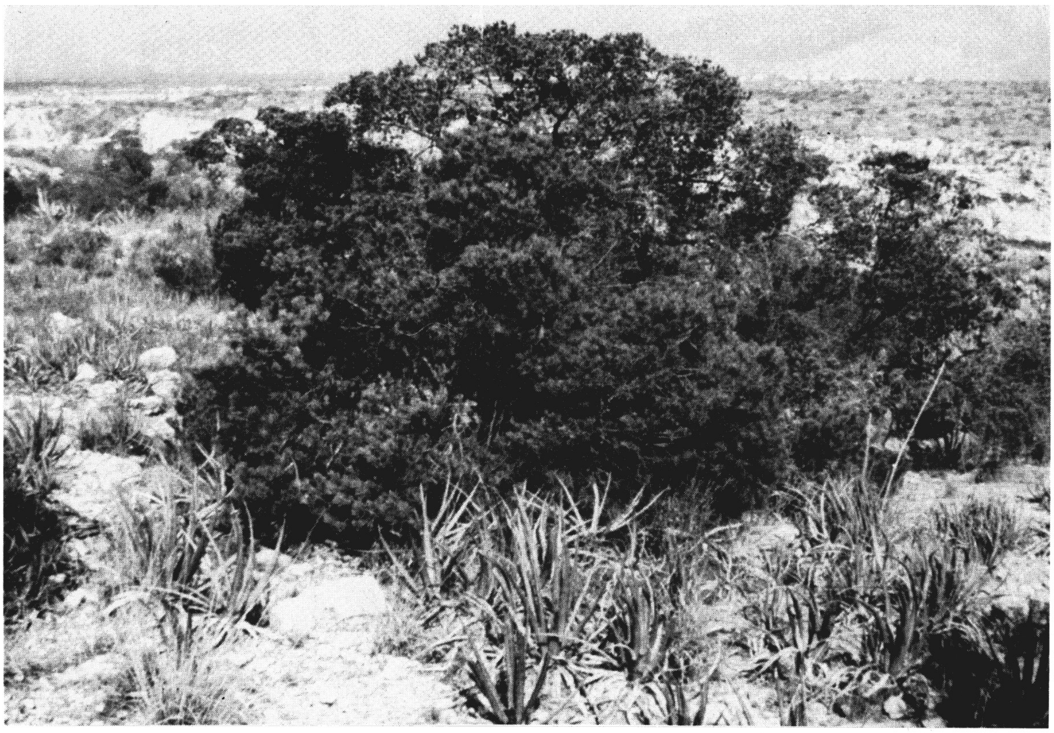
On each of the 10 trees taken at random in a population of homogeneous ecological conditions, 5 branches located at 1.30 meters high were collected in the populations of Sierra del Carmen, La Herradura and Paso de Carneros in Coahuila, Concepción del Oro, Zacatecas and La Laguna in Baja California Sur. The data are shown in Table 6.

TABLE 6. Frequency of the number of leaves per fascicle.

Población		Número de fascículos contados	Número de hojas %			
			1	2	3	4
Sierra del Carmen (Coahuila)	28°56’20”N 102°34’15”0	158 (3 árboles)	0	86	14	0
La Herradura (Coahuila)	25°23’00”N	263 (árboles)	3			0
Paso de Carneros (Coahuila)	25°07’30”N	4 224 (10 árboles)	1			
Concepción del Oro (Zacatecas)	24°37’00”N	2 367 (5 árboles)	3	48		
La Laguna (Baja California Sur)	23°34’00”N	5 709 (10 árboles)	1	28	71	0

In the case of the singleleaf fascicules, this one does not resemble that of *Pinus monophylla*,

Low formation with *Pinus culminicola* 3 meters high.
An isolated individual of *Pinus culminicola* is noted in a herbaceous formation with *Muehlenbergia sp.* and various Compositae; in the background: *Pinus teocote*, *Pinus arizonica*, *Pinus ayacahuite*.
25°21’40 “N, 100°31’30 “W, Municipality of Arteaga (Coahuila), 3 150 m of altitude
September 4th, 1975



Pinus catarinae, 3 meters high; in front Agave lecheguilla.
Highway from Monterrey to Saltillo, Municipality of Santa Catarina (Nuevo Léon)
February 10, 1978.

since in its triangular section 2 resiniferous channels are observed. The information presented in Table 6, allows us to distinguish two populations of pines, whose individuals have predominantly 3 leaves per fascicle: those of the Sierra del Carmen, in the north of the State of Coahuila (Figure 2), and those of La Herradura, in the municipality of Arteaga, Coahuila. Two other towns, Paso de Carneros, Coahuila, geographically very close to La Herradura, and La Laguna, municipality of Todos Santos, in Baja California Sur, generally have 3 leaves per fascicle.

There are variations within the population of Paso de Carneros: one tree had 58% of fascicles with 2 leaves and 42% of fascicles with 3; likewise, another tree had 63% of fascicles with 2 leaves and 37% with 3 (Table 7).

Frequency of the number of leaves per fascicle, in Paso de Carneros, Coahuila.

Número del árbol	Número de fascículos	Número de hojas por fascículo en %			
		1	2	3	4
1	200	0	27	73	0
2	200	0	11	89	0
3	120	0	34	66	0
4	160	0	58	42	0
5	200	0	63	37	0
6	160	0	19.5	80.5	0
7	190	0	16	82	2
8	133	8.5	26.3	65.2	0
9	488	1	38.75	60.25	0
10	2.373	1.25	30	68.75	0

In the population of Concepción del Oro, Zacatecas, the most important variations of Pinus johannis with respect to other populations were observed (Table 8).

TABLE 8. Frequency of number of leaves per fascicle, in Concepción del Oro, Zacatecas.

Número del árbol	Número de hojas por fascículo en %				Número de fascículos observados
	1	2		4	
1	1.2	29.6	69	0.2	1 007
2	2.4	92	5.6	0	412
3	5.8	31.8	62.4	0	362
5	0	65.9	43.1	0	208
6	8.9	60	30.5	0.6	318

In an individual you can notice more than 90% of fascicles with two leaves. The heterogeneity of this population makes us think that they are hybrids between pines with 2 leaves and pines with 3 leaves; *Pinus johannis* belongs to these.

The number of leaves per fascicle also varies in the population of La Laguna, Baja California Sur. However, fascicles with 3 leaves predominate (Table 9).

Perhaps we are in the presence of introgression phenomena. This supposes the existence of a population of pines with two leaves per fascicle, another with three leaves per fascicle. Hybridizations, successive back-crosses between 2 and 3 leaf pines could be the origin of

Pinus cembroides var. *lagunae*, 12 meters high. Notice the elongated trunk of this variety.
High formation cut and burned.
Sierra de La Laguna, Delegación de Todos Santos (Baja California Sur), 1 650 m altitude.
February 14, 1978.

the variability in the frequency of the number of leaves per fascicle.
Frequency of the number of leaves per fascicle in La Laguna, Baja California Sur.

Número del árbol	Número de hojas por fascículo en %				Número de fascículos
	1	2	3	4	
1	0	66	34	0	50
2	2.7	46.5	50.8	0	1 210
3	0	17.7	82.3	0	498
4	0	16	81.5	2.5	81
5	0	77	23	0	50
6	0	8	92	0	171
7	1	22.5	76.5	0	1 885
8	0	46.25	53.75	0	560
9	0	10	90	0	959
10	0	25	75	0	245

I. 4. 1. 2. Presence or absence of stomas on the dorsal side of the leaves

In the populations studied above, the leaves have stomas on the dorsal and ventral sides. Samples without stomata were found on the dorsal side from north to south Mexico and from east to west, however they were less numerous than samples with stomata on both sides.

Pines from San Buenaventura, Chihuahua, have leaves with dark green dorsal and light green ventral sides. The dorsal side has no stomas. Therefore, it is deduced that they could belong to the bicolor variety, described by Little in 1968, in Arizona. The 'bicoloured' characteristic of the leaves is not apparent in the samples noted above, but Little mentions that it often disappears when kept in the herbarium. The absence of stomas on the dorsal side is a common characteristic in *Pinus johannis*, *Pinus culminicola* and *Pinus quadrafolia*. This characteristic represents an individual or genetic variation. Little in 1968 and Bailey (In lit.) considered that this characteristic alone is not sufficient to define *Pinus cembroides* var. *bicolor*. However, subsequently, Bailey Hawkesworth in 1979 elevated *Pinus cembroides* var. *bicolor* to the species level, differentiating it from *Pinus cembroides* which they call *Pinus discolor*. The absence of stomas on the dorsal side, the bicoloured character of the leaves and the small size of the cone add other characters that differentiate this taxon from Pinus cembroides; they are

1. Sometimes three-leafed fascicles of *Pinus discolor* predominate over four-leafed fascicles; two-leafed fascicles are less frequent than four-leafed fascicles. The respective proportions are not indicated. Tables 7 and 9 show that in some individuals of *Pinus cembroides* it is possible to find high proportions of fascicles with three leaves.

2. Leaves of *Pinus discolor* live from 4 to 7 years, while those of *Pinus cembroides* last from 2 to 5 years, it was also observed that in *Pinus cembroides* this characteristic varies according to the water conditions of the season.

3. The composition of the terpenes is different. *Pinus cembroides* has a high percentage of α-pinero

4. *Pinus discolor* tends to have a dioecious character that increases as it approaches the south and is found in large proportions in the Sierra Madre Occidental and can be seen as far as the Sierra de San Miguelito, San Luis Potosí.

Observations of the leaves have shown a great variability in the populations of *Pinus cembroides*.

I. 4. 2. Study of seeds and seedlings

Seeds collected by INIF (today INIFAP), seeds from personal collections as well as those purchased at local markets were used.

The origin of the lots studied is shown in Table 10.

TABLE 10. Origin of seed lots.

Número del lote	PROCEDENCIA
INIF 235	San Antonio las Alazanas, Coahuila; 2 400 metros.
INIF 85	Zimapán, Hidalgo; 2 010 metros.
INIF 299	San Luis Atexcac, Puebla; 2 490 metros.
INIF 359	La Laguna, Delegación Todos Santos, Baja California Sur; 2 200 metros.
1	Rancho de San Luís Potosí de Los Pinos, municipio de Ajalpan, Puebla; 2 200 metros colectado.
2	Concepción del Oro, Zacatecas; 2 700 metros colectado.
3	Sierra de Arteaga, Coahuila; comprado.
4	San Miguelito, municipio de San Luís Potosí, San Luís Potosí; 2 200 metros colectado.
5	Vizarón, Hidalgo; comprado.
6	Cofre de Perote, Veracruz; comprado.

To make the differentiation as complete as possible, the external characteristics of the seeds and the seedling were noted.

1. 4. 2. 1. Seed data

Length of seeds in millimetres, Thickness of seeds in millimetres
Numbers of seeds per kilogram, Thickness of shell in millimetres
Percentage of empty seeds per kilogram

TABLE 11. Seed measurements (average 100 seeds)

Número del lote	Longitud en milímetros	Grosor en milímetros	Número de semillas por kilogramos	Semillas vanas en %	Espesor de la cáscara en milímetros
85	14	8.5	2 490	5	0.2 - 0.4
235	13	7.5	2 835	19	0.4 - 0.5
299	13	7.5	4 132	42	0.5 - 0.4
359	13.5	7	3 831	5	0.1 - 0.2
1	13	7.5		5	0.4 - 0.5
2	13.5	9	2 225	5	0.4 - 0.5
3	13	8		5	0.4 - 0.5
4	13	8		5	0.4 - 0.5
5	13.5	8.5		5	0.4 - 0.5
6	13	7.5		5	0.2 - 0.5

The number of seeds per kilogram is positively correlated with the length and thickness of the seeds, except in the case of seeds with very different shell thickness, or a high percentage of empty seeds. The higher percentage of empty seeds noted in the lot of San Luis Atexcac, Puebla, indicates difficult living conditions and presence of diseases.
The length and thickness of the seeds show a maximum fluctuation from one lot to another. Measurements of shell thickness allow separation of seeds from La Laguna (0, 1- 0, 2, millimeters) from those of other origins.

I. 4. 2. 2. Seedling data

Essentially, it was a matter of establishing the number of cotyledons and the growth rate of the seedlings.

I. 4. 2. 2. 1. Number of cotyledons

The seeds were sown in Paris, Brunoy and Toulouse. The data obtained are presented in Table 12.

TABLE 12. Average number of cotyledons

Número de lote	235	299	359	1	2	3	4	5	6
Número de plántulas	(15)	(63)	(310)	(757)	(62)	(178)	(224)	(88)	(64)
Número de cotiledones	10.46	9.21	12.62	10.59	10.56	10.95	11.22	10.74	10.53
Desviación estándar	0.94	0.82	0.57	0.33	0.99	0.60	0.54	0.64	0.70

Some lots had a low percentage of germination, as in the case of 235. It is noted that lot 359 has an average of 12.62 cotyledons, higher than the average of the other lots. Lot 359 is distinguished from the others by the number of cotyledons.
The pines of La Laguna, Todos Santos, Baja California Sur, differ from the other populations studied by the number of cotyledons, the thinness of the shell and its growth rate. Therefore, it is proposed to consider them as a variety of Pinus cembroides.

I. 4. 2. 2. 2. The seedling and the one-year-old individual

Seedlings from all lots have full edged euphils, not sawn off. Its characterization is moderately slow, within the same lot, some individuals form leaves grouped in bundles in the spring of the second year and others in the spring of the third year.
The pines of La Laguna, Baja California Sur, are distinguished from the other lots by their rapid growth: at equal age and identical growth conditions, its size is double. This faster growth was noted in Paris and also in the planting done at the Universidad Autónoma Agraria. In all lots the number of leaves per fascicle varied over the second and third year.

I. 4. 3. Conclusion

The fluctuation in the number of leaves per fascicle is noted in individuals from 2 to 3 years old under observation.

It is recalled that the number of leaves per fascicle is very variable within the populations of *Pinus cembroides*; this variability is also present in young plants. A more extensive study is needed to relate this data to those of the seed and seedlings.

On the other hand, the observations on seeds and seedlings allow to define a variety of *Pinus cembroides* var. *lagunae* var. nov., which differs from the type because its seed is thin-shelled (0.1 - 0.3 mm), the average of cotyledons (12.62) and the growth is faster than that of the type. The adult tree reaches 12 to 15 meters in height.

Type: ROBERT 10 021. Sierra La Laguna, Todos Santos Delegation, Baja California Sur, 23° 34' N, 109°55'0, crystalline bedrock. 1 650 meters 15.02.1978. (holo-, P ; iso-, MPU, TLJ, ENCB, INIF).

Tree 12-15 m high, citatius type crescens, Seminis putamen tenuous (0.1 - 0.3 mm nec 0.4 - 0.5 Cotyledones 12.62 in mediate (nec 0.54).

Tree of 12 to 15 m of height, with three leaves by fascicle, sometimes two, flexible and of gray green color. Stomas are located on the dorsal and ventral sides of the leaves. There are two resin channels. The mature cones are globose or subglobose. The seeds measure from 10 to 16 millimeters long (with an average of 12.7), from 6 to 10 millimeters thick. Its shell is thin (0.1 to 0.3 millimeters).

The seedlings have 9 to 17 cotyledons; the average, calculated on a batch of 310 seedlings, is 12.62. The growth is faster than that of *Pinus cembroides* var. *cembroides*.

It is observed in Baja California Sur, in places located between 1 600 and 2 200 meters of altitude. It forms forests of pure masses or associated with *Quercus sp*. In the low stratum exist *Dalea sp*. and *Bouteloua gracilis*, *P. cembroides* var. l*agunae* develops in soil coming from the degradation of crystalline rock, with silty-sandy texture and a pH of 4 or 5.

Due to its rapid growth this variety could be used to reforest dry areas; it supports soils with a pH of 7 to 8, as could be seen in the plantations of the Universidad Autonoma Agraria Antonio Narro, in Saltillo.

I. 5. Conclusion

P. edulis s.l. and *Pinus cembroides* s. 1. constitute a complex and dynamic group of populations.

A subsequent study should establish the relationship between the different systematic characteristics examined (number of leaves, absence or presence of stomas, seeds and cones) and to deepen the phenology of the main populations identified during this work. Further research is needed to establish the relationships of the main systematic data used and to clarify the phenology of the main populations already mentioned.

Following is the key to the pine trees of the cembroid group known in Mexico:

Shrub form, branched from the base
5-leaf fascicles, 1 dorsal resin channel
seeds with white endosperm, average
of 9 cotyledons — *Pinus culminicola*

Fascicles of 3 leaves, sometimes 2, rarely 4,
bicoloured, 2 resin channels, no stoma on the face
dorsal; white endosperm seed, average
8.7 cotyledons — *Pinus johannis*

2-leaf fascicles (sometimes 3), 2 to 4 channels
resinous, seed with a white endosperm. . . — *Pinus catarinae*

Tree shape, defined trunk

Long, hard leaves
Single leaves, 2 to 17 resin channels, seeds
with white endosperm, average 7 cotyledons.. — *Pinus monophylla*

2-leaf fascicles, 2 seed resin channels
with endorsement

2-leaf fascicles, 2 seed resin channels
with white endosperm, average 8.3 cotyledons — *Pinus edulis*

4 leaf fascicles, 2 resin channels, seed
with white endosperm — *Pinus quadrifolia*

Flexible sheets, in fascicles of 3 bicolour,
2 resin channels, no stomas on the dorsal side,
seed shell thickness 0.5 to 1 mm — *Pinus discolor*

2 to 3 leaf fascicles, 2 resin channels, thickness
of the seed from 0.2 to 0.5 millimeters endosperm of

pink, average 10.5 cotyledons *Pinus cembroides* var. *cembroides*

2 to 3 sheet fascicles (preferably 3), 2 channels resiniferous, thin seed shells from 0.2 to 0.5 millimeters pink endosperm; average 12.6 cotyledons *Pinus cembroides* var. lagunae

The pines of northwest Coahuila, incorporated in *Pinus edulis*, are not included in this key.

The phytogeographic and ecological study deals with *Pinus cembroides* sensu lato, which includes 4 species and two varieties of one of them: *Pinus johannis*, *Pinus catarinae*, *Pinus discolor*, *Pinus cembroides* var. *cembroides* and *Pinus cembroides* var. *lagunae*.

CHAPTER II

VEGETATION AND ENVIRONMENT

The tall woody formations of *Pinus cembroides* are mentioned in general studies of the vegetation of Mexico, or in some regional studies. Among the first ones, Leopold (1950) locates the "piñon - juniper woodland" in the arid hills or in the low mountains.
Shreve (1939) and Lesueur (1945), when studying the vegetation of Chihuahua, and Gentry (1957) when doing so in the grasslands of Durango State, pointed out some formations of *Pinus cembroides* in association with *Quercus pl. sp.*, *Arctostaphylos pungens* and *Juniperus pl. sp.*

Muller (1937 and 1939) cited the presence of *Pinus cembroides* in the State of Nuevo Leon, as a possible member of the formation he calls "western montane chaparral", which frequently accompanies *Quercus pl. sp.* and *Rhus virens*.
In 1965, Rojas Mendoza called the formations of *Pinus cembroides* in the State of Nuevo León as "forest under aciculiescuamifolio with *Pinus* and *Juniperus*". In the State of San Luis Potosi, Rzedowski in 1965 observed that *Pinus cembroide*s forests constitute almost pure masses, occupying the same habitat as the shrubby oak; he also indicated that the vegetative transition is notorious for the mixture of pines and oaks.
Puig mentioned in 1967, the existence of some forests of *Pinus cembroides* between the succulent steppe and the forest of *Pinus patula*, *Pinus teocote* and *Quercus sp.*, in the region of El Doctor, Querétaro, and between Zimapán and Jacala, Hidalgo. In Valle de Mezquital, Hidalgo, González Quintero (1968) reported the presence of *Pinus cembroides* combined with *Juniperus flaccida* scrub and *Quercus crassifolia* shrub.
The previous brief bibliographic review shows that at the beginning of the present research there were very scarce data on *Pinus cembroides* formations.

This study aims to specify the distinctive characteristics of *P. cembroides* formations and at the same time, to determine the living conditions and the composition of the flora existing in the forests of the mentioned species, as well as to highlight their differences with respect to adjacent plant formations.

II. 1. WORKING METHOD

II. 1. 1. Sampling

In order to know the distinctive characteristics of the environment where the woody formations of Pinus cembroides are found, a systematic sampling of the populations indicated by Martínez in 1948 was carried out. The populations were identified on the maps on a scale of 1:100,000, which were the only ones available in 1969. A stratified

sampling was utopian, because on one hand it was feared that there was a lack of large scale maps, and on the other hand there was a lack of roads near the populations of *Pinus cembroides*. Finally, access possibilities conditioned the sampling sites.
Observations were also made at different altitudes when the topography of the terrain was favourable.

Sampling was done during the months of July to October, the rainy season in Mexico, during the years 1969 to 1975.
Each sampling included the recording of ecological variables and flora composition.

II. 1. 2. Ecological variables

The ecological variables are distributed into the following four classes:

1. Geographical variables
2. Substrate variables
3. Vegetation variables
4. Anthropic variables

These variables were coded according to the "Vegetation Code" applied by the ECE-CNRS of Montpellier (Godron et al. 1968).
It should be clarified that the number of classes contained in Table 13 does not correspond to the number recorded in the field, but to that retained for statistical analysis of the data.

TABLE 13. Ecological variables

GEOGRAPHICS	Number of classes .
Latitude	9
Length	9
Climate according to Köppen	12
Precipitation	9
Temperature	7
Altitude	15
Exposure	9
Topography	5
Slope	8
SUBSTANCE	
Rock type	4
Reaction of rock to HC1	5
Soil texture (in the field)	13
HC1 from the soil (in the field)	2
Soil pH (in the field)	10
Soil colour (in laboratory)	3
Soil texture (in laboratory)	6
Soil pH (in laboratory)	8
Seasonal apparent humidity	5
Percentage of blocks	8

Percentage of gravel	14
Percentage of fine soil	7
Percentage of vegetation	8

VEGETATION

Type of training	7
First dominant species	7
Second dominant species	11
Coating of layer	I 5
Coating of stratum II	8
Coating of stratum III	8
Coating of stratum IV	5
Coating of layer V	7
Coating of stratum VI	8
Coating of stratum VII	8
Coating of stratum IX	5
Shrubbery coating	7
Herbaceous coating	6
Log diameter of P. cembroides	13

ANTHROPICS

Artificialization	5
Use	6
Logging	8
Animals, in particular pets	4

As noted below, the ecological profiling program operates with fewer than fifteen classes. Therefore, when the number of classes was greater than fifteen, regroupings were carried out, as was the case with the dominant species, climate according to Koeppen and altitude among other classes. These regroupings are arbitrary, so they should be avoided as much as possible to avoid errors even if slightly in the results obtained.
In case stratified sampling is used, clustering is unnecessary, but it was impossible to apply this method for the reasons explained.
Groupings within the dominant species variable are described below.

II. 1. 2. 1. Dominant species
The dominant species is a basic criterion for studying the dynamics of plant formations. But it is more subjective than other variables. In this case, it was assigned the meaning used by Flahault, quoted by Godron in 1968: “some species are dominant, either because they are characteristic of the plant stratum, because of the size, shape or duration of the individuals (social species). or because of the action they exert on the habitat, creating, so to speak, the season”. It is not always easy to follow the recommendations of the “Code for the methodical observation of vegetation and the environment”; “to keep in mind in the spirit that the objective of the research is to characterize globally the vegetation of the station and to record the most visible species”. Dominance can be dissociated from abundance: in pine forests, and *Yucca filifera* or *Y. carnerosana*, *Yucca* is the second dominant species, however, it “jumps to the eye” despite its low population. Recording

the dominant species allows for impressionistic knowledge of the vegetation to be studied. Dominance is the result of personal appreciation, linked on the one hand to the phenomenon of vision, and on the other to discernment.

Forty-five dominant species were recorded in the area studied, integrated into the first and second dominant species; this is a high number of species, rarely found in temperate regions. However, in order to use the mutual information program, which allowed the analysis of fifteen keys within each variable, species were regrouped according to their systematic affinities or their integration to a type of plant formation. In this way, seven keys were obtained, which are the following:

01 *Pinus cembroides*
02 *Quercus* spp.
03 Conifers: *Pinus engelmannii*, *P. arizonica*, *P. ayacahuite*, *Cupressus* sp., *Pseudotsuga sp*.
20 Pinos piñoneros diferentes de *P. cembroides*: *Pinus pinceana*, *P. nelsonii*, *P. culminicola*
16 Matorral submontano: *Fraxinus* sp., *Juglans* sp., *Acacia* sp., *Zizyphus* sp., Gramíneas
09 Chaparral: *Arctostaphylos pungens*, *Ceanothus* spp.
14 Matorral desértico micrófilo (*Maitenia* sp., *Agave lecheguilla*, *Gymnosperma glutinosum*, *Prosopis juliflora*, *Mimosa* sp., *Agave* sp.)

An identical procedure was followed to reduce the number of dominant species in the second term, retaining at the end 11 keys that are

15 Matorral desértico rosetófilo
28 Matorral desértico micrófilo
23 Bosque deciduo templado
09 Chaparral
34 Gramíneas
20 Pinos piñoneros diferentes de *Pinus cembroides*
03 *Juniperus* spp.
01 *Pinus cembroides*
02 *Quercus* spp. diferentes de *Q. rugosa*
06 *Quercus rugosa*
05 Coníferas diferentes de los pinos piñoneros

Some of the preserved species are common to the first and second dominant species. The total number of dominant species conserved was twelve.

Whatever the variable considered, there is no doubt that groupings produce loss of information and lead to slight modifications in the results.

The observations from the Eastern and Western Sierras Madre were treated separately, rejecting the dominant species whose presence was equal to or less than 2, this avoided groupings.

II. 1. 3. Plants

One specimen of each plant collected was deposited in the herbarium of the School of Biological Sciences of the National Polytechnic Institute of Mexico; with respect to the plants collected in the State of Coahuila a specimen was deposited in the herbarium of the "Antonio Narro" Autonomous Agrarian University, based in Buenaventura, Coahuila. A sample of the oaks and conifers was sent to the herbarium of the National Institute of Forest Research in Mexico City. Some conifer samples were sent to the herbariums of the botanical institutes of Montpellier and Toulouse. The herbarium was kept at the Natural History Museum in Paris. The floristic list of the study area consists of more than a thousand taxa.

A complete list of known plant species is lacking in Mexico. Therefore, in order to know the distribution of the families identified in the study area, it was decided to codify them, by means of the code of the orders and families established in the ECE by B. Descoings and N. Denelle (unpublished), based on Emberger's classification (1960), the families were classified alphabetically.

For each family, the list of genera and species found in the study area was drawn up. Each plant was assigned an eight-digit code; however, its use was discontinued because the programs used at the ECE-CNRS in Montpellier would have had to be modified. Therefore, for each plant the eight-digit code was replaced by a number from 1 to n, with n being the number of plants quantified in the study area. This number can easily be transcribed into the eight-digit code, which will allow, in the future, a chorological study and a phytogeographical discussion on the distribution of genera and families.

II. 1. 4. Data processing

The data from the 185 samples taken in 1974 and 1975 were analysed using computer methods. The factorial analysis of correspondences was used and another one that allows to associate, to each class of a variable, the list of species calculation of the mutual information and ecological profile.

After the beginning of this work, the Commission for National Territory Studies (CETENAL) mapped a portion of the eastern part of the study area, providing the data from the sampling carried out within the *Pinus cembroides* formations and neighboring formations. These observations, associated with the 185 already mentioned, constitute a set of 351 observations, in which the method of mutual information and ecological profiles was applied.

Two observations are necessary in this respect:

1. 1. It is preferable to analyse all the samples taken by the same operator or, failing that, samples taken for the same purpose (mapping, ecological study) Because this way, the samples have more homogeneity, due to the fact that the way of appreciating the outside world is different for each operator. These differences are accentuated when the objective of one operator is regional mapping and for the other is the study of a forest species. By grouping together observations made for different purposes, heterogeneity is introduced, the effect of which should not be underestimated. If this situation is unavoidable, it is possible to introduce a correction factor, which would be assessed later.

2. Rather than analysing a large number of observations to cover a wide geographical area, it is preferable to treat data sets of small geographical entities.

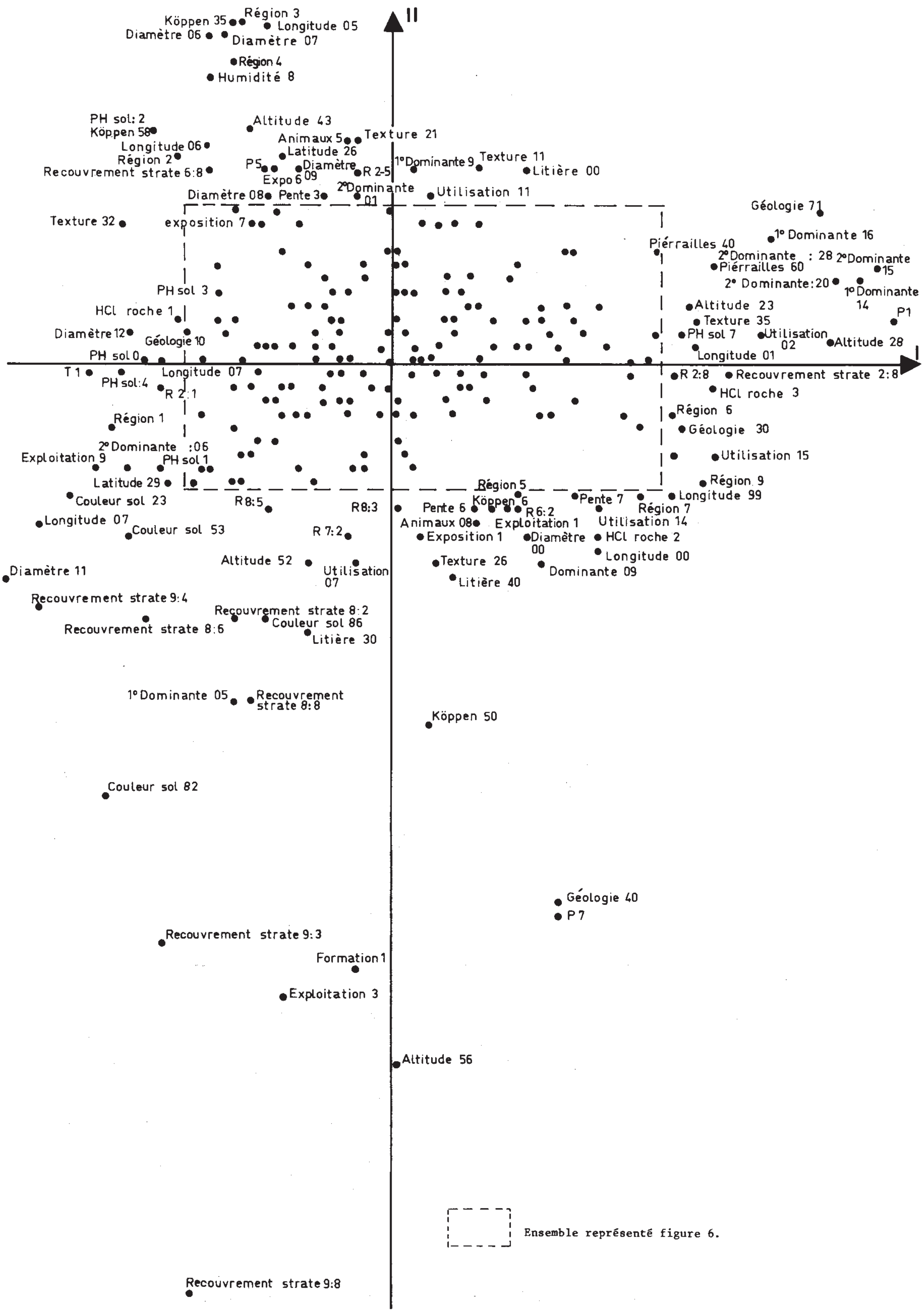


Figure 5. Factorial analysis of the 185 samples: diagram of the ecological variables in the plane of axes I and II (the numbers indicate the classes of the variables)

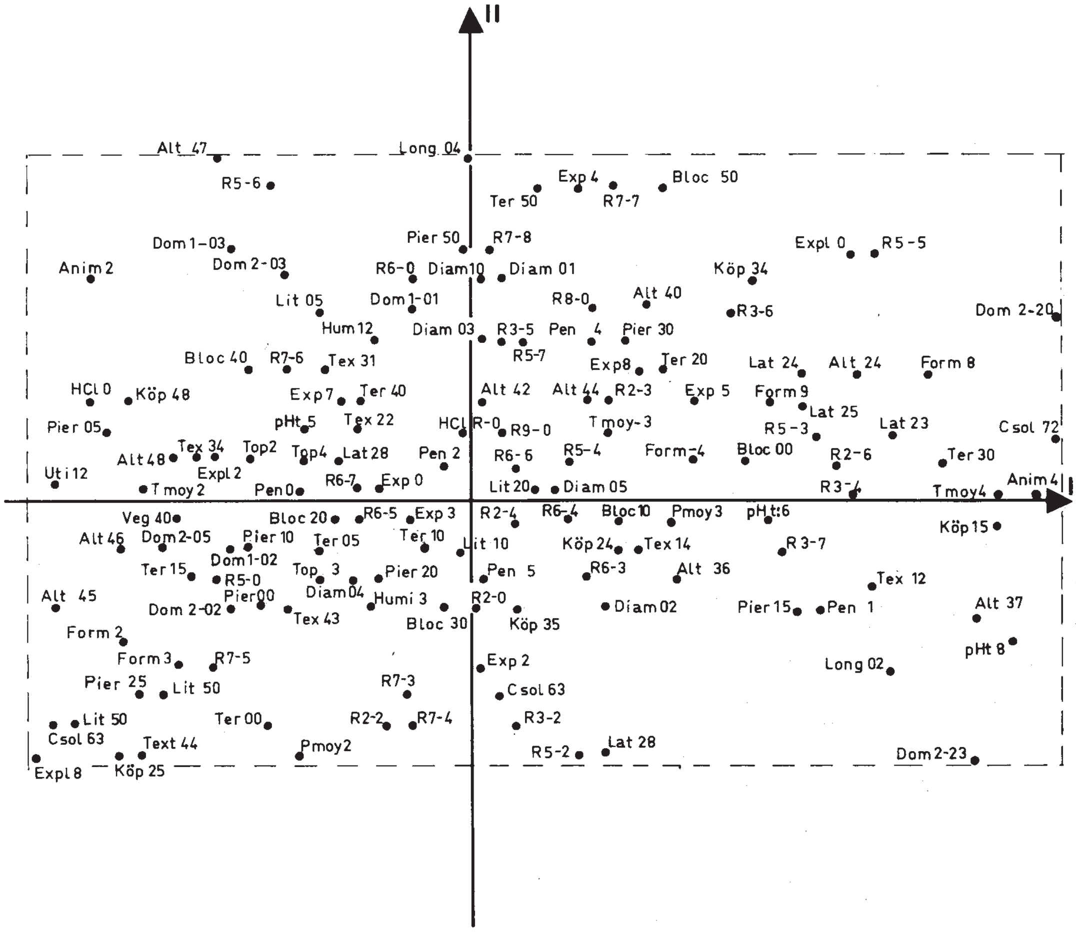


Figura 6. El centro de la figura 5 (las variables ecológicas de las cuales la lista aparecen en el cuadro por las primeras letras de su nombre)

II. 2. OVERALL ANALYSIS OF THE ENVIRONMENT AND VEGETATION

II. 2. 1. Factorial analysis of correspondences

Factorial analysis of correspondences is applied to a table formed by a set of individuals (species and observations) and a set of factor classes. Each individual is indicated, within each factor class, by its frequency. The explanation of the factor analysis was made with the methodology developed by Romane (1975), applied in the following way

Let us suppose that

p factor classes, numbered by 1, 2, ..., k are studied in

n species

and that the measurements obtained are noted by xkj, where

-k relates to the number of the factor class and can take the values from 1 to p;

-j represents the individual (species) in the sample and can take the values from 1 to n.

A factorial space of "p" dimensions is defined. With a system of orthogonal axes where each p coordinate axis corresponds to a variable. In such a space, each species is represented by a point, the set of points forming a cloud. The points are located in a space with as many "p" dimensions as there are classes of independent variables.

If the number of classes of variables is equal to 1, 2 or 3, it is easy to represent the similarity of the individuals in the space, based on the proximity of the points, but if the number of classes is greater than three, it must be completed by another method, for example, principal component analysis.

For further details, see the works of Goodall (1954), Benzecri (1973), Lacoste and Roux (1971, 1972), Romane (1972, 1977) and Hiernaux (1975).

