Description of cultivar

'Borrego': a new variety of xoconostle with nutritional and functional value for the Central Mesa region of Mexico

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Abstract

From a cultural point of view, the xoconostles (*Opuntia* spp.) Have been an important factor in the economic sustenance of the peasant of the semi-arid zones of Mexico; however, to date, although xoconostles are a plant genetic resource with great potential, there are few works that allow us to know their diversity or their very existence. The recent efforts of the integrated inter-institutional group within the framework of the Nopal Network of the National System of Plant Genetic Resources for Food and Agriculture (SINAREFI), have allowed the rescue and evaluation of an important part of the diversity of xoconostles existing in Mexico. A new horticultural form of the genus *Opuntia* Miller (Cactaceae), considered as a variety of common use, is found in Villa of Tezontepec Municipality, Hidalgo, Mexico, known as xoconostle 'Borrego' (*Opuntia oligacantha* Förster). It was evaluated from 2012 to 2015 and it was found that its fruit is of medium size (74 ±1.09 cm) and oboval shape, with floral scar strongly sunken and very long peduncle (15.4 ±0.217 cm), with an external coloration of irregular coloration medium red, walls of pink hue, wide (10.6 ±0.363 mm, characteristic of the xoconostles), acidic (pH 3.22 ±0.039, dry to semi-dry and tasteless pink fungus, firm consistency, low sugar content (6.9 ±0.169 °Brix) and with an average number of fully developed seeds (218 ±1.723). The average yield in four years of evaluation was 13.59 t ha^{-1} and its fruits remain for more than six months in the plant, after the beginning of the This variety has the definitive registration Number XOC-026-290212 of the CNVV-SNICS and has been validated under the conditions of the central table of Mexico, in order to increase the varietal pattern for the commercial production of cactus in the region.

Keywords: *Opuntia oligacantha* Förster, nutritional and functional quality, yield.

Reception date: January 2018
Acceptance date: February 2018

Introduction

Mexico is recognized as one of the centers of diversity of cacti, the highest diversity being found in its territory at the continental level (Bravo-Hollis, 1978, Hunt, 1999). In this context, the continental portion where the Chihuahuan desert is located, is one of the regions with the greatest cactus wealth, as well as a high level of endemism in specific and generic levels (Godinez-Álvarez and Ortega-Baes, 2007). A small, relatively discontinuous and southern zone of the Chihuahuan desert is the arid zone of Querétaro-Hidalgo, which contains one of the main assemblages of endemic cacti (Hernández *et al*., 2004; Hernández-Oria *et al*., 2007). It is estimated that there are 76 *Opuntia* species in Mexico (Guzman *et al*., 2003), although this estimate has varied in the past from 58 (Britton and Rose, 1919) to 93 (Hunt, 1999).

Most species produce fruit with sweet-tasting pulp called tunas (Gallegos-Vázquez *et al*., 2012), while a minority produces acid-tasting fruits which are known as xoconostle, from Nahuatl: xoco= acid; noxtle= tuna, (Bravo-Hollis, 1978), unlike the tunas, what is used are the thick walls of the fruits, which are consumed by different ethnic groups and are used in traditional medicine for their hypoglycemic effect, for the control of cholesterol and reduction of obesity (Gallegos-Vázquez *et al*., 2012).

The xoconostles are morphologically distinguished by presenting, precisely, broad, acidic shells, a thin outer wall, seeds arranged in the center of the fruit with semiprecious and insipid funicles (Bravo-Hollis, 1978; García-Pedraza *et al*., 2005; Scheinvar *et al*., 2009; Gallegos-Vázquez *et al*., 2012), with the particular characteristic that their fruits can remain on the cladodes for six months and in some cases for more than a year (Scheinvar *et al*., 2009; Gallegos-Vázquez *et al.*, 2012), probably due to their low rates of ethylene production at maturity (Ávalos-Andrade *et al*., 2006).

To date, although the xoconostles are a plant genetic resource with great potential, there are few works that allow knowing their diversity or their very existence, since only about 600 hectares of commercial plantations of xoconostle 'Cuaresmeño' have been registered (*O. matudae* Scheinvar) and a remarkably smaller area of xoconostle 'Manzano' (*O. joconostle* Weber), concentrated in the states of Mexico and Hidalgo, in the central region of the country (Gallegos-Vázquez *et al*., 2009), unknown the extension of wild nopaleras with xoconostles in the country (García-Pedraza *et al*., 2005), so the tasks of exploration, collection, description and evaluation are important that allow us to know the existing diversity and develop proposals for rescue, conservation and sustainable use of this important resource.

