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Associated diseases to prickly pear (*Opuntia ficus-indica* L. Mill.) in the South of Morocco

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Abstract

The prickly pear cactus plant is an important ecological component in dry and semi-arid areas, not only preventing desertification but also preserving biodiversity. In Morocco, the fruits are consumed as food, while the cladodes are used to feed cattle. The prickly pear cactus is regarded as a rich potential raw material for Moroccan industry. However, cladode and fruit rots have been detected in prickly pear cactus orchards in Morocco's primary producing regions. The infections were most prevalent in orchards where wild cochineal *(D. opuntiae*) is detected. The symptoms start with a color shift from brown to dark patches on the damaged cladode and fruit tissues, followed by superficial necrotic lesions with a bad odor. *Alternaria* sp, *Fusarium* sp, and *Mycosphaerella* sp were isolated from diseased tissues and identified as harmful to prickly pear cladodes. Pathogenicity testing indicated that these microorganisms cause cladode rot in prickly pear cactus in Morocco. These data illustrate the economic impact of cactus diseases, which can result in significant yield losses. Effective sustainability solutions are consequently necessary to combat these diseases.

***Keywords*:** Cladode rot, *Opuntia ficus-indica, Alternaria sp., Fusarium sp., Mycosphaerella sp.*

Introduction

Worldwide, prickly pear cactus (*Opuntia ficus-indica* L. Mill.) is an important crop in arid and semi-arid regions. Native to South America, it is well adapted to harsh environmental conditions, including drought, poor soils, and high temperatures (Fouque, 1972; Swart *et al.,* 2003; Arba, 2020; Naorem *et al.,* 2024; Tahiri *et al.,* 2025). The value of the crop is undeniable regarding its economic and ecologic functions. Historically, prickly pear has served in Morocco as a boundary around the douras and their fields in rural areas (Poupon, 1975; **Figure 1**) and has played a strategic role in subsistence agriculture (Bouharroud *et al.,* 2016; Habibi *et al.,* 2004).

The ecological significance of *Opuntia ficus-indica* lies primarily in its role in combating desertification and preserving biodiversity (Naorem *et al.,* 2024). Prickly pear plantations help to increase soil organic matter, improve moisture retention, and improve vegetation cover (Neffar *et al.,* 2011; Yous *et al.,* 2023). In contrast, long-term monocultures of conventional crops frequently degrade the soil. Integrating prickly pear crop into agricultural systems can help reverse this trend by reducing chemical fertilizers and boosting ecological stability (Hassan *et al.,* 2019). Despite its ecological and nutritional significance, this plant encounters various threats from biotic agents, particularly pests and diseases that considerably reduce the crop's yield and profitability (Méndez-Gallegos *et al.,*2009; Swart, 2009; Bouharroud *et al.,* 2016)

Fungal and bacterial diseases can cause problems to prickly pear cladodes during the pre-harvest and post-harvest stages and can hurt their yields (Ammar *et al.,* 2004; Swart 2009). Different phytopathogenic agents have been reported on cladodes such as *Alternaria tenuissima*, *Alternaria alternata, Lasiodiplodia theobromae, Fusarium sporotrichoides, Fusarium solani, Diplodia opuntiae, Phomopsis cacti, Pseudocercospora, Phyllosticta concave, Colletotrichum gloeosporioides*, *Fusarium lunatum* and *Curvularia lunata* (Farr *et al.,* 1989; Fisher *et al.,* 1994; Swart and Kriel, 2002; Ammar *et al.,* 2004; Quezada-Salinas *et al.,* 2006; Flores-Flores *et al.,* 2013).

Figure 1. Prickly pear plants used as borders of agricultural fields in Morocco.

The main symptoms are cactus anthracnose, charcoal spot, dry rot, foot rot, scorch or sunscald, soft rot, root rot, and stem rot, which cause considerable economic losses (Raabe and Alcon, 1968; Cacciola and Magnano, 1988; Varvaro *et al.,* 1993; Carballo *et al.,* 2000; Granata and Sidoti, 1997; Swart and Kriel, 2002). This study aims to isolate and identify the causal agents and their pathogenic capabilities affecting prickly pear in the Souss-Massa region of Morocco.

