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Article

# Population structure of *Agave gentryi* B. Ullrich in southern Nuevo León

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## Abstract

Agave has great economic demand in Nuevo León; of the 14 species reported, *Agave gentryi* B. Ullrich has the highest rate of utilization for distillation of individuals in juvenile stages and in harvesting, so based on the hypothesis that the population of these stages has decreased, the objective of the research was to evaluate the population structure of the phenological stages of this species. The study area was located in the Ejido La Canoa, municipality of Aramberri. Sampling was carried out twice a year at two sampling sites: the first in a harvesting area and the second in an area excluded from harvesting. A total of 10 quadrats 64 m² were established, from which the individuals were counted, classified into phenological stages, and morphometrically evaluated. The data follow a normal distribution, so a factor analysis and a Tukey test were performed. The results indicate a total of 3 687 and 6 156 individuals per ha for the sites under harvesting and without harvesting, respectively; there is a highly significant difference in quadrat coverage (F= 4.3, *p* # 0.01). In the non-harvested sites, the phenological stage corresponding to juvenile stage one registered the highest relative abundance with 36%, the adult stage presents relative dominance of 33.42%, and the juvenile stage two exhibits an importance value index of 50.48%; in contrast, in the harvested sites, the highest values correspond to the adult stage, relative abundance of 31.82%, relative dominance of 51.4%, and importance value index of 54.41%; a high demand was found in juvenile phenological stages one and three.

## Keywords:

Agave, harvesting, mezcal, non-timber, sustainable.

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# Introduction

The genus *Agave*, proposed by Linnaeus in 1753, was included in different families, such as Amaryllidaceae, Agavaceae, and, in recent years, based on morphological and molecular evidence, in Asparagaceae, subfamily Agavoideae (APG IV, 2016; APG III, 2009). Its natural distribution is from the south of the United States of America to the north of South America. Of the total species (210), 159 species are distributed in Mexico, and 61% are endemic to Mexican territory (García-Mendoza *et al*., 2019).

Magueys are among the most important plants that have sustained human groups in Mexico; 103 different uses have been documented (Gentry, 2004). Among its uses, it stands out as a source of food and fiber, and the production of beverages such as maguey sap, maguey syrup and mezcal (Solís *et al*., 2021).

For northeastern Mexico (Coahuila, Nuevo León and Tamaulipas), 28 species of maguey are reported. In the state of Nuevo León, 14 species are registered, with the following species standing out for their wide distribution: *Agave americana* L., *Agave scabra* Salm-Dyck, *Agave lechuguilla* Torr., *Agave striata* Zucc., and *Agave gentryi* B. Ullrich. In the rural communities of southern Nuevo León, in the municipalities of Dr. Arroyo, Mier y Noriega, Galeana, General Zaragoza, Aramberri, and Iturbide, the wild populations of *Agave gentryi* represent an important non-timber forest resource for the local economy and base income for families, since the individuals that are collected are used for the sale of plants as ornaments, reforestation programs, and the production of distillates (Núñez *et al*., 2021).

Nevertheless, overuse and the occurrence of forest fires, pests, and diseases have altered their distribution and deteriorated their populations (Aguirre and Eguiarte, 2013). The assessment of population structure is frequently used to implement species conservation actions and in harvesting permits (Cervera *et al*., 2018; Hernández *et al*., 2021; Valdivieso-Solís *et al*., 2021; SEMARNAT, 2024).

Based on the hypothesis that a high utilization of *Agave gentryi* at juvenile stages limits development to senile stages, the objective of this research was to describe the population structure of this species in harvested and non-harvested sites of the Ejido La Canoa, municipality of Aramberri, Nuevo León.

# Materials and methods

## Study area

The work was conducted in the Ejido La Canoa, municipality of Aramberri, at the geographical coordinates: longitude: 40° 96’ 05”, north latitude: 27° 06’ 09”, at an altitude of 2 600 m (Figure 1). In this area, Leptosols and Regosols with medium texture predominate. The climate is temperate with summer rainfall (Cw); the total annual precipitation is 300 to 400 mm, usually in June, with a maximum historical rainfall of 854.6 mm and an average annual temperature between 14 and 18 °C (INEGI, 2019).

