Essay

Conservation status of eleven wild bean (*Phaseolus* spp. Fabaceae) species in northeastern Mexico

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Abstract

Rare and endemic plants, such as the wild species of *Phaseolus* (Fabaceae) in northeastern Mexico, deserve high priority in conservation efforts because of their uniqueness and usefulness as plant genetic resource. This is particularly important because during the last decades, some of these species have become endangered because of anthropogenic and natural factors. The study aimed to determine the current conservation status of 11 reported wild bean species in northeastern Mexico, using wild bean data from 77 expeditions to the states of Nuevo León and Tamaulipas during the period 1869-2013.The conservation status of the different species was determined according to the Official Mexican Standard NOM-059-SEMARNAT-2010. The categories of risk were based on four indicators: amplitude of distribution, habitat status, biological vulnerability and impact of human activity. The following eight wild *Phaseolus* species are not at risk of extinction: *P. albiflorus*, *P. glabellus*, *P. leptostachyus*, *P. maculatifolius*, *P. neglectus*, *P. pedicellatus*, *P. vulgaris* and *P. zimapanensis*. On the other hand, *P. altimontanus* Freytag & Debouck is categorized as threatened; *P. novoleonensis* Debouck, in danger of extinction; and *P. plagiocylix* Harms, possibly extinct. Current *in situ* and *ex situ* conservation programs need to be strengthened and expanded for the medium- and long-term protection of wild bean species in northeastern Mexico.

Key words: bean breeding, endangered species, genetic erosion, Northeastern Mexico, wild beans.

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The majority of known wild species of *Phaesolu*s (Fabaceae) in the world grow in Mexico (Delgado-Salinas, 2012), and most of these are endemic (Delgado-Salinas 2012; Porch *et al*., 2013). They are distributed mainly in the central region, from Jalisco State to México State, and in the southern region, in Chiapas State (Freytag and Debouck, 2002). The number of species in other regions is smaller, but not less important (Acosta-Gallegos, 2012).

Northeastern Mexico is one of the regions recognized for the diversity of wild species of *Phaseolu*s. Unfortunately, over time, the populations of some of these wild species have become reduced or fragmented due to anthropogenic and natural factors. Urbanization, immoderate logging, overgrazing and forest fires negatively impact these species (Brush, 2000; Acosta-Gallegos, 2012). Climate change is another risk factor for *Phaseolus*.

Modeling studies of species distribution (Villers-Ruiz and Trejo-Vázquez, 2000; Torres-Meza *et al*., 2009; Torres-Meza *et al*., 2014) indicate that as temperature increases, *Phaseolu*s habitats in cold temperate forests (coniferous forest and holm oaks) and wet forests (mountainous mesophilic forests) are likely to disappear, while tropical deciduous forests and thorn forests will tend to occupy a larger surface area than at present.

Xerophilous scrub, which is also considered one of the habitats of wild bean, shows a lower degree of anthropogenic disturbance, but with the impact of climate change, its surface area could also be reduced (Gómez-Mendoza and Arriaga, 2007; Rojas-Soto *et al*., 2012). With 80 species of flora in Nuevo Leon considered in danger of extinction Alanis (2016), the richness of *Phaseolus* species in northeastern Mexico could be adversely affected by the decline of plant communities in areas where the greatest number of wild species is currently distributed.

Global food security in the context of climate change requires increased bean yields, particularly of the common bean (*Phaseolus vulgaris* L.), to match the rate of population growth (Porch *et al*., 2013). Common bean is a vital source of nutrition worldwide and a staple crop in low-income countries (Petry *et al*., 2015). To address the problem of current low yields of the common bean and the constraints presented by climate change (e.g. high temperature and drought stress), genetic improvement tapping the genetic diversity offered by crop wild relatives, such as those in northeastern Mexico, and related species must be explored. The genetic variants that can withstand climate-related stresses and diseases and produce greater yield need to be identified and utilized by bean-breeding programs (Porch *et al*., 2013).

While some species have been studied in this regard (eg. *P. maculatus* for cold tolerance, *P. acutifolius* for tolerance to drought and high temperatures, and *P. coccineus* for resistance to root rot) (López-Soto *et al*., 2005), others have not been tapped because of the lack of

knowledge about them. Information on existing and potential wild bean populations is therefore important for the detection of possible sources of genes for tolerance to adverse factors (high temperatures, drought, etc).