Origin

The area of origin of the variety of common use 'Borrego' (*O. oligacantha* Förster) is in Villa de Tezontepec, municipality of the same name, in Hidalgo, where the variety is located in backyard orchards and from where it was taken to incorporate it for its evaluation in the plantation for in situ conservation of native species of the state of Hidalgo. The geographical coordinates of the area are

19° 52’ 55”-19° 53’ 11” north latitude, 98° 49’ 16”- 98° 48’ 53” west latitude, with an average elevation of 2 329 meters above sea level; a temperate semi-dry climate prevails, with key $BS_1kw(w)(i')g$ (García, 1973). The predominant vegetation is the xerophilous scrub (*sensu* Rzedowski, 1978), with sedimentary soils.

Given the horticultural interest for the variety, it was incorporated into the gene pool of the National Depository of *Opuntia*, located in the Regional Center North of the Autonomous University Chapingo, located in Zacatecas, Zacatecas, Mexico (22° 44.7’ north latitude and 102° 36.4’ west longitude) for future reference, with the key O-337.

Inscription of the sequence of the internal transcribed space (ITS) in GeneBank

At the 4th International Bar Code Conference for Life, 2011, *matK*, *rbcL* and ITS were proposed as bar code candidates for plant species. Considering the above, genomic DNA of the variety Xoconostle ‘Borrego’ was extracted and the ITS was amplified; the product was sequenced in the Applied Biosystems model 3730xL (Applied BioSystems, Foster City, CA, USA), generating a consensus sequence with the software BioEdit version 7.0.5 (Hall, 1999), which was deposited in the GeneBank with number of accession KX247005. The nucleotide sequence of the ITS of the xoconostle Borrego, *Opuntia oligacantha* is as follows:

ATGTTTTCCCATGAACACGCAGGGAGGGGCGCCTCTGCCCCCTCCCTGGCGCAACAA
CAAACCCCGGCGCGAACCGCGCCAAGGAACACGAACTAAAGGCGTGCCCGCCCGCG
CCCGGTCCGCCGGCGCGCGGGGGCGGCACCTGTCCCTACTTAAAACGTAACGACTCT
CGGCAACGGATATCTCGGCTCTCGCATCGATGAAGAACGTAGCGAAATGCGATACTT
GGTGTGAATTGCAGAATCCCGTGAACCATCGAGTCTTTGAACGCAAGTTGCGCCCAA
AGCCTTCCGGCCGAGGGCACGTCTGCCTGGGCGTCACGCATCGCGTCTCCCCCCCGC
CTGCCGGGGGGAAGGATGATGGCCTCCCGTACCCTAACCGGGCGCGGCTGGCCTAA
AACGGGAGCCCGCGGCGACGAGCTGCAGCGGCGATTGGTGGTGGACGAGGCCTTCG
AGGCCCCCGTTTGCATCGCGTCGCGCACGCACGCCGTCGGAGAAGGGCTCGTTGGAC
CCTAAGG

Registration in the national catalog of plant varieties

For the purpose of seed certification, the variety of xoconostle 'Borrego' has the definitive registration number XOC-026-290212 and file number 2244 of the national catalog of plant varieties (CNVV) of the National Seed Inspection and Certification Service of the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA).

The characterization of this variety was made based on the test guidelines established in the varietal descriptors for tuna and xoconostles of the international union for the protection of plant varieties (UPOV, 2006). The plants are of habit of extended growth (Figure 1). Cladodes of broad oboval form, of very short length (26.4 ±0.606 cm) and narrow (18.4 ±0.045 cm), of light green color and strong serosity on the surface; It has thorns in all the areolae, in number from 3 to 4 in the central areola, of short length (13.7 ±0.733 mm), white, arranged in semi-erect position and of flexible consistency.

Figure 1. a) habit of growth and b) longitudinal and transversal cut and external appearance of fruit of the variety xoconostle 'Borrego' (*Opuntia oligacantha*).