In this work, the analysis was made with the ETAVAR program, elaborated in the C.E.P.E. (Montpellier) by David and F. Romane from a program conceived by G. Roux.

II. 2. 2. Analysis of the observations

The first five axes selected comprise 50 percent of the factors studied and of these only Axis I comprises 20 percent.

The classification of the ecological variables was made based on the order of participation, being placed from the hierarchical point of view as follows:

1 Geographic variables
2 Vegetation variables
3 Substrate variables
4 Anthropic variables

The distribution of the points in the plane of axes I and II presents a classic form within the factorial analysis (figures 5 and 6).

Some points escape from the set circumscribed by the curve: T5 and K14 at the right end of axis I; and A56 and K50 at the lower end of axis II. These points correspond to exceptional situations in relation to all the samples, for example, T5 represents an average annual temperature of more than 20°C, A56 corresponds to observations made between 2 700 and 3 200 metres in altitude.

On axis I, the classes of the variable average annual temperature are presented: classes between one and four are very close to axis I; class five, on the other hand, is more removed (figure 7).

TABLE 14. Participation of the groups of ecological variables in the range of each of the first axes.

VARIABLES	EJES				
	I	II	III	IV	V
Geográficas	41%	37.25%	55.3%	45.5%	55%
Sustrato	18.5%	11%	12.3 %	17.5%	13%
Vegetación	28%	38%	24.4%	31.3%	24.5%
Antrópicas	12.5%	13.5%	7.8%	5.8%	7.5%

The direction of an increasing temperature gradient from left to right can be attributed to the I-axis.

The variables longitude, latitude, type of rock, soil pH and region are distributed on both sides of axis II, as follows: in negative abscissas the classes present in the Sierra Madre Occidental and in positive abscissas those observed in the Sierra Madre Oriental. This segregation is also present with respect to the distribution of plant species; since the plants present only in the Sierra Madre Occidental have a negative abscissa, while the localities only in the Sierra Madre Oriental follow a positive abscissa. In the center of the graph are the plants common to the two sierras. Some species are outside this scheme, for example Fouquieria splendens, which is located on the right side of the figure on axes I and II, even though it is found in both Sierras.

Axis II represents a meridian that separates the Sierra Madre Occidental from the Sierra Madre Oriental.

The "coincidences" or "proximities" of the points representing the factors or species should be interpreted with caution, since these points are "midpoints" or centers of gravity. It is important to bring together in a figure the points that represent the classes of ecological variables on the one hand, and the species on the other, because in this way the interactions between multiple variables are explained and generally imperceptible relationships can be captured (Thurstone, 1955).

II. 2. 2. 1. Ecological variables

II. 2. 2. 1. 1. Regions[1]

The points corresponding to the sampling of the Sierra Madre Occidental are separated from those of the Sierra Madre Oriental.

It is observed that region 1 was more sampled than the other regions of the Sierra Madre Occidental and that it participates markedly in axis I. Around this point, the plants around the municipality of Ignacio Zaragoza, Chihuahua, are grouped, as well as the classes one and two of mean annual temperature, longitude 107° Oeste, latitude 29° N.

1 The study area was divided into regions defined by their latitude, which were coded as shown in the table below:

LATITUD	REGIONES	
	Sierra Madre Occidental	Sierra Madre Oriental
	1	5
28		
26	2	6
25	3	7
18		
24		8
22	4	9
20		10
18		

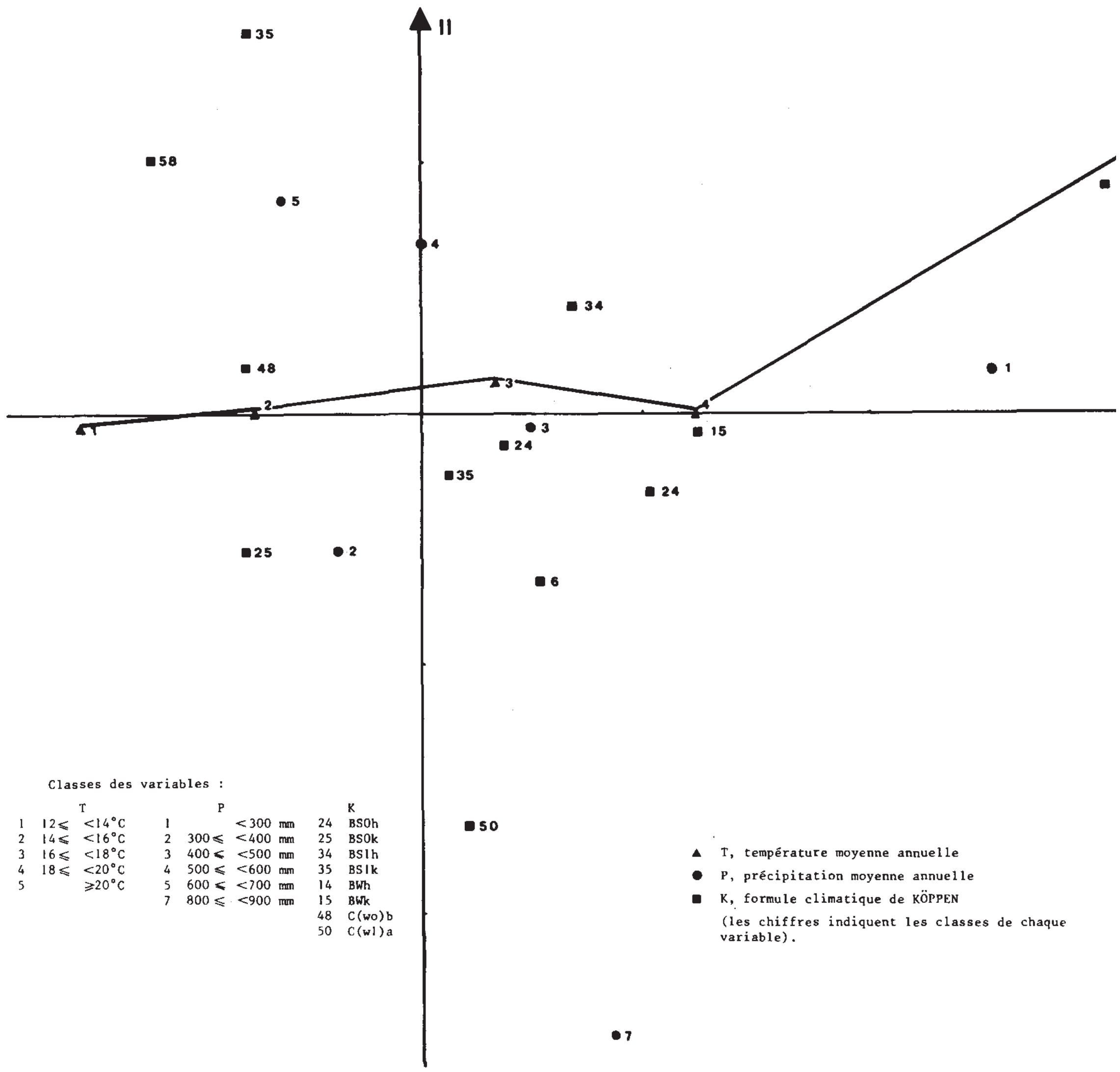


Figura 7. Analisis factorial de los 185 muestreos : diagrama de las variables climáticas en el plano de los ejes I y II. El eje I presenta una distribución lineal de la temperatura media anual.

On the other hand, region 5 is far from the regions of the Sierra Madre Oriental, being located only near the center. This region groups the observations of Sierra Madera del Carmen and Sierra Santa Fe del Pino, Coahuila. It also has affinities with the Sierra Madre Occidental in terms of climate and geological nature (eruptive or metamorphic rock).

II. 2. 2. 1. 2. Koeppen Climate Formula
The climate classes are distributed in no apparent order. However, it is observed that those present only in the Sierra Madre Occidental, 48 and 58, are located to the left of Figure 7, while those of the Sierra Madre Oriental are located to the right.
The climate factor is subordinate to the region, which plays the main role.

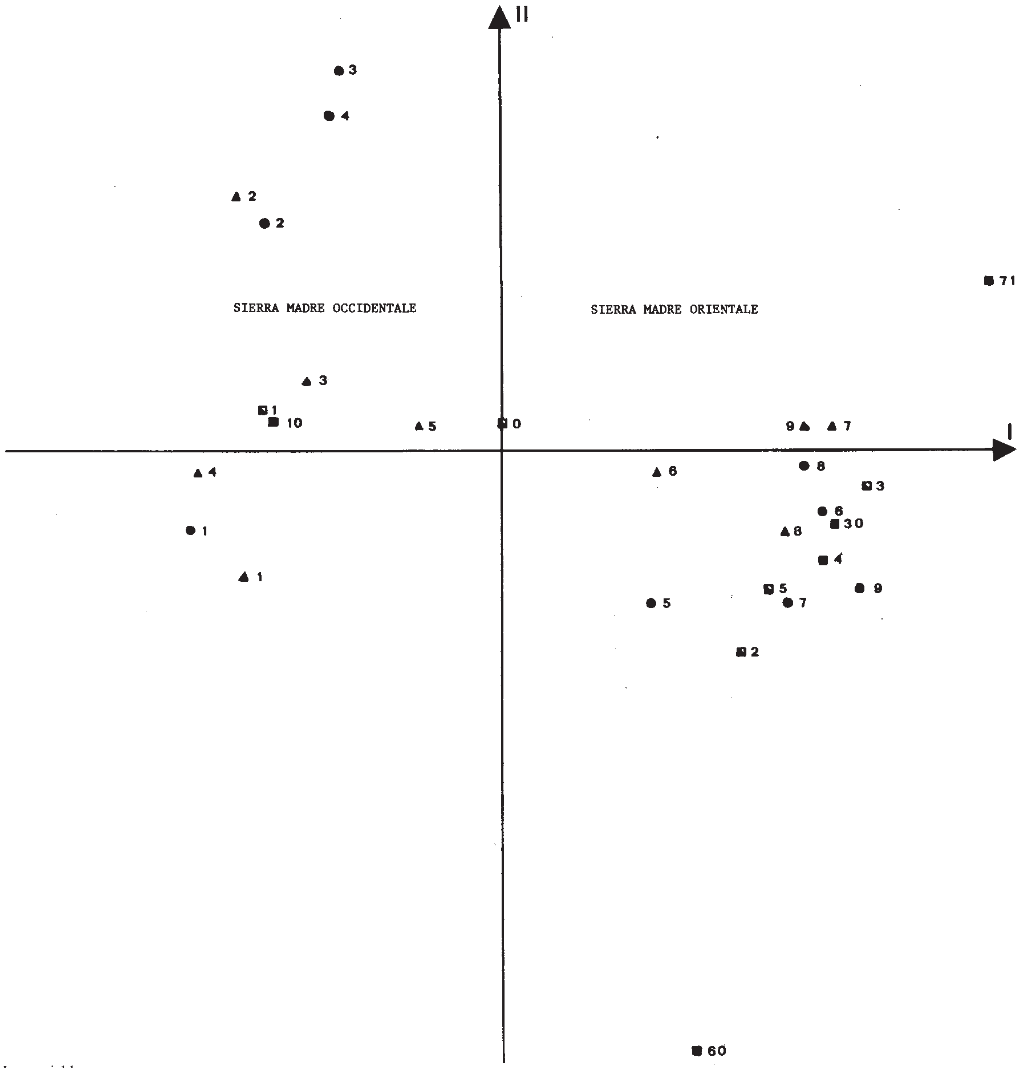
II. 2. 2. 1. 3. Average annual temperature
The average annual temperature is the only factor in which the classes are distributed linearly. Class 1, with temperatures between 12 and 14°C, is frequent in the study area, normally from points 28° N and 107° W; in contrast, class 5, with temperatures above 20°C, characterizes the eastern slope of the Sierra Madre Oriental (length 99° E). Schematically, the increasing distribution of mean annual temperatures corresponds, in the set analyzed, to the decreasing lengths from west to east, which represents a linear distribution of the mean annual temperature on axis I, at least for classes one to four (Figure 7).

II. 2. 1. 1. 4. Average annual rainfall
In the study area, the effect of average annual rainfall is related to the separation by region; however, it is observed that the highest rainfall corresponds to the Sierra Madre Occidental.

II. 2. 2. 1. 5. Altitude
Altitude class 28, which ranges from 1 250 to 1 700 metres and has a significant share of axis I, is situated at the extreme right of axis I, near the points representing, on the one hand, the average annual temperature of 20°C and, on the other hand, the average annual rainfall of 200 millimetres. These three variables are related.

Altitude class 56, located between 2,700 and 3,150 meters, is in the negative order and participates in axis II. In this way, the highest altitudes in the area of study occupy an extreme point on the axis, a fact that is observed in the case of class 7 of the precipitations (with 900 millimeters per year). It is worth asking if at those altitudes the average annual precipitation that occurs in the Sierra Madre Oriental reaches 900 millimeters, but no available average allows us to answer this question. From this we can deduce the need for precise climatic measurements.

II. 2. 2. 1. 6. pH of the soil surface horizon (in the field)
The classes derived from the variable pH are distributed in two groups: those with a pH less than or equal to 6 are grouped in negative abscissa, and those with a pH greater than or equal to 6.5 are represented in positive abscissa (Figure 8). The pHs of levels 3 and 7 have the highest participation in axis I. The soils with a markedly acidic pH were found in the Sierra Madre Occidental and in the Sierra del Carmen (to the east of the study area, an



Las variables:
. Regiónes

Sierra Madre Occidental	HCl en roca:	
1 al norte del 28° N	0 no aflora	
2 del 26 al 28° N	1 negativo	
3 del 24 al 26° N	2 muy sencillo	
4 del 22 al 24° N	3 sencillo	
Sierra Madre Oriental	4 fuerte	
5 al norte del 28° N	5 muy fuerte	
6 del 26 al 28° N		
7 del 24 al 26° N	pH del suelo:	
8 del 22 al 24° N	1 pH= 4	6 pH= 6,5
	2 pH= 4,5	7 pH = 7
Tipo de roca	3 pH= 5	8 pH= 7,5
10 eruptiva	4 pH= 5,5	9 pH= 8
30 sedimentaria	5 pH= 6	
71 yeso		
60 esquistos		

Figure 8. Factorial analysis of the correspondences: diagram of the variables, regions, HCl in rock, pH of the surface soil horizon in the plan of axes I and II. Axis II separates the Sierra Madre Occidental (on the left) from the Sierra Madre Oriental (on the right).
The names indicate the classes of each variable.

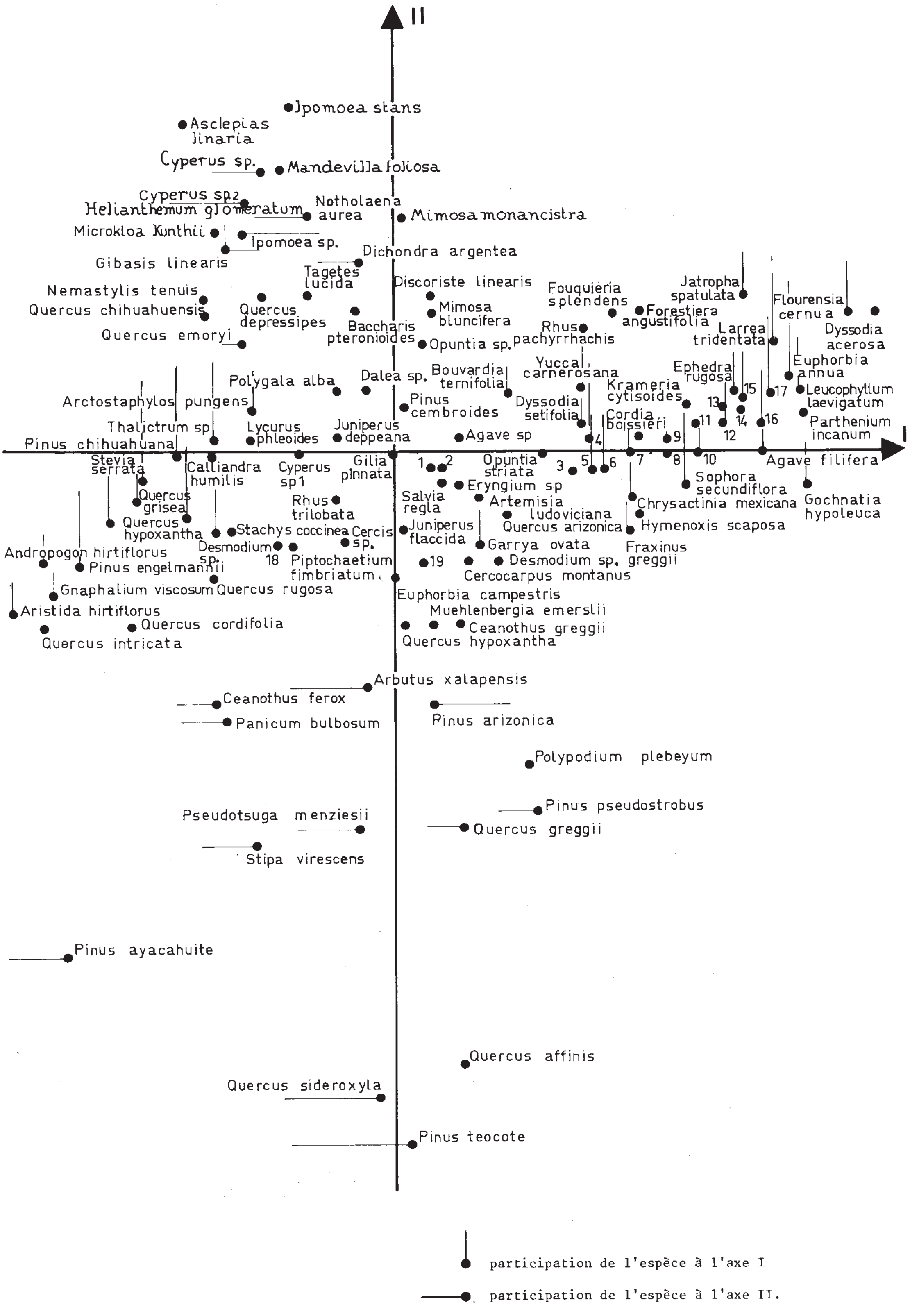


Figure 9. Factorial analysis of the 185 samples: diagram of 120 species in the plane of axes I and II

approximation of the points is observed, corresponding, on the one hand, to pH below 5 and a temperature below 14°C; samples that, on the other hand, are considered to have pH above 7 and a temperature above 20°C. It can be assumed that there is a relationship between average and low temperature and soil acidity. Therefore, on the same type of bedrock, the soils of a hot zone would be more alkaline than those of a cold zone.

II. 2. 2. 2. Plants

Of the list of plants present in the 185 samples, totalling 120, only the most frequent appear in the factorial analysis.

The interpretation of the points cloud (Figure 9) is complex: to the right there is a dense nucleus and some isolated species at the bottom. To facilitate interpretation, the participation of each species is indicated in the form of a vector perpendicular to the axis in which it participates.

The plants that occupy the extreme points of axis I are:

- en abscisa negativa:

  Gnaphalium viscosum *Arenaria lanuginosa*
  Aristida hirtiflorus *Pinus engelmannii*
  Andropogon hirtiflorus

- en abscisa positiva:

  Dyssodia acerosa *Gochnatia hypoleuca*.
  Flourensia cernua

Among these plants that participate considerably in Axis I, the former are associated with average annual temperatures of 12 to 14°C and length 107° 50' West (negative abscissa), while the latter correspond to average annual temperatures of 18°C or more (positive abscissa). In the centre are stenotic plants such as:

Pinus cembroides, *Gillia pinnata*
Juniperus deppeana.

On axis II, in negative order, the following three groups of plants are distinguished:

1. The group formed by the species:

   Pinus teocote *Quercus sideroxyla*
   Quercus affinis

are recorded at altitudes above 2 800 metres (class 56 of the altitudinal variable). These plants are present only in the east of the study area.

2. The second group of plants consists of:

   Pinus ayacahuite *Quercus greggii*
   Stipa virescens *Pinus pseudostrobus*
   Pseudotsuga menziesii *Polypodium plebeyum*

is at an altitude of 2,600 to 3,100 metres (classes 52 and 56)

3. The third group comprises :

   Panicum bulbosum *Quercus hypoxantha*
   Ceanothus ferox *Muhlenbergia emersleyi*

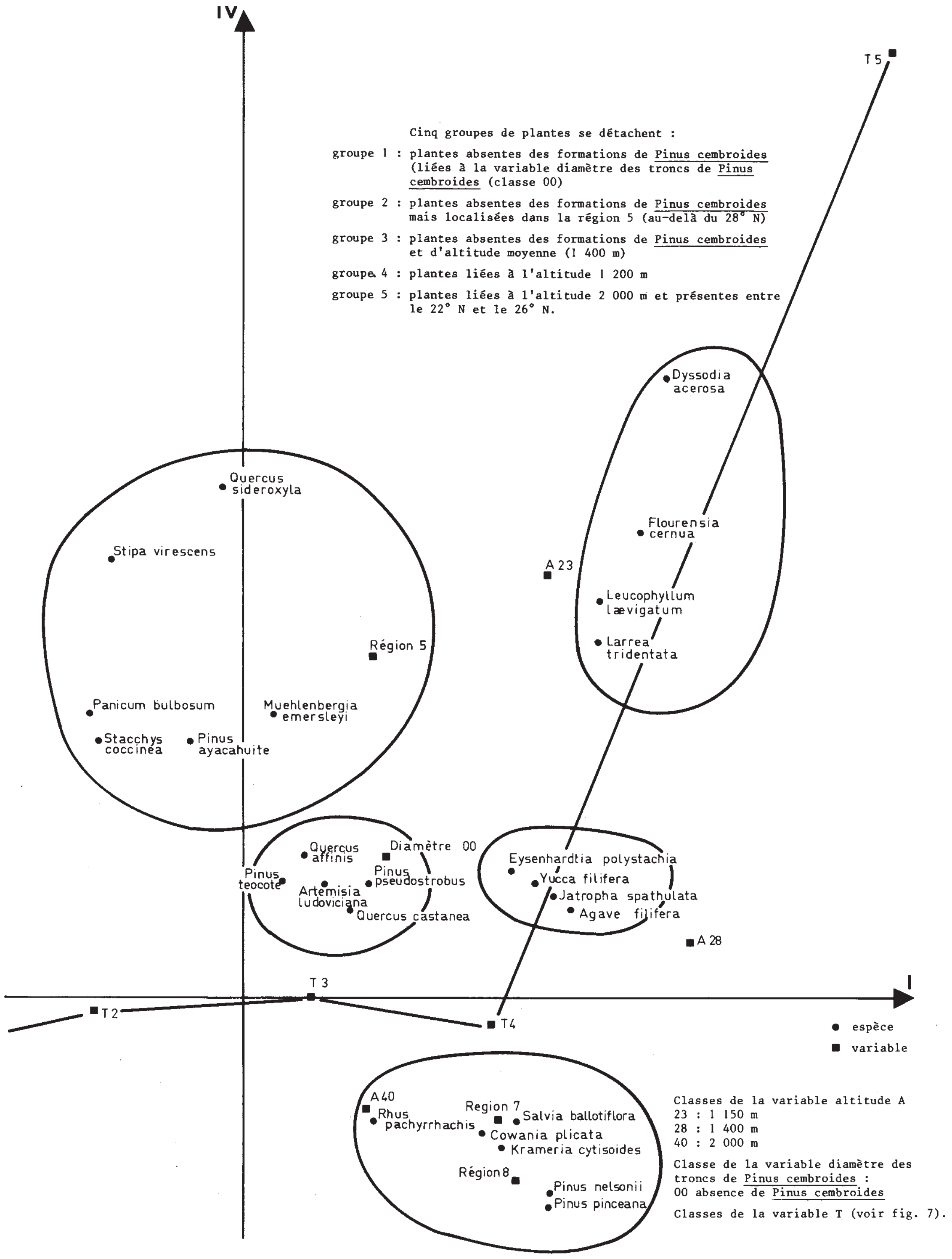


Fig. 10 - Analyse factorielle des 185 relevés, diagramme partiel des espèces et des variables dans le plan des axes I et IV.

Figure 10. Factorial analysis of the 185 samples: partial diagram of the species and ecological variables at the level of axes I and IV.

Arbutus xalapensis *Ceanothus coerulus*
Pinus arizonica
plants that thrive at altitudes between 2,600 and 3,100 meters.

In positive order, there is a group of plants in the Sierra Madre Occidental at an altitude of 2,150 meters (class 43), in which the following species are involved:

Ipomoea stans *Microchloa kunthii*
Asclepias linaria *Notholaena aurea*
Mandevilla foliosa *Gibasis linearis*.

In the plane of the axes I and IV (Figure 10), the central nucleus of species is constant, while the groups outside this nucleus allow the classification of five groups of plants unrelated to the formations of Pinus cembroides.

1. In the first group the elements presented are:

Pinus teocote *Quercus affinis*
Pinus pseudostrobus *Artemisia ludoviciana*
Quercus castanea.

The first three species thrive at an altitude above 2,600 meters in the study area.

2. The second group contains species associated with the altitude of 1,400 meters, standing out:

Eysenhardtia polystachya *Jatropha spathulata*
Yucca filifera *Agave filifera*

3. Species present in region 5 (north of 28°N) constitute the third group as:

Pinus ayacahuite, *Muhlenbergia emersli*
Quercus sideroxyla *Stipa virescens*
Panicum bulbosum *Stachys coccinea*.

4. The fourth group consists of plants associated, at the same time, with a medium-high temperature and an altitude of 1,150 meters as the following species:

Dyssodia acerosa *Leucophyllum laevigatum*
Flourensia cernua *Larrea tridentata*.

5. The fifth group of plants is associated with *Pinus nelsonii* and in it prevails:

Cowania plicata, *Salvia ballotiflora*
Krameria cytisoides *Pinus pinceana*.

This interpretation of the factorial analysis highlights the association of some plants with respect to ecological factors, either altitude or average annual temperature. It also confirms that the region is the preponderant variable to which all the others are subordinated.

The ecological study of the vegetation will then continue with the analysis carried out separately from the observations made in each of the Sierras Madres.

II. 2. 3. Sierra Madre Oriental

The factorial analysis of the 93 samples taken from July to November 1975, in the east of the study area, reports 245 species. For each one, the presence or absence is indicated in each observation.

II. 2. 3. 1. Axes

The degree of participation of the points cloud in the different axes is very low (59 percent), even lower than the degree of participation observed in the factor analysis of the species-observations as a whole. In a factorial analysis applied to 28 samples carried out

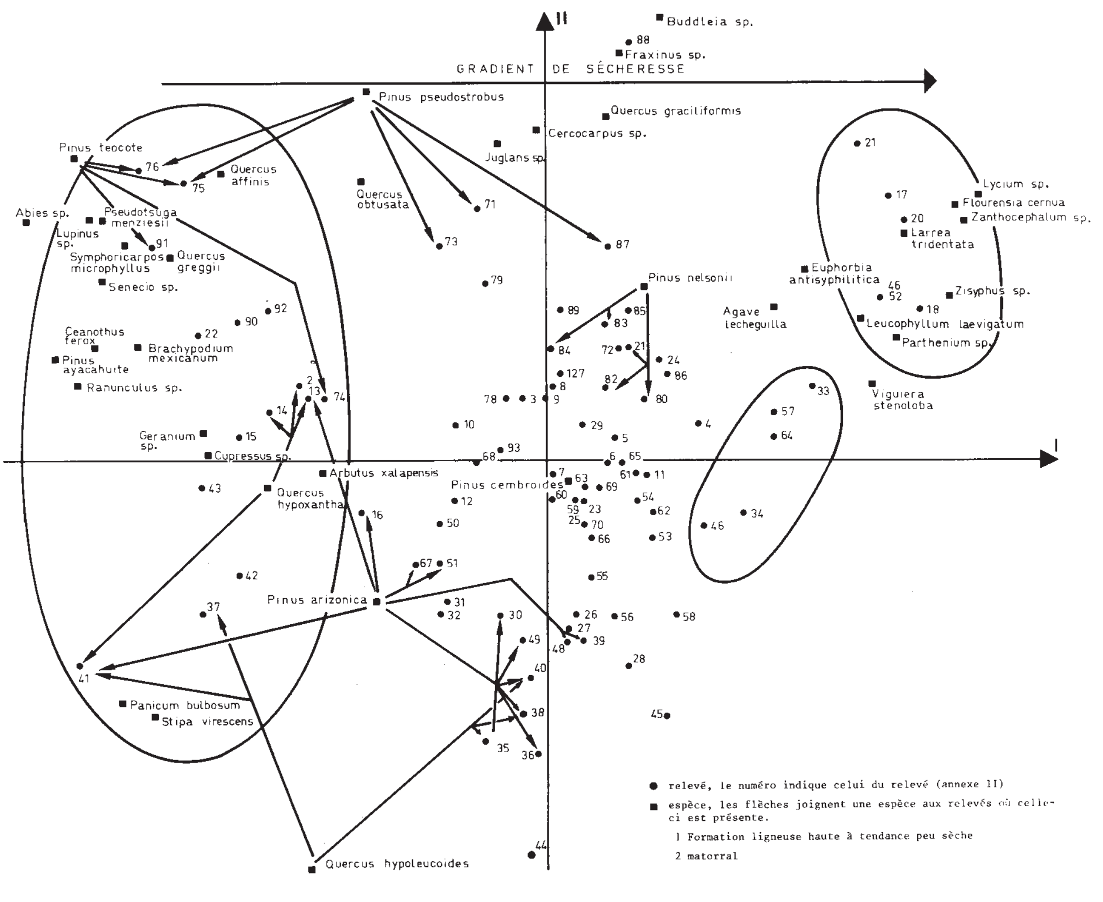


Figure 11. Factorial analysis of the 93 samples from the Sierra Madre Oriental: diagram of the species and the samples in the plane of axes I and II.

in a homogeneous zone, where 240 species were found, in 1971. Lacoste and Roux had low participation rates (12.1 to 6.9 percent).
In 1973, Benzecri indicated that the low degree of participation did not represent an obstacle to attempt the interpretation of the factorial analysis.
Figure 11, consisting of axes I and II, shows the sampling by means of points. At first glance, a nucleus of points appears in positive abscissa and small lots outside this nucleus, however, on closer examination it can be seen that the points located in negative abscissa correspond to high and dense formations, while in positive abscissa and on the extreme right are located the samples corresponding to bush vegetation. The high formations of Sierra Madre del Carmen are located in the lower left quadrant. Between the high and dense formations and the scrubland are distributed the high formations of *Pinus cembroides*, *Pinus pseudostrobus* or *Pinus arizonica*, as well as the formations of *Quercus intricata* and other holm oaks, the formations of *Pinus cembroides* and the formations of *Pinus nelsonii*.

Axis I corresponds to an increasing drought gradient from left to right. The observations in the centre correspond to interface samples.

This is confirmed by the figure of axes I and III, which takes the approximate shape of a parabola, whose lower left arm is occupied by the upper formations and the lower right arm by the shrubbery. In the concavity of the parabola are placed the samples made in the intermediate formations.

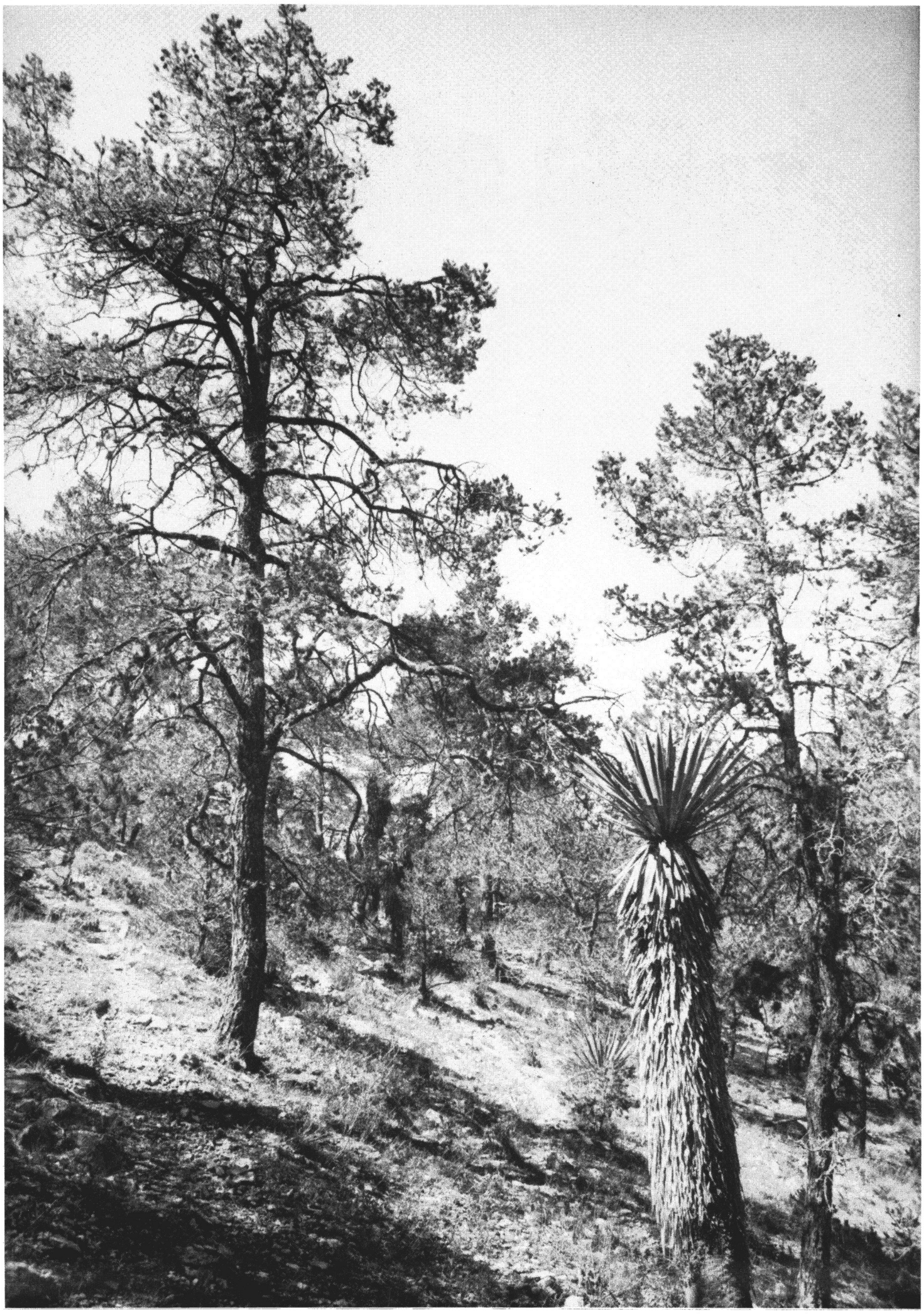
It is important to point out that the dominant samples in the axes are those derived from the sampling carried out outside the *Pinus cembroides* formations, which is in accordance with the information theory. In fact, the information depends on the frequency of a species in the set of samples. If a species is frequent in more than half of the samples made in the formations it is considered dominant.

II. 2. 3. 2. Plant formations
The field data and the distribution of the samples within figure 11, lead to the description of the main plant formations in the east of the study area and their distribution according to a drought gradient (see axis I). The formations of *Pinus cembroides* and adjacent plant formations were analyzed in order to better understand the ecology and floristic composition of *Pinus cembroides*.
II. 2. 2. 2. 1. Tall woody formations with low dryness
II. 2. 2. 1. 1. Soils of surface horizon with pH=5
in a high, dense woody formation dominated by *Pinus arizonica*, *Pinus ayacahuite* (samples 37, 41, 42, 43, Sierra Madera del Carmen, Coahuila, over 2,200m high)
- The layer of tall woody plants includes:

Pinus durangensis var. *quinquefolia* — *Quercus muhlenbergii*
Pinus reflexa — *Quercus sideroxyla*
Pseudotsuga menziesii — *Abies* sp.
Quercus hypoleucoides

- The stratum of low woody plants, not very dense, presents:

Cornus stolonifera — *Physocarpus monogynus*
Fraxinus velutina — *Prunus murryana*



High formation of *Pinus cembroides* with *Yucca carnerosana.*
25°07’50 “N, 101°28’15 “W, Palmas Altas Slope, Municipality of Saltillo (Coahuila)
2 050 m of altitude. August 21st, 1975.

Prunus serotina var. capuli *Salvia regla*

- Among the herbaceous species there are numerous grasses, standing out:

Agropyrum arizonicum *Koeleria cristata*
Bromus anomalus *Panicum bulbosum*
Bromus carinatus *Stipa virescens*
Festuca arizonica

as well as the following species:

Achillea millefolium *Geranium* sp.
Campanula rotundifolia *Potentilla* sp.
Monarda citriodora *Ranunculus* sp.