The objective of this work was to determine the status of the populations of 11 wild *Phaseolus* species in northeastern Mexico, in order to guide the development and prioritization of conservation plans for these important plant genetic resources.

Study area

The study used data from various collection expeditions to the states of Nuevo Leon and Tamaulipas in northeastern Mexico. The area is in the extreme northeastern corner of the Mexican Republic between parallels 22° 30' and 25° 45' N latitude and 99° 00' and 100° 30' W longitude. The predominant climates are: (1) semi-warm, sub-humid with an annual mean temperature of > 18 °C, temperature of <18 °C in the coldest month and >22 °C in the hottest month; an annual precipitation of 500-2 500 mm, with 0–60 mm during the driest month and 5-10.2% of the annual rain during summer; (2) temperate, semi-humid with an annual mean temperature between 12 and 18 °C, temperature of -3 and 18 ºC during the coldest month and < 22 °C during the hottest month; an annual precipitation of 200-1 800 mm, with 0-40 mm during the driest month and 5-10.2% of the annual rain during summer Köppen classification modified by García (1973).

The study area has low hills (500-700 masl) and mountain peaks (>3 000 masl). Vegetation is mainly coniferous, oak and pine-oak forest, plains with grassland and desert scrubland (INEGI, 2013). Predominant soil types are Lithosols, Rendzinas, Calcaric regosols and Chromic vertisols (INIFAP-CONABIO, 1995).

Database

A database was generated that contains the following information: year of collection, number of accessions and number of populations observed and place of collection for each of the eleven species under study. This database was derived from the collections of 77 expeditions to the states of Nuevo León and Tamaulipas during the period 1869-2013. It was developed and analyzed to determine the status of 11 wild species of *Phaseolus* (Table 1).

Cuadro 1. Poblaciones de especies silvestres de *Phaseolus* reportadas en la región noreste de México (Nuevo León y Tamaulipas).

Species	Year-collector-collection, accessions	State	Source	No. of populations
P. albiflorus Freytag & Debouck	1936, Taylor 194. 1978, D'Arcy 11801. 1985, Debouck *et al*. 1503, 1506, 1510, 1520, 1522 y 1527. 1989, Estrada-Castillón 1869. 1982, Grimes *et al*. 2355. 1948, Meyer *et al*. 3046. 1981, Poole 2401.	Nuevo León	Freytag y Debouck (2002)	12
	2010, 2011 y 2012, Hernández y Acosta 601, 602, 603, 604, 605, 606, 607, 608, 611, 612, 614, 615, 616, 617, 627, 628, 629, 630, 631, 632, 633, 656, 657 y 659.	Nuevo León	Acosta-Díaz *et al*. (2015)	24