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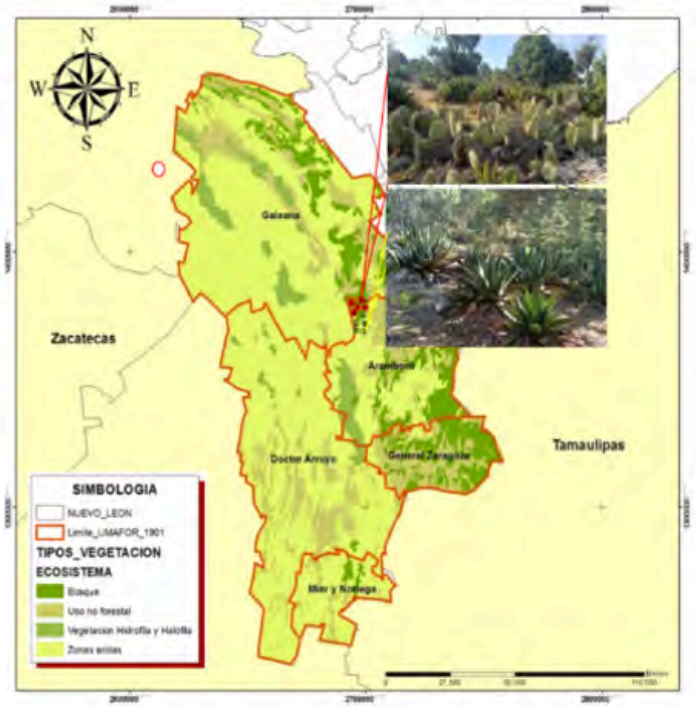
**Figure 1. Location of the study area of the green maguey in the Ejido La Canoa in southern Nuevo León.**

**Sitio de estudio**

| Unidad de muestreo | Coordenadas geográficas Latitud (x) | Longitud (y) |
|---|---|---|
| | Sin aprovechamiento | |
| 1 | 24°27´38" N | 99°53´12" W |
| 2 | 24°27´40" N | 99°53´14" W |
| 3 | 24°27´43" N | 99°53´12" W |
| 4 | 24°27´38" N | 99°53´11" W |
| 5 | 24°27´37" N | 99°53´14" W |
| | En aprovechamiento | |
| 6 | 24°27´46" N | 99°53´22" W |
| 7 | 24°27´53" N | 99°52´59" W |
| 8 | 24°27´50" N | 99°53´03" W |
| 9 | 24°27´44" N | 99°53´03" W |
| 10 | 24°27´42" N | 99°53´05" W |




The type of vegetation is pine-oak forest (Manzanilla-Quijada, 2021), with the presence of the following species standing out: *Pinus pseudostrobus* Lindl., *Pinus cembroides* Zucc., *Quercus laurina* Bonpl., *Juniperus deppeana* Steud., and *Opuntia robusta* H.L. Wendl. ex Pfeiff.

In the spring and summer of 2023, a point quadrat sampling was carried out, choosing two sites; the first in a harvested area with permanent extraction of individuals, the area does not have a previous population census nor are there criteria for the extraction of specimens from a certain phenological stage, all individuals with a height of # 65 cm are harvested and adult individuals are left to produce seeds. The second in a non-harvested area, which, due to the difficult access for harvesting, has individuals in adult and senile phenological stages.

A total of 10 quadrats 64 m² were established in a completely randomized design, with a sampling intensity of 10% and a 320 m² area per sampling site, placing quadrats one to five on the non-harvested site and quadrats six to ten on the harvested site. The phenological stages of the green maguey were classified based on the height of the plant (Figure 2).

