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Phenotypic diversity of *Opuntia ficus indica* (L.) MILL. in the Algerian steppe

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ABSTRACT

Opuntia ficus indica (L.) is interesting; it is used as forage, medicinal plant and as food (sweet fruits). Moreover, the cacti involve the CAM photosynthetic pathway which allows great water-use efficiency. In Algeria, despite their vegetative propagation, the wild accessions of this species showed significant diversity. In order to evaluate this diversity, 20 accessions of *O. ficus indica* L. were collected from different bioclimatic localities in Algeria. Morphological characterization of these accessions was performed. Thirty one qualitative and quantitative morphological features of six cladodes per accession were studied (measured or observed), then subjected to one-way analysis of variance (ANOVA), the principal component analysis (PCA) and the factorial correspondence analysis (FCA). The factorial analysis of the qualitative features separates the accessions into two forms (spiny and spineless). The bioclimatic effect on these features was negligible. However, ANOVA and PCA analysis of quantitative features allowed detecting a significant diversity within and between accessions. Spiny forms showed high variation in comparison to spineless forms; thus, under bioclimatic effect, three spiny groups were illustrated. This illustration allowed detecting a gradual variation of the following features: aptitude and length of spine, number of spine per areole, number of areole per face and cladode width. A significant correlation was found between these features and the classical Emberger's pluviometric quotient (Q_2). The results presented in this paper confirmed our hypothesis about the existence of a gradual variation of the spines and areoles traits, which seems to be a response to the bioclimatic effect.

1. Introduction

Opuntia ficus indica (L.) is commonly planted in arid and semi-arid lands of North Africa area. Its economic and ecological importance rises from the fact that it can be used as a forage crop for sheep (Anaya-Pérez, 2001; Nefzaoui and Ben Salem, 2001; Reynolds and Arias, 2001) or as a medicinal plant (Griffith, 2004). Similarly, it is considered as a human food where the sweet fruits or the young cladodes (called nopalitos) are consumed as a vegetable crop in Mexico (Griffith, 2004). The species *O. ficus indica* is native to Mexico where it was domesticated by the ancient Mexicans (Kiesling, 1998; Griffith, 2004). After the discovery of America, *O. ficus indica* was introduced into Spain by sailors, because of its anti-scurvy properties. Afterwards, it was introduced to other parts of the world; particularly to the Mediterranean region (Kiesling, 1998). A special interest has been attached to cacti because of their particular traits, such as spiny succulent cladodes that store water and perform photosynthesis by the CAM pathway metabolism (Nobel, 2001). *O. ficus indica* reproduces sexually and propagates vegetatively (Reyes-Agüero et al., 2005), where outcrossing (allogamous) is common among cacti (Pimienta and del-Castillo, 2002). It may lead to a certain degree of genetic diversity to this species. Generally, the cactus is present in different climatic ecosystems throughout the world. The greatest diversity of the cactus family is recorded in Mexico; followed by Brazil, Bolivia and Peru (Ortega et al., 2010). This diversity was positively associated with some environmental factors such as temperature and precipitation (Mourelle and Ezcurra, 1997). According to Mourelle and Ezcurra (1996), the cactus diversity of articulated species was positively related to the amount of rainfall in summer and the annual mean temperature. The domestication process of *Opuntia* was begun by producing spineless cladodes with large sweet fruits (Colunga Garcia Marine et al., 1986). The partial or total absence of spine is the main diagnostic character of *O. ficus indica* (Reyes-Agüero et al., 2005), where it has been mistakenly related to *Opuntia ameclya*, *Opuntia megacantha* and *Opuntia streptacantha* (Kiesling, 1998; Labra et al., 2003). *O. ficus indica* was considered as a synonym of *O. megacantha* since the presence or absence of spines is insufficient for separating them (Benson and Walkington, 1965). Based on the combination of the differential vegetative and reproductive characters, Reyes-Agüero et al. (2005) considered that *O. ficus indica* constitutes a taxonomic entity that differs from *O. megacantha* and *O. streptacantha*. Moreover, Kiesling (1998) suggested that the spiny and spineless specimens are only forms of *O. ficus indica*.

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The inheritance mode of the spineless character has not been identified. However, reversal of spineless back to spiny forms has been reported (Mondragón-Jacobo and Pérez-Gonzalez, 2001). Kiesling (1998) noted that new spiny and spineless specimens were developed in the new locations from seedlings that exhibited relic traits of the old-world parents. Furthermore, the recovery of spiny genotypes from spineless parents suggests that the parental genotypes each contained alleles for both spinelessness and spininess; it should be possible to obtain spineless individuals if the parents yield fertile progeny and if one of the parents were spineless (Felker et al., 2006). These clues suggest the existence of recessive genes associated with spininess (Mondragón-Jacobo and Pérez-Gonzalez, 2001). Subsequently and based on their studies, Felker et al. (2006) reported that the spineless is simply inherited. However, the inheritance of some features that can be related to the spininess was not identified. Previous works on phenotypic diversity of *O. ficus indica* were carried out with the aims to describe the variation of some spine features within the same environment. Peña-Valdivia et al. (2008) have worked in the Regional Arid ZonesUnit (URUZA) in Mexico, where accessions from different localities and variable level of domestication are located. The agriculture practices and environmental conditions at URUZA were similar; thus, they may be promoting morphological homogeneity among *Opuntia* accessions. As a result, only a few morphological quantitative characteristics are significantly different among spineless and spiny accessions. Therefore, the most relevant morphological characteristics among URUZA accessions belong to areoles, like spine presence or absence (Peña-Valdivia et al., 2008). However, the Algerian accessions cultivated in different localities appear to reveal more variation between or within spiny and spineless forms. This variation may involve many traits; particularly the spine features. It seems that they could show a gradual variation in nature between and within these two forms (spiny and spineless).