Species	Year-collector-collection, accessions	State	Source	No. of populations
	2013, Hernández y Acosta 701.	Tamaulipas	Acosta-Díaz *et al*. (2015)	1
	1964, Webster *et al*. 87.	Tamaulipas	Freytag y Debouck, (2002)	1
P. altimontanus Freytag & Debouck	1984, Lavin 4889. 1985, Debouck *et al*. 1525 y 1523.	Nuevo León	Freytag y Debouck, (2002)	3
	2004, Estrada-Castillón S. N.	Nuevo León	Estrada-Castillón *et al*. (2004)	1
	2013, Hernández y Acosta 653.	Nuevo León	Acosta-Díaz *et al*. (2015)	1
P. glabellus Piper	1941, Standford *et al.* 1016. 1950, Sharp 50235. 1956, Martinez *et al.* F-1925. 1957, Dressler 1993. 1960 Duke M3625.	Tamaulipas	Freytag and Debouck (2002)	5
	2013, Hernández y Acosta *732*.	Tamaulipas	Acosta-Díaz *et al*. (2015).	1
P. leptostachyus var. *leptostachyus* Benth	1937, White *et al.* 130. 1939, Muller 2829. 1947, Lacas 544. 1979, Hinton *et al.* 17697. 1985, Debouck *et al*. 1505, 1519, 1521 y 1524. 1986, Debouck *et al*. 2062.	Nuevo León	Freytag y Debouck (2002)	9
	2004, Estrada-Castillón *et* al. S. N.	Nuevo León	Estrada-Castillón *et al*. (2004)	1
	2010, 2011 y 2012, Hernández y Acosta 610, 619, 620, 621, 622, 623, 634, 635, 636, 637, 638, 639, 640, 641 y 658.	Nuevo León	Acosta-Díaz *et al*. (2015)	15
	1930, Bartlett 10137. 1959, Johnston *et al.* 4115. 1986, Debouck *et al*. 2066.	Tamaulipas	Freytag y Debouck (2002)	3
	2013, Hernández y Acosta 702, 712, 715, 717, 723 y 734.	Tamaulipas	Acosta-Díaz *et al*. (2015)	6
P. maculatifolius Freytag & Debouck	1985, Debouck *et al*. 1509.	Nuevo León	Freytag Debouck (2002)	1
	2004, Estrada-Castillón *et al*. 13238.	Nuevo León	Estrada-Castillón *et al*. (2004)	1
	2010 y 2012, Hernández y Acosta 654, 671 y 672.	Nuevo León	Acosta-Díaz *et al*. (2015)	3
	2013, Acosta y Hernández 709 y 710.	Tamaulipas	Acosta-Díaz *et al*. (2015)	2
P. neglectus Hermann	1985, Debouck *et al*. 1510, 1517, 1520, 1522 y 1527.	Nuevo León	Rodríguez *et al*. (1987)	5
	1939, Muller 2881. 1980, Villanueva 9.	Nuevo León	Freytag and Debouck, (2002)	2
	2004, Estrada-Castillón *et al*. S. N.	Nuevo León	Estrada-Castillón *et al*. (2004)	1
	2010, Hernández y Acosta 609.	Nuevo León	Acosta-Díaz *et al*. (2015)	1

Species	Year-collector-collection, accessions	State	Source	No. of populations
	1965, Webster *et al.* 223. 1986, Martínez 1346.	Tamaulipas	Freytag y Debouck (2002)	2
	2013, Hernández y Acosta 703, 704, 705, 708, 711, 735 y 737.	Tamaulipas	Acosta-Díaz *et al*. (2015)	7
P. novoleonensis Debouck	1985, Debouck *et al*. 2061.	Nuevo León	Salcedo *et al*. (2006)	1
	2004, Estrada-Castillón *et al*. 633.	Nuevo León	Estrada-Castillón *et al*. (2004)	1
	2010 y 2011, Hernández y Acosta 650 y 651.	Nuevo León	Acosta-Díaz *et al*. (2015)	2
P. pedicellatus Benth	1948, Meyer *et al*. 3029. 1869, Hinton *et al*. 17107. 1977, Wells *et al*. 313. 1985, Debouck *et al*., 1508, 1512 y 1516.	Nuevo León	Freytag Debouck (2002)	6
	2010, 2011, 2012 y 2013, Hernández y Acosta 642, 643, 644, 645, 646, 647, 648 y 649.	Nuevo León	Acosta-Díaz *et al*. (2015)	8
	2013, Hernández y Acosta 706, 707 y 736.	Tamaulipas	Acosta-Díaz *et al*. (2015)	3
P. plagiocylix Harms	1895, Seler, 1042. 1967, Weedon 4074.	Nuevo León	Freytag y Debouck (2002)	2
	2004, Estrada-Castillón *et al*. S.N.	Nuevo León	Estrada-Castillón *et al*. (2004)	1
P. vulgaris L.	1931, Von Rozynski 139.	Tamaulipas	Freytag Debouck (2002)	1
	2013, Hernández y Acosta 724, 725, 726.	Tamaulipas	Acosta-Díaz *et al*. (2015)	3
P. zimapanensis Delgado	1985, Debouck *et al*. 1504, 1511 y 1515.	Nuevo León	Freytag y Debouck (2002)	3
	2011 y 2012, Hernández y Acosta 655 y 670.	Nuevo León	Acosta-Díaz *et al*. (2015)	2
	1941, Stanford *et al.* 774. 1986, Debouck *et al*. 2065.	Tamaulipas	Freytag y Debouck, (2002)	2
	2013, Hernández y Acosta 713, 714, 716, 720, 721, 722, 728 y 733.	Tamaulipas	Acosta-Díaz *et al*. (2015)	8

The information was obtained from compilations of wild bean accessions reported in the literature by Hinton and Hinton (1995); Rodríguez *et al*. (1987); Freytag and Debouck (2002); Estrada-Castillón *et al*. (2004); Salcedo *et al*. (2006) as well as from the work recently carried out by Acosta-Díaz *et al*. (2015).