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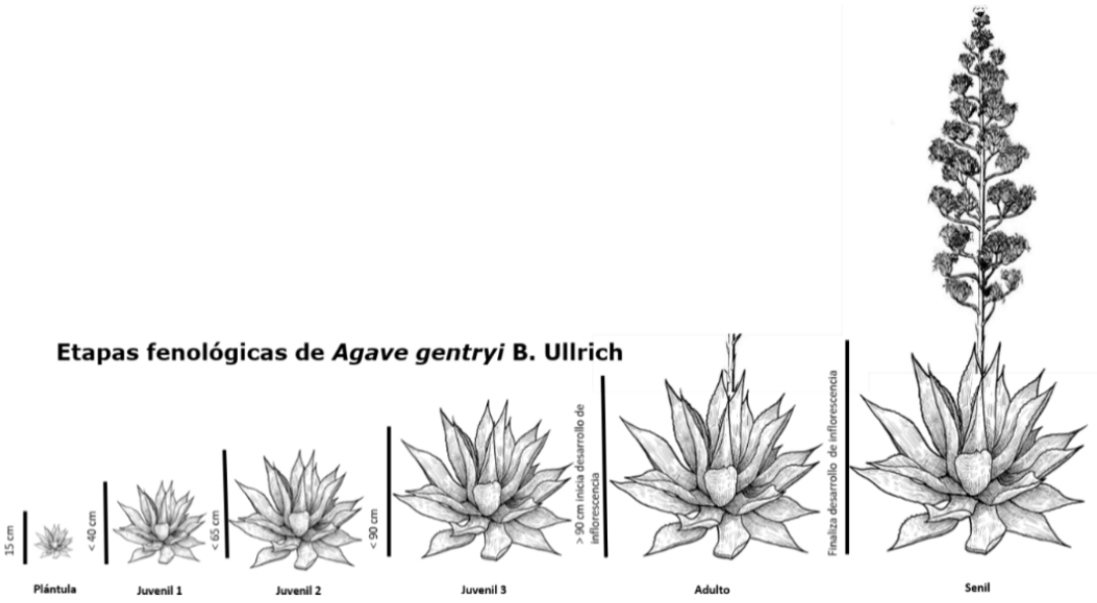
**Figure 2. Phenological stages of the green maguey. Seedling= height < 15 cm (1-3 years); juvenile 1= height < 40 cm (4-5 years); juvenile 2= height < 65 cm (6-7 years); juvenile 3= height < 90 cm (9-10 years); adult= height < 90 cm and inflorescence development begins (11-13 years); senile= inflorescence development is completed (13-15 years).**




For each stage, the Importance Value Index (IVI) was calculated with the average of the parameters of relative abundance (RA), relative frequency (RF) and relative dominance (RD) (Magurran, 2004), which are calculated with the following formulas:

**1)**

$$RA = \frac{ni}{N} x100$$

Where: ni= the number of individuals of species i; N= total number of individuals in the sample.

**2)**

$$RF = \frac{Fi}{\sum F} x100$$

Where: fi= the number of plots where the species is found.

**3)**

$$RD = \frac{Di}{\sum D} x100$$

Where: di= the basal area of the species.

Based on the methodology proposed by Huerta-Zavala (2018) and using a tape measure, the following values were evaluated: coverage (cm), height (cm), total number of leaves, leaf length (cm), and leaf width (cm) (Figure 3).

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**Figure 3. Evaluation of the morphometric characters of the green maguey in the non-harvested sites.**

The morphometric traits follow a normal distribution; an analysis of variance was carried out, considering the harvesting type as the treatment and phenological stage as the factor (Steel and Torrie, 1980).

## Results and discussion

The harvested area has a coverage of 1 468.75 m² $ha^{-1}$, a value lower than the non-harvested area (2 471.55 m² $ha^{-1}$). Plot one stands out with the broadest coverage. The ANOVA was performed based on absolute values, showing significant differences in coverage in the adult and senile stages under harvesting (F= 4.3, $p \leq 0.01$).