Material and methods

Plant material and isolation

Infected cladodes were collected from prickly pear with rot symptoms in the Souss region, Morocco. The isolation was carried out according to protocol described by Quezada-Salinas *et al.* (2006) with modifications. Tissue pieces of 0.5 cm^2 were cut on cladodes and disinfected with 1.5% sodium hypochlorite (NaClO) for1 min 30s. Then, they were washed three times with sterilized distilled water and dried using sterilized paper towels. The pieces were plated onto potato dextrose agar (PDA) plates and incubated at 26±2°C for ten days. Dishes were daily inspected and the colonies found were isolated, and maintained separately in PDA plates. For the identification of fungi, the mycelial discs (5 mm) of each isolate were placed in the center of Petri plates containing PDA. For morphological characterization, the description of mycelia and spores was carried out by considering taxonomical keys according to the literature (Ellis, 1971; Sutton, 1980; Leslie and Summerell, 2006;

Table 1. Morphological identification of the fungal isolates obtained from cladodes of prickly pear.

Symptoms	Pigment in PDA medium	Mycelium (colony and texture)	Spores (color and shape)	Identification
Circular spot	Brown-black	Grey. Nonaerial	Medium brown ellipsoidal	*Alternaria* sp.
Yellowing of the cladode	Rose-red	white cream mycelium	Microconidia, Macroconidia and chlamydospores	*Fusarium* sp.
Pad spots	dark brown	-	Conidia were oval and 0-2 septate	*Mycosphaerella* sp.

Figure 2. Symptoms of *Alternaria* on a cactus plant.

Domsch *et al.,*2007; Simmons, 2007).

Pathogenicity tests

The isolated fungi were used for pathogenicity tests. Healthy cladodes were washed and disinfected as already mentioned. 20 µl of the fungal suspension (10^5 conidia/ml) from a 7-day-old culture, was poured into a whole (5-mm-diam.) made by a sterilized cork borer in the desired plant organ. Control treatments were inoculated with distilled water only. The inoculated plant materials were kept in plastic moist containers with moistened cotton to maintain high humidity. Disease incidence for cladodes was determined 10 days after inoculation. To confirm Koch's postulates, fungal isolates that showed any symptoms of pathogenicity were re-isolated from the margins of the lesion on PDA. The fungus colonies obtained were purified by serial dilutions and later monosporic cultures were done (Swart *et al.,* 2003 and Flores-Flores *et al.,* 2013).

Results

Fungal isolation and identification

Disease incidence in the Souss-Massa area indicates its widespread occurrence. Infections initially begin at the top of cladodes, appearing as brown to dark brown spots on one side of the affected tissues. The spots are distinctly zoned at first, but they gradually enlarge until they encompass both sides of the cladodes, which eventually become rotted, cracked, or die. The percentages of natural infection vary significantly depending on the types of prickly pear. Three different fungi, *Alternaria* sp., *Fusarium* sp., and *Mycosphaerella* sp. were isolated, being *Alternaria* sp. and *Mycosphaerella* sp. the most frequently found, while *Fusarium* sp. was the less frequent.

***Alternaria* sp.**

The fungus *Alternaria* sp causes golden spot disease known as Mancha de Oro in Mexico (**Figure 2**).

Figure 3. Symptoms of *Mycosphaerella* sp. on a cactus pad.

It is present in many countries that grow cactus pears, including Italy, Mexico, and South Africa. On the PDA medium, the fungus displayed dark, simple, relatively short, or elongated conidiophores that bear a simple or branched chain of conidia. Conidia are typically dark, featuring both cross and longitudinal septa. The conidia can exhibit various shapes, ranging from obclavate to elliptical or ovoid. A characteristic symptom is a slightly raised, circular, or irregularly shaped spot. The dark green underlying tissue lightens to a greenish hue, and the spot turns golden. As the disease progresses, the dark-centered spots are surrounded by yellow crusts, while the remaining area stays yellow (Granata and Sidoti, 1997).