Determining status of species

The following 11 species were included in the study: *P. albiflorus*, *P. altimontanus*, *P. glabellus*, *P. leptostachyus*, *P. maculatifolius*, *P. neglectus*, *P. novoleonensis*, *P. pedicellatus*, *P. plagiocylix*, *P. vulgaris* and *P. zimapanensis.*

The conservation status of the species was determined according to the Official Mexican Standard NOM-059-SEMARNAT-2010 (SEMARNAT, 2010), which defines the risk categories as follows.

Possibly extinct species in the wild are those native species whose populations have disappeared in the wild, as proven thus far by documentation and studies, and of which there are known specimens in national germplasm banks or outside the national territory.

Endangered species are those species whose distribution areas or population sizes in the regional territory have been drastically reduced, putting at risk their viability throughout their natural habitat, due to factors such as the destruction or drastic modification of the habitat, diseases or predators.

Threatened species are those species that could be in danger of disappearing in the short term if the factors that negatively affect their viability will continue to operate, causing deterioration or modification of their habitat or directly reducing the size of their populations.

Species at no risk of extinction are those species whose populations and distribution areas are not vulnerable to endangerment in the near future.

Each species was assigned a category of risk based on these four indicators (SEMARNAT, 2010): a) amplitude of distribution (from very broad= 1 to very restricted= 4); b) habitat status (from slightly limiting= 1 to very limiting = 3); c) biological vulnerability (from low= 1 to high= 3); d) impact of human activity (from low= 2 to high= 4).

The categorical values of indicators 1 and 2 were assigned based mainly on the number and distribution of observed populations contained in the database and presented in Table 1. The values for indicators 3 and 4 were assigned based on the number of observed populations, as well as on observations on the degree of disturbance of the habitat, due to such causes as urbanization, grazing or deforestation, which were verified visually (Figure 1).

The total value of the four indicators was used to assign the category of risk of the species, which was determined as follows: 5-9= no risk of extinction; 10-11= threatened; 12-13= in danger of extinction; and over 13= possibly extinct.

Populations not at risk

Study results indicate that the following eight *Phaseolus* species are not at risk (i.e., their populations and distribution areas are not vulnerable to endangerment in the near future): *P. albiflorus*, *P. glabellus*, *P. leptostachyus*, *P. maculatifolius*, *P. neglectus*, *P. pedicellatus*, *P. vulgaris* and *P. zimapanensis.* However, *P. maculatifolius* and *P. vulgaris*, which had accumulated values of 9 (Table 2) are close to being in the threatened category because of the impact of human activity on their habitats.