A total of 3 687 individuals per ha were counted for the harvested sites and 6 156 individuals per hectare for the non-harvested sites, the number of maguey individuals in the harvested sites is greater, and there is a significant difference between the individuals present in the phenological stages of seedling, juvenile three, and senile (F= 3.99, $p \leq 0.01$) (Figure 4; Figure 5)

**Figure 4. Number of *Agave gentryi* individuals by phenological stage by harvested site.**

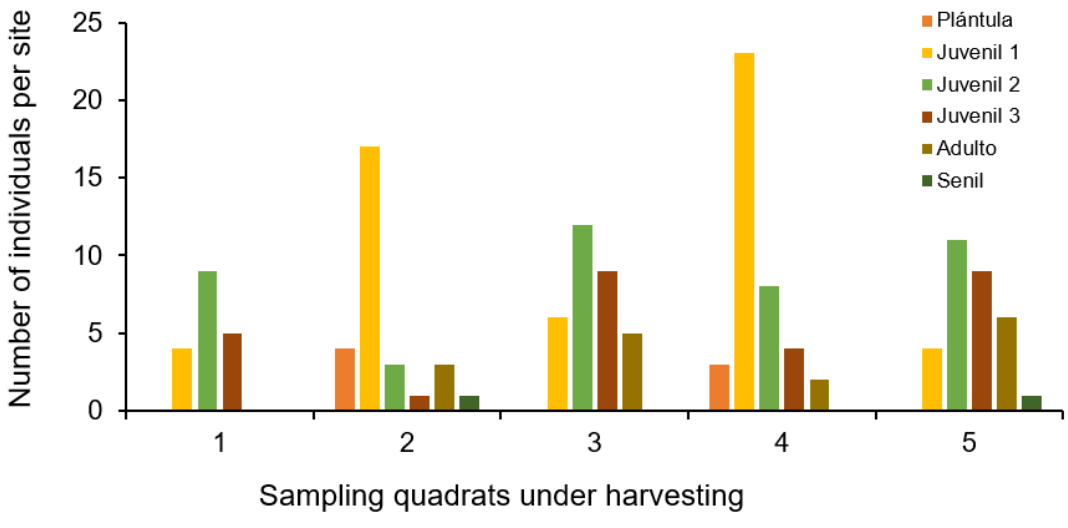

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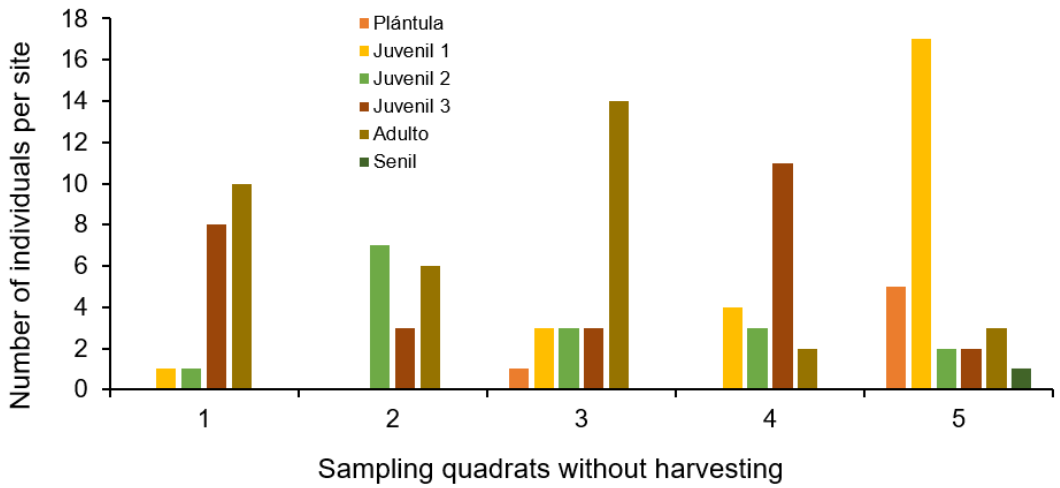
**Figure 5. Number of *Agave gentryi* individuals by phenological stage in non-harvested areas.**




**Relative abundance (RA).** In the non-harvested areas, the phenological stage corresponding to juvenile one registered the highest RA at 36%, whereas in the harvested areas, adult-stage plants had the highest RA at 31%.

**Relative dominance (RD).** In the non-harvested areas, the adult phenological stage had an RD of 33.42%, whereas in the harvested areas, it was 51.4%.