A large number of the species mentioned have northern affinities.

II. 2. 3. 2. 1. 2. Soils of surface horizon with pH= 6

These high formations are dominated by *Pinus pl. sp.*, with the presence of *Pseudotsuga menziesii* being frequent. Factorial analysis indicates the presence of three subgroups characterized by one or more tree species.

1. High and clear formation of *Pinus teocote*, *Pinus pseudostrobu*s, and *Quercus affinis*, which is sometimes associated with *Abies sp*. (samples 75, 76, 91). This formation occurs in the above mentioned locations from 2,250 to 3,200 meters of altitude (samples 2, 13, 14, 15, 22, 75, 76, 90, 91, 92). In addition to the species cited, the upper stratum includes:

Taxus sp. *Quercus sideroxyla*
Budleia sp. *Loeselia coerulea*
Ceanothus ferox *Sambucus mexicanum.*

While in the herbaceous stratum they are identified:

Ageratum corymbosum *Pteridium aquilinum*
Eupatorium sp. *Senecio seemanii*
Penstemon sp. *Stevia berlandieri*
Phaseolus sp. *Zaluzania megacephala.*

2. high formations of *Pinus pseudostrobus* which develop at an altitude between 1,900 and 2,000 metres (samples 71-73)

In the stratum corresponding to the woody plants of low bearing is notorious the presence of:

Amelanchier denticulada *Quercus intricata*
Eysenhardtia polystachya

and within the herbaceous populations they stand out:

Bouvardia ternifolia *Sanvitalia ocymoides*
Chrysactinia mexicana *Verbena elegans*
Parthenium histerophorus

3. High formation of *Pinus pseudostrobus*, *Pinus teocote* and *Quercus graciliformis*, located at an altitude of up to 1 200 meters on the eastern slope of the Sierra Madre Oriental (between Linares and Galeana). The following species can be observed in the

lower woody stratum:

Amelanchier denticulada *Dioon edule*
Cowania plicata *Ptelaea trifoliata*.

II. 2. 3. 2. 2. Dry-trend high formations
The “drought” referred to is related to the result of climatic conditions, and to the lithic nature of the soil which causes poor water retention depriving the plants of moisture.
II. 2. 3. 2. 2. 1. Tall formations of *Pinus arizonica*
The high formations of *Pinus arizonica* are frequently found between 1 900 and 2 000 meters of altitude but sometimes they are also observed above 2 500 meters for example, at the top of the Sierra de la Marta (Coahuila). In this case, the formations could be derived from those described above.

- In the high formations of *Pinus arizonica* in the Sierra Santa Fe del Pino, Coahuila, the following species are distinguished in the lower stratum:

Pinus arizonica *Juniperus deppeana*
Quercus canbyi
Quercus sideroxyla x *hypoxantha*.

- Among the low woody species were identified:

Ceanothus greggii *Quercus intricata*
Cercocarpus paucidentatus var. *montanus*
Garrya ovata *Rhus trilobata*.

- El estrato herbáceo incluye algunas gramíneas:

Andropogon divergens *Bromus anomalus*
Andropogon scoparius *Muhlenbergia emersleyi*
Bouteloua curtipendula *Piptochaetium fimbriatum*.

- The herbaceous layer includes some grasses:

Aster sp. *Lesquerella purpurea*
Bouvardia ternifolia *Polygala alba*
Castilleja sp. *Salvia microphylla*
Helianthella mexicana *Seymeria scabra*.

II. 2. 3. 2. 2. 2. Upper and lower formations of *Pinus cembroides*

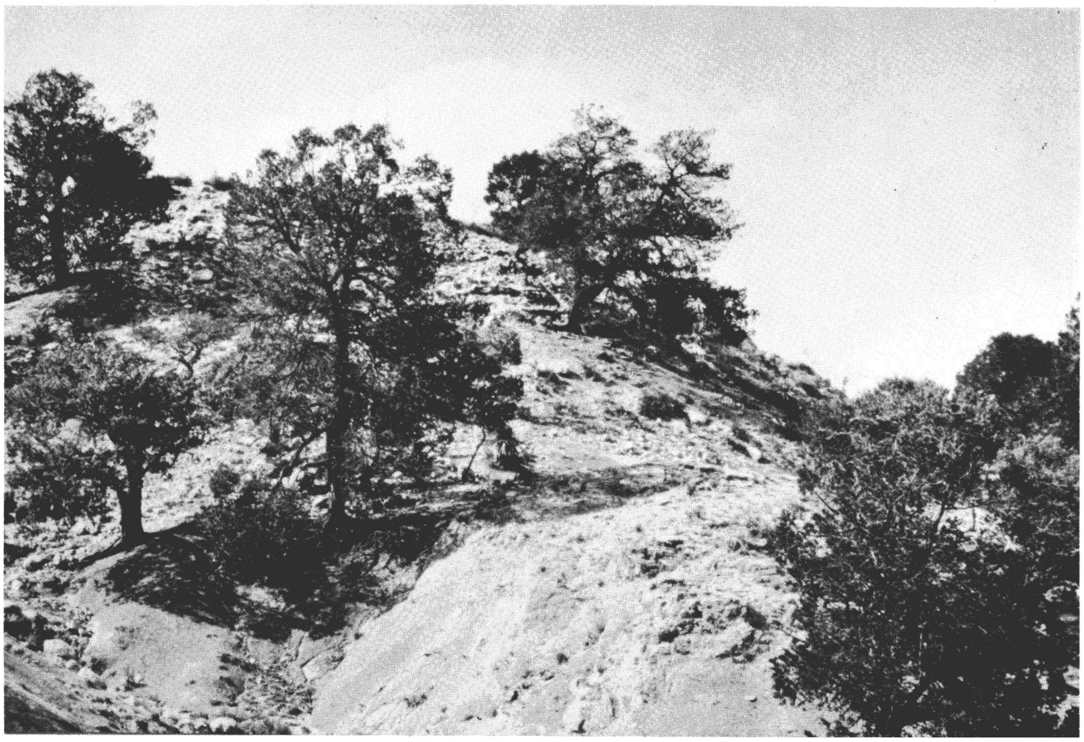
The upper and lower formations of *Pinus cembroides* are subdivided into four types:

1. Low formation of *Pinus cembroides* with P*inus arizonica* and *Quercus canbyi*, which comprises samples 27, 30, 35, 36, 37, 38, 39, 40, 49 and 50. In it the shrub and herbaceous strata are composed of the same species observed within the upper formation with Pinus arizonica.

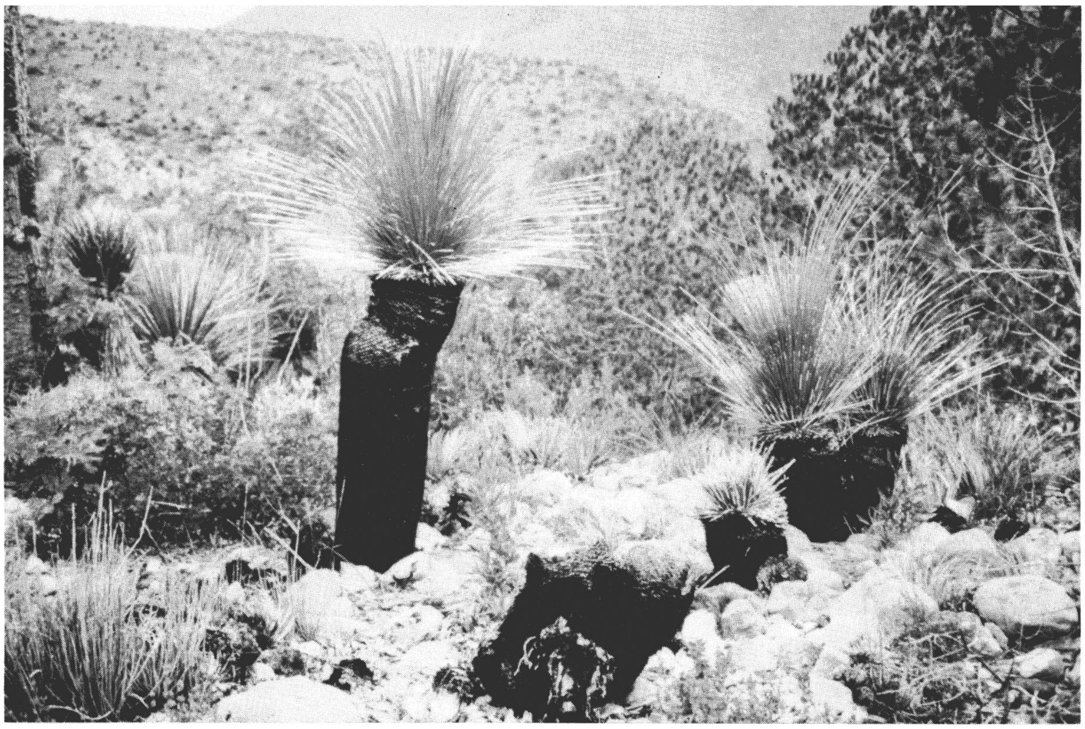
2. High and clear formation of *Pinus cembroides* with Gramíneas (observations 12, 26, 50, 56). The composition of this formation is similar to that of the following one.

3. Tall and clear formation of *Pinus cembroide*s with *Yucca carnerosana* and Gramíneas

I



Heavily altered lower formation of *Pinus cembroides* with *Juniperus flaccida* on limestone. 1 800 m altitude. 25°17'10 "N, 101°36'20 "W, Municipality of General Cepeda (Coahuila)
August 21st, 1975.



Complex woody formation with *Dasylirion longissimum*, *Pinus nelsonii, Agave lecheguilla* and *Euphorbia antisyphilitica* 2 050 m altitude.
23°27'30 "N, 99°49'30 "W, Municipality of Jaumave (Tamaulipas)

(Samples 7, 23, 25, 59, 60, 61, 63, 69).

- The stratum of high woody plants has a very low population density, in its composition are observed:

Dasylirion sp. | *Lindleyella mespiloides*
Juniperus flaccida | *Quercus intricata*
Juniperus deppeana | *Nolina sp.*

- Between the Gramíneas they are identified:

Bouteloua curtipendula | *Stipa eminens*
Setaria geniculata | *Stipa lobata.*

4. *Pinus cembroides* formations with *Juniperus deppeana*

The four types of plant formation, indicated above, are distributed throughout the study area of the Sierra Madre Oriental, with the exception of the formation of *Pinus cembroides* with *Pinus arizonica*, which is absent in the southern part of the State of San Luis Potosi and in the States of Hidalgo and Puebla (Robert, 1973).

II. 2. 3. 2. 2. 2. Low formations of *Pinus nelsonii* alone or associated with *Pinus cembroides* (samples 80, 81, 83, 84, 85, 86)

- Among the low woody plants stand out:

Astrocassia phyllanthoides | *Juniperus deppeana*
Berberis trifoliata | *Krameria cytisoides*
Brahea sp. | *Mimosa biuncifera*
Cowania plicata | *Quercus castanea*
Dasylirion longissimum | *Rhus pachyrrachis*
Dodonaea viscosa | *Sophora secundiflora.*

- Herbaceous plants are few and far between:

Aristida sp. | *Salvia melissodora*
Bouteloua curtipendula | *Seteria geniculata.*

II. 2. 3. 2. 3. Complex xerophyte formations (Samples 8, 1, 18, 20, 21, 33, 34, 46, 57, 64)

Complex formations include herbaceous, low and high woody plants, the latter often being scarce or even absent, with low woody plants predominating. The term “scrub” includes all complex xerophytic formations. Their floristic composition varies greatly as very frequent species can be mentioned:

Flourensia cernua | *Prosopis juliflora*
Larrea tridentata | *Viguiera stenoloba*
Leucophyllum laevigatum.

The plant formations present in the Sierra Madre Oriental have been defined by the dominant tree species.

The following information includes an attempt at more complete interpretations of the factorial analysis. Lacoste and Roux, in 1972, demonstrated that the figure or figures formed by factor analysis easily contain the components of the plant associations already known to them. Based on the works previously mentioned, as well as on those carried out by Benzecri, in 1973, the inverse procedure was attempted, since different authors found in the figures well defined associations, being able to raise the hypothesis that the groups of plants form associations. Instead of identifying the groups of related plants with the name of association, it is proposed to call them a cenological group. This term comes from the Greek and was proposed by Godron (1979) as preferable to sociological. Furthermore, it does not imply any of the restrictions of interaction and hierarchy contained in the word sociological.

II. 2. 3. 3. Cenological groups

The cenological groups were determined using both the values of the participation of the species in the five axes and the position of the points that represent them, in the planes of axes I, II, I-III and I-IV. Nearby species constitute a cenological group. This proximity results, among other factors, from presence-absence relationships. Thus, in eastern Mexico there are twenty zenological groups.

In the same way that was attributed to the axis I the sense of a drought gradient, it is considered that, within the same group, the plants of negative abscissa are of less dry tendency if they are compared with those of positive abscissa. Between the groups of negative abscissa there are two subgroups inside each cenological group: the first one expresses a mesophilic tendency and the second one a xerophytic tendency.

Some of the cenological groups are described below:

In the first group, which includes *Pinus cembroides*, two subgroups can be distinguished:
1. of mesophilic tendency, it classifies, among other species to

Juniperus deppeana	*Bouvardia ternifolia*
Bouteloua curtipendula.	

2. of xerophilic tendency, it is satisfied with plants like:

Pinus pinceana	*Berberis trifoliata*
Rhus microphila	*Parthenium incanum*
Mimosa zygophila	*Lycurus phleoides*
Mimosa biuncifera.	

Pinus pinceana belongs to the subgroup with a more xeric tendency than *Pinus cembroides*, which was determined through numerous field observations made from General Cepeda, Coahuila, to San Luis Potosi.

Pinus pinceana and *Pinus cembroides* sometimes cohabit (observations made towards Concepción del Oro, Zacatecas), but when alone, *Pinus pinceana* occupies the western exposed slopes and is associated with the species mentioned above, as well as several endemic species of the Chihuahua desert, such as, *Fouquieria splendens*.

Plants from subgroup 2 are often found in *Pinus cembroides* formations. In this regard, it is interesting to compare the cenological group determined in this way and the list of

species most frequent in the formations of *Pinus cembroides* in the east of the study area (Table 15).
The dominant species in the samples belong to the cenological group of *Pinus cembroide*s.

It is important to note that the three most frequent species of *Pinus cembroides* in eastern Mexico do not belong to the same zenological groups.
The *Pinus nelsonii* group includes the following species:

Rhus pachyrrhachis *Agave atrovirens*
Rhus virens *Gymnosperma glutinosum*
Dasylirion longissimum

and, species which, with the exception of *Dasylirion longissimum*, have been found in the company of *Pinus cembroides*.
These groups are of limited value, as they are usable only in the study area. As they are, they provide a useful distinction within the formations described above and can serve as a basis for further research.

TABLE 15. Frequency of species within the 48 samples with *Pinus cembroides* .

Frecuencia en %	NOMBRE
54	*Bouvardia ternifolia*
50	*Bouteloua curtipendula*
46	*Juniperus deppeana*
42	*Chrysactinia mexicana*
40	*Bouteloua gracilis*
40	*Nolina* sp.
33	*Yucca carnerosana*
29	*Rhus virens*
29	*Sophora secundiflora*
25	*Dasylirion* sp.

One of the postulates on which the phytoecologist builds his research, indicates that vegetation is a good indicator of environmental conditions. Therefore, he is oriented to investigate the relationships between the components of the cenological groups and the environment. An attempt was made to do this by using ecological profiles in the past.

II. 2. 4. Sierra Madre Occidental

The 91 samples taken in the Sierra Madre Occidental during the period July-August 1974 and September 1975, as well as the 220 species present more than twice in all of these samples, were subjected to correspondence analysis.
The participation, location of the points, in the different axes is identical to that observed previously in the analysis of the observations from the Sierra Madre Oriental (5 percent for axis I, and 15 percent for the first three axes).
The samples (Figure 12) are distributed in two lots: on the left are the 1975 observations

and on the right are the 1974 observations. This leads to a separate consideration of each of the groups and makes the interpretation of the figure resulting from the observations, obtained by factorial analysis, very difficult. It is preferable not to group together in a single analysis the observations made during different campaigns, even if the operator is the same. The sampling rigidity of 1975 was stricter than that of 1974. By associating these two groups of observations, an unevaluated heterogeneity was introduced. In addition, 1974 was a very dry year, resulting in a delay in the development of vegetation. In August 1974, the oaks with their fallen leaves began to sprout, while the grasses and herbaceous plants were rare and difficult to identify.

These two reasons may explain the graphic segregation of the 1974 and 1975 observations even when they were made in the same geographical region.

In relation to the distribution of *Pinus chihuahua*, *Pinus engelmanii* and *Pinus ayacahuite*, these were found to be located to the left within figure 12. *Pinus ayacahuite* occupies a very eccentric position in the plane of axes I and II, which explains its low frequency in

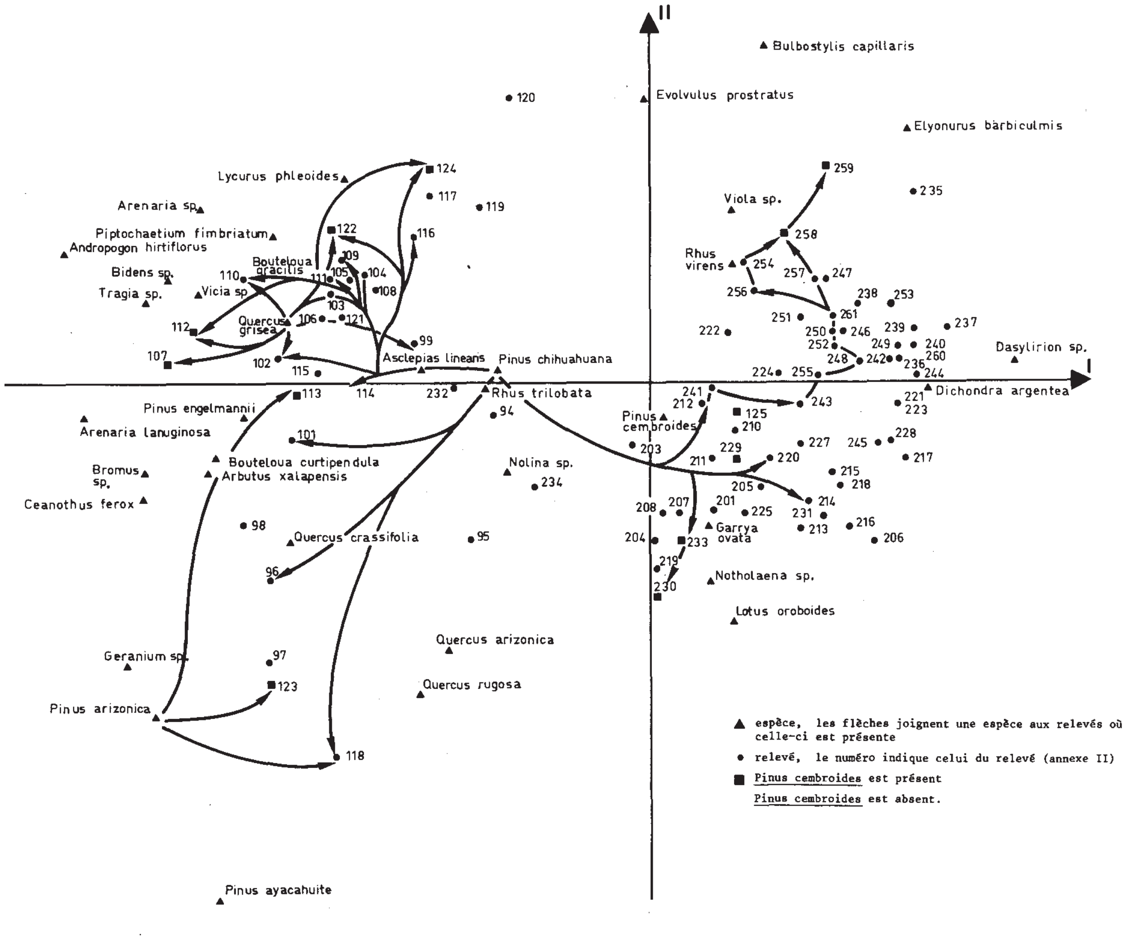


Figure 12. Factorial analysis of the samples from the Sierra Madre Occidental: diagram of the species and the samples in the plane of axes I and II.

the dition. In general terms, the tall woody formations of *Pinus pl. sp*. are to the left of the figure in question and the formations of *Pinus cembroides* are to the right. Here too, axis I can be attributed to the direction of a drought gradient. The plant formations are more homogeneous than to the east.

TABLE 16. Frequency of species within the 71 samples with *Pinus cembroides*

Frecuencia en %	NOMBRE
71	*Cyperus* sp. 2
71	*Cyperus* sp 3
61	*Juniperus deppeana*
36	*Rhus trilobata*
30	*Arctostaphylos pungens*
	Ipomoea capillacea
29	*Stevia serrata*
	Quercus grisea
26	*Quercus hypoxantha*
25	*Dichondra argentea*

II. 2. 4. 1. Cenological groups

The interpretation of Figure 12 and the distribution of the points, within the axes I - III, I - IV, allows the identification of some cenological groups, in which two subgroups are distinguished that correspond to more or less dry trends. Group I demands, due to its importance, more attention, which is why its subgroups are mentioned.

1.1. Mesophilic tendency subgroup, together with other species

Pinus engelmannii *Commelina dianthifolia*
Quercus grisea *Asclepias linnaria*
Gilia pinnata *Eriogonum undulatum*
Stevia serrata.

1. 2. Xerophilic tendency subgroup. This comprises

Pinus cembroides *Bouteloua hirsuta*
Juniperus deppeana *Bouvardia ternifolia*
Salvia regla *Ipomoea capillacea*.

If the cenological group is compared with the list of the most frequent species within the samples where *Pinus cembroides* dominates, it can be seen that the two lists coincide less than to the east of the studied area.

II . 2. 5. Conclusion

The previous study shows that the floristic composition of the *Pinus cembroides* formations of the Sierra Madre Oriental differs from that present in the Sierra Madre Occidental.

In the formations of *Pinus cembroides* of the Sierra Madre Oriental, *Bouteloua curtipendula*, Gramínea observed in a very wide area, appears outside a ubiquitous plant of the Rubiaceae family as the most frequent species. *Juniper*, *Juniperus deppeana*, is frequent but not very abundant in the high formations of *Pinus cembroides*, that species is scattered and hardly reaches 4 meters in height. On the contrary, in the clearings it spreads and develops its normal height. In other words, it suffers from lack of light, but it remains in protection in dense populations of *Pinus cembroides*. In certain foothills it grows alone, and in the shade of its crown numerous species germinate (oaks, grasses), which in this way are protected from intense sunlight.

In the western region of the area studied the most frequent species are different. In the first place, two species of *Cyperus*, typical of the Sierra Madre Occidental and related to the relative acidity of the soil, are noted. *Juniperus deppeana* is more frequent than in the east. In addition, it invades the areas recently cut down more than in the east of the study area. The virulence or competitiveness of this species seems to be currently greater than in the east. This invasive nature of juniper was pointed out by Johnsen (1960) in Arizona. *Arctostaphylos pungens* is also more frequent in the *Pinus cembroides* formations of the west than in those of the east.

The most represented plant forms are the following:

- phanerophytes: *Juniperus deppeana*;
- camephites: *Rhus trilobata*;
- hemicryptophytes: *Bouteloua curtipendula*;
- cryptophytes: various species of the genera *Dalea*, *Desmodium*, *Ipomoea*, *Oxalis* and *Thalictrum*.

Cenological groups provide a start to the understanding of the plant formations in the area of study and allow future research to be guided on a more precise basis.

The relationships that unite the species of the cenological groups with the environment are also addressed, comparing the mutual information provided by the species-variable group.

II. 3. PLANT SPECIES AND ECOLOGICAL VARIABLES

The factorial analysis allowed the study of the relationships of the set of species with the set of variables, plus the method of the ecological profiles aims to establish the relationships between a species and a variable.

Some definitions necessary for the understanding of this method of analysis will be recalled here; for greater precision, the reader may consult Godron (1966, 1968), Guillerm (1971), Daget (1970, 1976) and Gauthier (1977). For a given variable, the overall ecological profile corresponds to the number of samples taken in each class of the variable, representing an absolute frequency distribution. The relative frequencies obtained by dividing the absolute frequencies by the total number of samples are comparable to probabilities of presence and absence.

If sampling is sufficient, the samples are distributed equally among the different classes of the ecological variable. A variable then has an equal chance of being in one class or another, the relative indeterminacy of this variable being large. Such indeterminacy can be estimated by calculating the H (L) entropy of this variable (Abrason, 1963, quoted by Daget et al., 1970), given by:

H (L) = Σ1NKR(K)/ NR log2 NR/ R (K)

where:

R (K) is the number of observations made in class K
NR the total number of observations
H(L) entropy expressed in bits.

The distribution of a species in the classes of an ecological variable constitutes the ecological profile of that species. This allows the amount of information provided by that species to be evaluated in relation to an ecological factor, i.e. the *mutual information* (HIM) between the species and the ecological variable. It is defined as follows:

HIM = H(L) - H (L/A)

in which H(L) indicates entropy before sampling
H(L/A) entropy after sampling, i.e. after the presence or absence of species A in the environment defined by the variable L.

For each variable studied, mutual information was calculated for all species present more than twice in the set of samples. Only the first hundred species appear in the results tables. The mutual information and entropy allow us to determine, on the one hand, the most active ecological variables in the set studied, and on the other hand, the species that best characterize some ecological variables (indicator species).

II. 3. 1. Active ecological variables

The average of the mutual specimen-factor information, calculated for the hundred species that provide the most information, compared to the entropy-factor (Figure 13), allows the classification of the ecological variables according to their activity.

In Figure 13, the well-sampled factors (high entropy) are located on the right, and the poorly sampled factors (low entropy) on the left. The active variables are located at the top. The distribution of the variables, observed in the figure, is summarized in Table 17; the ecological variables are classified in order of decreasing HIM and according to the HIM ratio: entropy-factor. The following can be deduced from Table 17:

1. The type of rock, although poorly sampled, is an active variable. For this reason additional sampling will be necessary.

2. The region is the most active variable in the set of 185 samples (it was not introduced in the set of 351 samples). The region also has a high HIM in the Sierra Madre Occidental, but its position in Figure 13 indicates that it was poorly sampled.

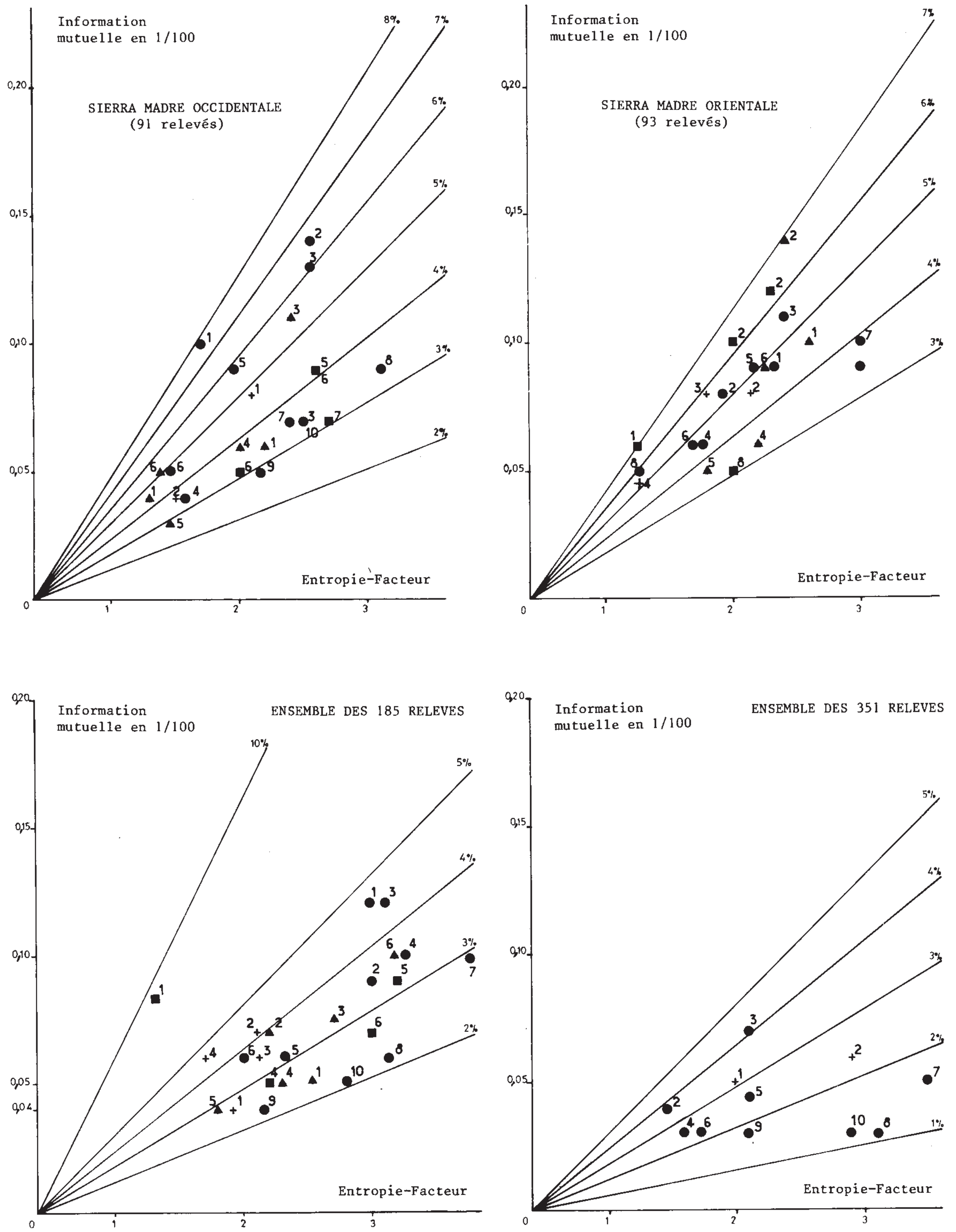


Figure 13. Relationship between specimen-factor mutual information and entropy-factor
Ecological variables: 1, region; 2, latitude; 3, longitude; 4, climate according to Köppen; 5, mean annual precipitation (P); 6, mean annual T; 7, altitude; 8, exposure; 9, topography; 10, slope.
Soil variables: 1, rock type; 2, HCl reaction; 3, pH; 4, % blocks; 5, % gravel; 6, % fine soil; 7, % vegetation; 8, % litter.
Vegetation: 1, type of formation; 2, first dominant species; 3, second dominant species; 4, % of cover of the low woody ones; 5, % of cover of the herbaceous ones; 6, diameter of the trunks of *Pinus cembroides*.
Anthropic variables: 1, artificialization; 2, utilization; 3, forest exploitation; 4, animals

3. In the set of 185 and 351 samples, longitude is a variable with a high HIM, predominating over latitude in the Sierra Madre Oriental, but its HIM is less elevated than the pH and soil reaction to the HCI. In the Sierra Madre Occidental, by contrast, latitude has a higher HIM than longitude.

TABLE 17. Variables classified in order of decreasing mutual information and according to the HIM/entropy-factor ratio.

Sierra Madre Occidental	**Sierra Madre Oriental**	**185 muestras**	**351 muestras**
Region	1sp. dominante	Rock	Longitude
Latitude	Rock	Region	1e esp. dominante
Longitude	Soil pH	Longitud	Latitud
2e sp. dominante	Soil HC1	Use	2e esp. dominante
Precipitation	Longitud	Animals	Precipitation
% de gravas	Latitud	Diameter	Köppen
% de litera	Precipitation	Köppen	Temperature
Artificialisation	Diameter	Latitud	Altitud
	Region	% de grava	
Exposure to sun	Use	2e esp. dominante	
	Altitud	1e esp. dominante	
		Altitud	

It is important to point out that the large relief lines are directed approximately from NO-SE, which causes in the area of study that the length has a preponderant role over the other biogeographic variables. The folds of the Sierra Madre Oriental also have a NO-SE orientation. In contrast, the Sierra Madre Occidental is a more compact massif. However, this does not suggest a satisfactory explanation for the high latitude HIM in this region.

4. Of all the climatic variables, the climate defined by Köppen is the first active variable in the set of 185 samples; elsewhere, this variable has an approximate value of HIM (3-4 %), but was poorly sampled. This has a simple explanation. In the set of 185 observations, the 12 classes indicated by Köppen were retained. In the West, in order to have more or less balanced cash in each class, a drastic grouping was made: only three classes survived, but they were not sampled equally. In the East, the groupings retained only four classes which are BSO, BS, BW and C(wo), and they were the only ones taken into account in all 351 samples.

5. The average annual rainfall variable has a high HIM, both in the Sierra Madre Oriental and in the Sierra Madre Occidental. Although it was poorly sampled, it appears to be a more active variable than the Köppen climate classes. The same is true for the average annual temperature.

6. At equal sampling quality, utilization plays a more important role than temperature.

7. Altitude was poorly sampled in the interior of the Sierra Madre Occidental. The second dominant species and altitude have the same sampling quality, with the second dominant species being more active.

8. Ecological variables, such as slope and exposure, are not active in the sample sets analyzed.

Thus the set of 351 samples is sensitive to longitude, first dominant species, latitude, second dominant species and climatic variables. The rock is not part of the variables analyzed in this set.

The rock variable is the most active in the set of 185 samples, followed by the region, longitude, anthropic variables, diameter of the trunks of *Pinus cembroides* and the climate defined by Köppen.

Within the samples of the Sierra Madre Oriental, the first dominant species appears as the preponderant variable, which can be related to the great diversity of plant formations present. This variable precedes the edaphic, geographic and climatic variables.

The type of rock has a preponderant place in the set of 185 observations, which is not observed in the Sierra Madre Occidental. This is because the Sierra Madre Occidental is essentially made up of acidic eruptive rocks, while the observations of the Sierra Madre Occidental include areas of sedimentary origin and areas such as the Sierra del Carmen (Coahuila) of an eruptive nature.

II. 3. 2. Indicator species in the whole of the area studied

The ecological profile method allows us to analyze the relationships between a species and a variable. There are different types of ecological profiles, among which the corrected frequency profile is the most used. “Corrected frequency is the ratio of the relative frequency of a species in a class of the variable and its relative frequency in the set of samples”. From the corrected ecological profiles, a program established by P. David and F. Romane (ECE) allows the calculation of indexed ecological profiles (Gauthier el al., 1977). The latter make “the degree of significance of the number of each species in each class of the variable appear” (work cited).

The indexed ecological profiles for the most active variables are presented below.

For each of the classes of the variable, the possible results are the following:
1. The species is significantly sensitive, in a positive way, for the class of the variable to the limit of 5%, 1 or 0.1 %.
2. The species is significantly sensitive, in a negative way, for the class of the variable to the limit of 5%, 1 or 0.1 %.
3. The species is not significantly sensitive for the class of the variable: it is indifferent.
4. The number of observations for the class of the variable considered is insufficient or the species is absent. Esta última situación incluye una ambigüedad que pueda suprimirse fácilmente, introduciendo otro signo en el programa, para distinguir la ausencia de la

especie en la clase de la variable de un muestreo insuficiente en esta misma clase.