***Fusarium* sp.**

Fusarium sp. is the causal agent of *Fusarium* wilt. It has been reported in Mexico (Gutierrez, 1992). it is characterized by a yellowing of the cladodes, which ends with browning and death plant. On PDA medium, *Fusarium* colonies are fast growing, rose-red, but may start as white. *Fusarium* produces sparse to abundant, white cream mycelium. It produces oval Microconidia. Macroconidia have three to four septa on average, which are slightly curved. They are also wide and thick-walled and may have a slightly blunted apical end. Microconidia are abundant, oval to kidney-shaped and formed in false heads on very long mono phialides. *Fusarium* sp. also produces chlamydospores. Prevention is the most effective control measure such as avoiding the use of infected soil and infected plant propagation material for cultivations.

***Mycosphaerella* spp.**

The genus *Mycosphaerella* poses a severe problem to cacti. This phytopathogenic fungus causes pad spots, which weaken plant tissues and diminish cactus yield and quality (**Figure 3**). In the advanced stage, little black specks (pycnidia or perithecia) may form in the core of the lesions, indicating fungal reproduction. At 25 °C, the colonies in PDA media were white, dense, and spherical. After one week of incubation, the colonies turned dark

green towards the center. Then they turned into dark brown colonies that were raised in the center, had a wave pattern, and a wrinkled surface.

Pathogenicity tests (*Alternaria* sp.)

The rot on the cactus cladodes was produced by a fungus with a grayish-white aerial mycelium on PDA media. After one week of incubation at 25±2°C, the growth rate was moderate (**Figure 4**), with a diameter of 5 to 7 cm. Microscopy examination revealed that the mycelium of this isolate is septate, with transverse, longitudinal, and/or oblique septa (**Figure 5**). Although the structures' shape and size can vary greatly, the conidia are often brown in color and initially oval in shape, with an apex that gradually elongates, eventually resembling a paddle or club shape (Flores-Flores *et al.,* 2013). These findings place the isolate in the Ascomycetes class Dothideomycetes family Pleosporaceae genus *Alternaria*.

Discussion

In worldwide cultivated regions, prickly pear trees are threatened by many diseases such as cladode and fruit rots (Raabe and Alcon, 1968; Granata and Sidoti,1997 Swart *et al.,* 2003). Its symptoms were already noticeable by the former research (Varvaro *et al.,* 1993; Granata and Sidoti, 1997; 2000; Swart and Kriel, 2002). Our findings showed that prickly pear in Morocco's Souss-Massa region was correlated with *Alternaria* sp., *Fusarium* sp., and *Mycosphaerella* sp. In the pathology test on cladodes, these pathogens reproduced typical disease symptoms. These results are comparable to those obtained in other studies (Varvaro *et al.,* 1993; Granata and Sidoti, 1997; 2000; Swart and Kriel, 2002; Ammar *et al.,* 2004). Ammar *et al.* (2004) reported that four different pathogens *A. alternata*, *F. solani*, *B. theobromae,* and *A. niger* were associated with necrosis of cactus pear cladodes in Egypt. The difference in disease incidence and fungi isolated from different countries is traced back to varietal differentiation and/or variation in climatic conditions, as Turner reports (1981). Also, different reports attributed the diseases to varying pathogens. Swart and Kriel (2002) in South Africa, concluded that *Alternaria tenuissima, Fusarium sporotrichosis,* and *Lasiodiplodia theobromae* were associated with necrosis of cactus pear cladodes. Similarly, the symptoms were found on both cladodes and fruits caused by *Phialocephala virens*, *Lasiodiplodia theobromae,* and *Fusarium* spp. (Swart *et al.,* 2003). The cactus can be attacked by cactus rust (*Phillostica opuntiae*) and cactus downy mildew (*Phytophtora cactorum* and *P. omnivera*), particularly in humid areas (Agrimaroc, 2018). The disease can be controlled by pesticides (Chase, 1987; Ammar *et al.,* 2004). However, significant differences among the tested chemicals and the reaction of each pathogen differed from one to another at a particular concentration. The variations obtained among the different fungicides could be attributed to the degree of permeability of the cell, the degree of the resistant action of the fungal cell, and the chemical composition of fungicides (Waard and Ragsdale, 1977; Watkins *et al.,* 1977; Giffin, 1981; Carnegie *et al.,* 1990; Ammar *et al.,* 2004). For the biocontrol of fungi,