This cultivar blooms once a year and depending on the distribution of rainfall during the cycle, it usually reaches commercial maturity in October and remains for up to six months in the plant. The flower of this cultivar presents a perianth of yellowish-green coloration, pink style and from 8 to 9 lobes of green stigma. The most important morphological characteristics of the fruit for the description of the variety 'Borrego', are presented in Table 1. It produces medium-sized fruits and an oboval shape with a very long peduncle, with a strongly depressed receptacular scar (15.4 ±0.217 mm). The fruits of this cultivar at maturity have an irregular coloration of the surface red color medium, walls of pink hue, wide (10.6 ±0.363 mm, characteristic of the xoconostles), acidic (pH 3.22 ±0.039), pink funiculars, of firm consistency, medium juiciness and low content of sugars in the funicules (6.9 ±0.169 °Brix).

Table 1. Structure, characteristics and description of phenotypic components of the variety 'Borrego' (*Opuntia oligacantha* Förster).

Structure	Characteristics	Description	Average
Fruit	Length (cm)	Median	74.1 ±1.095
Fruit	Maximum diameter (mm)	Narrow	45.8 ±0.512
Fruit	Density of areolas	Mean	72.15 ±0.816
Fruit	Thickness of the shell (mm)	Very thick	10.6 ±0.363
Fruit	Weight of the shell (g)	Heavy	61.2 ±1.442
Fruit	Weight of the pulp (g)	Very light	16.7 ±0.896
Fruit	Size of the seed	Medium	3.24 ±0.034

The average yield in four years of evaluation (2012 to 2015) registered an increase of 76%, between the first and the fourth productive cycle, due to the greater vigor and the full condition of the productive stage of the plant, being of the order of 13.47, 14.41, 15.58 and 23.83 kg plant^{-1} in 2012, 2013, 2014 and 2015, respectively, which when considering a population density of 800 plants ha^{-1} would reach an approximate production in the period of 13.059 t ha^{-1}.

The xoconostle 'Borrego' has a thick shell and on average a total sugar content of 0.60 mg g^{-1}, 0.16 mg g^{-1} in reducing sugars, 92.32% humidity, 0.26% ash, 0.15 g 100 g^{-1} in fat and 5.23 g 100 g^{-1} of carbohydrates. In addition, the usable portion of the fruit has properties that benefit health; this is evidenced by the range of found values of some compounds of nutritional and functional interest, as reported below.

The fruit of the xoconostle 'Borrego' presented average protein value of 4.52%, which are higher values than those reported (3.1%, dry weight basis) by García-Pedraza *et al*. (2005) for xoconstle 'Colorado' (*O. joconostle* Weber). In relation to the content of betalains in the edible part of the xoconostle 'Borrego', values of between 4.9 to 12.34 mg 100 g^{-1} were found, while the content of betacyanins was of the order of 1.46 to 8.67 mg 100 g^{-1}. In this regard, López-Martínez *et al*. (2015) reported a higher content of betalains, in the shell of the xoconostle 'Cambray' fruit (*Opuntia duranguensi*s Britton and Rose) in the order of 36.06 mg 100 g^{-1} fresh weight.

In relation to the found values of total phenols, the xoconostle 'Borrego', presented contents of 135 to 196 mg EAG 100 g^{-1} in shell, which are values above those reported by Guzman-Maldonado *et al*. (2010) who found values between 128 to 168 mg EAG 100 g^{-1}, for the xoconostle 'Cueresmeño' (*O. matudae* Scheinvar), which is the xoconostle with the highest consumption in Mexico.

Finally, the xoconostle 'Borrego' showed a higher antioxidant activity (6.99 mmol TE 100 g^{-1} fresh weight) to that reported by Proteggente *et al*. (2002) in fruits of strawberry, raspberry, red plum, grapefruit, orange, pear and apple (2.59, 1.85, 1.83, 0.86, 0.85, 0.28, 0.34 mm TE 100 g^{-1} fresh weight, respectively). This characteristic is important because natural antioxidants are essential elements that protect the biological macromolecules in the human body from oxidation. In addition, antioxidant protection in the body is key to the control of chronic diseases, which has great relevance in preventive medicine (Urquiaga *et al*., 1999).

Conclusions

This variety that is presented, shows good characteristics and fully complies with the guidelines for selecting species or horticultural variants for incorporation into the crop in areas of the states of Mesa Central de México. On the other hand, the interest in nutraceutical compounds has increased in the world due to its potential to prevent oxidative stress and chronic diseases, this has generated the tendency to produce food with nutritional and functional quality, such as the xoconostle, reason why this new variety is an alternative for the arid zones and constitutes an important source of food given its nutritional and functional attributes.

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