Table 18. Species with positive sensitivity for geographic region variables

ESPECES	fréquence	Information mutuelle en binons	classes	1	2	3	4	5	6	7	8	9
			effectifs	48	16	20	7	21	15	25	16	17
Pinus cembroides	124	0.15783		+		++		---	-	.		.
Juniperus deppeana	87	0.12911		+	.	+	.	.	---	.	.	.
Quercus emoryi	17	0.10158		++		+						
Pinus chihuahuana	31	0.17839		+++	.	.	+	-				
Quercus grisea	30	0.28011		+++	.	-		-		-		
Stevia serrata	29	0.18537		+++		.		-		-		
Thalictrum sp.	36	0.16703		+++	.	.			.	--		-
Pinus engelmannii	15	0.13578		+++								
Calliandra humilis	15	0.12832		+++								
Rhus trilobata	48	0.11691		+++				.	.	-		
Desmodium sp.	27	0.11592		+++				.		-		
Vicia sp.	15	0.11533		+++								
Bidens sp.	15	0.11481		+++								
Commelina dianthifolia	19	0.10700		+++								
Ipomoea sp.	16	0.10270		++								
Lycurus phleoides	26	0.09641		+++						-		
Quercus rugosa	13	0.09004		+								
Cyperus sp.	64	0.08857		++	.	.		.		--	.	.
Ipomoea capillacea	27	0.24631		.	+	+++	+++			-		
Helianthemum glomeratum	20	0.22852		-	+++	+++	++					
Arctostaphylos pungens	41	0.16879		.	++	+	.	--	-	.	-	
Hypoxis sp.	13	0.13549			+	+++						
Microchloa kunthii	14	0.12382			+	++						
Quercus hypoleucoides	30	0.21575		+++	.	-		.		-		
Bromus sp.	15	0.08458		+++								
Gibasis linearis	19	0.15747		+	+++	.						
Commelinacées	23	0.11114			+++					.		
Evolvulus sp.	12	0.10382			++							
Cheilanthes sp.	16	0.08644		.	+							
Cyperus sp.2	23	0.32627		-	.	+++	+++					
Notholaena aurea	21	0.17370			.	+++	+++					
Calochortus barbatus	12	0.12117				++	+++					
Cyperus sp.3	13	0.19699		-		+++						
Ipomoea stans	10	0.17366				+++						
Composées	49	0.15107		--	.	+++	.			.		.
Dyschoriste linearis	24	0.12584		--		++	.	.		.		
Mimosa biuncifera	22	0.11190				+++	.					
Salvia sp.	57	0.10986		---	.	+++	.	.	.	.		.
Mandevilla sp.	7	0.10836				+++						
Quercus chihuahuensis	15	0.10256		.		+						
Papilionacées	25	0.10007		.	.	++				.		
Malvacées	8	0.09413				+++						
Dalea sp.	54	0.09329		.	.	+++	.	.		.	.	.
Sisyrinchium sp.	8	0.08635				+++						
Polygala sp.	27	0.08413		-		++	.		.			
Dichondra argentea	25	0.08159		.	.	+	.			-		
Verbesina sp.	14	0.09224		-			+			++		
Mandevilla foliosa	7	0.08669					+					
Bulbostylis capillaris	4	0.08400					+++					
Quercus eduardi	4	0.08400					+++					
Elyonurus barbiculmis	3	0.08235					+++					
Viola sp.	9	0.08122					+++					
Leucophyllum laevigatum	6	0.08075						+	+			
Bouteloua curtipendula	41	0.20578		--	-	--		+++	.	.	+++	.
Verbena sp.	21	0.15517		--				+++	.	.		
Artemisia ludoviciana	9	0.09040						+++				
Lesquerella purpurea	6	0.08791						+++				
Tradescantia crassifolia	6	0.08560						+++				
Panicum bulbosum	10	0.08373		.				++				
Cirsium sp.	9	0.08342						+				
Garrya ovata	23	0.12769		.				.	++	+		
Eysenhardtia polystachya	7	0.08219							+		+	
Acalypha sp.	17	0.12922		--				.	+	.		
Quercus canbyi	10	0.11474							+++			

ESPECES	fréquence	Information mutuelle en binons	classes	1	2	3	4	5	6	7	8	9
			effectifs	48	16	20	7	21	15	25	16	17
Salvia regla	17	0.11112		--				.	+			
Berberis trifoliata	15	0.10566		-					++			
Rhus virens	23	0.08978		-					+	.	.	.
Oenothera sp.	7	0.08718							+++			
Fraxinus greggii	11	0.08640							+			
Haplopappus spinulosus	5	0.08225							+++			
Lindleyella mexicana	13	0.14489		-						+++	+ .	
Chrysactinia mexicana	28	0.20445		---				.		+++	.	+++
Labiées	23	0.10580								+++		+
Dasylirion sp.	24	0.13478		---						+++	.	
Dyssodia setifolia	16	0.11356		-						++	.	
Cowania plicata	9	0.09212								++		
Viguiera sp.	8	0.08901								+++		
Quercus sp.	43	0.08664		-	.	.			.	+++		.
Quercus pringlei	5	0.08170								+++		
Lindleyella mespiloides	6	0.08024								+++		
Cercis sp.	7	0.09975									.+	++
Pinus pseudostrobus	6	0.08446									+	+
Yucca carnerosana	25	0.13754		--						.	+++	
Bouvardia ternifolia	53	0.10547		---		.		.	.	.	+	
Bouteloua gracilis	42	0.10053		.		--		.		.	+	.
Gymnosperma glutinosum	16	0.09860								.	+++	
Oxybaphus sp.	17	0.08400									+	
Amelanchier denticulata	9	0.07922									++	
Castilleja sp.	20	0.07895						.		.		+
Sophora secundiflora	20	0.17880		--					.	.	.	+++
Pinus nelsonii	6	0.12037										+++
Euphorbia antisyphilitica	12	0.11761		-								+++
Ceanothus greggii	14	0.11255		-						.		++
Croton sp.	17	0.10341		--						.		
Agave lecheguilla	11	0.10220										++
Quercus affinis	5	0.09894										+++
Krameria cytisoides	6	0.09517										+++
Boraginacées	8	0.09189										++
Eupatorium sp.	16	0.08178										+++
Pinus arizonica	18	0.09324						.	.	.		

+++ Espèce significativement sensible de façon positive au seuil de 1°/°°
++ " " " " " " " " " 1 %
\+ " " " " " " " " " 5 %
--- Espèce significativement sensible de façon négative au seuil de 1°/°°
-- " " " " " " " " " 1 %
\- " " " " " " " " " 5 %
. Espèce non significativement sensible

Le nombre des relevés est insuffisant pour conclure.

Sierra Madre Occidental
1: al norte del 28° N
2: del 26 al 28° N
3: del 24 al 26° N
4: del 22 al 24° N

Sierra Madre Oriental
5: al norte del 28° N
6: del 26 al 28° N
7: del 25 al 26° N
8: del 24 al 25° N
9: del 22 al 24° N
10: del 18 al 22° N

II. 3. 2. 1. Geographical region indicator species.

Table 18 shows the species that have a positive sensitivity, either for the Sierra Madre Oriental or for the Sierra Madre Occidental. By comparing the ecological profiles of the corrected frequencies and the indexed profiles, it is possible to separate the species that are really absent from certain classes of the region variable, from those for which sampling, in those classes, is insufficient.

The indicator species of the Sierra Madre Occidental are presented in order of decreasing HIM within each group (Tall, short and herbaceous woody species).

Woody tops:

Quercus emoryii	*Pinus engelmannii*
Pinus chihuahuana	*Quercus rugosa*
Quercus grisea	*Quercus chihuahuensis*
Quercus hypoleucoides	*Quercus eduardi*.

Downy woody:

Rhus trilobata	*Mimosa biuncifera*
Calliandra humilis.	

Herbaceous:

Stevia serrata	*Lycurus phleoides*,
Thalictrum sp.	*Dyschoriste linearis*
Commelina dianthifolia	*Dichondra argentea*
Ipomoea sp.1	*Mandevilla foliosa*
Ipomoea sp. 2.	*Bulbostylis capillaris*
Ipomoea stans	*Cyperus* sp. 3.

The indicator species of the Sierra Madre Oriental are also presented in decreasing order of HIM within the three groups.

Woody tops:

Eysenhardtia polystachya	*Quercus affinis*
Quercus canbyi	*Pinus pseudostrobus*
Fraxinus greggi	*Pinus arizonica*
Quercus pringlei.	

Downy woody:

Yucca carnerosana	*Lindleyella mespiloides*
Pinus nelsonii	*Sophora secundiflora*
Salvia regla	*Euphorbia antisyphilitica*
Berberis trifoliata	*Ceanothus greggii*
Rhus virens	*Agave lecheguilla*
Dasylirion sp.	*Krameria cytisoides*
Cowania alicata	*Cercis* sp.

Herbaceous:

Bouteloua curtipendula	*Haplopappus spinulosus*
Verbena sp.	*Chrysactinia mexicana*

Cuadro 19. Perfiles ecológicos indiciados de las cien primeras especies clasificadas con signo para la variable temperatura media (número total de muestras: 351)

E S P E C E S	fréquence	Information mutuelle en binons	classes	12-14°	14-16°	16-18°	18-20°	20°
			effectifs	18	82	185	55	10
Juniperus deppeana	86	0.12440		++	+++	---	.	
Thalic trum sp.	36	0.11131		+++	+++	---		
Pinus chihuahuana	32	0.09492		+++	+++	---	--	
Stevia serrata	34	0.07997		+++	+++	---	-	
Arctostaphylos pungens	50	0.07426		+++	+++	--	-	
Quercus hypoleucoides	30	0.07345		+	+++	---	.	
Quercus rugosa	13	0.07023		+	+++	---		
Cyperus sp.	67	0.07020		++	++	---	.	
Pinus engelmannii	15	0.06495		++	+++	---		
Commelina dianthifolia	19	0.05821		+	++	---		
Ipomoea capillacea	27	0.05205		+	++	.	-	
Gibasis linearis	19	0.05134		++	++	--		
Vicia sp.	16	0.04696		+	+	---		
Bidens sp.	16	0.07346		+++	.	---		
Rhus trilobata	48	0.05274		+	.	---	.	
Tradescantia sp.	13	0.05263		+++	.			
Piptochaetium fimbriatum	21	0.05213		++	.	---	.	
Aristida hirtiflorus	6	0.04696		+++		-		
Andropogon histiflorus	3	0.3766		+++				
Arenaria lanuginosa	5	0.03579		++		-		
Cologania sp.2	5	0.03579		++		-		
Donnelsmithia sp.	5	0.03579		++		-		
Gnaphalium viscosum	4	0.03438		+++				
Desmodium sp.	28	0.03334		++	.	-		
Gaura sp.	3	0.02465		+				
Xanthocephalum sp.	8	0.02449		+		-		
Lycurus phleoides	35	0.02399		++	.	.		
Quercus grisea	38	0.08323		.	+++	--	--	
Senecio sp.	18	0.04919			+++	-		
Quercus emoryi	18	0.04631			+++	-		
Oxalis sp.	39	0.04196		.	++	.	-	
Salvia sp.	63	0.03527			+	--	.	
Cologania angustifolia	18	0.03508			++	--		
Ombellifères	9	0.03242			+	-		
Eriogonum undulatum	7	0.03235			++	--		
Piptochaetium sp.	22	0.03196			++	--	.	
Bromus sp.	16	0.03189			++	.		
Cologania sp.	19	0.03115			+	.		
Caryophyllacées	11	0.03082			++	--		
Calliandra humilis	15	0.02995			+	-		
Quercus chihuahuensis	17	0.02982			+	-		
Ceanothus ferox	13	0.02900			++	-		
Solanum sp.	11	0.02834			+	--	.	
Trifolium sp.	6	0.02685			++	-		
Calochortus barbatus	13	0.02620			++	.		
Cyperus sp.3	13	0.02620			++	.		
Phaseolus sp.	14	0.02607			+	.		
Hypoxis sp.	13	0.02503			+	.		
Evolvulus sp.	12	0.02488			+	-		
Pennela sp.	4	0.02422			++			
Xanthocephalum sericocarpum	4	0.02422			++			
Commelina sp.	19	0.02362			+	-	.	
Yucca carnerosana	86	0.10312		-	---	+++	.	
Juniperus monosperma	49	0.08675			--	+++	--	
Dasylirion sp.	71	0.07417		-	---	+++	.	
Quercus potosina	17	0.04595			-	+++		
Gymnosperma glutinosum	50	0.03804			-	++	.	
Yucca sp.	12	0.03209				+++		
Nolina sp.	63	0.02885			--	++	.	
Aristida pansa	14	0.02753			-	++		
Jatropha spathulata	19	0.02606				+		
Quercus pungens	9	0.02392				++		
Selaginella sp.	9	0.02392				++		
Larrea tridentata	17	0.04584			-	.	+	+
Leucophyllum laevigatum	6	0.04531				-	+	+
Berberis trifoliata	26	0.07433			-	.	+++	

E S P E C E S		Information mutuelle en binons	classes x	1	2	3	4	5	6	7
			effectifs	19	100	152	41	30	2	7
Evolvulus sp.	12	0.04494			–		.	++		
Anthericum sp.	6	0.04353						++		
Pinus nelsonii	6	0.04353						++		
Euphorbia sp.2	4	0.04149						+++		
Donnelsmithia sp.	5	0.04003						+++		
Commelinacées	23	0.03779			.	–		+++		
Quercus chihuahuensis	17	0.03569				.		+++		
Cologania sp.2	5	0.03484						+		
Rhus pachyrrhachis	11	0.02918				.		++		
Gomphrena decumbens	8	0.02840				–		+		
Dodonaea viscosa	14	0.03567				.			++	
Santivalia ocymoides	3	0.03245							+	
Cordia boissieri	3	0.03118							+	
Habenaria sp.	3	0.02796							+	
Quercus affinis	7	0.08014								++
Cercis sp.	7	0.05608				–				+
Pinus teocote	10	0.05046								++
Eupatorium sp.	20	0.04194				.	.	.		++
Quercus sideroxyla	5	0.03518								++
Juglans sp.	3	0.03446								++
Quercus obtusata	3	0.03446								++
Quercus rugosa	13	0.03388			.	–				+
Ageratum corymbosum	12	0.03233				.				+
Pteris aquilinum	3	0.03077								++
Polypodium plebeyum	5	0.03069								++
Loeselia coerulea	3	0.02904								++
Juniperus flaccida	28	0.02834			.	.				+
Ceanothus oceruleus	12	0.03228			–		.			
Pinus cembroides	257	0.03009			.	.	.	.		.
Asclepias sp.	16	0.02897			.	–				
Dyssodia sp.	5	0.02828								
Pinus arizonica	34	0.02756			.	.				
Bacopa procumbens	4	0.02686								
Brahea sp.	4	0.02686								

+++ Espèce significativement sensible de façon positive au seuil de 1°/°°
++ " " " " " " " " " 1 %
+ " " " " " " " " " 5 %
--- Espèce significativement sensible de façon négative au seuil de 1°/°°
-- " " " " " " " " " 1 %
- " " " " " " " " " 5 %
. Espèce non significativement sensible
Le nombre des relevés est insuffisant pour conclure.

x Signification des classes

Artemisia ludoviciana *Dyssodia setifolia*
Lesquerella purpurea *Bouteloua gracilis*
Tradescantia crassifolia *Gymnosperma glutinosum*
Panicum bulbosum *Commelina dianthifolia*.

Pinus cembroides has positive sensitivity for the Sierra Madre Occidental (Table 18) and particularly for regions 1 and 3 (north of 28°N and between 24 and 26°N). However, this pine shows negative sensitivity in the Sierra Madre Oriental for regions 5 (north of 28° N) and 6 (between 26° and 28° N). This plant is indifferent to regions 7 (between 25 and 26° N) and 9 (22-24° N). Sampling was insufficient in the other regions.

Juniperus deppeana offers a negative sensitivity for region 6 (26-28° N), in the East of the dition; in contrast, it is slightly positively sensitive to regions 1 and 3 of the Sierra Madre Occidental and indifferent to all other regions.

Arctostaphylos pungens presents positive sensitivity to regions 2 and 3 of the Sierra Madre Occidental, negative sensitivity to regions 5, 6 and 8 of the Sierra Madre

Oriental. It is indifferent to regions 1, 4 (Sierra Madre Occidental) and 7 (Sierra Madre Oriental). Sampling of the region was insufficient to conclude on the sensitivity of the species considered for that region.

Finally, *Bouteloua curtipendula* presented negative sensitivity for regions 1, 2 and 3 of the Sierra Madre Occidental; sampling of region 4 was insufficient to conclude. *Bouteloua curtipendula* has positive sensitivity for regions 5 and 8 of the Sierra Madre Oriental and is indifferent to regions 6, 7 and 9 of the Sierra Madre Oriental.

In conclusion, while the extensive area of *Pinus cembroides*, J*uniperus deppeana* and *Arctostaphylos pungens* covers a large part of the Sierras Madre Oriental and Occidental, its current preferential area corresponds to the Sierra Madre Occidental (particularly in regions 1 and 3). The above results are interesting and should be further developed.The opposite is true for the center of the *Bouteloua curtipendula* area which is located in the Sierra Madre Oriental (regions 5 and 8).

II.3.2.2. Average annual temperature indicator species

Within the set of 351 samples, the following groups are distinguished (Table 19):

Species indicating an average annual temperature (T) between 12 and 16 °C:

Juniperus deppeana	*Quercus hypoleucoides*
Thalictrum sp.	*Pinus engelmannii*
Pinus chihuahuana	*Commelina dianthifolia*
Stevia serrata	*Gibasis linearis*
Arctostaphylos pungens.	

Indicator species of 14 ≤T <16° C:

Quercus grisea	*Eriogonum undulatum*
Quercus emoryi	*Calliandra humilis*
Cologania angustifolia	*Quercus chihuahuensis*.

Indicator species of 16 ≤T <18° C :

Yucca carnerosana	*Quercus potosina*
Juniperus monosperma	*Nolina* sp.
Dasylirion sp.	*Aristida pansa*.

Especies indicadoras de 18 ≤T < 20° C :

Berberis trifoliata	*Acacia berlandieri*
Pinus nelsonii	*Chrysactinia mexicana*
Sophora secundiflora	*Karwinskia humboldtiana*
Euphorbia antisyphilitica	*Clematis pitcheri*
Bouteloua curtipendula	*Prosopis juliflora*
Quercus canbyi	*Rhus virens*
Larrea tridentata	*Leucophyllum laevigatum*,

These last two species are positively sensitive to T ≥ 20°C.

Table 20. Indicated ecological profiles of the first 100 species classified with sign, for the average annual precipitation variable (total number of samples: 351)

E S P E C E S		Information mutuelle en binons	classes x	1	2	3	4	5	6	7
			effectifs	19	100	152	41	30	2	7
Calliandra sp.	10	0.06903		+++	.	--				
Plantago sp.	4	0.03251		+						
Nolina sp.	63	0.02795		+	.	.	.			
Quercus sp.	96	0.02794		+	--	.	.	.		
Juniperus deppeana	86	0.14011		--	+	---	+++	+++		
Lycurus phleoides	35	0.04639			+	--	+	.		
Bidens sp.	16	0.06548			+++	---				
Desmodium sp.	28	0.06523			+++	---		.		
Commelina dianthifolia	19	0.06068			+++	---				
Vicia sp.	16	0.05712			+++	-				
Stevia serrata	34	0.05317			+++	---	.	.		
Quercus hypoleucoides	30	0.04833			++	---	.	.		
Panicum bulbosum	10	0.04309			+++	--				
Bouteloua curtipendula	62	0.04144			+	.	.	--		
Quercus grisea	38	0.04027			++	--	.	.		
Tradescantia crassifolia	7	0.03450			+	-				
Pinus engelmannii	15	0.03228			++	--				
Ombellifères	9	0.03271			+++					
Verbena elegans	8	0.03243			+	-				
Piptochaetium fimbriatum	21	0.03192			+	--				
Piptochaetium sp.	22	0.03163			+++	.				
Aristida hirtiflorus	6	0.03151			+++					
Rhus trilobata	48	0.03069			++	.	.			
Bromus sp.	16	0.02979			++	.				
Gochnatia hypoleuca	14	0.02744			+	.				
Lindleyella mespiloides	19	0.02714			+	.				
Ranunculus sp.	5	0.02695			+					
Gymnosperma glutinosum	50	0.03384			.	+	.		+	
Yucca carnerosana	86	0.06882		.	---	+++	.			
Juniperus monosperma	49	0.05443			.	+++	-	-		
Dasylirion sp.	71	0.05296		.	.	++	--	-		
Quercus potosina	17	0.03812				+++				
Bouteloua sp.	37	0.03231		.	-	++	.			
Dasylirion parryanum	8	0.02802				++				
Salvia sp.	63	0.04523			.	-	+	+		+
Ipomoea capillacea	27	0.12320			---	--	+++	++		
Cyperus sp.2	23	0.10403			---	-	+++	+++		
Helianthemum glomeratum	22	0.09210			---	.	+	+++		
Gibasis linearis	19	0.08218			--	.	+	+++		
Cyperus sp.	67	0.07045			.	---	+	++		
Notholaena aurea	21	0.06244			-	-	+++	+		
Pinus chihuahuana	32	0.06129			.	---	++	+		
Cyperus sp.3	13	0.05906			-		++	++		
Hypoxis sp.	13	0.04935			-		++	+		
Composées	53	0.04611		.	.	--	++	+		
Cheilanthes sp.	16	0.04071					+	+		
Cologania angustifolia	18	0.03921			-	.	+	+		
Mimosa biuncifera	25	0.03752			.	-	++	+		
Pinus pseudostrobus	6	0.06104					+			++
Panicum sp.	12	0.05422				-	+++			
Bouvardia ternifolia	62	0.05201			.	.	+++	.		
Papilionacées	25	0.04888			--	.	+++	.		
Polygala sp.	27	0.04720			.	.	+++			
Calochortus barbatus	13	0.04581					++			
Ipomoea stans	13	0.04529			-	.	+++			
Thalictrum sp.	36	0.04479			.	--	++	.		
Commelina sp.	19	0.04443				.	++	.		
Dalea sp.	78	0.04369			.	.	+++	.		
Malvacées	8	0.02938					+			
Bulbostylis capillaris	4	0.02778					+			
Acacia schaffneri	3	0.02689					++			
Peperomia campylotropa	3	0.02689					++			
Quercus graciliformis	3	0.02689					++			
Arctostaphylos pungens	50	0.06867			.	.	.	+++		
Microchloa kunthii	14	0.05412				-	.	+++		
Tradescantia sp.	13	0.04507						+++		

E S P E C E S		Information mutuelle en binons	classes x	1	2	3	4	5	6	7
			effectifs	19	100	152	41	30	2	7
Evolvulus sp.	12	0.04494			–		.	++		
Anthericum sp.	6	0.04353						++		
Pinus nelsonii	6	0.04353						++		
Euphorbia sp.2	4	0.04149						+++		
Donnelsmithia sp.	5	0.04003						+++		
Commelinacées	23	0.03779			.	–		+++		
Quercus chihuahuensis	17	0.03569				.		+++		
Cologania sp.2	5	0.03484						+		
Rhus pachyrrhachis	11	0.02918				.		++		
Gomphrena decumbens	8	0.02840				–		+		
Dodonaea viscosa	14	0.03567				.			++	
Santivalia ocymoides	3	0.03245							+	
Cordia boissieri	3	0.03118							+	
Habenaria sp.	3	0.02796							+	
Quercus affinis	7	0.08014								++
Cercis sp.	7	0.05608				–				+
Pinus teocote	10	0.05046								++
Eupatorium sp.	20	0.04194				.	.	.		++
Quercus sideroxyla	5	0.03518								++
Juglans sp.	3	0.03446								++
Quercus obtusata	3	0.03446								++
Quercus rugosa	13	0.03388			.	–				+
Ageratum corymbosum	12	0.03233				.				+
Pteris aquilinum	3	0.03077								++
Polypodium plebeyum	5	0.03069								++
Loeselia coerulea	3	0.02904								++
Juniperus flaccida	28	0.02834			.	.				+
Ceanothus oceruleus	12	0.03228			–		.			
Pinus cembroides	257	0.03009			.	.	.	.		.
Asclepias sp.	16	0.02897			.	–				
Dyssodia sp.	5	0.02828								
Pinus arizonica	34	0.02756			.	.				
Bacopa procumbens	4	0.02686								
Brahea sp.	4	0.02686								

+++ Espèce significativement sensible de façon positive au seuil de 1°/°°
++ " " " " " " " " " 1 %
+ " " " " " " " " " 5 %
--- Espèce significativement sensible de façon négative au seuil de 1°/°°
-- " " " " " " " " " 1 %
- " " " " " " " " " 5 %
. Espèce non significativement sensible
Le nombre des relevés est insuffisant pour conclure.

x Signification des classes

1 = 200 - 300 mm
2 = 300 - 400 mm
3 = 400 - 500 mm
4 = 500 - 600 mm
5 = 600 - 700 mm
6 = 700 - 800 mm
7 = 800 - 900 mm

The first two groups belong to the indicator plants of the Sierra Madre Occidental.

II. 3. 2. 3. Species indicating average annual rainfall (P)

Within the set of 351 samples, the following six groups can be identified (Table 20):

Indicator species of 200 ≤P < 300 millimetres

Nolina sp.

Indicator species of 300 ≤P < 400 millimeters:

Commelina dianthifolia *Pinus engelmannii*
Stevia serrata *Piptochaetium fimbriatum*
Bouteloua curtipendula *Rhus trilobata*
Quercus grisea.

Indicator species of 400 ≤P < 500 millimeters:

Yucca carnerosa *Bouvardia ternifolia*
Dasylirion sp. *Ipomoea stans.*

Indicator species of 500 ≤P < 600 millimeters:

Ipomoea capillacea *Pinus chihuahuana*
Cyperus sp. 2 *Cyperus* sp. 3
Helianthemum glomeratum *Cologania angustifolia*
Notholaena aurea.

Indicators species 600 ≤P < 700 millimeters:

Arctostaphylos pungens *Quercus chihuahuensis*
Microchloa kunthii *Rhus pachyrrhachis*
Pinus nelsonii.

Indicator species 800 ≤P < 900 millimeters:

Quercus a ffinis *Quercus sideroxyla*
Pinus teocote *Quercus obtusata.*

Pinus pseudostrobus is positively sensitive to P = 400 millimeters and P = 900 millimeters.

Pinus cembroides is indifferent to average rainfall between 300 and 700 millimeters on the one hand, and between 800 and 900 millimeters on the other. In the other two classes sampling is insufficient. The average annual rainfall is an inactive variable for this species.

The above results are confirmed by the analysis of the table of indexed corrected profiles established within the 185 samples.

TABLEAU 21 - Profils écologiques indicés des cinquante premières espèces classées sur signe pour la variable : pH du sol (nombre total de relevés = 185)

ESPECES	Fréquence	Information mutuelle en binons	classes	4	4,5	5	5,5	6	6,5	7	7,5	8
			effectifs	9	6	32	11	16	3	12	7	7
Cyperus sp.3	11	0.17120			+++			.				
Cyperus sp. 2	19	0.15478			+			.				
Gibasis linearis	13	0.15255			++							
Helianthemum glomeratum	15	0.13170			++	.						
Cologania sp.	11	0.12480			+							
Euphorbia sp.2	4	0.09899			+							
Pinus chihuahuana	22	0.15472			.	.	+					
Caryophyllacées	8	0.10370					++					
Croton sp.	6	0.18673							+	++		
Seymeria scabra	5	0.13749							+			
Quercus emoryi	10	0.10474							+			
Chrysactinia mexicana	18	0.22293								+++		
Nolina sp.	22	0.16924				.				+++		.
Dyssodia setifolia	10	0.16752				–				++		
Dasylirion sp.	16	0.16467								+		.
Verbena sp.	9	0.14730								+++		
Bouteloua curtipendula	22	0.13243				.				++		.
Erigeron sp.	15	0.12080				.				++		
Mimosa zygophylla	4	0.10220								++		
Pinus pinceana	4	0.10220								++		
Salvia ballotiflora	6	0.09666								+		
Viguiera sp.	6	0.09666								+		
Bouvardia ternifolia	32	0.19357				.	–	.		.	++	.
Parthenium incanum	7	0.15866									+++	
Gibasis karwinskiana	4	0.10253									+	
Yucca sp.	17	0.18524								.		
Quercus grisea	26	0.17706				.	.	.		–		
Lindleyella mexicana	12	0.15636								.		
Cyperus sp.	43	0.15380				.	.	.		.		–
Quercus hypoleucoides	19	0.15069				.		.				
Stevia serrata	25	0.14925				.	.	.				
Hedyotis sp.	7	0.11705										
Castilleja sp.	11	0.11658									.	
Commelina dianthifolia	16	0.11653				.		.				
Microchloa kunthii	12	0.11399				.						
Polygala sp.	17	0.11380			.	.		.		.		
Bromus sp.	10	0.11290										
Quercus sp.	27	0.11163			.	.		.		.		
Graminées	40	0.11087			.	.	.	.		.		
Acacia sp.	9	0.10986										
Muhlenbergia sp.	11	0.10857										
Rhus virens	11	0.10481										
Lycurus phleoides	23	0.10442				.		.				
Milla biflora	8	0.10426										
Arctostaphylos pungens	24	0.10288				.		.				
Bouteloua gracilis	32	0.10057		.		.	.	.		.		.
Salvia sp.	33	0.10029				.		.		.		
Pinus cembroides	77	0.09991			.	.					–	.
Polygala alba	11	0.09926				.					.	
Commelina sp.	13	0.09892						.				

+++ Espèce significativement sensible de façon positive au seuil de 1°/°°
++ " " " " " " " " " 1 %
+ " " " " " " " " " 5 %
--- Espèce significativement sensible de façon négative au seuil de 1°/°°
-- " " " " " " " " " 1 %
- " " " " " " " " " 5 %
. Espèce non significativement sensible

Le nombre des relevés est insuffisant pour conclure.

II. 3. 2. 4. Species indicating the defined climate, according to the Koeppen formula
These species are distributed based on the type of climate defined by the Koeppen formula:

Climate Indicator Species BSohwm:
Salvia regla *Bouteloua curtipendula*
Tradescantia crassifolia *Lotus oroboides*
Artemisia ludoviciana.
Climate Indicator Species BSohw':
Fraxinus greggii *Quercus canbyi*
Garrya ovata *Lesquerella purpurea*
Berberis trifoliata *Quercus cordifolia.*
BSok climate indicator species:
Quercus grisea *Quercus hypoleucoides*
Stevia serrata *Pinus engelmannii.*
Climate Indicator Species BSh:
Pinus nelsonii.
Climate indicator species BSkw (w):
Notholaena aurea *Asclepias linaria*
Dichondra argentea *Calochortus barbatus*
Dyschoriste linearis *Quercus eduardi*
Ipomoea stans.
Climate Indicator Species BSkw:
Arbutus xalapensis.
Climate indicator species C(wl) a:
Quercus affinis *Pinus pseudostrobus*
Pinus teocote.
Climate indicator species C(wl) s:
Arctostaphylos pungens *Gibasis linearis.*
Simultaneous indicator species for BSkw(w) and C(wl)s climates
Heliathemum glomeratum *Cyperus* sp 3
Ipomoea capillacea *Microchloa kunthii*
Pinus chihuahuana.
With the exception of Microchloa kunthii, the plants in this group are characteristic of a climate where average annual rainfall fluctuates between 400 and 600 millimeters.

Pinus cembroides is negatively sensitive to BWhwm and C(wl) a type of climate. It is also indifferent to BSo, BS and C(wo) climates.

Arctostaphylos pungens is positively sensitive to C(wl)s type of climate and negatively sensitive to BSohw type of climate. At the same time, it is also sensitive to average annual rainfall P between 600 and 700 mm and indifferent to other P values.

II. 3. 2. 5. Soil pH indicator species (Table 21)
Soil pH indicator species are divided into the following five groups:

Soil pH indicator species = 4.5:

Cyperus sp. 2 — *Gibasis linearis*
Cyperus sp. 3 — *Helianthemum glomeratum*

Species indicating pH = 5.5:

Pinus chihuahuana

Species indicating pH = 6.5:

Seymeria scabra — *Quercus emoryi*

pH=7 indicator species:

Chrysactinia mexicana — *Bouteloua curtipendula*
Nolina sp. — *Mimosa zygophylla*
Dyssodia setifolia — *Pinus pinceana*
Dasylirion sp. — *Salvia ballotiflora*

Especies indicadoras de pH = 7.5:

Bouvardia ternifolia — *Parthenium incanum*

To make a higher ranking, a complementary sampling is required. The different sensitivity of two related grasses should be noted: Bouteloua curtipendula and Bouteloua gracilis. The former behaved as positively sensitive to pH = 7, and indifferent to pH = 5 and 8. In contrast, Bouteloua gracilis is indifferent to these pH classes, as well as the others (Table 21).

II. 3. 2. 6. Altitude indicator species

Bouteloua curtipendula is a plant that is positively sensitive to the altitude classes between 1 200 and 2 000 metres, negatively sensitive to the altitude class of 2 500 metres and unresponsive to higher altitudes.
Pinus cembroides is insensitive to the 1 250 and 1 500 m classes, indifferent to the 2 000 and 2 500 m classes and positively sensitive to the 2 250 m class.
Stevia serrata and *Quercus grisea* (species of the Sierra Madre Occidental) are indicative of the 2,250 m class.
Arctostaphylos pungens, *Pinus chihuahuana* and *Quercus chihuahensis* are indifferent to the 2 250 m class, but positively sensitive to the 2 500 m class.

Arbustus xalapensis, although indifferent to the 1,700 to 2,500 m altitude classes is positively sensitive to the 2,750 and 2,850 m classes.

II. 3. 2. 7. Topographical indicator species
Pinus cembroides appears as a species insensitive to flat lands, on the contrary, this tree is indifferent to other classes (rounded top, high slope, medium slope, low slope).
Nolina sp. reacts in the same way as *Pinus cembroides* to topography.
As *Pinus chihuahuana*, it presents a positive sensitivity for flat land which is confirmed by its positive sensitivity to land with no slope.

II. 3. 2. 8. Indicator species of the first dominant species
Only the species indicating the formations of dominant *Pinus cembroides*, of dominant stone pines (other than *Pinus cembroides*), of dominant *Quercus pl. sp.* and of conifers, other than the dominant stone pines, shall be mentioned. The other dominant species that were grouped together (cf. II.1. 2.1.) are difficult to interpret.

Four groups of species are distinguished:

1. Species indicating Pinus cembroides formations:

Opuntia sp.
Yucca carnerosana
Dichondra argentea
Bouvardia ternifolia.
Quercus emoryi
Notholaena aurea
Bouteloua gracilis

2. Indicator species of pine tree formations other than Pinus cembroides

Euphorbia antisyphilitica
Agave lecheguilla
Brahea sp.
Krameria cytisoides
Gochnatia hypoleuca
Fouquieria splendens.
Dasylirion longissimum
Ptelea trifoliata
Mimosa zygophylla
Karwinskia humboldtiana
Agave atrovirens

3. Indicator species of Quercus pl. sp. dominant:

Garrya ovata.

4. Indicator species of conifers other than stone pines

Geranium sp.
Arbutus xalapensis
Lupinus sp.
Quercus sideroxyla
Philadelphus sp.
Ceanothus ferox

To these indicator plants we will add the plants common to two or more of the formations mentioned. For example: *Opuntia sp.*, *Yucca carnerosana*, *Dichondra argentea*, *Bouvardia ternifolia*, which are positively sensitive to *Pinus cembroides*, are indifferent to *Quercus pl. sp.*

Geranium sp. positively sensitive to conifers, is indifferent to *Pinus cembroides* and *Quercus pl. sp.*
Arctostaphylos pungens is indifferent to *Pinus cembroides*, *Quercus pl.* sp. and other conifers.

These results confirm the field observations: no species distinguish the formations of Pinus cembroides as dominant from those of *Quercus pl. sp.* as dominant.
These two formations are closely related and occupy identical environments.

It should be remembered that the groups of indicator species, established for the most active variables, are likely to occur within the study area and depend on sampling.

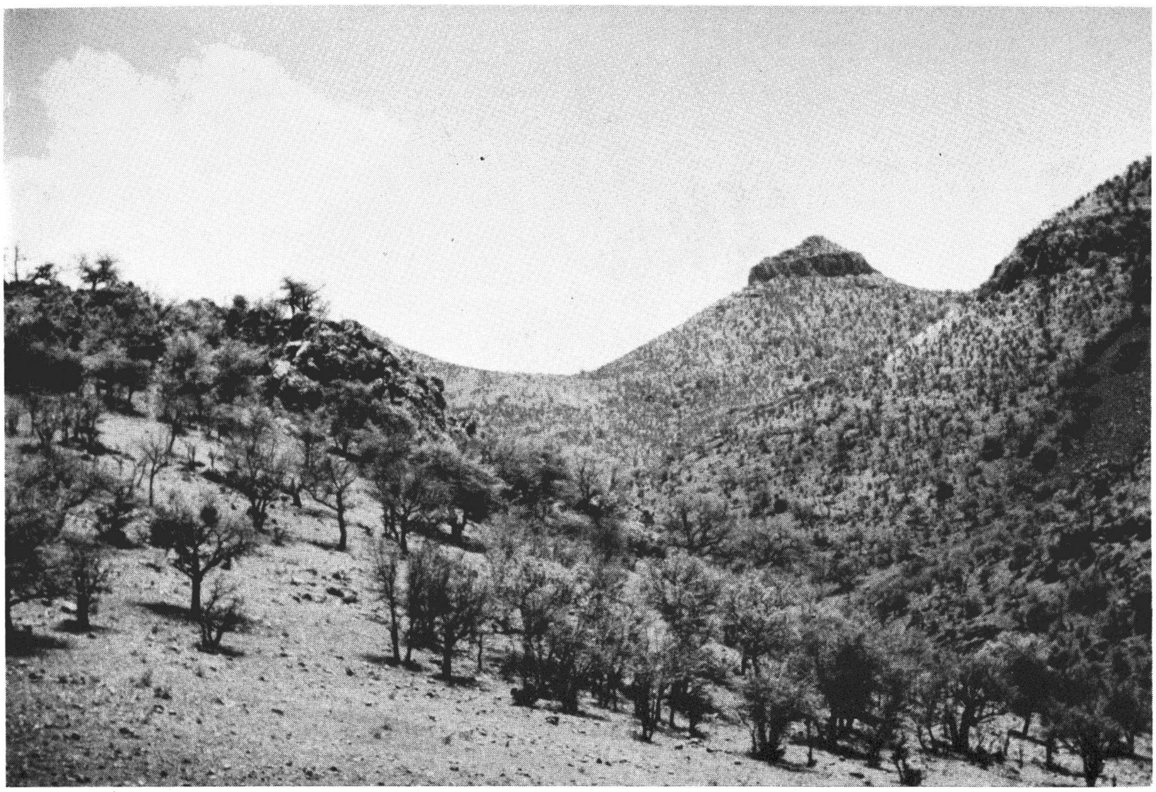
Figure 13 shows the preponderant role of the region variable, a situation that had already been perceived in the factor analysis. This observation leads to the analysis of the ecological profiles within the two Sierras.