Figure 4. Monitoring the *in vitro* progression of *Alternaria* infection on cactus cladodes – Control cladode (Right) and treated cladode (Left).

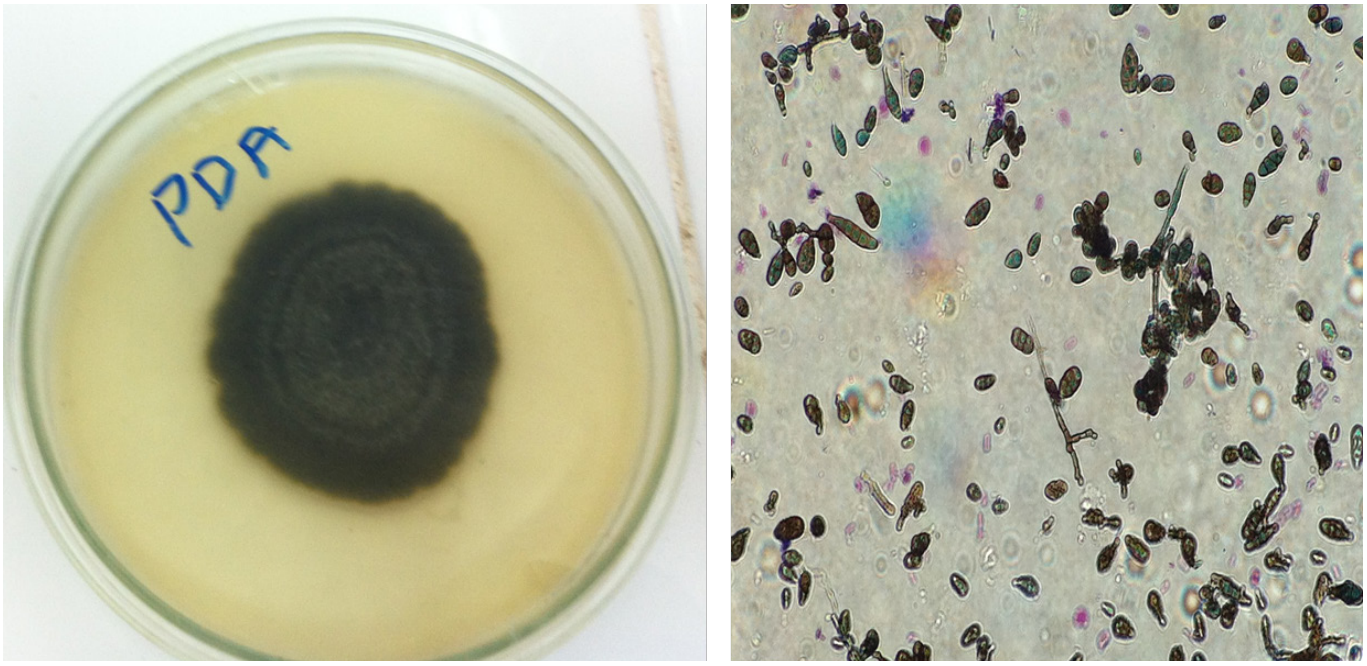

Figure 5. Macroscopic and microscopic aspects of *Alternaria* – Colony morphology on PDA medium and spore structure under the microscope.

chitosan applications diminished the disease incidence caused by *C. Gloeosporioies* and *F. lunatumin* (40 and 100%, respectively) (Flores-Flores *et al.,* 2013). These strategies may be useful to protect prickly pear and the services it provides to rural populations. The current study is a starting point towards understanding the fungal diseases in Morocco.