**Relative frequency (RF).** In the non-harvested areas, individuals of all phenological stages were found; in contrast, in the areas subjected to harvesting, a higher percentage of individuals belong to juvenile stages one, two and three and a lower percentage to the seedling and senile stages. The highest importance value is found in the non-harvested areas at the juvenile stage two (50.48%) and in the harvested areas at the adult stage (54.41%) (Table 1).

**Table 1. Values of the structural variables evaluated.**

| Reproductive stage | Relative abundance | Relative dominance | Relative frequency | Importance value |
|---|---|---|---|---|
| | | Non-harvested | | |
| Seedling | 4.67 | 0.33 | 100 | 35 |
| Juvenile 1 | 36 | 7.45 | 100 | 47.82 |
| Juvenile 2 | 28.67 | 22.77 | 100 | 50.48 |
| Juvenile 3 | 18.67 | 24.3 | 100 | 47.66 |
| Adult | 10.67 | 33.42 | 100 | 48.03 |
| Senile | 1.33 | 11.74 | 100 | 37.69 |
| | | Harvested | | |
| Seedling | 5.45 | 2.53 | 40 | 16 |
| Juvenile 1 | 22.73 | 10.05 | 100 | 44.26 |
| Juvenile 2 | 14.55 | 8.61 | 100 | 41.05 |
| Juvenile 3 | 24.55 | 22.94 | 100 | 49.16 |
| Adult | 31.82 | 51.4 | 80 | 54.41 |
| Senile | 0.91 | 4.47 | 40 | 15.13 |

A study carried out with other individuals of the species *Agave americana*, *lechuguilla*, and *striata* shows similar values in their abundance; however, it reported a lower dominance due to the

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physiognomy of the species and therefore a lower IVI than *A. gentryi* (Mata, 2014). Tukey's analysis brings together the individuals from the non-harvested and harvested sites in a statistical group that has very similar mean heights, except for the senile phenological stage (149.4 ±0.89 a), which is placed with the highest height (Table 2).

**Table 2. Average values of morphometric traits.**

| Phenological stage | Number of individuals | Coverage (cm) | Number of leaves | Leaf width | | Height (cm) |
|---|---|---|---|---|---|---|
| | | | | base (cm) | apex (cm) | |
| | | | Non-harvested | | | |
| Seedling | 3 ±1.41bc | 0.03 ±0.6c | 15.1 ±6.65ef | 1.8 ±1.09e | 2.04 ±0.61d | 14.8 ±1.09g |
| Juvenil 1 | 7 ±5.61a | 0.31 ±0.8c | 16.2 ±6.87def | 8.9 ±2.47d | 2.02 ±0.59d | 34.76 ±7.68f |
| Juvenil 2 | 3.8 ±1.92a | 0.48 ±0.67bc | 20.8 ±11.8cde | 10.2 ±1.98d | 2.38 ±2.39bc | 60.04 ±7.89e |
| Juvenil 3 | 6.2 ±4.44ab | 0.74 ±0.33bc | 21.6 ±4.56cde | 12.4 ±2.43bcd | 2.88 ±0.98ab | 75.8 ±9.64d |
| Adult | 7 ±5a | 1.35 ±0.31bc | 28.6 ±4.93cd | 15.1 ±1.19abc | 3.06 ±0.95a | 103.5 ±5.07c |
| Senile | 1 ±0.71c | 0.84 ±0.97bc | 48.8 ±1.3a | 19.8 ±0.44a | 1.94 ±0.09cd | 149.4 ±0.89a |
| | | | Harvested | | | |
| Seedling | 1 ±0.55bc | 0.04 ±1.03c | 7.8 ±3.27f | 3.5 ±0.94e | 0.42 ±0.18d | 8.5 ±2.78g |
| Juvenil 1 | 9.2 ±6.49a | 0.19 ±0.87c | 13 ±1.22ef | 8.8 ±1.9d | 0.86 ±0.41d | 29.48 ±1.19f |
| Juvenil 2 | 11.6 ±4.92a | 0.63 ±0.54bc | 20 ±2.35cdef | 12.8 ±1.56bcd | 2 ±0.68bc | 54.79 ±2.99e |
| Juvenil 3 | 6.2 ±4.32ab | 1.16 ±0.12bc | 29.6 ±5.13bc | 14.58 ±1.83bc | 2.24 ±0.15ab | 78.16 ±1.72d |
| Adult | 9 ±5.96a | 1.84 ±0.07ab | 29.8 ±8.49bc | 17.2 ±5.09ab | 2.24 ±0.3a | 100.08 ±4.83c |
| Senile | 3 ±2c | 2.87 ±0.36a | 42 ±7.04ab | 15.52 ±7.18ab | 1.5 ±0.5cd | 132.64 ±11.8b |