II. 3. 3. Sierra Madre Occidental

II. 3. 3. 1. Indicator species for the geographical region

The eastern fringe of the Sierra Madre Occidental, where the observations are made, was divided into four regions: (1) north of 28° N; (2) located from 26° to 28° N; (3) from 24° to 26° N; (4) from 22° to 24° N.

Some plants are indicative of a region. The in-depth analysis in Table 18 shows that species strictly limited to one region are rare. Therefore, certain species behave this way in Table 18, the reason being that sampling is insufficient (*Calliandra humilis*, for example, is positively sensitive to region 1; but its response to the other regions is not known).



Low woody formation of *Quercus emoryi and Quercus grisea* 1 900 m altitude.
Road between Buenaventura and Ignacio Zaragoza (Chihuahua)

ESPECES	REGIONS			
	1	2	3	4
Quercus grisea	+++	+		
Quercus hypoleucoides	+++	+		
Rhus trilobata	+++	+		
Pinus engelmannii	+++	++		
Gibasis linearis	+	+++	+	
Quercus emoryi	+	+	+	
Microkloa kunthii		+	+	
Bouvardia ternifolia			+++	
Ipomoea stans			+++	
Cyperus sp.2		+	++	+++
Notholaena aurea		+	+++	+++
Ipomoea capillacea		+	+++	+++
Helianthemum glomeratum		+	+	+
Dichondra argentea		+	+	+
Mimosa biuncifera			++	+
Dyschoriste linearis			++	+
Calochortus barbatus			+	+++
Quercus eduardi				+++
Acacia schaffneri				++

+++ espèce très liée à la région
++ espèce liée à la région
+ espèce faiblement liée à la région

TABLE 22: Ecological profiles of some species for the region

Of the groups of indicator species mentioned in the previous paragraph, they will be presented here in a sequential manner (table 22), these are the species overlapping in “scales” (Godron, 1967; Daget et al., 1970).

11. Indicator species of *Pinus cembroides*

Among the indicator species of *Pinus cembroides* we distinguish a group of three that although they do not indicate with all certainty the presence of the mentioned species in many occasions they live in an environment suitable for this one, they are

Bouteloua gracilis *Dichondra argentea*
Garrya ovata.

II. 3. 4. Sierra Madre Oriental

II. 3. 4. 1. Indicator species for geographical regions
Sampling does not allow evidence of overlapping groups of scales, and only indicator species from each region can be proposed, which should be verified later.

In the east of the dition, those which were distinguished by five regions were numbered from 5 to 9.

Indicator species from region 5 (north of 28°N):

Linum sp. — *Artemisia ludoviciana*
Panicum bulbosum — *Lesquerella purpurea*
Quercus hypoleucoides — *Monarda citriodora*
Tradescantia crassifolia — *Muhlenbergia emersleyi*.

Region 6 indicator species (from 26 to 28°N)

Quercus canbyi

Region 7 indicator species (from 25 to 26°N)

Lindleyella mespiloides — *Quercus pringlei*
Dasylirion sp. — *Arctostaphylos pungens*
Quercus hypoxantha.

Region 8 indicator species (24 to 25°N) :

Yucca carnerosana

Region 9 indicator species (from 22 to 24°N)

Gymnosperma glutinosum — *Sophora secundiflora*
Quercus affinis.

II. 3. 4. 2. Indicator species of Pinus cembroides
To determine the indicator species of Pinus cembroides the indexed ecological profile was used, established for the variable "diameter of the trunks of Pinus cembroides".

The following group of indicator species of Pinus cembroides is individualized:

Yucca carnerosana — *Monarda citriodora*
Rhus virens — *Chenopodium graveolens*
Dyssodia setifolia — *Chrysactinia mexicana*

Bouteloua gracilis	*Bouteloua curtipendula*
Tradescantia crassifolia	*Dichondra argentea.*

Bouvardia ternifolia appears as a species indifferent to Pinus cembroides, even though it appeared as an indicator of the dominant formations of that plant in the set of 185 samples.

Conclusions

The ecological profiling method revealed groups of *Pinus cembroides* indicator plants whose composition differs in the east and west of the study area. These groups can be compared with the previously described cenological groups. A parallelism between these groups is established below within each Sierra Madre.

Western Sierra Madre:
Indicator species: Cenological group

Bouteloua gracilis	*Juniperus deppeana*
Dichondra argentea	*Salvia regla*
Garrya ovata	*Bouteloua hirsuta*
	Bouvardia ternifolia
	Ipomoea capillacea.

Sierra Madre Oriental:

Indicator species	Cenological group
Yucca carnerosana	*Juniperus deppeana*
Bouteloua curtipendula	*Bouteloua curtipendula*
Bouteloua gracilis	*Bouvardia ternifolia*
Rhus virens	
Dyssodia setifolia	
Opuntia sp.	
Chrysactinia mexicana	
Dichondra argentea	
Chenopodium graveolens	

The most frequent species in the woody formations of *Pinus cembroides* are part of either the indicator species groups or the cenological groups. Most of the species in one or other group are indicators of climatic factors, which are presented in Table 23.

TABLE 23. Indicator species for mean annual temperature (t) or mean annual rainfall (p)

ESPECIES	T ° C	P en mm
Stevia serrata	12-16	300-400
Juniperus deppeana	12-16	
Arctostaphylos pungens	12-16	600-700
Quercus grísea	14-16	300-400
Yucca carnerosana	16-18	400-500
Dasylirion sp.	16-18	200-300
Nolina sp.	16-18	200-300
Sophora secundiflora	18-20	
Bouteloua curtipendula	18-20	300-400

Rhus virens	16-20	
Rhus trilobata		300-400
Bouvardia ternifolia		400-500
Ipomoea capillacea		500-600
Cyperus sp. 2		500-600
Cyperus sp. 3.		500-600

Soil surface horizon pH indicator species:

Cyperus sp. 2	pH = 4,5
Cyperus sp. 3	pH = 4,5
Chrysactinia mexicana	pH = 7
Nolina sp.	pH = 7
Dyssodia setifolia	pH = 7
Dasylirion sp.	pH = 7
Bouteloua curtipendula	pH = 7
Bouvardia ternifolia	pH = 7.5
Parthenium incanum	pH = 7.5

The ecological profile method confirms the predominant role of two closely related variables: geographical regions and climate variables. The groups of indicator species that have become evident do not conflict with the previously determined cenological groups, providing further information. It should be added that the results of the two treatment methods are only probable for the study conditions described in this text.
Factorial analysis and the ecological profile method complement each other; the former provides a global perspective of factors, species and observations, while the latter associates each species with each class of variable, provided that sampling allows for it.

II. 4. Species mapping

From the 351 samples, the distribution masses of the species found in the *Pinus cembroides* formations, or in the neighbouring woody formations, were elaborated. Most of the mapped plants are woody.

The observation of the charts allows the species to be distributed in the five groups indicated below:
1. Species with a wide distribution in Mexico.
2. Species located in the Sierra Madre Occidental and the mountainous massifs of the southern Central Altiplano.
3. Species located in the Sierra Madre Oriental.
4. Species found in northern Mexico.
5. Species limited to the south of the study area.

II. 4. 1. Wide-ranging taxa

Woody species:

Arbutus xalapensis	*Juniperus deppeana*
Arctostaphylos pungens	*Juniperus flaccida*
Bouvardia ternifolia	*Mimosa biuncifera*
Cercocarpus montanus	*Quercus intricata*

Garrya ovata *Salvia regla*.

Herbaceous species:

Dichondra argentea *Lycurus phleoides*,

as well as the genera Cyperus, Dalea and Oxalis.

II. 4. 2. Species located in the Sierra Madre Occidental and in the southern mountainous massifs of the Central Highlands

Woody species:

Ipomoea capillacea *Quercus chihuahuensis*

Ipomoea stans

Especies herbáceas:

Gibasis linearis *Helianthemum glomeratum*.

II. 4. 3. Taxa located in the Sierra Madre Oriental

Woody species:

Berberis trifoliata *Pinus nelsonii*

Cowania plicata *Pinus pinceana*

Fraxinus greggii *Sophora secundiflora*

Lindleyella mespiloides.

Herbaceous species:

Chrysactinia mexicana *Notholaena parviflora*

Dyssodia setifolia *Parthenium incanum*

Gymnosperma glutinosum.

As well as the Croton genus.

II. 4. 4. Species located in Northern Mexico

Woody species:

Quercus hypoleucoides *Rhus trilobata*.

Herbaceous species:

Dyschoriste linearis *Piptochaetium fimbriatum*.

II. 4. 5. Species located south of the dition

Woody species:

Amelanchier denticulata *Quercus potosina*

Dodonaea viscosa *Rhus pachyrrhachis*.

Herbaceous species:

Ageratum corymbosum.

Although this information is not definitive, it is of great interest, since the five determined groups cover some of the floristic provinces proposed by Rzedowski in 1972. In this respect, it is necessary to recall here some features of the Mexican flora.

The floristic richness of Mexico is largely due to the current geographical and climatic conditions, as well as to the numerous migrations of species of holoartic and tropical origin, which have taken place in the course of previous geological eras. (SHARP, 1953;

Dressler, 1954; Rzedowski, 1978). In addition, Mexico has been identified as an important center for the evolution of flora since the Tertiary and Quaternary periods (Hemsley, 1897-1888; Rzedowski, 1965, 1972, 1978), which explains the presence of numerous endemics.
In 1972 Rzedowski, distinguished 17 floristic provinces grouped in four regions, which are: North American Pacific, Mesoamerican mountainous, Mexican xerophytic and Caribbean.
The Mesoamerican mountainous region includes, in particular, the Sierra Madre Oriental and Occidental. The Central Highlands are included in the Mexican xerophytic region. The five taxon groups described above occupy a place either in the Mesoamerican mountainous region or in the Mexican xerophytic region.
The Mesoamerican mountainous region belongs to both the holoarctic and neotropical floristic groups, whose boundaries are not defined (Rzedowski, 1965). This author indicated in 1978 that the Mexican xerophytic region is contained in the neotropical floristic group.
Among the taxa of holoarctic origin there are some common taxa to Mexico and to the south of the United States, such is the case of *Arbutus*, *Arctostaphylos*, *Bouvardia*, *Cercocarpus*, *Cyperus, Fraxinus, Garrya, Juniperus* and *Oxalis*. In 1978, Rzedowski considered that some genera, such as *Eupatorium, Muhlenbergia, Quercus, Salvia, Senecio* and *Stevia* “have, in the Mesoamerican mountainous area, an important centre of differentiation”. For his part, Puig in 1974, interpreted Amelanchier denticulata and *Juniperus flaccida* as Mexican holoarctic species.

The tropical floristic group includes:
- Pantropical taxa, that is, those belonging to the tropical regions of the world: Croton, Dodonaea, Mimosa and Rhus.
- Neotropical taxa found in the warm zones of South and North America: *Calliandra* and *Dyssodia*.

The third floristic element is endemic to the arid and semi-arid zone which includes *Dasylirion, Fouquieria splendens, Parthenium incanum, Yucca carnerosana* (Rzedowski, 1973).

The groups II. 4. 1., II. 4. 2 . et II. 4. 4. comprising the wide-ranging taxa, the species located in the Sierra Madre Occidental, as well as in the mountainous massifs of the southern Central Altiplano and the species located in northern Mexico, include species common to Mexico and the southern United States (with the exception of Juniperus flaccida, which is a Mexican holoarctic element).

Group II. 4. 5. represented by the species located south of the dition associates both Mexican holoarctic species such as Amelanchier denticulata, *Quercus potosina*, *Rhus pachyrrhachis* and a species of neotropical origin: *Dodonaea viscosa*.

Finally the group II. 4. 3. located in the Sierra Madre Oriental, includes:
- Mexican holoarctic taxa: *Fraxinus greggii*, *Pinus nelsonii*, *Pinus pinceana*.
- A taxon of pantropical origin: Croton (Rzedowski, 1959).
- Taxa limited to the Mexican arid and semi-arid zone: *Cowania, Gymnosperma,*

Lindleyella, Parthenium (Rzedowski, 1959).

All the floristic influences listed above are therefore within the group of taxa located in the Sierra Madre Oriental. This brief essay shows what information theory can provide to the chorological study of Mexican flora.

It should be noted that both in the cenological groups and within the indicator species of *Pinus cembroides*, there appear taxa that have a wide distribution; among the latter, Arctostaphylos pungens seems interesting, since it is rare in the formations of *Pinus cembroides* in eastern Mexico, but it is associated with the higher formations of *Pinus pl. sp*. A more detailed study of the distribution of the species will help to understand the origin of the formations of *Pinus cembroides* and to improve the knowledge of the migration of the species in Mexico.

CHAPTER III

PINUS CEMBROIDES FORMATIONS

This chapter will review the distribution of *Pinus cembroides* formations, their climate, boundaries and dynamics.

III. 1. DISTRIBUTION OF *PINUS CEMBROIDES* FORMATIONS

Critchfield and Little in 1966, produced a distribution chart for *Pinus cembroides*, which is reproduced in Figure 14. Comparing this chart with the one drawn up for the arid zones by Miranda in 1965, it can be seen that *Pinus cembroides* is located at the limits of the arid zones (Figure 15), or on the isolated mountain massifs located within them. This species is absent in the limits of the arid zones of Guerrero and Tepehuanes, as well as in the limit of the Yucatecan zone.

The charts drawn up by the National Institute of Forestry Research (INIF), as well

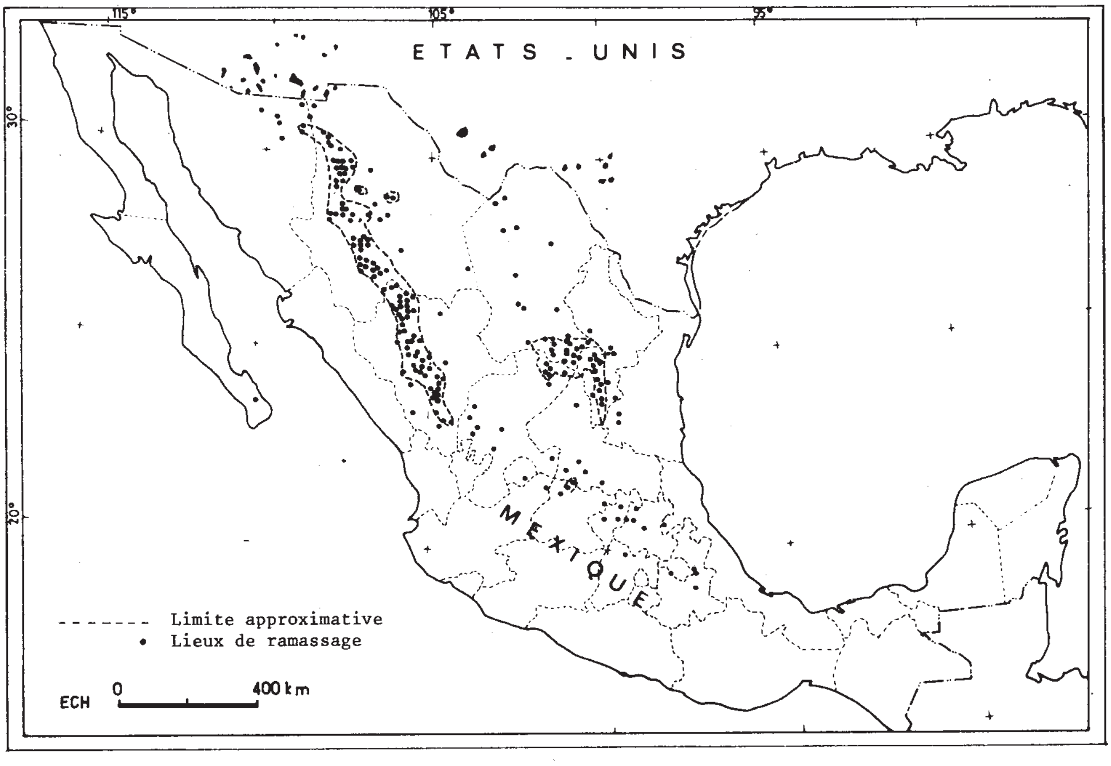


Fig. 14 - Distribución de *Pinus cembroides* en México, según Critchfield y Little, 1966, completado y modificado por M.-F. Robert-Passini.
---- Límite aproximativo • Lugares de colectas

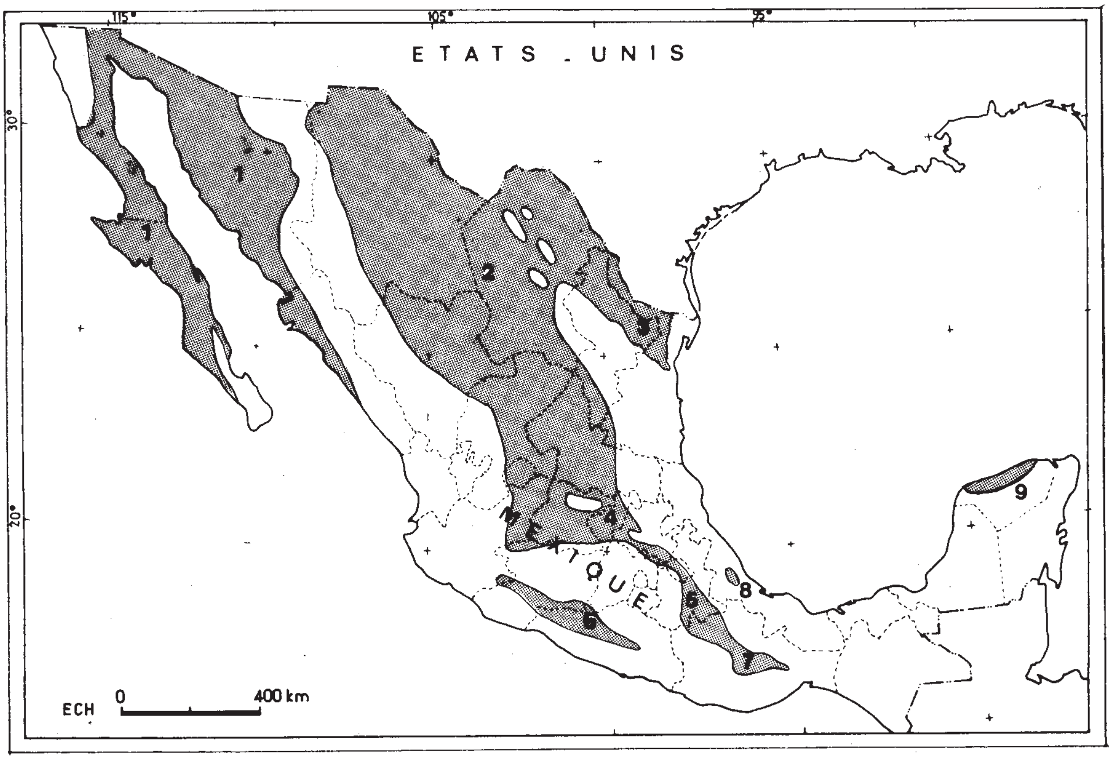


Fig. 15 - Drylands in Mexico according to Miranda, 1965 :
1. Sonoran; 2. Chihuahuan; 3. 4. Hidalguense; 5.
Poblana, 7. Tehuantepeca; 8. Veracruzana; 9.

as the field notes of that institution, were used for the west and east of the study area. In addition, a synthesis was made of the 1/50,000 scale maps published by the National Territorial Studies Commission (CETENAL).

III. 1. 1. Sierra Madre Occidental

The species *Pinus cembroides* occupies an almost continuous strip from Nuevo Casas Grandes to the south of the State of Durango (Figure 16), which extends to the State of Zacatecas and deviates towards the east, becoming fragmented (Figure 14).

The eastern limit of this strip, which is very irregular, overlaps with low formations of oaks (Lesueur, 1945), with meadows of *Bouteloua gracilis* and other grasses (Shreve, 1939; Hernández, X. E. 1959) or with areas dedicated to agricultural crops.

In contrast, the western boundary is fairly regular and follows the main curvature of the eruptive massif of the Sierra Madre Occidental. In this limit the formations of *Pinus cembroides* meet the forests of *Pinus pl. sp*. Among the most frequent species are *Pinus engelmannii*, *Pinus chihuahuana*, *Pinus durangensis* var. *quinquefolia*, *Pinus arizonica* and *Pinus ayacahuite*. Between 2,400 and 2,500 meters of altitude, in the humid parts of the Sierra, the genera *Pseudotsuga*, *Abies* and *Picea* are present. In some places, it is notorious the interface between the forest of *Pinus pl. sp*. and the formation of *Pinus cembroides* that is characterized by the presence of a small number of the species of

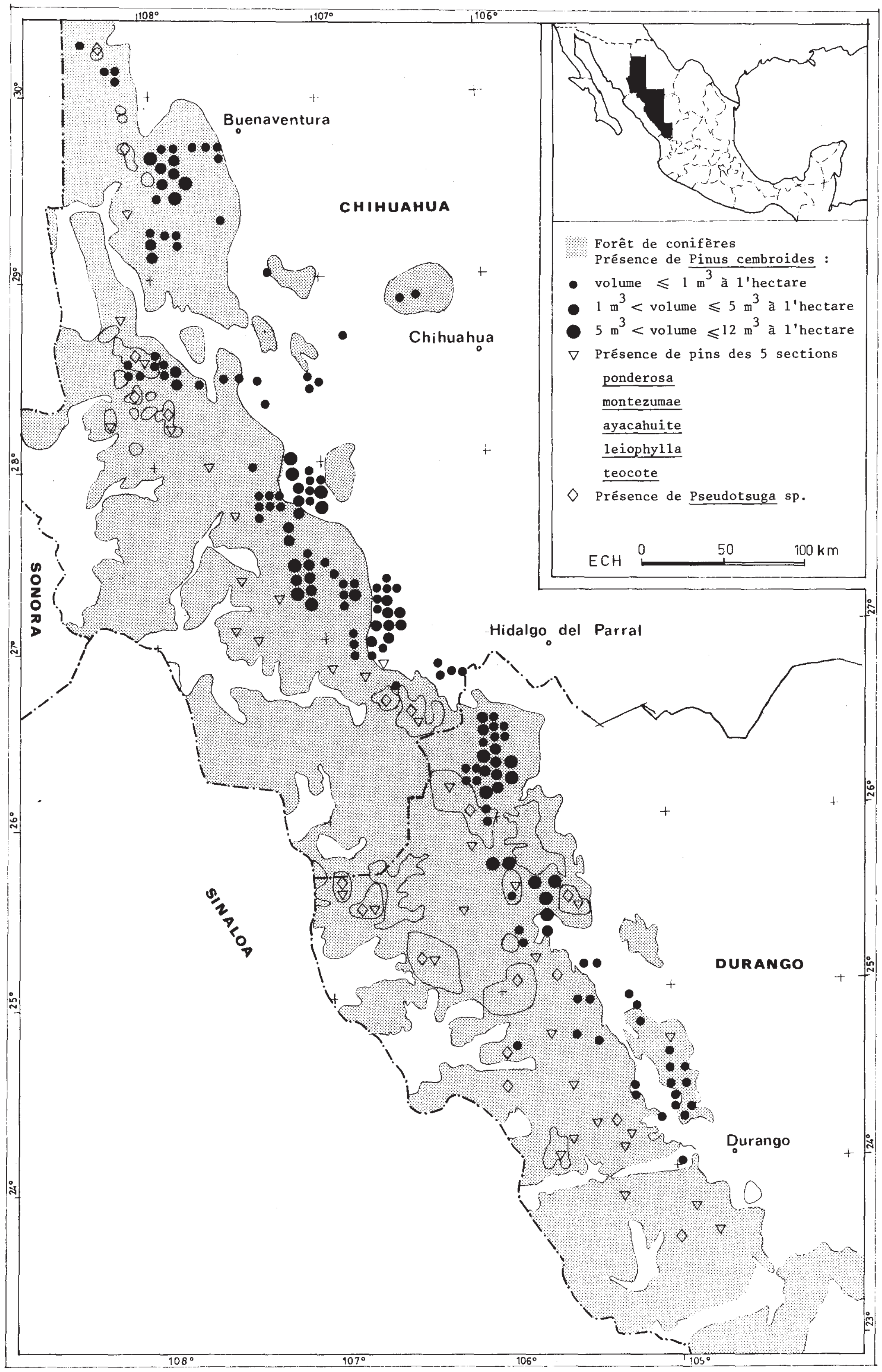


Fig. 16. Distribution map of Pinus cembroides in the Sierra Madre Occidental made by the author based on the forest maps of the States of Chihuahua and Durango, I.N.I.F., 1964.

interest within a formation of *Pinus pl. sp.*, or by the presence of some *Pinus pl. sp.* within the formation where *P. cembroides* dominates. This interface is deeply modified by human action. The human pressure exerted since the 16th century, in the vicinity of the mining cities (Zacatecas, Hidalgo del Parral, Chihuahua and Santiago Papasquiaro, Michoacán..., Bakewell, 1971), since the end of the 19th century in the interior of the Sierra, especially during the construction of the Topolobambo-La Junta railroad, is currently intensifying. Indeed, the construction of roads in the Sierra Madre Occidental facilitates the exploitation of the forest.

Figure 16 shows that the western limit of the *Pinus cembroides* formations corresponds to a climatic limit, an aspect that will be specified later.

III. 1. 2. Sierra Madre Oriental

In the north of the State of Coahuila, the formations of *Pinus cembroides* are found in isolated mountainous massifs (Sierra Santa Fe del Pino, Sierra Madera del Carmen, among others). The map of Critchfield and Little cannot be given accuracy (Figure 14). However, a map of the *Pinus cembroides* formations in the Monterrey mountain range was made (Figure 17). These formations extend along the folds of the eastern Sierra Madre, constituting an important nucleus north of Galeana, Nuevo Leon.

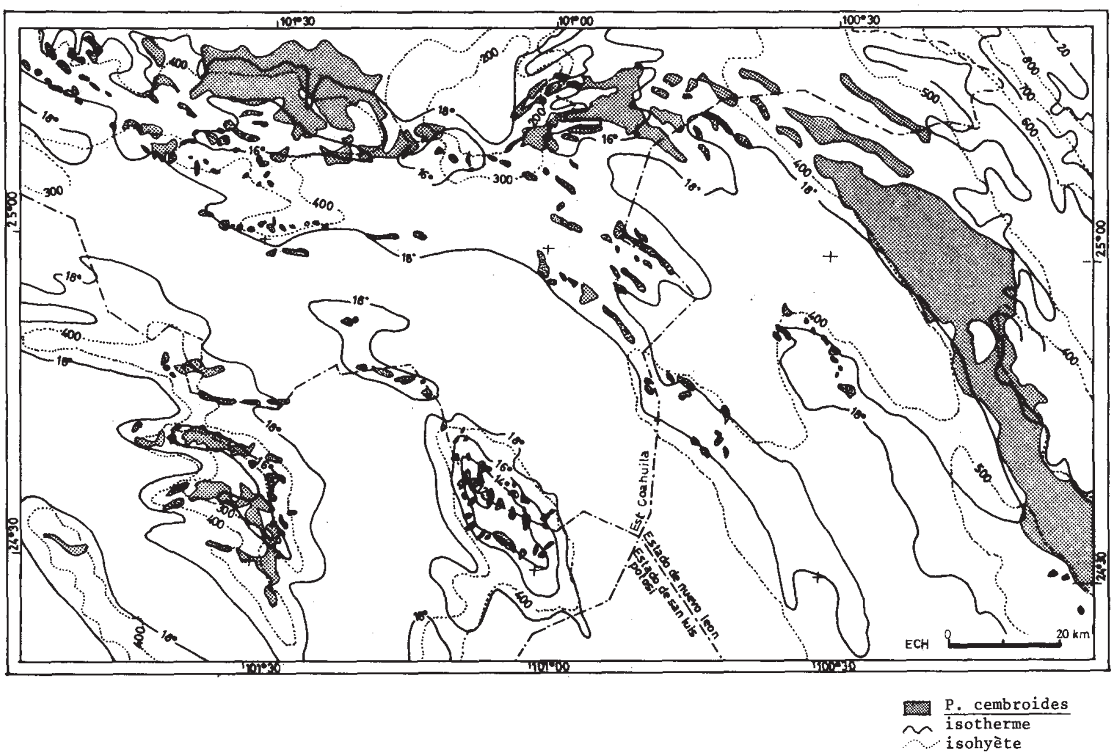


Fig. 17- Distribution map of Pinus cembroides in Sierra Madre Oriental, at the border of the States of Coahuila, Nuevo León, San Luis Potosí and Zacatecas

Adjacent formations consisting of *Pinus pl. sp.* forests, low formations of oaks, crops and various thickets, are very varied, and are not mentioned in the map of Figure 17. On the other hand, human pressure has been greater in this area than in the Sierra Madre Occidental and often causes the disappearance of the primary lower and upper limits (as will be seen below). Figure 17 shows the isotherms and isohyetes; a coincidence between these and the Pinus cembroides cover is evident.

The observation of the distribution of *Pinus cembroides* in the Sierra Madre Occidental leads us to try to define the climate supported by the formations of this species.

III. 2. BIOCLIMATE OF PINUS CEMBROIDES FORMATIONS

The Köppen climate classification used in the previous chapter is not used here. It should be mentioned that *Pinus cembroides* appeared indiscriminately in the climates BSo, Bs and C(wo) and behaves as a species negatively sensitive to climates of type BWhwm and C(w) a, which prevents the formation of a clear idea of the climatic conditions that correspond to it.

III. 2. 1. General

Weather stations located within or near *Pinus cembroides* formations are rare; Table 24 shows the data recorded at these stations. There are two groups of stations: one with an annual temperature range above 10°C and the other with a temperature range below 10°C.
Average ombric conditions vary from 266 (Ramos Arizpe) to 580 millimeters (Mazapil). When locating the area occupied by *Pinus cembroides* in the climatic maps of Mexico, the following data were required.

III. 2. 1. 1. Thermal conditions
In climate maps on a scale of 1/500 000 (E. Garcia, 1971), of which Figure 17 gives an example, it can be seen that Pinus cembroides is subject to average annual temperatures of between 12 and 18°C. The hottest month is often June, and may be May or July. The coldest month may be December or January.
In the States of Chihuahua and Durango, the average temperatures of the coldest month are below 10°C and the number of days with frost is above 100. In contrast, the average temperatures of the coldest month are above 10°C (at an altitude below 2,500 meters) in the States of Coahuila, Nuevo León, San Luis Potosí, Hidalgo, Querétaro and Baja California Sur. The number of days with frost, in the mentioned States, is less than 100.

The annual thermal amplitude, which is the difference between the average temperature of the hottest month and that of the coldest month, decreases towards the south. The map drawn by Maull in 1936 indicates the existence of a sinuous line (Figure 18), near the Tropic of Cancer, to the south of which the annual thermal amplitude is equal to or less than 10°C. North of this line, on the contrary, the annual thermal amplitude is greater than 10°C. Paffen (Figure 18), drew a line where the annual thermal amplitude is equal to the daily thermal amplitude, this second line is located slightly north of the previous one. The high diurnal thermal variations have effects on the physiological rhythm of plants.

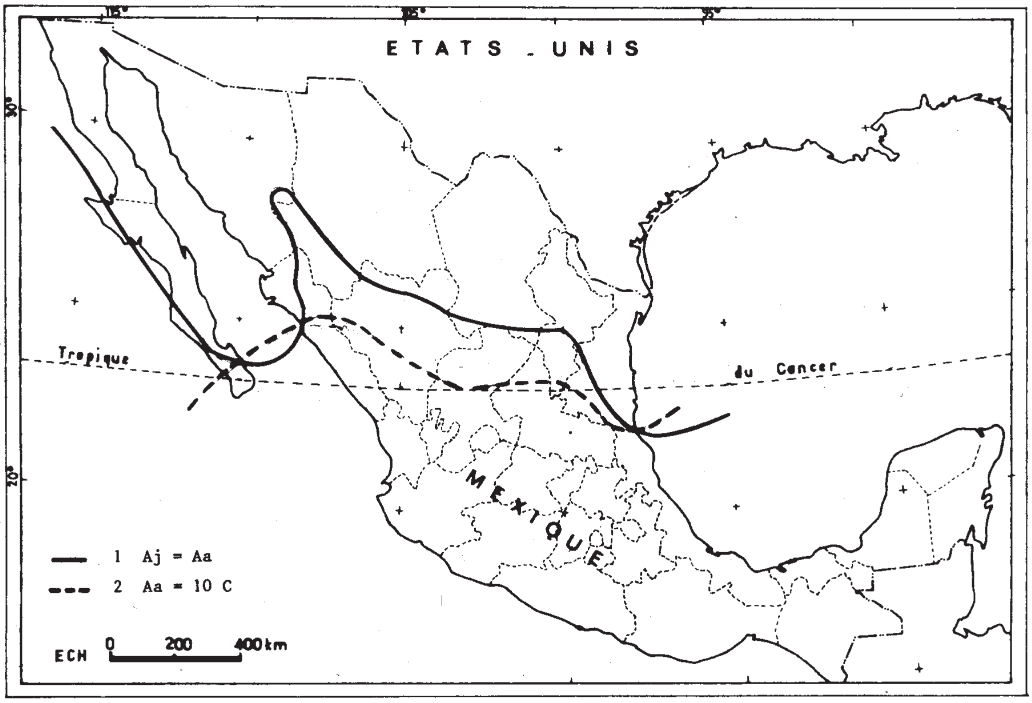


Fig. 18 - Geographical distribution of the daily and annual thermal amplitude according to Lauer, 1973
1. daily temperature range Aj = annual temperature range Aa
2. annual temperature range Aa = 10°C

This allows us to distinguish the following types of formations:

1. Formations of *Pinus cembroides* subject to an annual temperature range of more than 10°C, in the States of Coahuila, Chihuahua, Durango and Baja California Sur.

2. Pinus cembroides formations subject to an annual thermal amplitude lower than 10°C in the States of San Luis Potosi, Guanajuato, Queretaro, Hidalgo, Veracruz and Puebla.

III. 2. 1. 2. Ornamental conditions
The formations of Pinus cembroides are located in the area where the average annual rainfall is between 300 and 700 millimeters (Figure 17). Rainfall occurs in summer and early fall, with the exception of the northern part of the Baja California Peninsula, which receives more than 36 percent of total annual rainfall, during the winter (E. Garcia, 1969).

TABLE 24. Data from seasons near Pinus cembroides forests (UNAM, 1973)

ESTACIONES	Latitud	Longitud	Altitud (metros)	TEMPERATURA				PRECIPITACION		I
				Mf	M	Mc	Mc-Mf	P (mm)	No. meses secos	
La Junta (Chihuahua)	28°28’	107°20’	2 060	8,5	16,8	24,5	16	474	8	18
Cuauhtémoc (Chihuahua)	28°25’	106°51’	2 210	8,9	15,6	23,1	14,2	398	8	16
Carichic (Chihuahua)	27°56’	107°08’	2 038	6,5	13,7	20,6	14,1	509	3	21
Tepehuanes (Durango)	25°22’	105°42’	1 788	9,4	16	22,5	13,1	484	7	18
Santiago Papasquiaro (Durango)	25°02’	105°26’	1 720	11,2	17,6	23,5	12,3	468	8	17
Ramos Arizpe (Coahuila)	25°33’	100°58’	1 399	11,6	17,9	23	11,4	266	11	9
Mazapil (Zacatecas)	24°39’	101°34’	2 250	11,8	17,2	21,7	9,9	580	4	21
Mexquitic (San Luis Potosí)	22°17’	101°06’	2 062	14,8	18,3	21,4	6,6	360	8	13
Zimapan (Hidalgo)	20°44’	99°23’	1 720	16,6	20,2	22,1	5,5	391	9	13

Mf °C Average temperature of the coldest month
M °C Average annual temperature
Mc °C Average temperature of the hottest month
Mc-Mf Annual thermal amplitude
P mm Average annual rainfall
I Index of MARTONNE
x According to BAGNOULS and GAUSSEN

Northern Mexico is subject to frequent rainfall irregularities (Fritts, 1955; Jauregui and Klaus, 1976). Years with high rainfall coincide with intense cyclonic activity in the northern hemisphere (Jauregui, 1972).
The information given below will try to situate the formations of *Pinus cembroides* in relation to the other plant formations.