The main interest of this work was to evaluate the morphological diversity among *O. ficus indica* accessions in the Algerian steppe and assess the probable existence of a gradual variation of some morphological features within the species and the bioclimatic effect on these features.

2. Materials and methods

2.1. Sample collection and morphological features

Twenty accessions of the *O. ficus indica* germplasm from the Algerian steppe were used in this study (Fig. 1). These accessions were sampled from 20 localities in three regions (Djelfa, Laghouat and Tebessa) between November 2014 and March 2015 (Fig. 2). These regions are distant and covering a different range of bioclimatic stages in the Algerian steppe; so, they may allow the observation of a significant

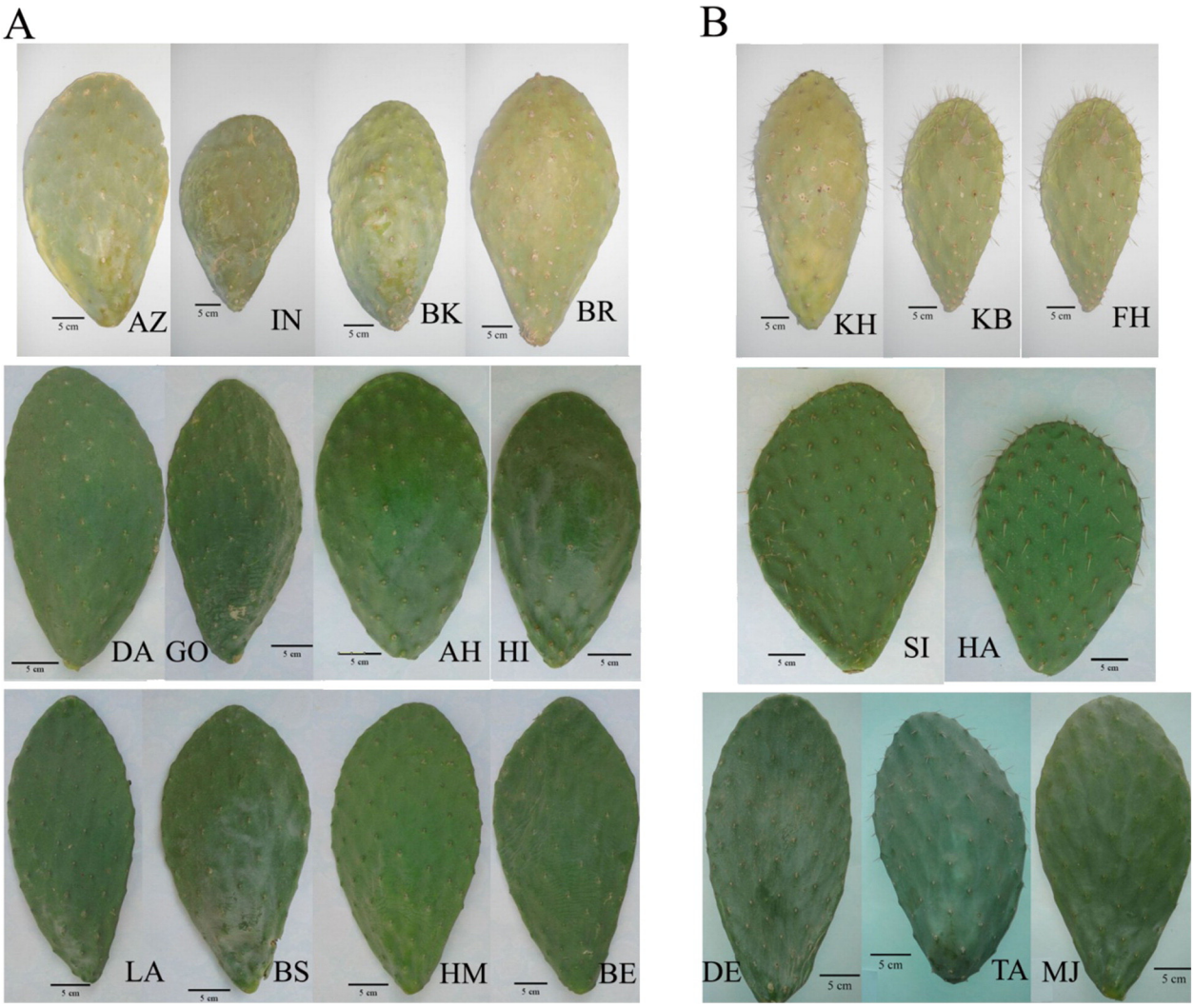

Fig. 1. Sample photos showing spineless (A) and spiny (B) cladodes of *O. ficus indica*, AZ: Azouza; IN :Henchir ElHdid; BK: Belkefif; BR: Berrezgal; DA: Daldoul; GO: Gouraita; AH: Amera; HI: Hiohi; LA: Laghouat; BS: Borj Snossi; HM: Hamada; BE: Benkhdaje; KH: ElKhabna; KB: Kabel El Batna; FH: Faijet L'Hmam; DE: Demad; TA: Tamdite; SI: Sed Rahal; MJ: Moudjbara; HA: Hania. (Scale bars = 5 cm).