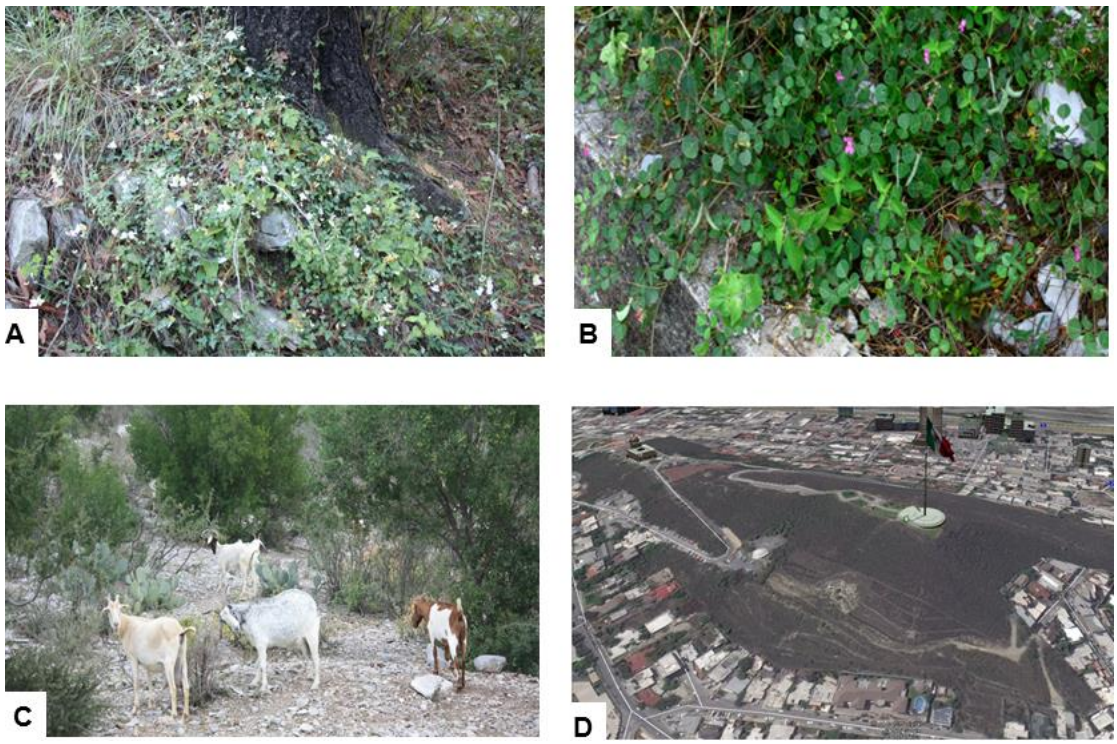

Figure 1. A) genetic erosion of *P. altimontanus* due to immoderate logging and forest fires at the site in El Manzano in the municipality of Santiago, Nuevo León, Mexico. B) genetic erosion of *P. novoleonensis* due to the maintenance of roads along the Allende-Rayones inter-municipal road, Allende municipality, Nuevo León, Mexico; C) genetic erosion of *P. plagiocylix* due to intensive grazing of cattle and goats at Las Grutas de García in the municipality of García, Nuevo León, Mexico; and D) genetic erosion of *P. plagiocylix* in Cerro del Obispado. This is a 2016 photo showing the center of Cerro, with the Mexican flag pole erected in 2000.

P. vulgaris is considered an important grain legume because it is a significant source of nutrition worldwide (Mederos, 2006). It is the main source of iron for East African and Latin American populations exceeding 300 million (Petry *et al*., 2015). As a staple crop, it contributes to food security in low-income, food-deficit countries. Mexico has 110 known populations of *P. vulgaris*, although 420 possible populations are estimated. Unfortunately, only a few of these populations are in protected areas (Porch *et al*., 2013).

Phaseolus altimontanus Freytag & Debouck was found to be in the threatened category (Table 2). Endemic to the state of Nuevo León (Delgado-Salinas, 2012), this species with white flowers with very light white-lilac banner Freytag and Debouck (2002) grows on stony soils rich in organic matter in semi-open environments of *Pinus* and *Quercus* that are difficult to access. It was collected growing sympatrically with *P. leptostachyus*. It does not share the climbing growth habit of other wild species (Freytag and Debouck, 2002; Acosta-Díaz *et al*., 2015).

Five populations of *P. altimontanus* were reported in four expeditions (Table 1). The first population was reported more than 30 years ago, in 1984, by Lavin (4889), 24.1 km north of the tourist site Cola de Caballo, in the municipality of Santiago (Freytag and Debouck, 2002). Two

other populations were reported one year later, in 1985, by Debouck *et al*.; one (1525) was 2.5 km south of Laguna de Sánchez, on the route to El Tejocote Port (25º 20' N, 100º 15' W, 1 850 masl) in the municipality of Santiago, and another (1523), 2.5 km to the north of the Ciénega de González, in the Manzano (25º 22' N, 100º 12' W, 1 460 masl), on the route to Laguna de Sánchez, also in the municipality of Santiago.

The fourth population of *P. altimontanus*, small and with few individuals present, was reported by Hernández and Acosta (2013), on a single site along the Federal Highway 85 - Laguna de Sánchez route, in the tourist area of El Manzano (25º 21' N, 99º 11' W, 1 550 masl), in the municipality of Santiago (Acosta-Díaz *et al*., 2015).