III. 2. 2. Sierra Madre Occidental

Despite the fact that the state division is very artificial for a climate study, it was the one that was adopted, as the most available data are obtained in the states.

III. 2. 2. 1. Bioclimatic study of the State of Chihuahua
The network of weather stations in the State of Chihuahua is quite dense; they depend on one of the three following services: Meteorological Service of the State of Chihuahua, General Direction of the National Meteorological Service, and Regional Union of Cattlemen. In 1974, A. Alvárez published detailed data from 15 years of observation, grouping the state’s stations in the following climatic regions: mountainous, border, central and southern.

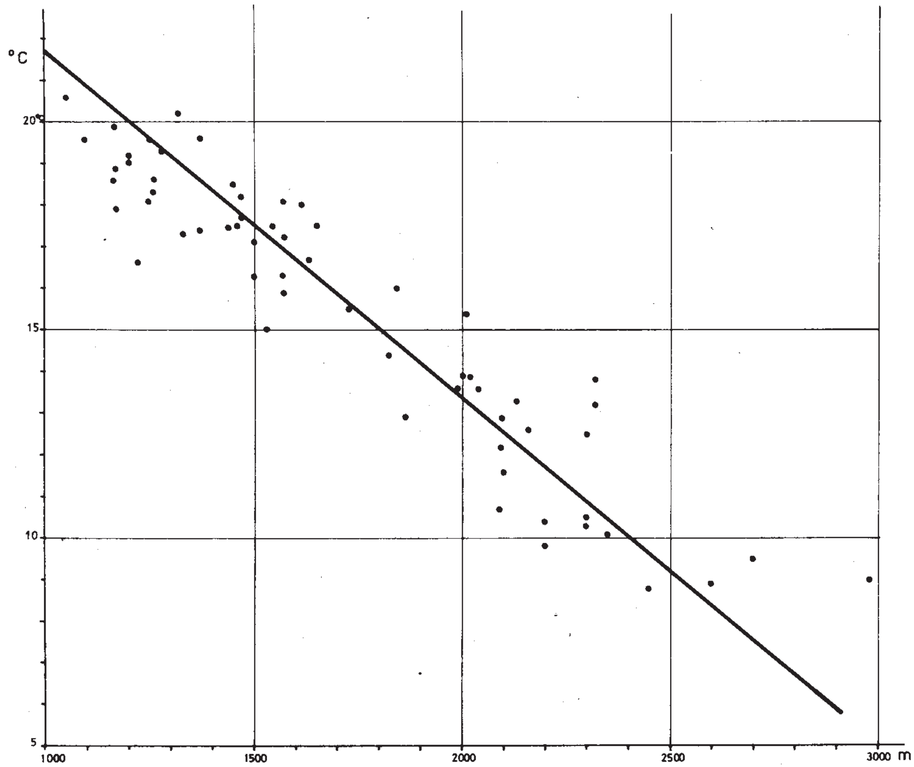


Fig. 19 - Correlación gráfica entre la tempertura media anual y la altitud a base de datos de las estaciones de la Sierra Madre Occidental entre el 25°N y el 32°N

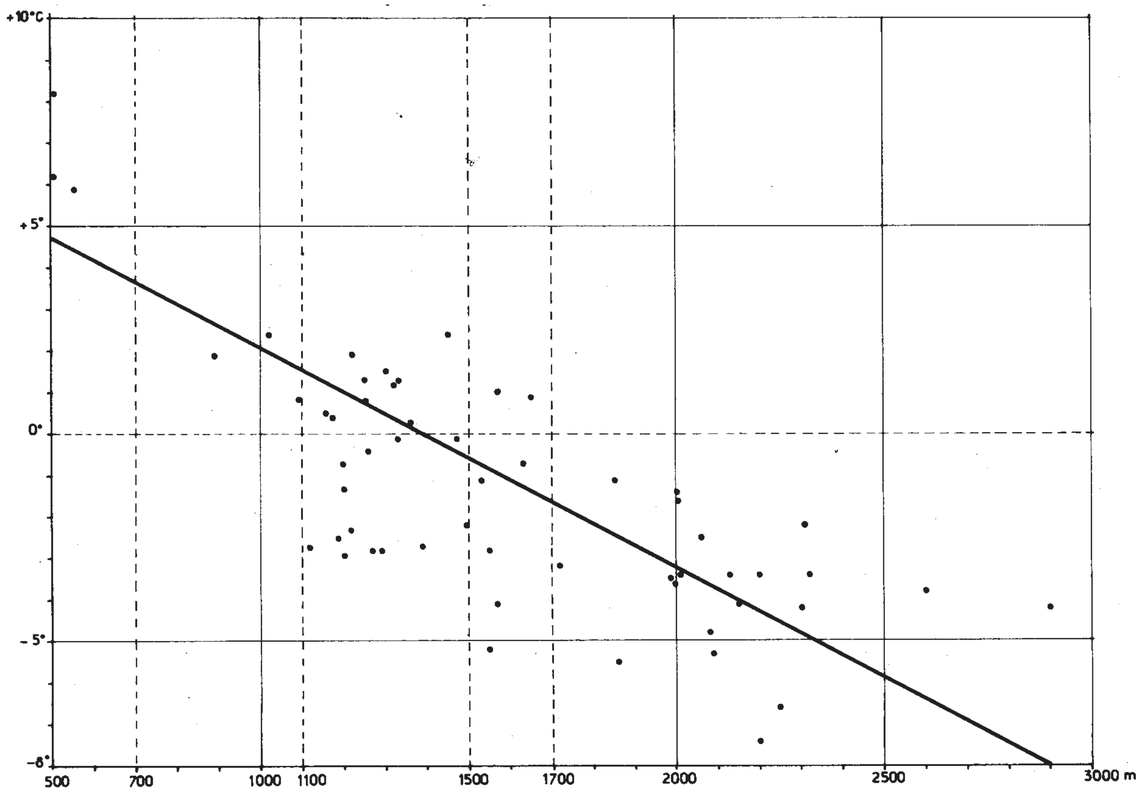


Fig. 20 - Distribution of mf as a function of altitude
mf: average minimum temperatures of the coldest month

The mountainous region includes the stations of the Sierra Madre Occidental, located at altitudes above 1 600 meters. Annual rainfall exceeds 500 millimetres. The border region, arid and semi-arid, is characterized by low and irregular rainfall, in the order of 200 to 300 millimeters per year. Thermal oscillations are very marked. Altitudes vary between 800 and 1 500 meters. The central and southern region of the State has an altitude varying between 1 000 and 1 600 meters and receives an annual rainfall of 250 to 400 millimeters. A detailed analysis of the climatic characteristics of all the stations in the State will make it possible to specify the data for the climatic regions.
The data available for the stations are as follows

- average annual temperatures,
- average maximum temperatures of the hottest month (Mc),
- average minimum temperatures of the coldest month (Mf),
- date of first and last frost, number of frost-free days,
- rainfall, number of days without rain.

III. 2. 2. 1. 1. Temperature

III. 2. 2. 1. 1. Average temperature

Average annual temperatures vary from 10 to 22°C; in the annual isotherms there is a NO-SE direction band, where the average annual temperature ranges from 10 to 12°C. This orientation corresponds to the area of the valleys and ridges located in the center and east of the Sierra Madre Occidental. To the NE and SW of this band, the annual average temperatures are higher than 12°C. The hottest month is June or July, while December and January are the coldest months. In Batopilas, Chinipas and Urique, places located at 500 meters of altitude, the average temperature of the coldest month is above 14°C. In the cities of Camargo and Jimenez it is 10°C. In many mountain resorts it is less than 10°C.

In the Sierra Romurachic, to Guachochic, Guadalupe y Calvo, Ciudad Madera and Majalca, the average temperature of the hottest month is less than 20°C. In Ciudad Ojinaga, Batopilas and Chinipas, they are above 30°C. In the other seasons considered, the average temperatures are between 20 and 30°C.

III. 2. 2. 1. 1. 2. Thermal gradient

The thermal gradient that was established, using data from the stations in the center of the State and the eastern slope of the Sierra Madre Occidental (Figure 19), is 0.70°C for every 100 meters between 1,000 and 2,500 meters of altitude. At 2,700 meters the average annual temperature would be 7.5°C.
This gradient has a value close to that calculated for the leeward slope of the Sierra Madre Oriental, between 25° 30' and 23° 27' N, which was 0.80°C for every 100 meters (M.-F. Robert, 1973). In contrast, the thermal gradient observed in the central highlands and in the leeward slope of the Sierra Madre Oriental, between 22° 36' and 21° 20' N, was only 0.5°C for every 100 meters (M.-F. Robert, 1973); a value that is very close to that found by Rzedowski in 1965, in the State of San Luis Potosí, and which corresponded to 0.40°C for every 100 meters.
According to the thermal gradient, the decrease in temperature due to an increase of 100 meters in altitude is greater in the north of the Tropic of Cancer than in the south, both in the central highlands and in the leeward slopes of the Eastern and Western Sierras Madres. The thermal gradient of the Sierra Madre Occidental is 0.70°C in January and 0.90 in

July (Figure 21). This means that the temperature decreases more sharply as the altitude increases, in summer (rather wet season) than in winter (dry season).
This result agrees with those obtained in 1974 by Puig, who found that the average monthly gradient in the Huasteca is low during the dry season - 0.30° to 0.40°C - and higher - 0.60° to 0.80°C - during the rainy season. For this author, "variations in the monthly thermal gradient are influenced by the relative abundance of precipitation in the rainy season, which causes a decrease in temperature.
In 1973, Lauer pointed out this phenomenon in the region of Puebla, where the January gradient is 0.30°C for every 100 meters and the July gradient is 0.50°C for every 100 meters. According to Lauer, the increase in the thermal gradient could explain why the boreal species descend to low altitudes, while the tropical species reach higher altitudes. This hypothesis should be kept in mind since it can be applied in the study area.

III.2.2.1.1.3. Thermal amplitude
In the stations of the south of the state, the annual thermal amplitude (difference between the average temperature of the hottest month and the coldest month) is 11 to 12°C. In all other places it is over 14°C; in Ojinaga it reaches 31°C. This is in accordance with the studies carried out by Maull in 1936, for Mexico (Figure 18). South of the Tropic of Cancer the annual temperature range is less than or equal to 10°C.
In Figure 18, it is shown that the annual thermal amplitude is equal to the daily thermal amplitude in a large part of Mexico. However, daily values of minimum and maximum temperatures are not available, but the extreme monthly thermal amplitude provides an approximate value of the daily thermal amplitude. The extreme monthly thermal amplitude, which is the difference between the average minimum monthly temperature (m) and the average monthly temperature (M), in the six stations of the State of Chihuahua, varies from 13 to 22.5°C.

In Chinipas, located on the western slope of the mountainous region, the extreme monthly thermal amplitude is greater in March and April (15.6°C), it presents a decrease in July, August and September, months during which it is less than 10°C. In that locality, the maximum extreme thermal amplitude is equal to the annual thermal amplitude.
In Carichic, the extreme thermal amplitude is greater than in Chinipas, since it reaches 20.4°C in December and presents a decrease in the months of July, August and September. The extreme thermal amplitude of these summer months is equal to the annual thermal amplitude. The same happens in the towns of Rancho Las Varas and Hidalgo del Parral; the maximum extreme thermal amplitude is reached in December, when it is 18°C.
In the stations of the border region, the extreme thermal amplitude is high, reaching 22.5°C in Samalayuca; the decrease of the extreme thermal amplitude during the summer months is notorious in Ciudad Juárez, but although it is lower, it is observed in Samalayuca. In Ciudad Juárez, the annual thermal amplitude is greater than the extreme amplitude, 22°C instead of 20°C, the maximum value reached by the monthly thermal oscillation.
Therefore, during the dry season plants are subjected to very marked daily thermal variations.
The minimum temperatures are then determined.
III. 2. 2. 1. 1. 4. Minimum temperatures
Figure 20 shows the distribution of the average minimum temperatures of the coldest

month (mf), as a function of altitude. Below 700 meters of altitude, mf is positive and above 5°C. From 700 to 1 100 meters in altitude, mf varies from 0 to 3°C. Between 1 100 and 1 500 meters mf ranges from -3 to 3°C. Finally, at altitudes above 1 500 meters mf it is negative. When ascending 100 meters mf it decreases by 0.50°C, which is lower than the thermal gradient calculated above for average temperatures.

In figure 20 we distinguish, according to the average of the minimum temperatures of the coldest month, three thermal substages with cold, cool or mild winter.

- mild winter mf ≥ 5°C
- cool winter 0 ≤ mf < 5°C
- cold winter mf < 0° C

The notion of thermal limit was proposed by Emberger in 1955 and 1966, but with different values for the Mediterranean climate. All the seasons with mild winter are on the wind exposed slope of the Sierra Madre Occidental and at 500 meters of altitude. The stations of the Sierra Madre Occidental and the Western Central Highlands are characterized by generating data corresponding to cold winters. The stations with fresh winter data are unevenly distributed in the border and central regions. The number of days with frost is not very important according to the records of the stations classified as mild winter. Thus, in Batopilas, the average number of frost days is fifty per year, and the absolute minimum temperature observed is -7°C. It is also known that the number of frost days increases with altitude, which is not characteristic of western Mexico.
Absolute minimum temperatures can reach -26°C (San José Babicora, 2 250 meters of altitude).
The extreme negative temperatures are due to the invasion of continental polar air, generally dry, from Canada and the United States of America, (Mosiño Aleman, 1966). The northern air masses are accompanied by north and northwest winds called “nortes”, which are violent winds that blow between November and March. Hill in 1969, showed that the passage of the cold front causes, in a few hours, a decrease in temperature of 5°C or more. The high values of the daily thermal amplitude, in winter, are due, in part, to the “nortes”. It is these winds that lower the lower limit of frost to 500 meters. The resulting extreme minimum temperatures have a negative influence on seedlings and young plants of tree and shrub species.

III. 2. 2.1. 2. Rainfall measurement

III. 2. 2. 1. 2. 1. Annual rainfall

The observation of the chart of the isoyets, elaborated by A. Alvarez, shows that the precipitations increase from east to west. In the border region, average annual rainfall is between 210 and 370 millimeters. Rainfall occurs from July to October and total rainfall varies from year to year. The central and southern stations record 208 to 507 millimeters per year on average, and this data is also subject to large annual variations. Finally, the records of the stations on the oceanic side, in the mountainous region, indicate 800 to 1 000 millimetres and appreciable annual variations.

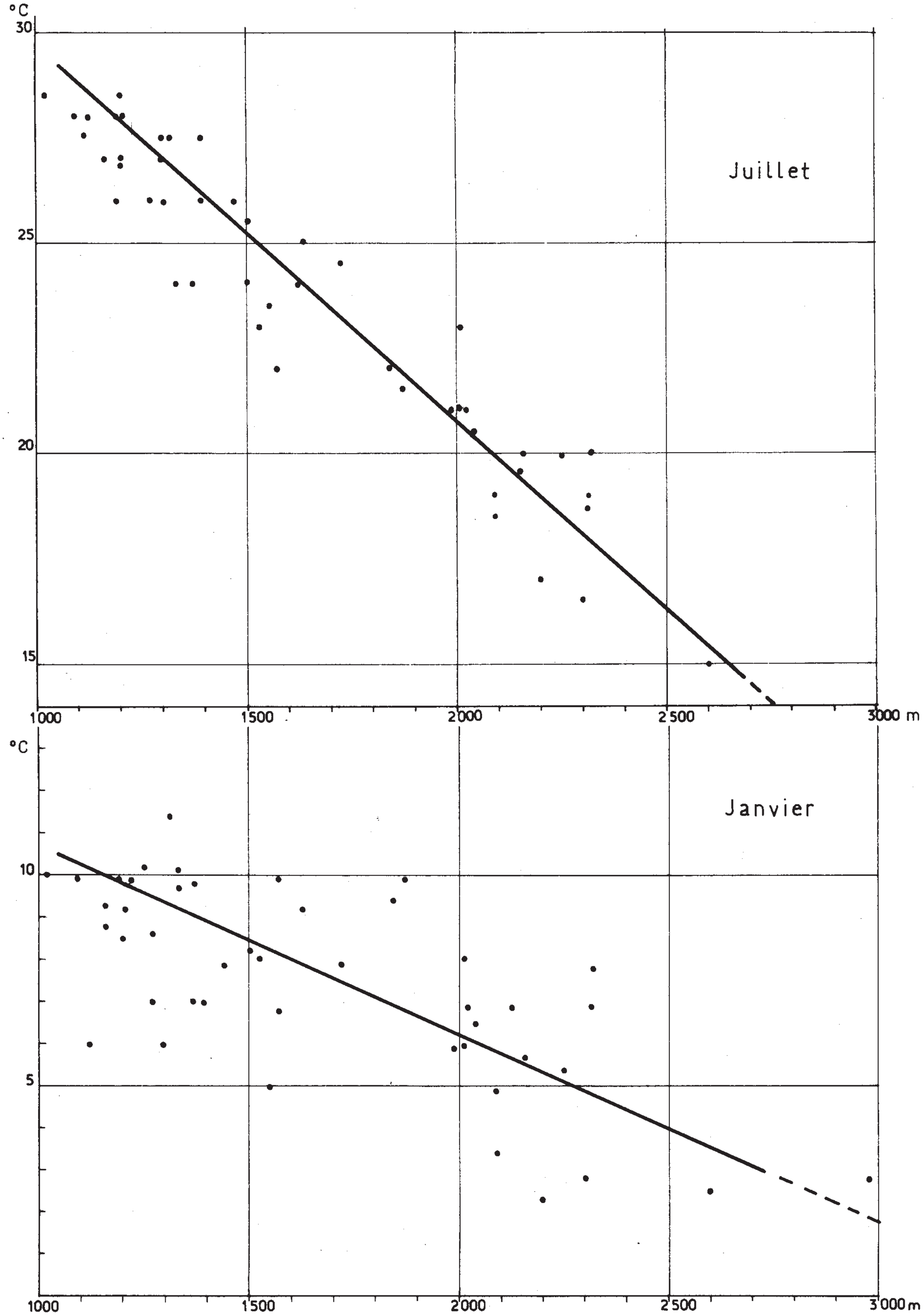


Fig. 21 - Thermal gradient in the months of January and July to the NE of the Sierra Madre Occidental and in the central Altiplano, in the state of Chihuahua

III. 2. 2. 1. 2. 2. Drought

In 1943, Bagnouls and Gaussen noted that a “dry month is one in which the total monthly precipitation, expressed in millimetres, is equal to or less than twice the average monthly temperature, expressed in degrees Celsius” (P ≤2T). Figures 22 and 23 present the ombrothermic diagrams of 6 selected stations in the three regions defined by Alvárez in the State of Chihuahua. The dry months appear clearly.

The stations in the State of Chihuahua indicate the existence of 1 to 11 dry months. In the mountainous region, Concheño and La Junta, 5 dry months occur frequently; in the border region more than 8 dry months. Finally, in the central and southern stations, the number of dry months varies from 8 to 10 (Buenaventura).

III. 2. 2. 1. 2. 3. Probable year

It has already been indicated that the total annual precipitation varies from year to year; therefore, the number of dry months also varies. By studying the monthly values of precipitation (P) year after year, a probable year can be defined (Legris, 1969). The variations of P and the number of dry months, in fifteen years of observation for six stations in the mountainous area, are presented in table 25.

TABLE 25. Variation of precipitation (P) and of the number of dry months (Ms)
x The star years are indicated
`

Estaciones	P en (mm)	Variación de P (mm^x)	P. mensual máxima (mm)	Ms	Ms más frecuente	Ms Máxima
Montaña						
BATOPILAS	620	1964:482	327	7	8	9
		1968:819	Jul. 1966			
GUADALUPE Y	1066	1962:780	354	4	4	6
CALVO		1961:1432	Jul. 1969			
CIUDAD MADERA	595	1964:444	227	2	5	9
		1958:861	Ago.1957			
CARICHIC	509	1965:247	287	7	8	9
		1966:768	Ago.1966			
CIUDAD GUERRERO	495	1970:393	370	7	8-9	9
		1959:674	Ago.1959			
CIUDAD	408	1970:280	207	9	8	10
CUAUHTEMOC		1966:631	Sept. 1958			
Centro y Sur						
H. DEL PARRAL	507	1957:266	481	8	8	11
		1968:1019	Sept. 1958			
BUENAVENTURA	316	1969:134	167	9	9-10	11
		1958:466	jul. 1962			
Fronteriza						
CIUDAD JUAREZ	217	1964:120	220	11	11	12
		1958:461	jul. 1968			

Guadalupe y Calvo is a wet season, as in thirteen years there were records of one to five dry months and the probable year was four dry months. In Batopilas, the numbers of dry

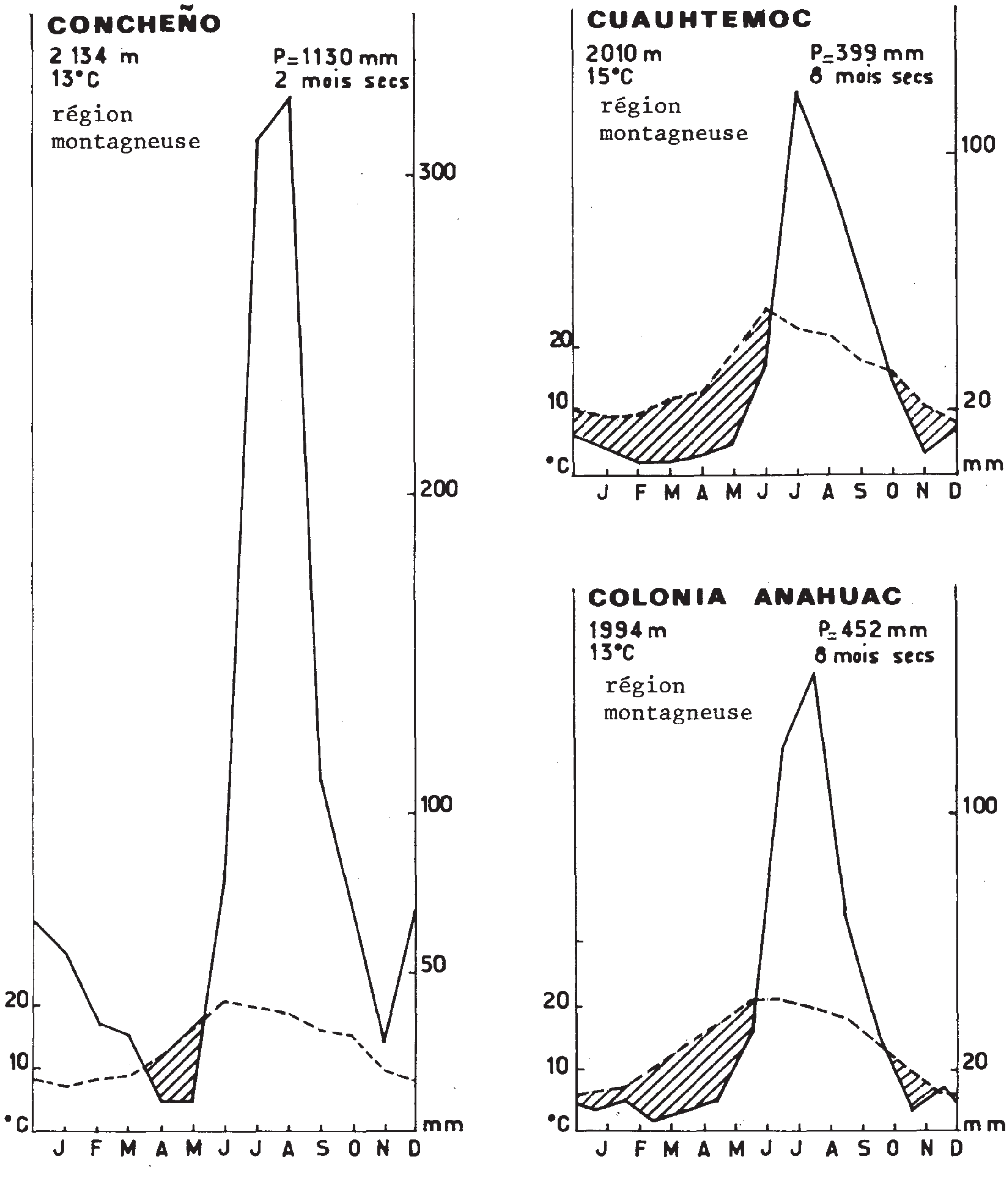


Fig. 23 - Ombrothermic diagrams (Bagnouls and Gaussen)
P: Average monthly rainfall in mm T: Average monthly temperature in °C
////: mois sec $P \leq 2T$

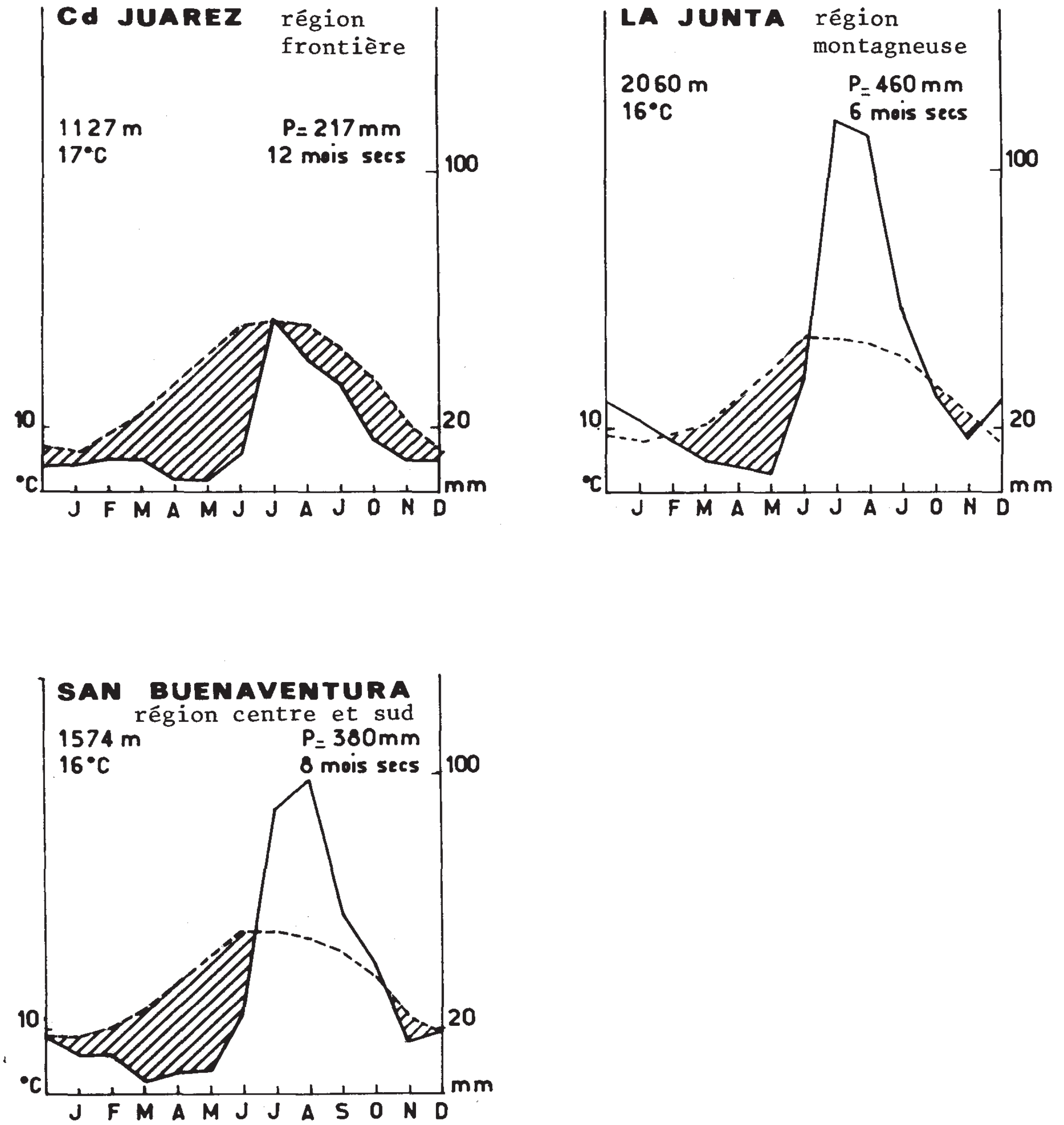


Fig. 22 - Diagramas ombrotérmicos (fórmula de Bagnouls y Gaussen)
P: Precipitación media mensual en mm T: Temperatura media mensual en °C
////: mois sec $P \leq 2$ T

months varied between five and nine, the probable year corresponding to eight dry months. This data was obtained using the average annual rainfall. In contrast, in Ciudad Madera, where it rains 596 millimeters a year, the average number of dry months is two, while the probable year consists of five dry months. In Ciudad Guerrero, the average number of dry months is seven and the probable year is eight to nine dry months. In the seasons of Carichic and Ciudad Cuauhtémoc, the probable year resembles that of Ciudad Guerrero.

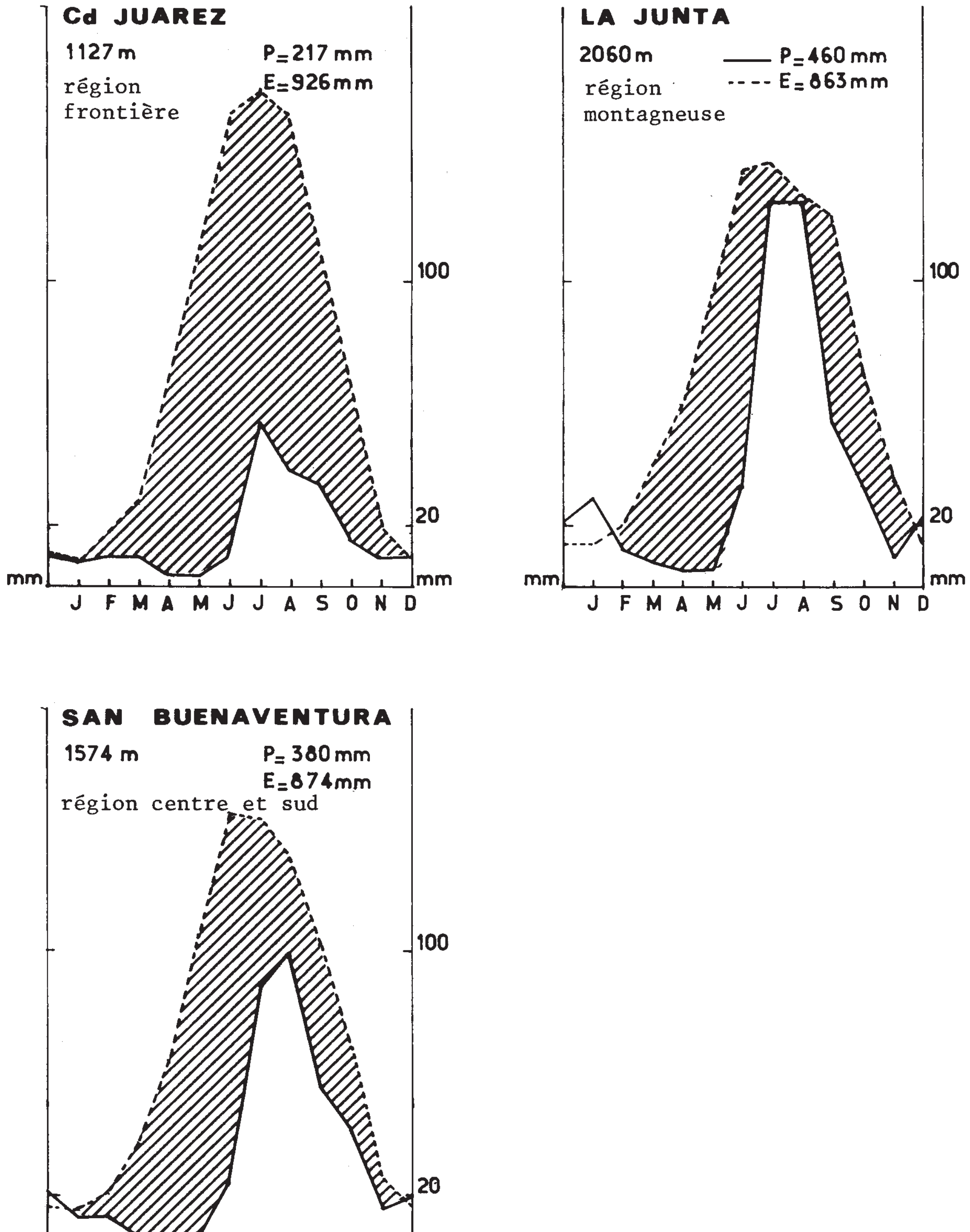


Fig. 24 - Climograms according to the Thornthwaite method

//// : E ≥ P
E : evaporation P : precipitation

In the central and southern seasons - with the exception of Majalca and Hidalgo del Parral - the annual variations of P are such that the number of dry months can vary by about three from the average.