References

Agrimaroc (2018). Bulletin figuier de barbarie. Transfert de technologie en agriculture: https://www.agrimaroc.net/2018/05/23/figuier-de-barbarie/

Ammar MI, Shltout AM, Kamhawy MA (2004). Cladode and fruit rots of prickly pear (*Opuntia ficus-indica L. Mill*.) in Egypt. *Egypt J Phytopathol* 32:119-128.

Arba M (2020). The potential of cactus pear (*Opuntia ficus-indica* (L.) Mill.) as food and forage crop. In Hirich A, Choukr-Allah R, Ragab R (eds), *Emerging Research in Alternative Crops* (pp. 335-357). Springer International Publishing. doi:10.1007/978-3-319-90472-6_15

Bouharroud R, Amarraque A, Qessaoui R (2016). First report of the Opuntia cochineal scale *Dactylopius opuntiae* (Hemiptera: Dactylopiidae) in Morocco. *EPPO Bulletin* 46(2):308-310.

Cacciola SO, Magnano DSLG (1988). Foot rot of prickly pear cactus caused by *Phytophthora nicotianae*. *Plant Dis*. 72(9):793-796.

Carballo S, Peralta S, Wright ER (2000). Stem blight of *Opuntia ficus-indica* in Santiago del Estero and Catamarca provinces of Argentina. *Fitopatologia* 35(3):187-190.

Carnegie SF, Ruthven A, Lindsay DA, Hall TD (1990). Effect of fungicides applied to seed potato tubers at harvest or after grading on fungal storage diseases and plant development. *Ann. Appl. Biol*. 116:61-72.

Chase AR (1987). Compendium of ornamental foliage plant diseases. American Phytopath. Soc.

Domsch KH, Gams W, Anderson TH (2007). Compendium of soil fungi. IHW-Verlag, Eching.

Ellis MB (1971). Dematiaceus Hyphomycetes. Commonwealth Mycological Institute, Kew

Farr DF, Bills GF, Chamuris GP, Rossman AY (1989). Fungi on Plants and Plant Products in the United States. St Paul, MN, USA, APS Press.

Fisher PJ, Sutton BC, Petrini LE, Petrini O (1994). Fungal endophytes from *Opuntia stricta*: a first report. *Nova Hedw* 59:195–200.

Flores-Flores Rosalba, Velázquez-del Valle MG, León-Rodriguez R, Flores-Moctezuma HE, Hernández-Lauzardo A (2013). Identification of fungal species associated with cladode spot of prickly pear and their sensitivity to chitosan. *Journal of phytopathology* 161(7-8):544-552.

Fouque A (1972). Espèces fruitières d'Amérique tropicale. III, Les cactacées, genre *Opuntia*. *Fruits* 27(3):201-207.

Giffin DH (1981). Fungal Physiology. John Wiley and Sons., New York, Toronto, and Singapore, 383 pp.

Granata G, Sidoti A (1996). The appearance of *Alternaria* golden

spot on cactus pear in Italy. III International Congress on Cactus Pear and Cochineal 438.

Granata G, Sidoti A (1997). The appearance of *Alternaria* golden spot-on cactus pear in Italy. *Acta Hort.* 51: 231-237.

Granata G, Sidoti A (2000). Survey of diseases discovered on *Opuntia ficus-indica* in producer countries. IV International Congress on Cactus Pear and Cochineal 581.

Habibi Y, Heyraud A, Mahrouz M, Vignon MR (2004). Structural features of pectic polysaccharides from the skin of *Opuntia ficus-indica* prickly pear fruits. *Carbohydrate Research* 339(6):1119-1127.