Although only thirty years have passed since the first report on the presence of *P. altimontanus*, there is currently evidence of only one existing population (653), collected in 2013 by Acosta-Díaz *et al*. (2015) (Table 1) on the eastern slope of the Sierra Madre Oriental, where natural vegetation has been disturbed by immoderate *Pinus* logging and by forest fires (Figure 1 A). In view of these findings, this taxon is in the threatened category (Table 2).

Table 2. Risk categories of wild *Phaseolus* species reported in northeastern Mexico.

Species	A) amplitude of distribution†	B) habitat status with respect to natural development‡	C) intrinsic biological vulnerability§	D) impact of human activity¶	Total††	Category of risk ‡‡
P. albiflorus	1	1	1	2	5	No risk of extinction
P. altimontanus	4	2	2	2	10	Threatened
P. glabellus	3	1	1	2	7	No risk of extinction
P. leptostachyus	1	1	1	2	5	No risk of extinction
P. maculatifolius	3	2	2	2	9	No risk of extinction
P. neglectus	1	1	1	2	5	No risk of extinction
P. novoleonensis	4	3	2	4	13	In danger of extinction
P. pedicellatus	1	1	1	2	5	No risk of extinction
P. plagiocylix	4	3	3	4	14	Possibly extinct
P. vulgaris	2	2	2	3	9	No risk of extinction
P. zimapanensis	1	1	1	2	5	No risk of extinction

†Widely distributed or very wide= 1; moderately restricted or broad= 2; restricted = 3; very restricted= 4; ‡propitious or slightly limiting= 1; intermediate or limiting= 2; hostile or very limiting= 3; §low vulnerability = 1; average vulnerability = 2; high vulnerability= 3; ¶low impact= 2; average impact= 3; high impact= 4; †† total of A, B, C and D indicators; ‡‡ Based on total value of indicators and categories defined by SEMARNAT (2010).

Endangered species

Phaseolus novoleonensis Debouck is a creeping type with indeterminate growth habit that is considered part of the *Coriacei* Freytag Section because of its leathery leaflets. Although this species is close to the subspecies of *P. maculatus*, i.e., s*ubsp. maculatus* and *subsp*. *ritensis*, it is easily differentiated from other *Phaseolus* species by its trifoliate leaves in the first nodes, small round leaflets, clusters with few insertions and flat cream seeds.

Also endemic to the state of Nuevo León (Delgado-Salinas, 2012), *P. novoleonensis* was collected on the eastern slope of the Sierra Madre Oriental of the state of Nuevo León (Salcedo *et al*., 2006). Its distribution range is limited to this area, where four populations have been reported by different authors (Table 1). The first population, reported in 1986 by Debouck & Muruaga Martínez collection number 2061, was found 2 km east of Los Altares and 0.5 km west of the Santa Rosa bridge (99º 50' W, 24º 43' N, 970 masl), near the village of El Ebanito, in the municipality of Iturbide.

The second population, reported in 2005 by Estrada-Castillón collection number 633, (personal communication, Autonomous University of Nuevo León, Mexico), was described as an abundant population at the same site. However, when Acosta-Díaz *et al*. (2015) made several expeditions to the referred sites, they found no evidence of the presence of this species. Instead, they found two new populations in two sites relatively close by. The first population (collection 650) was located at 25 ° 05' N, 99° 59' W, 1150 masl and the second collection (651), at 25 ° 05' N, 99 ° 59' W, 1 291 masl.

Just like the other wild bean species in Nuevo León, *P. novoleonensis* has been seriously affected by the historical trend towards goat-raising in mountain pastures (The state occupies the tenth place in goat meat production in Mexico [SIAP, 2017]), which has caused great damage to the native flora. Also having adverse effects has been the establishment of roads by local councils that has affected two small populations of *P. novoleonensis* found by the roadside between the municipalities of Allende and Rayones (Acosta-Díaz *et al*., 2014; Acosta-Díaz *et al*., 2015), exposing them to irreversible damage (Figure 1 B). The small number of *P. novoleonensis* populations places this taxon in the endangered category (Table 2).