III. 2. 2. 1. 2. 4. Evapotranspiration

Until the date of this work, no evaporation measurements had been made at the stations studied. By means of the method proposed by Thornthwaite in 1948, an approximate value can be obtained. The evapotranspiration E, is obtained using the average temperature and the total of the precipitations. In figures 24 and 25 are presented the climograms according to Thornthwaite, of the six stations already studied, according to the method of Bagnouls and Gaussen. The graphs show a permanent water shortage in Ciudad Juárez, a station that has 11 dry months. In San Buenaventura there is a water shortage for 11

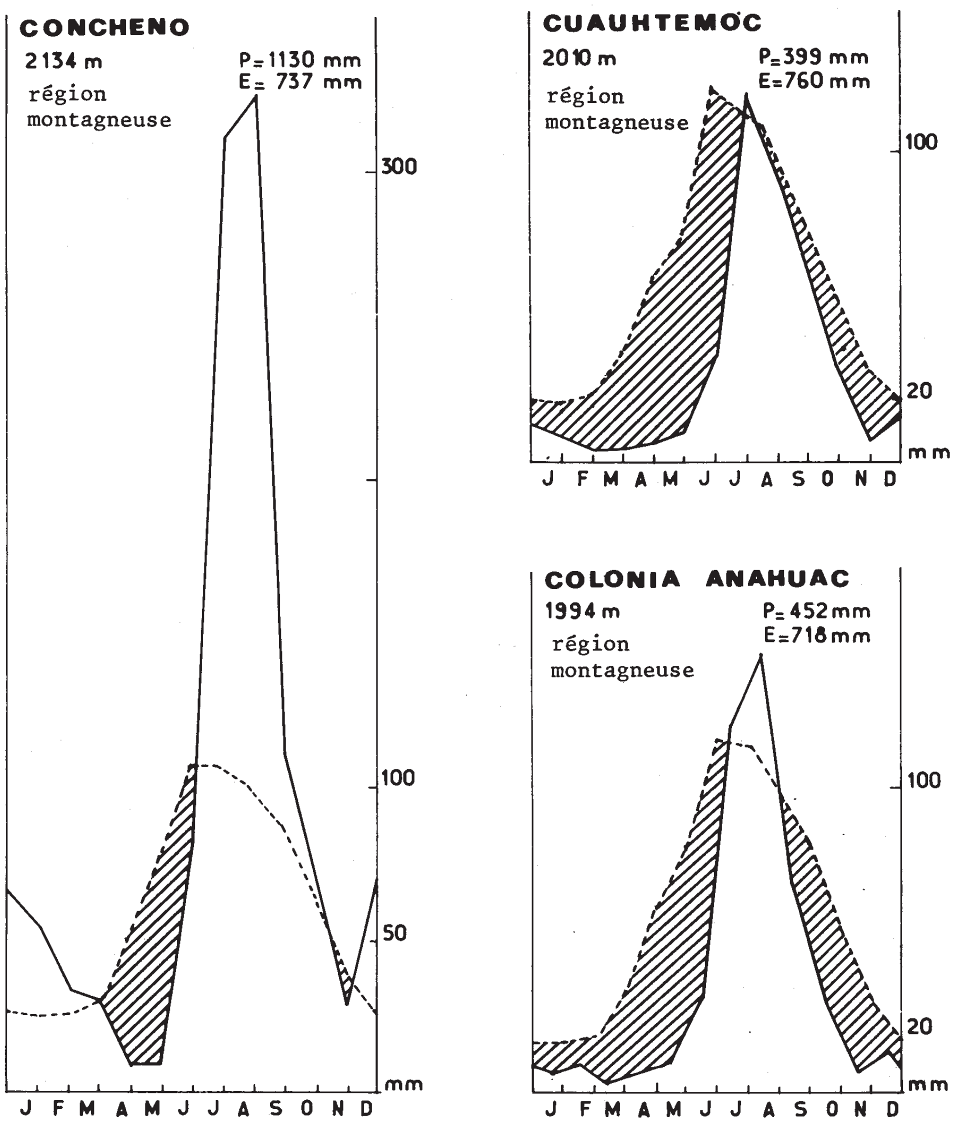


Fig. 25 - Climograms according to the Thornthwaite method
//// : E ≥ P E : evaporation P : precipitation

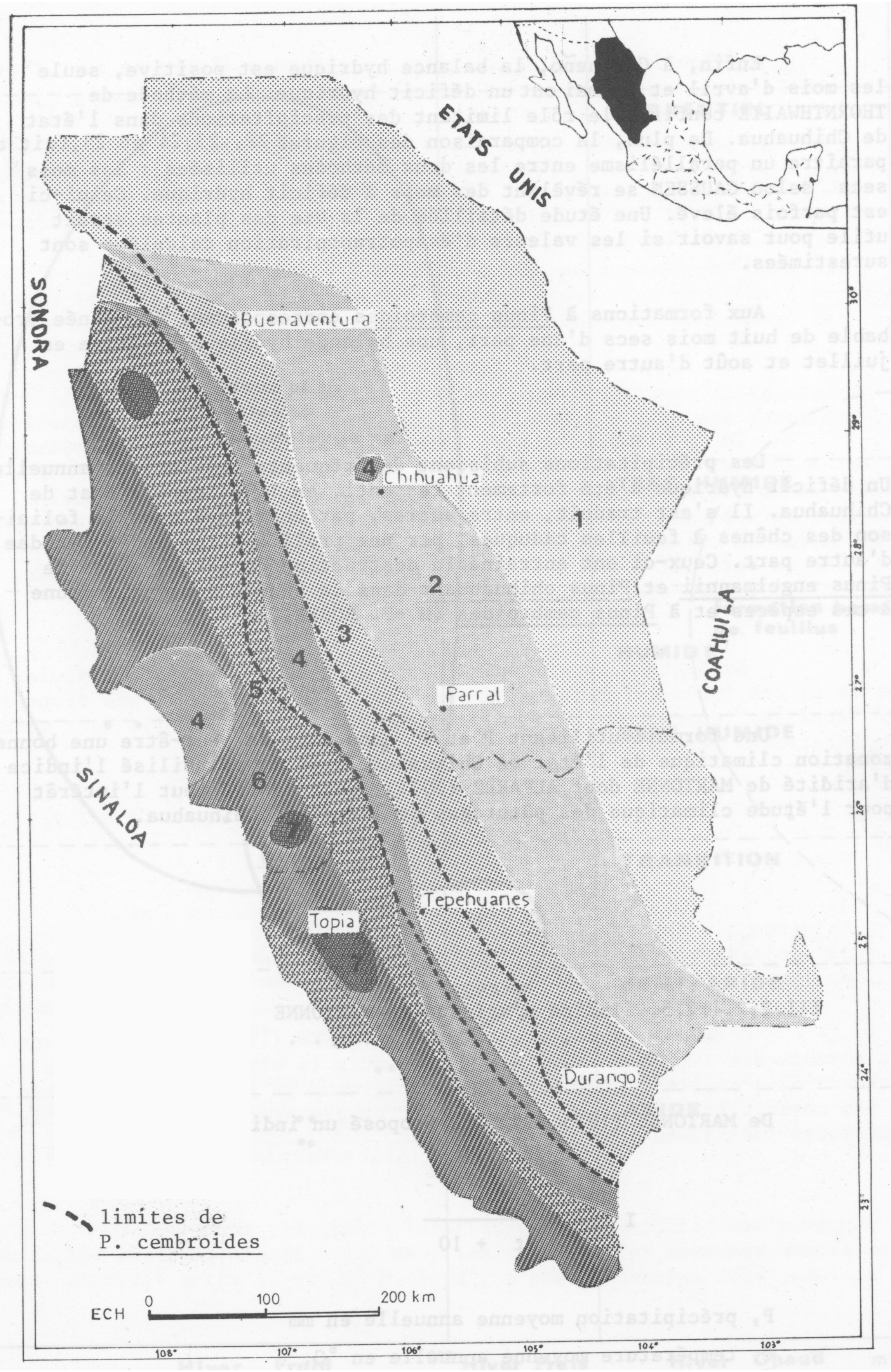


Fig. 26 - Types of climate based on the Martonne formula in the States of Chihuahua and Durango: 1. arid; 2. semi-arid; 3. transition; 4. semi-wet; 5. wet; 6. very wet ;7. torrential

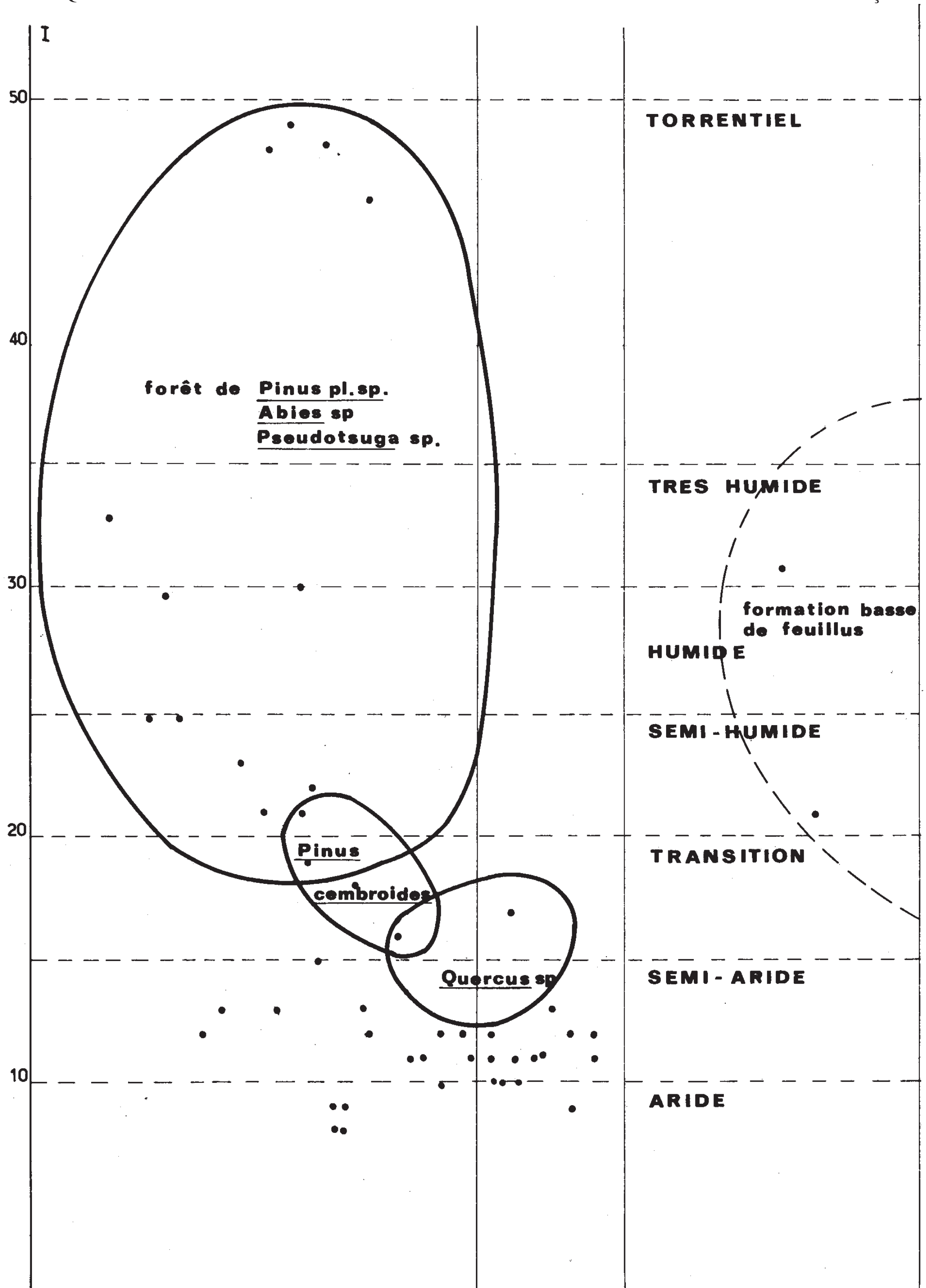


Fig. 27 - Bioclimatic levels in the State of Chihuahua
abscissa : mf in °C
ordered : I, index of Martonne

months, but in December the water balance is slightly positive. In the Junta, the water balance balances in August, is positive in December and part of January; in the remaining months, evapotranspiration exceeds the amount of water available.

In the stations of Colonia Anáhuca and Ciudad Cuahtémoc the behavior of evapotranspiration is identical; during the warm months (July and August) the water balance is positive; in the remaining months, the balance is negative. It is noted that July and August are wet months, while the months from October to June are dry months (Figure 27).

Finally, in Concheño, the water balance is positive; only the months of April and May have water shortages. The Thornthwaite method confirms the limiting role of precipitation in the State of Chihuahua. In addition, when comparing Figures 22, 23, 24 and 25, a similarity is noted between the two methods used: the dry months according to Gaussen are months with water shortages, which are sometimes high. It would be useful to study in detail the life of the plants, to know if the calculated evapotranspiration values are overestimated. The formations of *Pinus cembroides* have a probable year of eight dry months and a positive water balance in July and August.

Rainfall is subject to frequent annual variations. The State of Chihuahua suffered, in 1974, a water shortage, which caused, on the one hand, a delay in the foliation of the oaks of fallen leaves and, on the other hand, a proliferation of scoliths, these caused the destruction of vast areas of *Pinus engelmanni* and *Pinus chihuahuana*, in the ecotone strip common to these species and to Pinus cembroides (M.-F. Robert, 1977).

A good climatic zoning of the State of Chihuahua can be obtained by means of a formula using P and T. In this case, the Martonne aridity index was used, of which Alvárez in 1974, demonstrated its utility in the climatic study of the pastures of the State of Chihuahua.

III. 2. 2. 1. 2. 5. Martonne Aridity Index

Martonne in 1925 and 1926, proposed an aridity index which is expressed as follows:

$I = P/(t + 10)$

where: P = average annual rainfall in mm

t = average annual temperature in °C.

According to the value of the index, the author distinguishes seven types of climate (Figure 26):

I Climate type

0 to 5 desert

5 to 10 aggregate

10 to 15 semi-arid

15 to 20 transition

20 to 25 semi-wet

25 to 30 wet

30 to 35 very wet

> 35 torrential

From east to west of the State of Chihuahua, all types of climates are found from arid to torrential (Figure 27). The mountainous region defined by A. Alvarez, includes five types: transitional, semi-wet, wet, very wet and torrential climates. In the central and southeastern region, semi-arid or arid climates dominate; but within this zone, the Sierra de Majalca, which reaches an altitude of 2,400 meters, is subject to a semi-humid climate. The border region assumed an arid-type climate, except in the northwest where the semi-arid type is noted.

The limits of the climatic types should not be considered rigidly, due to the annual variation in rainfall. In fact, a “scale” arrangement is better suited to them, but is less immediately understandable.

III. 2. 2. 1. 3. Bioclimatic levels

A climagram of the State of Chihuahua was elaborated taking as reference the method proposed by Emberger in 1930, but associating the average of the minimum temperatures of the coldest month, mf, to the Martonne index. In this chymogram seven bioclimatic levels are shown, with three thermal variables (Figure 27).

The coniferous forests take advantage of the semi-wet, wet, very wet and torrential levels. The forests of *Pinus pl.* sp. (other than *Pinus cembroides*), *Abies* and *Pseudotsuga menzíesii*, are found at the torrential level with cold winter. The forests of *Pinus chihuahuana* and *Pinus engelmannii*, thrive preferably in a semi-humid climate with cold winter.

The formations of *Pinus cembroides,* correspond to the semi-humid levels or transition, with cold winter. On the other hand, the Bouteloua meadows and other grasses, as well as the shrubby oak groves, are found in the semi-arid or transition levels, with cold or cool winter.

In the semi-humid or humid level with hot winter, located on the western slope of the Sierra Madre Occidental (Batopilas, Urique), the presence of deciduous woody formations is noted.

Finally, in the arid and semi-arid levels, with warm or cool winter, there are several shrubs of *Fouquieria splendens, Larrea tridentata, Agave lecheguilla, Dasylirion sp., Prosopis juliflora* and some *herbaceous*.

III. 2. 2. 2. State of Durango

For the State of Durango, available climate data are less abundant than those for the State of Chihuahua; in particular, minimum temperature averages are missing from the publications of the General Directorate of Meteorology.

Based on the ambrothermic area of the plant formations of the State of Durango (Figure 29), it should be noted that *Pinus cembroides* thrives in climatic conditions very similar to those defined previously for the State of Chihuahua (Figure 28). However, the lower limit of the average annual precipitation reaches values higher than 450 millimeters and the average annual temperature extends from 14 to 20°C. There are no precise data on the number of days with frost, but according to Jauregui (1970), the average is over 100 days per year, which suggests values greater than 0°C for mf. The average annual thermal amplitude is greater than 10° C.

The distribution of the Martonne index calculated for all the stations in the State of Durango is shown in Figure 26.

As in the State of Chihuahua, the formations of *Pinus cembroides* are located in places of semi-humid climate or transition. In the case of the area with a transitional climate, these formations are located in the western strip, while in the eastern strip there are meadows and low oak formations (Gentry, 1957).

III. 2. 3. Sierra Madre Oriental

The Martonne index, calculated with the meteorological data of the State of Coahuila varies from 4 to 14, which translates into three types of climates: desert, arid

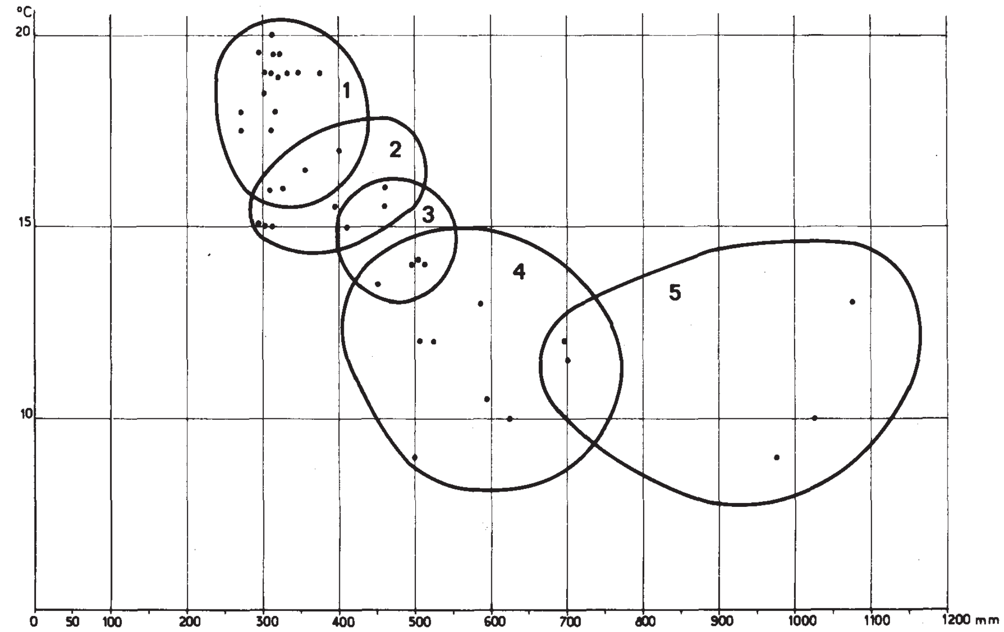


Fig. 28 - Ombrothermic areas of plant formations in the State of Chihuahua: 1. xerophytic formation: *Larrea tridentata*, *Fouquieria splendens*, *Agave sp.*; 2. meadow or low oak formation; formation of *Pinus cembroides* dominant; 4. forest of *Pinus pl. sp.* dominant; 5. forest of *Pinus pl. sp.*, *Pseudotsuga, Abies* and *Picea sp.*

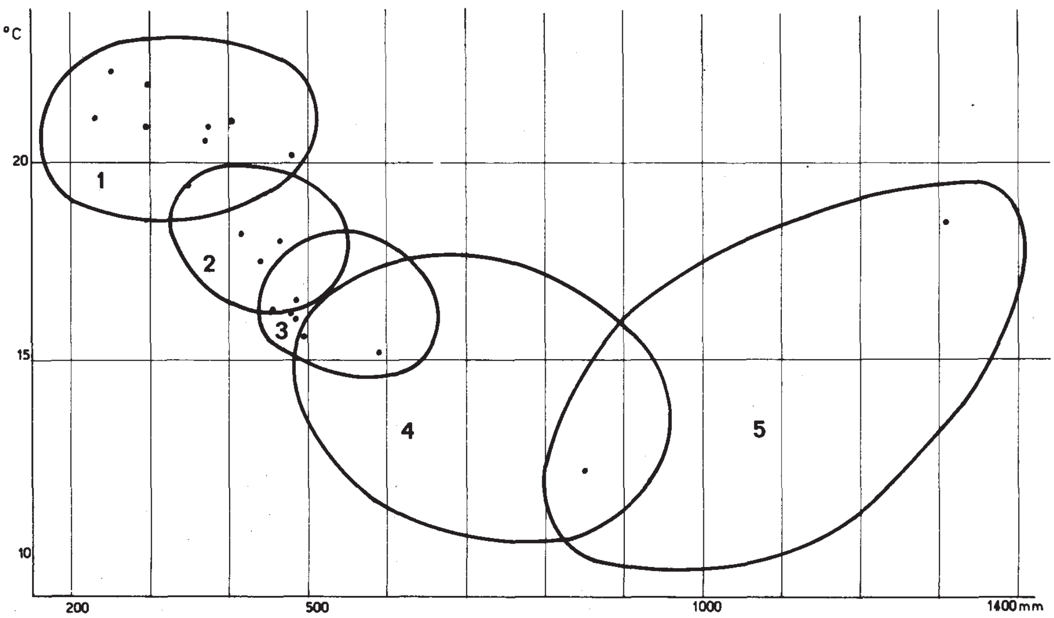


Fig. 29 - Ombrothermal areas of plant formations in the State of Durango: 1. xerophytic formation; 2. meadow; 3. dominant *Pinus cembroides* formation ; 4. dominant *Pinus pl. sp.* forest ; 5. forest of *Pinus pl. sp.*, *Pseudotsuga*, *Abies* and *Picea sp.*

and semi-arid. The formations of *Pinus cembroides* are found in areas with a climate of the last type.

In the State of Nuevo León, on the contrary, the existence of the seven climatic types defined by Martonne is observed. The formations of Pinus cembroides develop in regions with a transitional climate.

The ombrothermic areas delimited for the States of Coahuila, Nuevo León, San Luis

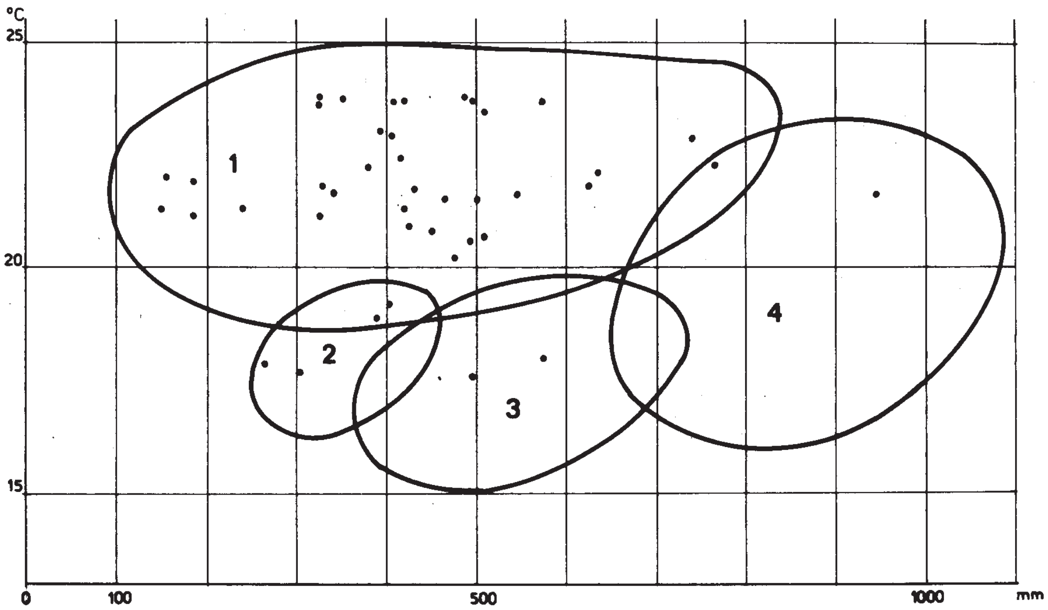


Fig. 30 - Ombrothermal areas of plant formations in the states of Coahuila and Nuevo León : 1. *xerophytic* formation with *Larrea tridentata*, Opuntia sp.; 2. formation of *Pinus cembroides* dominant ; 4. formation of *Pinus arizonica* dominant ; 5. mesophilic forest

Potosí and Zacatecas, show the climate where formations of *Pinus cembroides* prosper (figures 30 and 31) and also, place them in relation to the other vegetal formations.

In the states of Coahuila and Nuevo León, the xerophytic formations of *Larrea tridentata* are superimposed on the other formations, predominating in those areas whose average annual rainfall is of the order of 200 to 500 millimeters but with average annual temperature close to 20°C, that is, higher than that supported by the other formations. In the Sierra Madre Oriental, the area occupied by *Pinus cembroides* has a drier climate than that of the Sierra Madre Occidental (the average annual precipitation varies from 250 to 400 millimeters, and also warmer (the average annual temperature reaches values in the order of 17 to 20°C.).

In the states of Zacatecas and San Luis Potosi, conditions are similar to those described for the states of Coahuila and Nuevo Leon. It is necessary to mention here an overlapping of the three following formations: of xerophytic plants, of *Quercus pl. sp.*, and of *Pinus cembroides,* reason why it can be considered that these three formations besides being linked are derived from each other.

I n

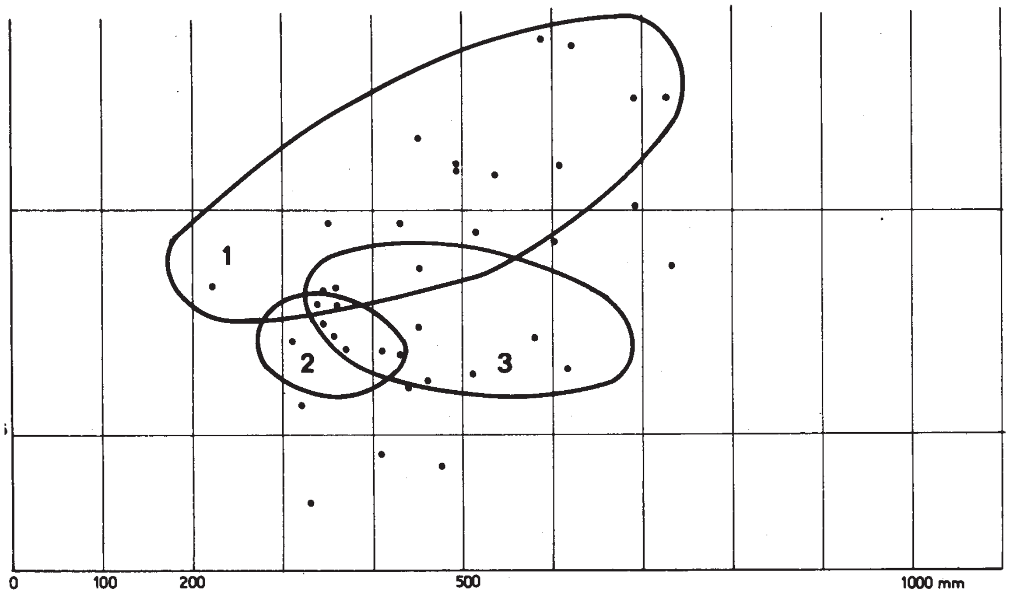


Fig. 31 - Ombrothermal areas of plant formations in the States of Zacatecas and San Luis Potosi : 1. xerophytic formation with *Larrea tridentata, Opuntia sp.*; 2. formation of *Quercus sp.*; 3. formation of *Pinus cembroides*

central Mexico, due to the importance of the crops it is difficult to establish the ombrothermic area of the plant formations.

III. 2. 4. Conclusions

The previous study indicates, despite the scarcity of climatic data, that *Pinus cembroides* formations develop in climates of one of the three following types: semi-wet, transition or semi-arid. On the other hand, the average annual temperature is the factor that distinguishes the formations of Pinus cembroides in Mexico.

The boundary between the formations of *Pinus cembroides* and the forests of *Pinus pl. sp.* is clearly defined, conditioned by climatic factors, as found in the Sierra Madre Occidental. While the limit of *Pinus cembroides* formations with the grasslands or the low formations of oaks, which thrive also in areas with transition climate, is more difficult to define. This last limit should rather be related to the influence of man.

To deepen the present study and answer some questions that for the moment cannot be solved, a study of phenology and physiology of *Pinus cembroides* is needed, together with precise temperature measurements. Among the questions, the following two are mentioned:

1 Can the false growth rings of *Pinus cembroides* be attributed to variations in precipitation?

2 Is seed production irregular, as is evident in eastern Mexico, where harvesting is good every four or five years (Anuario de las Producciones Forestales, 1959-1969).

Because the seed (pine nut) trade is underdeveloped in western Mexico, no data are available.
Farmers in the Eastern and Western Sierras Madre point to a relationship between seed production and harsh winter, which is not the only determinant. It should also be mentioned that, every year, the wholesalers of La Merced, Mexico City's market, are supplied with pine nuts by small traders coming mainly from Vizarrón, Hidalgo, or Matehuala (San Luís Potosí). For this reason, it is assumed that other climatic factors have intervened in the fructification of this species.

III. 3. ALTITUDINAL LIMITS OF PINUS CEMBROIDES FORMATIONS

In Mexico, the lower altitudinal limit of *Pinus cembroides* s.l. reaches 1 100 meters; at this altitude *Pinus catarinae* is known, whose taxon was described in the first chapter. The upper altitudinal limit reaches up to 2 900 meters where *Pinus johannis* develops, in Concepción del Oro (Zacatecas).
The place of the *Pinus cembroides* formations among the altitudinal succession of the plant formations is described in more detail below.

III. 3. 1. Altitudinal succession of the Sierra Madre Oriental

In the northwest of the State of Coahuila, in the Sierra Santa Fe del Pino, is *Pinus edulis* at an altitude of 2 000 to 2 100 meters on the northern slope of a ravine; this species is accompanied by some specimens of *Pinus arizonica*, the only tree species present on the southern slope. The population of *Pinus edulis* is situated within a group of heterogeneous formations of low woody plants and grasses, where one of the following species predominates: *Quercus intricata*, *Cercocarpus montanus*, *Arbutus xalapensis, Andropogon gerardi, Botriochloa sp*. and some individuals of *Quercus canbyi* or *Pinus arizonica* which stand out from this low formation. In the valley bottoms a high and open woody formation of *Pinus arizonica* develops, with grasses. Recently large areas of low formation have been set on fire. The immoderate logging and fires disturb the vegetal formations of this mountain range, in which *Pinus edulis* subsists only in the central region.
On the western slope of the Sierra Santa Fe del Pino, the altitudinal succession of species is as follows

- 1 500 meters: *Juniperus deppeana*, 1 meter high, is present among the shrubs of *Yucca carnerosana*, *Agave lecheguilla*, *Prosopis juliflora, Buddleia sp*., *Bouteloua gracilis* and *Bouteloua curtipendula*. Sporadically, there are dense and low formations of *Juniperus deppeana*.

- 1 650 meters: in addition to the species mentioned above, there is *Quercus intricata*, 2 meters high.

- In places located at 1 700 meters of altitude the community is characterized by the presence of *Pinus arizonica* and *Juniperus deppeana*, 5 to 6 meters high; as well as *Berberis trifoliata, Sophora secundiflora, Rhus trilobata* and some low spots of *Quercus intricata*; this heterogeneous woody formation, indicates disturbances of human or animal origin.

In this Sierra, *Pinus arizonica* reaches an altitude lower than that of *Pinus edulis*.

However, in the Sierra Encantada, *Pinus edulis* was found at 1 600 metres in a very disturbed plant formation and in the vicinity of a mining area.

In the Sierra Madera del Carmen, which is more difficult to access than the Sierra Santa Fe del Pino, there is a more obvious altitudinal succession of species. After the thickets of *Dasylirion sp*., the succession on the southwest slope is the following:

- at altitudes of 1 500 meters: the lower formation of *Quercus intricata* predominates.
- from 1 750 to 1 800 metres: the low formation of *Pinus cembroides* is observed, with *Juniperus deppeana* and *Quercus canbyi*.
- at 2 300 metres: the closed upper formation of *Pinus ayacahuite*, *Pinus durangensis* and *Pinus cooperi* can be seen, with *Quercus canbyi*.

The formations of *Pinus cembroides* in the interior of the Sierra are higher than those observed on the outer slope.

Although the Sierras Santa Fe del Pino and del Carmen are in similar latitudes, their zoning is slightly different. Furthermore, no specimens of Pinus arizonica have been found in Sierra Madera del Carmen. This absence is perhaps due to the nature of the mother rock, which is calcareous in Sierra Santa Fe del Pino and eruptive in Sierra Madera del Carmen.

Further south, in the Sierra de la Paila, *Pinus arizonica* is present. The altitudinal succession of the species on the northern slope is as follows

- from 1 200 to 1 400 meters: the submontane shrubbery of *Koeberlinia spinosa* and *Leucophyllum laevigatum*, etc...
- between 1 400 and 1 500 metres: Juglans microcarp abounds in the scrub described above.
- from 1 500 to 1 650 meters: a complex woody formation, high and low, of *Berberis trifoliata, Quercus invaginata, Quercus laceyi, Quercus gravesii, Fraxinus cuspidata* and *Prosopis juliflora*.
- from 1 650 to 1 850 meters: in some places it dominates *Pinus arizonica*.
- from 1 850 to 1 950 meters: *Pinus cembroides* stands out.

This altitudinal succession occurs continuously and the boundaries between one formation and the next are not well marked. The oak formation includes many species of the *genus Quercus*.

In the humid valleys of the interior of the Sierra de la Paila, at an average altitude of 1 850 metres, there are meadows or high woody formations of *Pinus cembroides* with grasses. The interior slopes, which reach an altitude of 2 300 metres, are covered by a mixed woody formation of *Pinus arizonica* and oaks. The specimens of *Pinus cembroides* that are found in the interior of the Sierra de la Paila, are among the straightest and highest that were observed in the plant group of the study area. This is undoubtedly due to the very particular microclimate conditions prevailing in this place. In summer, the center of the Sierra de la Paila receives precipitation of the same order as that recorded in the Sierra de Arteaga, Coahuila.

However, the conifers of the Sierra de la Paila are threatened by fire; in fact, the old and dry trees burn easily when they are reached by the sun's rays, causing devastating fires.

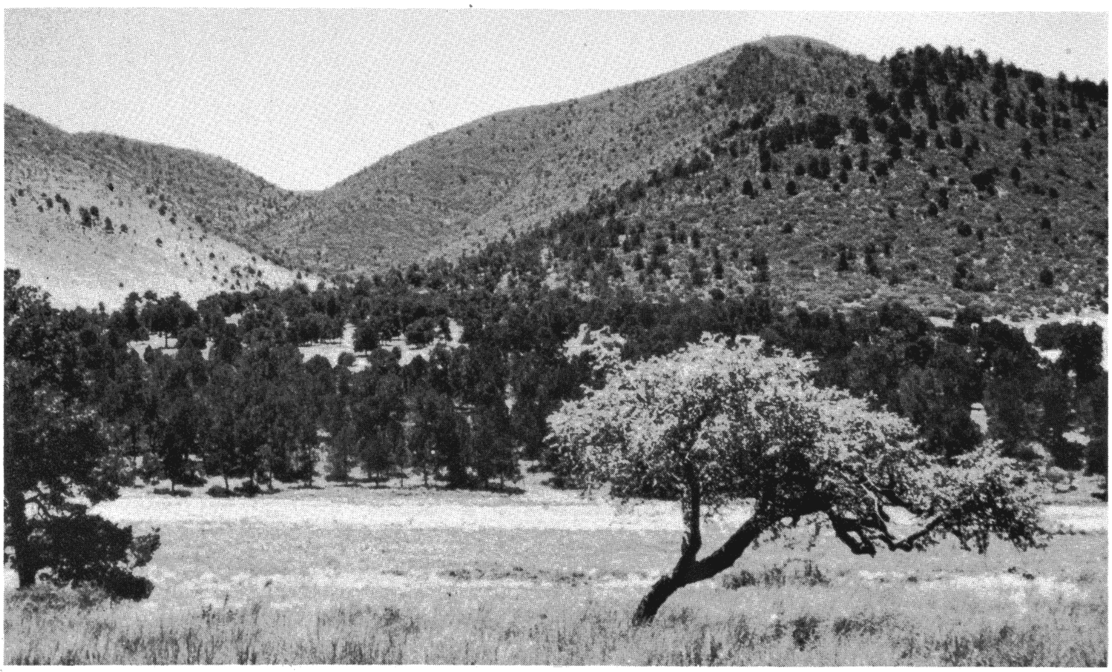
In the interior valleys of the Sierra de la Marta (Municipality of Arteaga, Coahuila), between 2,100 and 2,500 meters of altitude, the woody formations of *Cupressus sp*. or *Pinus arizonica* predominate. On the other hand, the formations of Pinus arizonica reach 3 100 meters of altitude. On the outer slopes of the Sierra de la Marta, the lower altitude limit of *Pinus cembroides* is 1 900 metres, developing within a complex formation of low woody and grasses with *Larrea tridentata, Yucca carnerosana, Bouteloua pl*. sp.

A situation similar to the one described for the Sierra Santa Fe del Pino is presented near Galeana, Nuevo León, where *Pinus arizonica* and *Pinus cembroides,* located at 1 800 meters of altitude, grow together on gypsum soil. On an east-west profile, at the level of Cerro Potosí (Figure 32), it can be seen that the lower altitudinal limit of Pinus cembroides on the western slope is close to 2 300 meters; its upper limit does not exceed 2 500 meters. On the eastern slope, Pinus arizonica reaches an altitude of 1 300 meters, in an open formation of *Juniperus deppeana*, which is interrupted by low formations of oaks.

The formation of *Pinus cembroides* is in contact, in its lower limit, with a complex formation of low woody, together with *Agave lecheguilla* and *Euphorbia antisyphilitica,* among other species, while the upper limit borders on a low woody formation of *Quercus grisea* (chaparral) of secondary origin. This formation hides the interface between the high forest of *Pinus ayacahuite* and the formation of *Pinus cembroides* and *Pinus arizonica*. These three formations grow in a soil of lithic yield, poor in organic matter content and with an alkaline pH of 8. The presence of these three types of formations is not due to edaphic variables, but to those of anthropic origin. In particular, the chaparral has developed and multiplied thanks to the systematic felling of pine trees and frequent fires.

Finally, in the center of the Sierra Madre Oriental, near Aramberri, Nuevo León, from 1 400 meters of altitude, grows Pinus arizonica in isolation, within a low and complex

Formación leñosa alta de *Pinus cembroides* con *Stipa tenuissima*, *Stipa eminens* y *Nolina* sp.
1 800 m de altitud.
25°55’20”N, 101°33’20”W, Sierra de la Paila, Municipio de Ramos Arizpe (Coahuila).
5 de agosto de 1975.



Formación alta de *Pinus cembroides*, primero una pradera secundaria con *Quercus pringlei*. Al fondo, a la derecha, une formación baja de *Quercus* sp. y *Pinus cembroides*. 2 250 m de altitud.
25°10'30"N, 101°34'W, Municipio de Saltillo. 21 agosto de 1975.

Formación leñosa de *Pinus cembroides* recientemente destrosada. En el hueco de la cañada, se nota una plantación de manzanos y melocotoneros; a la derecha, sobre el vertiente sur, una formación baja de *Quercus cordifolia*. 1 900 m de altitud. Valle de los Lirios, Municipio de Arteaga (Coahuila).
1 de agosto de 1975.