Hassan S, Inglese P, Gristina L, Liguori G, Novara A, Louhaichi M, Sortino G (2019) Root growth and soil carbon turnover in *Opuntia ficus-indica* as affected by soil volume availability. *Eur. J. Agron.* 105:104-110. doi: 10.1016/j.eja.2019.02.012

Hernández Gutiérrez L (1993). Plagas y enfermedades del nopal en México.

Leslie J, Summerell BA (2006). The *Fusarium* Laboratory Manual. Ames, IA, USA, Blackwell Publishing Professional.

Méndez-Gallegos SJ, Talavera-Magaña D, García-Herrera EJ (2009). Identificación y control de las principales enfermedades del nopal. *Rev. Salud Pub. Nut.* 2:2-13.

Naorem A, Patel A, Hassan S, Louhaichi M, Jayaraman S. 2024. Global research landscape of cactus pear (*Opuntia ficus-indica*) in agricultural science. *Frontiers in Sustainable Food Systems* 8:1354395.

Neffar S, Fraga-Beddiar A, Redjel N, Boulkheloua J (2011). Effets de l'âge des plantations de figuier de Barbarie (*Opuntia ficus indica* f. inermis) sur les propriétés du sol et la végétation à Tébessa (zone semi-aride de l'est algérien). *Ecol. Mediterr.* 37:5–15.

Poupon JE (1975). Cactus et ressources fourragères. Note technique et Aménagementdes ressources fourragères. Projet PNEUD/FAO. MOR 73-016. Ministère del'Agriculture et de la Mise en Valeur Agricole, Division des Productions Agricoles, 21p.

Quezada-Salinas A, Sandoval-Islas JS, Alvarado-Rosales D, Cárdenas-Soriano E (2006). Etiologıa de la mancha negra del nopal (*Opuntia ficus-indica* Mill.) en Tlalnepantla, Morelos. Mexico. *Agrociencia* 40:641-653.

Simmons EG (2007). Alternaria an Identification Manual. Utrecht, Netherlands. CBS Fungal Biodiversity Centre.

Sutton BC (1980). The Coelomycetes: fungi imperfecti with pycnidia, acervuli, and stromata. Commonwealth Mycological Institute, Kew.

Swart W, Oelofse R, Labuschagne MT (2003). Susceptibility of South African cactus pear varieties to four fungi commonly associated with disease symptoms. *J Prof Assoc Cactus Devel* 5:86-97.

Swart WJ, Kriel WM (2002). Pathogens associated with necrosis of cactus pear cladodes in South Africa. *Plant Disease* 86(6):693-693.

Swart WJ (2009). Strategies for the management of cactus pear diseases: a global perspective. *Acta Hort* 811:207–216

Tahiri A, Ait Aabd N, Qessaoui R, Mimouni A, Bouharroud R (2025). Genetic diversity and breeding of cactus (*Opuntia* spp.). In *Breeding of Ornamental Crops: Potted Plants and Shrubs* (pp. 153-193). Cham: Springer Nature Switzerland.

Turner PD (1981). Oil palm diseases and disorders, Oxford Univ. Press.

Varvaro L, Granata G, Balestra GM (1993). Severe *Erwinia*-caused damage on *Opuntia ficus-indica* in Italy. *Journal of Phytopathology* 138(4): 325-330.

Waard MA, Ragsdale NN (1977). Fenarimol, a new systemic fungicide, Systemic Fungicides. Berlin, Internat. Sympos. Reinhardsbrunn, Acad. Emie-Verlag, 187-194.

Watkins JE, Littlefield LJ, Statler GD (1977). Effect of the systemic fungicide 4-n-butyl-1, 2, 4-triazole on the development of *Puccinia recondite* f.sp. triticiin wheat. *Phytopathology* 67:985.

Yous FZ, Ferradous A, Elgadi S, Mostakim L, Hafidi M, Ouhammou A *et al.* (2023). Effects of the continentality and the age of prickly pear (*Opuntia ficus-indica* (L. Mill.) plantations on soil properties along a coastal and continental transect in a pre-saharan region of south-Central Morocco (ait baamrane). *Appl. Ecol. Environ. Res.* 21:869–887.