In each column, means with the same letter are not significantly different (Tukey, 0.05). Mean ± standard deviation.

The Anova indicates that there is a significant difference in 9 of 10 quadrats for the number of leaves (F= 4.8, $p \leq 0.01$) (Table 2). The width values of the outer leaves at the base show similarity in the seedling stage and juvenile stage one, whereas for the rest of the stages, there is a significant difference. For the measurement of the apex of the outer leaves, there is no statistical difference (F= 4.03, $p \geq 0.01$) (Table 2).

Álvarez-Ríos (2020) attributes the difference between the number of individuals present at the sites to the lack of a management plan that guarantees the replacement of the extracted individuals. The number of *A. gentryi* individuals for the study area is larger than that documented for other mezcalero agaves. For *Agave potatorum* Zucc., Torres *et al*. (2013) recorded an availability of 12 to 16 adult agaves per ha and Álvarez-Ríos (2020) reported 1 340 individuals per hectare; in contrast, Cervera *et al*. (2018) documented 7 956 individuals per hectare for *Agave angustifolia* Haw. High dominance values indicate that individuals at harvestable age contribute to ecosystem productivity (Salvador, 2005; Loera-Gallegos *et al*., 2018). The high relative frequency of seedlings in non-harvested sites is attributed to the fact that each individual in the adult stage is capable of producing offspring. The study by Loera-Gallegos *et al*. (2018) reports that there are no scientific elements or normative criteria that regulate or optimize the correct harvesting of maguey, so they are harvested in inappropriate phenological stages, which limits the probability of sexual reproduction and the development of individuals until maturity (Lara-Ávila, 2016; Roldán, 2023).

The floral biology of *Agave gentryi* provides ecological bases for its proper utilization. Overexploitation of this species has had a harmful effect on the plants and animals associated with them. Castillo-Hernández (2009) concluded that the production of nectar and concentration of sugars in *Agave gentryi* flowers are related to the characteristics of bat pollination, as they have greater nectar production, concentration of sugars during the night, and the receptivity of nocturnal stigma. Therefore, this species is closely related to bats, providing food and shelter.

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## Conclusions

The objective of this research was to identify the population structure of this species in harvested and non-harvested sites of the Ejido La Canoa, municipality of Aramberri, Nuevo León. There was a high harvesting rate for distillation and sale of plants as ornaments in specimens aged four to nine years, which should be done from the tenth year onwards. *A. gentryi* is a monocarpic species (Gentry, 2004) that, when harvested before completing the development of the inflorescence, interrupts its only reproductive event. It was determined that, in the harvested sites, there are changes in the vegetation cover, there are 31% of individuals in the adult stage, which have the largest size and dimension of heart, a characteristic of relevance for distillation; likewise, there is a high demand for the phenological stages corresponding to juveniles one and three, which must be protected to guarantee their long-term harvesting. By modifying their reproductive behavior, the existence of a large number of organisms whose survival depends on this species is put at risk. It is recommended to provide sustainable management for individuals in the seedling and senile stages that guarantees the production of germplasm. It is necessary to implement public policies for harvesting *Agave gentryi* in order to carry out sustainable utilization. The population values by phenological stage will serve as a basis for future conservation and management studies that contribute to adequate non-timber forest use.

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# Population structure of *Agave gentryi* B. Ullrich in southern Nuevo León


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