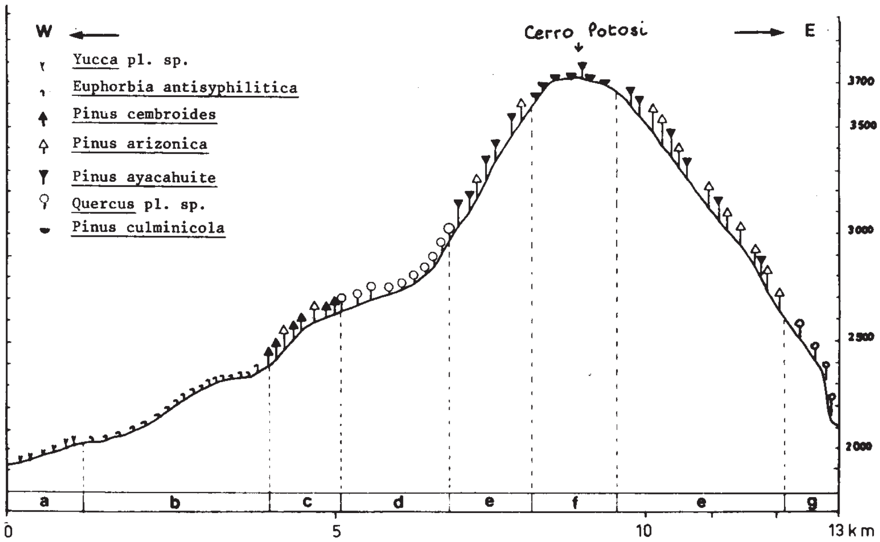


Fig. 32- E-W cut in the Sierra Madre Oriental, west of Galeana (Nuevo Leon) according to the Galeana land use map (CETENAL, 1976)

a. Low woody formation (5 meters high) of Yucca carnerosana and *Yucca filifera,* with *Larrea tridentata, Flourensia cernua* and *Opuntia imbricata*
b. Low, complex woody formation of *Flourensia cernua*, *Agave lecheguilla, Euphorbia antisyphilitica* and *Parthenium incanum*
c. Woody, tall formation of *Pinus cembroides* and *Pinus arizonica* with *Arctostaphylos pungens* and *Quercus grisea*
d. Low, woody formation of *Quercus grisea* (2 meters high) with *Arctostaphylos pungens*
e. Woody, tall formation of *Pinus ayacahuite, Pseudotsuga macrolepi*s, *Pinus hartweggii and Abies vejari*
*f. Woody, low formation of Pinus culminicola with Lupinus sp. and Euphorbia cam*pestris
g. Woody formation, lower than Quercus intricata, *Q. greggii* and *Q. emoryi,* with *Arbutus xalapensis, Yucca carnerosana, Garrya ovata and Rhus trilobata*

woody formation, composed mainly of *Prosopis juliflora*, *Acacia constricta*, *Rhus virens, Agave sp*. and *Brahea berlandieri*. After this formation comes another one, of *Juniperus deppeana*, between 1 400 and 1 500 meters of altitude. Towards 1 500 meters the previous formation is replaced by *Pinus cembroides*, which in turn is replaced by *Pinus arizonica* at 1 700 meters. The strip of *Pinus cembroides* present here is very narrow.

From the above descriptions it is clear that the lower limit of *Pinus cembroides s*. str. is at 1 400 meters in the east of the study area. At this altitude the formations of this species are low and not very extensive. Therefore, 1 400 metres represents the extreme lower altitude limit for Pinus cembroides, its optimum growth zone being between 1 900 and 2 400 metres. However, this species grows up to 2 800 metres in Concepción del Oro (Zacatecas), in an area where it is sympatric with *Pinus johannis*. The highest formations of *Pinus cembroides* are found in the closed and humid valleys of the Sierra de la Paila and the Sierra de Arteaga.

Due to its upper limit, the formation of *Pinus cembroides* borders on high woody formations of pines such as *Pinus arizonica* and *Pinus ayacahuite*, among others. The passage from one formation to another is progressive. At the lower limit, the formation of *Pinus cembroides* borders on some of the following formations:

1. Lower formation of oaks

2. Low juniper formation

3. Complex formation of grasses and *Yucca carnerosana, Larrea tridentata,* among other species.

4. Formation of herbaceous plants.

In total, the altitudinal succession is as follows:

1. Sub-mountainous shrubbery
2. Low formation of *juniper* and *oak*
3. Low woody formation of *Pinus cembroides*
4. High woody formation of *Pinus pl. sp.*, different from *Pinus cembroides*.

The above substitution is similar to the one described by Whittaker in 1975, for the Santa Catalina Mountains, Arizona, even though the species of pines and oaks are different.

In the mountains of northwest Zacatecas, the only species present are *Pinus cembroides*, *Pinus pinceana* and *Pinus johannis*. But from 2 400 meters of altitude *Pinus pinceana* is absent.

III. 3. 2. Altitudinal succession in the Sierra Madre Occidental

A schematic east-west cut, north of the State of Chihuahua, in the region from San Buenaventura to Ignacio Zaragoza (Robert, 1979), indicates an altitudinal succession of species, common to the Sierra Madre Occidental as a whole (Figure 34), which is as follows:

1 500 m.: meadows of *Bouteloua repens* and *Andropogon sp.*

1 650 m.: low formation of *Quercus emoryi*

1 850 m.: *Pinus cembroides* appears in the low holm oak forests

2 000 m: low formation of *Pinus cembroides*, with *Quercus grisea* and *Quercus rugosa*.

2 500 m.: high woody formation of *Pinus engelmannii* and *Pinus chihuahuan*a, with *Quercus sp. pl.*

On the northern and northeastern slopes, the upper altitudinal limit of *Pinus cembroides* reaches 2 300 m; while on the southern and southwestern slopes this line is between 2 400 and 2 500 m. The above-mentioned altitudinal sequence is identical in the south of the State of Chihuahua, towards Balleza. However, in some places situated along the road to Topia (Durango) the formation of *Pinus cembroides* can be found up to 2 700 metres in altitude, in an area of little extension nestled in the high forest of *Pinus engelmannii* and *Pinus chihuahuana*. In the interior of the Sierra, *Pinus cembroides* is found between 2 300 and 2 350 meters of altitude.

Further south, in the State of Durango, the lower limit of the *Pinus cembroides* formation is a complex woody formation of *Yucca sp.* or *Fouquieria splendens*.

III. 3. 3. Altitudinal succession south of the Central Plateau

The example of an isolated massif in the Central Highlands is the Sierra de San Miguelito in San Luis Potosi (Robert, 1973). An east-west section of this orography presents the following altitudinal succession (Figure 33):

1 800 m.: Complex formation of low woods and grasses, with Opuntia sp., ...
1 900 m.: Low Quercus potosina formation
2 000 m.: Formation of *Pinus cembroides* with *Quercus potosina*
2 400 m.: High woody formation of Pinus with *Quercus potosina*

In this Sierra, the lower and upper altitudinal limits of the *Pinus cembroides* formation, differ from the eastern to the western slope.

In the Sierrra de Zongolica (Puebla), the southern end of the *Pinus cembroides* area, this species establishes itself at 2 100 metres altitude, in contact with the lower formation of *Quercus microphylla*. The formation of *Pinus cembroides* develops up to 2300 meters of altitude. But, near San Luis Atexcac, Puebla, its upper limit reaches 2 700 meters while the lower limit is located at 2 300 meters, where *Pinus cembroides* is in contact with a low and complex woody formation of *Yucca spp*, *Dasylirion sp*. and *Opuntia sp*.

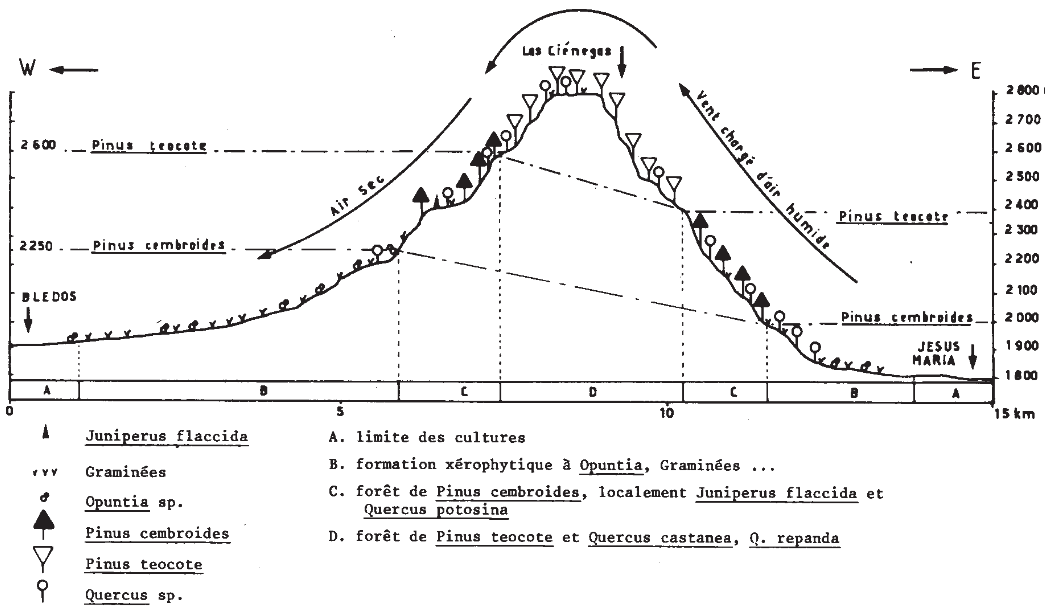


Fig. 33 - Schematic view of the Sierra de San Miguelito (San Luis Potosí)

III. 3. 4. Conclusion

The upper and lower altitudinal limits of *Pinus cembroides* formations vary within their range. The most constant limits are observed in the Sierra Madre Occidental, where the lower boundary is between 1 800 and 1 900 metres and the upper boundary between 2 300 and 2 500 metres.

However, throughout the range, Pinus cembroides occupies a specific place within the altitudinal succession of species. As a reminder, the following sequence is cited:

- lower level: low formation of *Quercus sp*. or *Juniperus sp*.

- upper level: high woody formation of *Pinus pl. sp*., different from *Pinus cembroides*.

Within this scheme the following exceptions are presented:

1. contact of the formation of Pinus cembroides, in its lower part, with the xerophytic formation of *Yucca, etc*.

2. Absence of the high woody formation of *Pinus pl. sp*.

The possible relations between the altitude at which the formations of *Pinus cembroides* are found and their dynamics will be specified below.

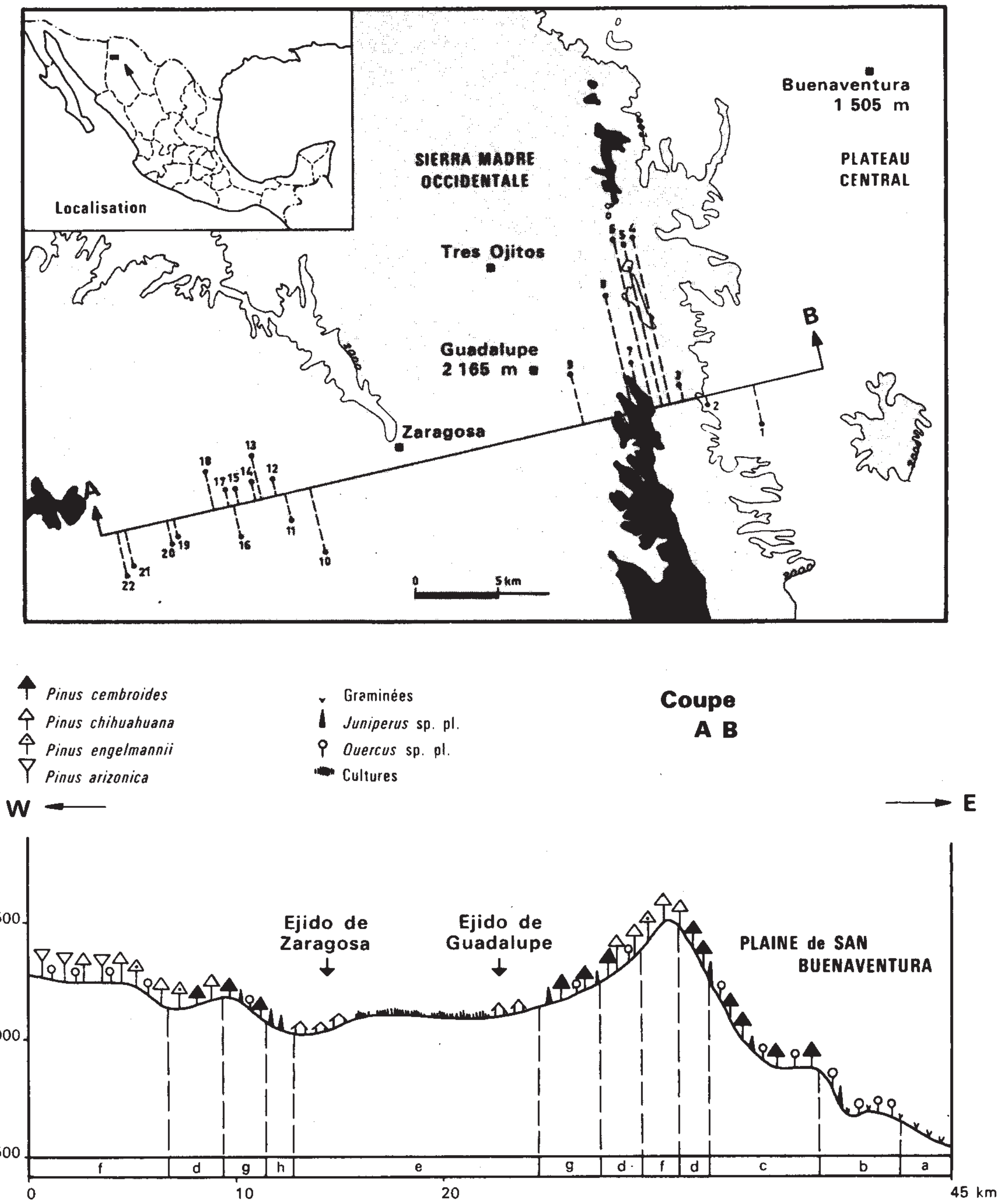
III. 4. DYNAMICS OF PINUS CEMBROIDES FORMATIONS

The dynamics of *Pinus cembroides* formations is related to the anthropic variable. In fact, the structure of the formation, and in particular the diameter of the trunks of *Pinus cembroides,* give notion of the recent action of man and the direction of the extension, of the formation.

On the previous assertion, we have an example in the types of woody formations existing in the surroundings of Ignacio Zaragoza, Chihuahua; where, by means of a profile in the Sierra, in an east-west direction, from San Buenaventura to Ignacio Zaragoza, the main plant formations present are identified (Robert, 1977):

(a) the prairie
(b) a low formation of *Quercus emoryi*
(c) a low formation of *Pinus cembroides* with *Quercus pl. sp*.
(d) an ecotone belt approximately 20 km wide
(e) crops
(f) the tall woody formation of *Pinus pl. sp*. with *Quercus pl. sp*.
(g) the open formations of *Pinus cembroides*
h) a low formation of *junipers*.

The data on the conditions of the samples, as well as the composition of the tree stratum and the average age of the trees appear in Table



a. prairie basse, claire à *Bouteloua repens*, *Andropogon* sp. pl.
b. formation basse de *Quercus emoryi*
c. forêt primaire de *Pinus cembroides*, *Quercus* sp. pl. à *Juniperus* sp. pl.
d. forêt de *Pinus chihuahuana*, *Pinus engelmannii* et *Pinus cembroides*
e. cultures
f. forêt de *Pinus arizonica*, *Pinus chihuahuana*, *Pinus engelmannii* à *Quercus* sp. pl.
g. formation secondaire de *Pinus cembroides* à *Quercus* sp. pl.
h. formation secondaire de *Juniperus* sp. pl.

26

Fig. 34 - Cutting in the Sierra Madre Occidental

The detailed information of the formations from which the information was taken is as follows:
(a) Grassland: located between 1 500 and 1 750 metres above sea level, in this area the ground is covered by a low grassland of *Bouteloua repens*, *Andropogon pl. sp.*, *Aristida sp.* and *Sporobolus sp.*, locally supplanted by islets of *Fouquieria splendens*, *Opuntia intricata* or *Prosopis juliflora*

b) Towards 1 650 meters, the first oaks, *Quercus emoryi*, begin to appear, isolated, that little by little, they are constituting a low formation (sample 1, Figure 34), in which the gramineae abound. The first individuals of *Pinus cembroides* are found at 1 850 meters of altitude.

c) At 2,150 metres there is a formation of *Pinus cembroides* with *Quercus grisea* and *Quercus rugosa* (sample 2), of little height, in which there may be some junipers among the most frequent are *Juniperus deppeana* and *Juniperus flaccida*. This formation reaches an altitude of 2,500 metres on the southern and south-western slopes, while on the northern and north-eastern slopes it can be seen at 2,300 metres. At higher altitudes, this formation is supplemented by a high formation of *Pinus engelmannii* and *Pinus chihuahuana* (Figure 34) that crosses the rocky barrier at the level of gullies affected by erosion.

d) Progressively, the woody formation of *Pinus cembroides* located east of Guadalupe at 2300 meters of altitude, passes to a high formation of *Pinus chihuahuana*, *Pinus engelmannii* and *Pinus cembroides*, in which *Quercus grisea* and *Quercus hypoleucoides* are more or less abundant. This formation, where dry ecology pines and mesophilic pines are mixed, is given the name of ecotonal strip. The ecotonal strip is presented in discontinuous fragments from one side of the crops to the other (segment "e", Figure 34), east of Guadalupe (sample 8) and west of Ignacio Zaragoza. In some places, the ecotone strip has been replaced by very open formations of *Pinus cembroides* and oaks (samples 6 and 11) or by a low formation of *junipers* (segment "h", Figure 34). The formation of *junipers* is located on the overhangs and rocky slopes with thin soil normally situated in the vicinity of the settlements. The fruit of the juniper is edible after frosts and its seeds are propagated by man and animals, invading open and eroded spaces. Some *juniper* formations can be seen in photographs from 1960, others are less than 10 years old, but all junipers are highly branched and have a large basal covering. It is indicated that the wood has been, and still is, used as posts in the construction of fences.

Further to the west, crossing this *juniper* formation, one enters the ecotone strip that insensitively becomes a humid forest.

e) Locally, the upper primary formation of *Pinus chihuahuana, Pinus engelmannii, Pinus arizonica var. stormiae* and *Pinus ayacahuite* with *Quercus crassifolia* (samples 14 and 17), has been cut down, regenerating frequently. Sometimes, *Quercus pl. sp.* and *Juniperus pl. sp.* are dominant (sample 19); in some places, *Pinus cembroides* colonizes this forest (sample 22).

Likewise, the high woody formation of *Pinus pl. sp.* is found to the east of Gudadalupe,

1 N° des relevés 2 Lieu	1 Municipio San Buenaventura	2 Cuesta las Emas, San Buenaventura	6 Municipio I. Zaragoza	7 Los Puentes, Guadalupe I. Zaragoza	8 Arroyo Seco, Guadalupe
3 Altitude 4 Exposition 5 Pente	1 350 m N.-E. 16-24 %	2 170 m E. 36-48 %	2 400 m W.	2 270 m N.	2 250 m S.-W.
Surface couverte par :					
6 roche dure et blocs	40 %	30 %	5 %	10 %	5 %
7 pierrailles	5 %	15 %	20 %	20 %	25 %
8 terre fine	20 %	10 %	40 %	10 %	35 %
9 végétation	30 %	40 %	32 %	30 %	30 %
10 litière	5 %	5 %	3 %	30 %	5 %
11 Type de formation	complexe : herbacées et ligneux bas, très claire	ligneuse peu haute	ligneuse peu haute	ligneuse haute, claire	ligneuse haute, claire
12 Composition de la strate arborée	95 % *Quercus emoryi* hauts de 2 à 4 m 54 % *Juniperus flaccida*	30 % *Pinus cembroides* hauts de 5-6 m 15 % *Quercus rugosa* et *Quercus grisea* 5 % *Juniperus flaccida*	90 % *Pinus cembroides* 5 % *Juniperus flaccida* 5 % *Quercus rugosa*	25 % *Pinus engelmannii* hauts de 15-20 m 25 % *Quercus rugosa* hauts de 4 m 20 % *Juniperus deppeana* 15 % *Q. hypoleucoides* de 6 à 8 m de haut 5 % *Pinus cembroides*	55 % *Pinus cembroides* hauts de 8 m 30 % *Quercus grisea* 10 % *Juniperus deppeana* 5 % *Pinus chihuahuana* hauts de 15 m
13 Indications sur l'âge et la hauteur des arbres			Parmi les pins 10 % ont un diamètre de 40-50 cm soit un âge moyen de 250 ans.	Nombreux jeunes *Pinus engelmannii* hauts de 20 à 50 cm.	Pas de régénération de *Pinus chihuahuana* : *Pinus cembroides* est coupé.

1 N° des relevés 2 Lieu	11 La Casita I. Zaragoza	14 La Mesa del Porvenir I. Zaragoza	17 Cerro de la Mojonera I. Zaragoza	19 Laon, I. Zaragoza	22 Cocono, I. Zaragoza
3 Altitude 4 Exposition 5 Pente	2 100 m S.-E. 9-15 %	2 250 m aucune 0-0,9 %	2 300 m N. 9-15 %	2 270 m aucune 0-0,9 %	2 250 m N.-W. 36-48 %
Surface couverte par :					
6 roche dure et blocs	20 %	25 %	10 %	35 %	35 %
7 pierrailles	20 %	20 %	10 %	5 %	10 %
8 terre fine	20 %	10 %	5 %	15 %	15 %
9 végétation	30 %	40 %	30 %	35 %	35 %
10 litière	5 %	15 %	45 %	10 %	15 %
11 Type de formation (*)	ligneuse peu haute, claire	ligneuse haute, dense	ligneuse haute assez claire	ligneuse peu haute, claire	ligneuse peu haute, claire
12 Composition de la strate arborée	30 % *Pinus cembroides* hauts de 4 m 20 % *Arctostaphylos pungens* hauts de 4 m 20 % *Quercus incarnata* 15 % *Juniperus deppeana* 10 % *Pinus chihuahuana* 5 % *Pinus engelmannii*	70 % *Pinus engelmannii* 5 % *Pinus chihuahuana* 12 % *Q. hypoleucoides* 8 % *Quercus incarnata* 5 % *Juniperus deppeana*	70 % *Pinus arizonica* var. *stormiae* 5 % *Pinus chihuahuana* 25 % *Quercus crassifolia*	35 % *Juniperus deppeana* 4 m de haut 5 % *Juniperus deppeana* hauts de 10 à 15 m 25 % *Q. grisea* 20 % *Pinus engelmannii* hauts de 20-25 m 10 % *Pinus cembroides* de 8 à 12 m de haut 5 % *Q. hypoleucoides*	50 % *Quercus grisea* 45 % *Juniperus deppeana* hauts de 4 m 5 % *Pinus engelmannii* de 25 m de haut
13 Indications sur l'âge et la hauteur des arbres	La population de pins est constituée d'individus jeunes.	Les pins ne dépassent pas 12 m de haut : de nombreuses plantules et des plants de 20 cm à 1 m de haut sont observables. Quelques plantules de *Pinus cembroides*.	Les pins se régénèrent : nombreuses plantules et individus dont les diamètres s'échelonnent entre 5 et 25 cm.	Age moyen des pins : *Pinus engelmannii* 120-150 ans (**) *Pinus cembroides* 250-300 ans (*).	Les plantules de *Pinus cembroides* sont plus nombreuses que celles de *Pinus engelmannii*.

(*) Age déterminé en comptant les anneaux de croissance sur des carottes prélevées à la tarière de Pressler.
(**) Déterminé en comptant les anneaux de croissance sur des troncs coupés.

TABLE 26 - Data on sample conditions, tree stratum composition and average tree age

on the north and northeast exposed slopes, at an altitude above 2 300 meters (sample 7).

This description indicates that the transition between the prairie and the primary formation of *Pinus cembroides* with *Quercus pl. sp*. is observed in the vicinity of the Sierra Madre Occidental and the Central Altiplano. The front of Sierra Madre Occidental, represents the limit of extension of *Pinus chihuahuana* and *Pinus engelmannii,* where it is observed protected at more than 2 300 meters of altitude, in the less sunny slopes. But in this place, its biological balance is precarious, as demonstrated by the effects caused by the 1973-1974 drought. Most of these formations of *Pinus pl. sp*. dried up during the summer of 1974, due to the attack of the escolitic insects.

Pinus cembroides extends further west into the Sierra Madre Occidental. The woody formations of *Pinus chihuahuana*, *Pinus engelmannii* with *Quercus pl. sp*. and *Juniperus sp*. overlap in the ecotone band, where the limits of both formations are confused and lose their sharpness. Human activity causes deeper changes in this strip than in the centre of the neighbouring formations. Since crops have been grown mainly at the expense of this strip, causing a slight aridification of the climate, as it seems to indicate on the one hand, the fact that the *Pinus engelmannii* and *Pinus chihuahuana* of the ecotone strip, were victims, in 1974, of the attack of escolitides and on the other hand, *Pinus engelmannii* and *Pinus chihuahuana* do not regenerate, or if they do, it is very slow and over the mountain slopes. The individuals of *Pinus cembroides* existing in the secondary open formations (sample 6), or in the ecotone strip, reach an approximate age of 250 to 300 years, indicating that this species was part of the arboreal stratum.

The ecotone strip between the forest of *Pinus pl. sp*. and the forest of *Pinus cembroides*, disappears due to human exploitation of the forest and overgrazing. *Pinus cembroides, Quercus emoryi* and *Quercus grísea*, gradually invade the formations of *Pinus pl. sp*. extending their area towards the west. This slow progression of *Pinus cembroides* is also observed in the centre of the Sierra, near Bachiriachic.

We attach that in many places of the Sierra Madre Occidental, plots of forest used for cattle grazing have been fenced in, so no renewal is observed. Again, some cattle ranchers cut down the pines, favoring the development of the oaks, since their acorns are eaten by the cattle; while other cattle ranchers, on the contrary, cut down the oaks and respect the pines. These practices could explain the juxtaposition of formations constituted either only by oaks, only by pines, or mixed formations; this mosaic of formations is frequently observed, both in the east and in the west of Mexico.

In the east, in the Sierra de la Marta, Coahuila, it was found that the high forest of *Pinus cembroides* is in regression, to the benefit of the apple and peach plantations. However, there are formations of *Pinus cembroides* that are constantly renewing themselves, while others, such as those in the Sierra de la Paila, do not. The direct cause of this phenomenon seems to be, without doubt, the continuous grazing of goats.

The dynamics of *Pinus cembroides* formations have three general development trends which are: conquest, status and regression.
Statuquo may be accompanied by the sprouting of seedlings or young plants or, conversely,

may be lacking in sprouting.
In the east, conquest is observed at an altitudinal level lower than the formation of *Pinus cembroides*, at the expense of the lower formation of *Larrea tridentata, Yucca,* or open formations of grasses. In the west, on the contrary, the conquest is observed at the upper altitudinal limit of the formation of *Pinus cembroides*, at the expense of the slow occupation of the territory of *Pinus pl. sp*.

OVERALL CONCLUSION

The area of *Pinus cembroides s.l.* within the Sierra Madre Occidental and in the northern half of the Sierra Madre Oriental has been specified. It is observed that *P. cembroides var. lagunae,* a taxon described in this work, is found only in a massif in the State of Baja California Sur. *P. cembroides var. cembroides* is the only one of all the taxa of the *Cembroides* group that reaches the southern latitudinal limit of the group: at 18° N, in the State of Puebla, while *Pinus edulis* and *Pinus remota* are absent further south than 25° N.

Within the forests of *Pinus cembroides* and the adjacent plant formations, cenological groups are individualized. Each of them presents two tendencies: one of them is mesophyll and the other xerophyll. Cenological groups in the Pinus cembroides forests of the Sierra Madre Occidental are different from those of the Sierra Madre Oriental.

The ecological profiling method established in the Centre Emberger of the C.N.R.S. of Montpellier (France) has allowed establishing relationships between plant species and ecological variables. Climatic and anthropic variables appear as the most direct influence variables on *Pinus cembroides* forests. On the other hand *P. cembroides* appears as a species indifferent to the pH of the soil surface horizon and the mother rock. There are very few indicative plants of *Pinus cembroides* and they differ from east to west of Mexico. As well as the species of the cenological groups they present a very wide distribution. No species differentiated the formations of dominant *Pinus cembroides* from the adjacent formations of dominant *Quercus pl. sp*.

The forests of *Pinus cembroides* in the Sierra Madre Occidental and in the south of the State of Baja California Sur, develop in a semi-humid climate or in transition with a cold winter. Meanwhile, the forests of the Sierra Madre Oriental and of the south of the Central Plateau are situated in a semi-arid or transitional climate. Within the Sierra Madre Oriental, *P. cembroides* is adapted to a drier and warmer climate than that present in the Sierra Madre

Occidental.

The lower altitudinal limit of the forests of *Pinus cembroides s. 1.* is located at 1 100 meters: *Pinus catarinae*, a taxon described in this work, reaches this limit. *P. cembroides* var. *cembroides* is not observed below 1 500 m but reaches 2 900 m, the upper altitudinal limit of *P. cembroides* s.l. At this altitude, it coexists with *Pinus johannis*. It is interesting to note that *Pinus cembroides* has dwarf forms at the extreme limits of its altitudinal range.

Many variations have been observed and described within *P. cembroides* during the course of this research. However, in the future it is necessary to carry out complementary studies to understand the relationship between ecology and systematics of the *Cembroides* group, in particular of *Pinus cembroides s. 1.*

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SUMMARY

The Pinus cembroides Zucc., American Pine, constitutes in Mexico tree formations that frequently assure the transition between the dry formations of the Central Plateau and the high altitude forests of the Eastern and Western Sierras Madre. Its wood, very hard, has been widely used in the 19th century and the beginning of the 20th century. Its seeds or pine nuts are, at the same time, the object of a domestic handicraft trade and of export to the United States.

These two aspects explain the interest towards a spice about which there were few elements of information at the beginning of this study in 1969. It was necessary to specify, on the one hand, the current boundaries of the area of Pinus cembroides forests, and on the other hand, its floristic composition and the ecological conditions of its development.

As the phytoecological study progressed, the full systematic complexity of these stone pines of the cembroides group appeared to us, which led us to describe new taxa and to study the characteristics of the group in a systematic way. However, the ecological study of each of the taxa we are going to describe has not been possible, so this phytogeographic study is carried out on a complex group called Pinus cembroides s. l.

This publication comprises three parts: the first one is dedicated to the systematics of the pines of the Cembroides group; the second one specifies the correlations between the forests of Pinus cembroides s. l. and the environment, particularly the adjacent plant formations; and finally, the third one deals with the distribution, bioclimate and dynamics of the forests of Pinus cembroides.

This work began in 1969, and continued during the summers of 1970, 1971, 1975, 1976 and February and March 1978. Subsidized by the French Archaeological and Ethnological Mission, the CNRS and the CONACYT, this research has been supported by different Mexican Research Institutes: the National Institute of Forest Research, the Institute of Arid Zones of San Luis Potosi (SLP), the Agrarian University "Antonio Narro", Saltillo (Coah.) and the Laboratory of Phanerogamy of the National Polytechnic Institute of Mexico directed by Dr. J. S. Rzedowski. A copy of all the specimens collected in the course of each field study has been deposited in the herbarium of this Institute mentioned above.

I. SYSTEMATICS OF THE PINES OF THE CEMBROID GROUP

The Pinus cembroides is a pine from the Haploxylon section, with an aptera seed. Briefly, it was possible to make the history of the difficulties of classification of the pines of this

group, of which Engelman already realized. Recently, Lanner proposed to gather in a cembroides group, all the pine trees, except P. maximartinezii, P. nelsonii and P. pinceana. We have adopted this point of view.

One of the characteristics commonly used for the systematics of pines is the number of leaves in each fascicle and this makes the keloid group appear as an evolutionary series whose two poles are Pinus monophylla (single-leaf fascicle) and Pinus culminicola (five-leaf fascicle).

The color of the endosperm has seemed to us a good characteristic to separate, on the one hand the pines similar to the Pinus edulis and of the other the Pinus cembroides and its varieties. Indeed, the endosperm of Pinus edulis, like that of Pinus monophylla and Pinus culminicola, is white, while that of Pinus cembroides is pink (colour due to phenolic compounds).

We have had to describe two new taxa, of which one is assimilated to Pinus edulis. The tree populations attributed so far to Pinus edulis in Northern Mexico are differentiated by the number of resin channels of the species. Before finishing this work, two American researchers (Bailey and Hawksworth) have assured, based on the observation of herbarium samples, that these pines should be catalogued as the remote Pinus.

We do not share this point of view and we distinguish the dwarf pines of Santa Catarina, from more than two resiniferous channels and white endosperm, from the tall and straight pines, from more than two resiniferous channels of the Northwest of the State of Coahuila. The dwarf form is called Pinus catarinae sp. nov.

As regards Pinus cembroides s. str. defined by a pink endosperm, the systematic enumerations of the leaves in six different populations, show that the number of them per fascicle, is a fluctuating character.

The enumeration of the cotyledons, the observation of the growth of the young plants, make appear a fast growing variety: Pinus cembroides var. nov.

Finally, the author proposes a system to distinguish the various taxa of the cembroid group.

II. VEGETATION AND ENVIRONMENT

It was necessary, at the same time, to specify the floristic composition and ecological variables of the Pinus cembroides formations and to situate it in relation to the neighbouring plant formations.

For this reason, we have proceeded to systematically collect samples from the populations of Pinus cembroides, indicated by Martinez (1948). Whenever the topography allowed us, these samples were collected in different height classes. A large amount of this data has been verified.

The information on the vegetation and the environment has been treated according to two complementary mathematical methods: the factorial analysis of similarities and the ecological profile method. These methods are rigorous, but the results obtained have no other meaning than the precise framework of this study, since any extrapolation must be done with caution.

The factorial analysis of similarities has allowed us to globally associate the notes taken throughout our study, the ecological variables and the plant species, and makes the primordial importance of temperature variation in altitude appear. The factorial analysis leads the author to propose some cenological groups, groups of related plants. Within each of them, two tendencies can be distinguished: one mesophilic and the other xerophilic. The formations of Pinus cembroides have as a whole a very poor floristic cortex: that of the Sierra Madre Orientale differs from that of the Sierra Madre Occidental. Some species like Juniperus deppeana, Arctostaphylos pungens are more frequent in the West than in the East.

The ecological profile method allows us to characterize the elemental relationships between each species and each ecological variable and thus to order and distinguish the indicator species of each important ecological variable. For the first time it has been possible to establish numerous relationships between species and ecological variables.

The indicator species and the components of the cenological groups have a wide distribution and if we add that the Pinus cembroides is located in the marginal or transition areas, we can conclude that the distribution of the Pinus cembroides areas is linked to two factors: on the one hand the climatic variations and on the other hand the anthropic variables.

III. THE FORMATIONS OF PINUS CEMBROIDES

Many observations made on Pinus cembrooides forests, which are difficult to code, could not be included in the previous chapter; however, they allow us to specify the formations of Pinus cembrooides and their current dynamics.

Until now there was only one map of Pinus cembroides distribution, the one of Critchfield and Little; we propose two maps at a large scale, of the presence and distribution of Pinus cembroides; one in the Sierra Madre Occidental and the other in the Sierra Madre Oriental, between degrees 24 and 26 of North latitude.

The available climatic data have been analyzed with diverse methods, which makes it appear that in the Sierra Madre Occidental the formations of Pinus cembroides are located in a transitional climate, sometimes semi humid with cold winters. In the East, the climatic conditions are a little different, particularly in the State of Coahuila, where the Pinus cembroides formations benefit from a semi-arid climate. In the other Eastern States, they develop in a drier and warmer transition climate than in the West.

The succession of the altitudes, very complex in the field, is presented by some cuts-types chosen in the two Sierras Madres Oriental and Occidental, as well as in the south of the Central Plateau.

Finally, three trends are observed in the current dynamics of the Pinus cembroides forests, both in the West and in the East of Mexico:
- a slow conquest of both xerophytic vegetation and Pinus pl. sp. forests;
- a state of equilibrium;
- a retreat due to systematic cutting.

A detailed study done in the State of Chihuahua shows that the ecotone strip between Pinus cembroides formations and adjacent vegetation is frequently altered by human occupation.

This study will later establish a relationship between ecology and systematics of the various species of stone pine, described here and whose existence was unknown in 1969.