Possibly extinct species

Phaseolus plagiocylix Harms is also endemic to northeastern Mexico (Delgado-Salinas, 2012). This species has been reported in at least three expeditions in the state of Nuevo León (Table 1). Freytag and Debouck (2002) mention that this species, found in the western mountains of Monterrey, Nuevo León, on rocky and limestone soils, is very difficult to collect, and only a few accessions are known.

These authors refer to two herbarium specimens, one collected at Cerro del Obispado on 12 October 1895 by Seler 1042 (25º 45' N, 100º 30' W, 652 masl) and another one, at 4.2 km north of Grutas de García, collected on 5 September 1967 by Weedon accession number 4074 (25º 52' N, 100º 31' W, 914 masl). The first specimen was collected 122 years ago at a site that is now part of the center

of the city, where urban development has caused plant populations to disappear. The second specimen was collected much later, 50 years ago. However, during recent explorations, the species was no longer found at the collection site, which has suffered considerable deterioration from goat overgrazing (Figure 1 C).

Other reports indicating the presence of *P. plagiocylix* in Nuevo León are those of Estrada-Castillón *et al*. (2004) in the municipality of Linares. However, his report suggests that the specimens reviewed may have come from samples of herbaria.

Results of the recent explorations carried out by Acosta-Díaz *et al*. (2015) in the region suggest that *P. plagiocylix* is possibly extinct because no evidence of it was found in areas where the six populations of this species had been collected. The site of the first *P. plagiocylix* collection made almost two hundred years ago has been seriously disturbed by human activity; it is now part of an urban area in the city of Monterrey (Figure 1 D). The disturbance has intensified even though the Cerro del Obispado and Loma Larga, which are part of the Sierra Madre de las Mitras, was designated as Protected Natural Areas in 2015, and a management program has been in place since 2008.

Implications for conservation efforts

P. altimontanus P. novoleonensis and *P. plagiocylix*, the species that show different degrees of genetic erosion, share the following characteristics: endemic to the northeastern region of Mexico, populations with low number of individuals, delicate stems and tuber-like roots, collected a long time ago. In addition, they present damage due to recurrent drought, intensive grazing of goats and cattle, and pests and diseases that attack domesticated beans. The accelerated growth of urban areas, the increase in crop and livestock areas, intensive agriculture, and the destruction of natural environments have contributed to the loss of wild *Phaseolus* populations (Brush, 2000; Acosta-Gallegos, 2012).

In view of these findings, the conservation efforts for *Phaseolus* should give high priority to these three species that show genetic erosion. It is necessary to carry out more explorations in their known sites as well as in adjacent areas and areas with similar soil and climatic conditions, to determine the existence of their populations and collect germplasm. It is important to note that *P. leptophyllus*, one of the 52 wild *Phaseolus* species reported in Mexican territory (although not in the northeast region), is already considered possibly extinct.

First collected in the eighteenth century in the mountains surrounding Chilpancingo, Guerrero, it has not been found again, despite several searches in that region (Freytag and Debouck, 2002).

Hence, current *in situ* and *ex situ* conservation programs in northeastern Mexico should be strengthened and expanded for the medium- and long-term protection of all wild bean species, especially the three species that suffer from genetic erosion. The main conservation actions for *Phaseolus* species should be the protection of existing wild populations and the expansion of their current habitats as well as the establishment of populations in places where favorable environmental conditions for endangered and threatened species will prevail in the future.

Conclusions

Three of the eleven species studied show varying degrees of genetic erosion. *P. altimontanus* is threatened due to its very restricted distribution (only one population) and the impact of *Pinus* logging and forest fires in its habitat. *P. novoleonensis* is in danger of extinction due to its very restricted distribution (two small populations and the high impact of human activity and animal-grazing grazing on its habitat that has made it hostile to natural development. *P. plagiocylix* may have become extinct because no populations were found during recent explorations at former collection sites.

Eight of the eleven wild *Phaseolus* species studied continue to thrive in northeastern Mexico and are not considered endangered. However, *P. maculatifolius* and *P. vulgaris* are close to being in the threatened category due to the impact of human activity on their habitats.

It is urgent to intensify exploration efforts and the systematic collection of germplasm of the genus *Phaseolus* in northeastern Mexico to avoid irreversible losses due to genetic erosion and the consequent loss of diversity

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