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RESEARCH PAPERS

Incidence and etiology of postharvest diseases of fresh fruit of date palm (*Phoenix dactylifera* L.) in the grove of Elx (Spain)

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Summary. The incidence and etiology of postharvest diseases affecting fresh date fruit in the palm grove of Elx (Spain) were determined under local environmental conditions. Latent and wound pathogens were assessed for two consecutive seasons on fruit of two important commercial cultivars, 'Boufeggous' and 'Medjool', grown in different orchards. Healthy dates were either surface-disinfected or artificially wounded in the rind and placed in humid chambers at 20ºC for up to 7 weeks. Irrespective of cultivar, season, orchard, and type of infection, the most important causal agents of disease were *Penicillium expansum*, *Alternaria alternata*, *Cladosporium cladosporioides*, and a black aspergillus species belonging to the *Aspergillus niger* clade. These fungi were identified by macroscopic and microscopic morphology and/or DNA amplification and sequencing. Their pathogenicity was demonstrated by fulfilling Koch's postulates. Disease development at 20 and 5ºC was characterized on artificially inoculated dates.

Key words: date palm fruit, postharvest decay, latent infection, wound infection, pathogenicity.

Introduction

Date palm (*Phoenix dactylifera* L.) is the most important subsistence crop in the hot arid regions of the Arabia Peninsula, North Africa, and the Middle East, where date fruit have been the main income source and staple food for local populations for centuries (Chao and Krueger, 2007). The world production of dates is over 7.5 million tonnes, and the major producing countries are Egypt, Iran, Saudi Arabia, Algeria, and Iraq (FAO, 2013). In Southern Europe, date palms are also cultivated for their fruit and leaves in small plantations throughout Spain, Italy, and Greece. The palm grove of Elx (Alacant province, SE of Spain), with an area of over 600 ha and a production of approx. 4,000 tonnes of fresh dates (MAGRAMA, 2012) is the only commercially cultivated date palm area in the Iberian Peninsula. This grove is considered as a world heritage site (Ferry *et al*., 2002).

There are several limitations for the cultivation of date palms in Elx related to the peculiarities of this relict grove. First, during the critical months of fruit maturation, temperatures are below the optimal levels for proper ripening. Consequently, fruit within clusters develop and ripen slowly and unevenly, and it is common to find fruit at different ripening stages in the same bunch at the same time. Typically, date fruit maturation processes comprise four stages of development that are designated by their Arabic names as 'Kimri' (immature green stage), 'Khalal' or 'Bisr' (physiological maturity, mature, full-colour stage), 'Rutab' (full ripe, soft brown stage), and 'Tamr' (over ripe, dried, hard raisin-like stage) (Abbas and Ibrahim, 1996). In order to successfully gather the fruit, date harvesting in Elx may require several ascents of each palm. Since this is not economically viable, all fruit must be picked in only one harvest regardless of ripeness stage, and

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subsequent artificial ripening is hence required. In addition, dates from the Elx grove are commercialized as 'fresh' fruit, i.e. with moisture content greater than 30% at full ripeness ('Rutab' stage). This is a gourmet product that requires the application of preservation technologies. In previous research, postharvest technologies were developed, to obtain uniform ripening and preserve Elx's dates for fresh consumption (Vilella-Esplá, 2004). The influence of these artificial ripening and cold storage technologies on the incidence of postharvest diseases has been assessed (Palou *et al*., 2011).

Besides irregular ripening, the most important problems limiting the storability of fresh dates are weight loss and microbial spoilage caused by yeasts, bacteria, and postharvest fungal diseases. Fruit rot incidence depends on factors such as cultivar, weather conditions (especially rain and humidity) through the whole fruit growing and harvest seasons, cultural practices in the grove, and postharvest handling and storage conditions. It has been estimated that general losses due to fruit diseases may account for 10 to 50% of the harvest in many date-growing areas (Zaid *et al*., 2002), although they can be reduced to 5% in areas such as California where strict control measures are applied (Ploetz *et al*., 2003). Date fruit at the 'Tamr' stage (commercial dried fruit) are relatively resistant to fungal development because of their low water activity (a_w) due to high sugar and low water contents. However, fruit in the previous 'Khalal' and 'Rutab' stages are much more sensitive to fungal attack (Abbas and Dris, 2001). Depending on location, growing, and postharvest conditions, common fungi that have been reported as causing decay on date palm fruit include *Aspergillus niger* and *Citromyces ramosus* causing calyx-end rot, and species of *Alternaria*, *Helminthosporium*, and *Macrosporium* causing side-spot decays or brown spots (Fawcett and Klotz, 1932; Ploetz *et al*., 2003). In Iraq, Al-Shaickly *et al*. (1986) identified species of *Aspergillus*, *Penicillium*, *Alternaria*, and *Pythium* as the most frequently isolated fungi from decayed dates, while nine different genera (*Aspergillus*, *Cladosporium*, *Eurotium*, *Malbrachae*, *Monascus*, *Paecilomyces*, *Penicillium*, *Lasiodiplodia*, and *Rhizopus*) were found responsible for postharvest disease of dates in Nigeria (Abbas and Dris, 2001; Omamor and Hamza, 2007). In Saudi Arabia, the most abundant fungi isolated from harvested dates were species of *Aspergillus*, *Penicillium*, *Alternaria*, *Fusarium*, *Bipolaris*, and *Chaetomium* (Abalkhail *et al*., 2004; Al-Sheikh, 2009). Etiology and potential incidence of postharvest diseases of date palm fruit in the grove of Elx have not been reported. This information is of fundamental importance to determine the most appropriate control strategies to minimize economic losses, especially taking into account that no chemical fungicides are currently permitted for postharvest treatment of dates in Spain.

The objectives of the study reported here were: i) to identify and quantify latent and wound pathogens causing postharvest disease on fresh dates from the Elx grove, and ii) to test the pathogenicity and characterize the development of fungi frequently isolated from infected dates.

Materials and methods

Fruit

Date palm fruit (*Phoenix dactylifera* L.) 'Boufeggous' and 'Medjool' (yellow skin), and 'Hayani' (red skin) from local date palm orchards in the Elx area (Alacant province, Spain) were harvested at the beginning of the season in a single ascent to the palm trees and transported the next day to the Pathology Laboratory at the Postharvest Technology Center (CTP) of the Valencian Institute of Agricultural Research (IVIA). Healthy dates of uniform size at the 'Khalal' stage were selected, randomized, and used for the experiments the same day. All experiments were conducted for two consecutive growing seasons (2006 and 2007).

Assessment of disease caused by latent pathogens

Intact 'Boufeggous' and 'Medjool' date fruit were surface-disinfected by immersion in 0.5% sodium hypochlorite for 2 min, then rinsed thoroughly with deionized water, and dried with paper towels. Each disinfected fruit was then placed in a sterile 55 mm diam. plastic Petri dish base or lid located inside a humid chamber. These chambers consisted of 5 L capacity plastic containers with lids that had been previously surface-disinfected by spraying with 98% ethanol and left to air dry at room temperature. Water-soaked paper towels had been placed on the bottom of each container to ensure humidity greater than 95% was maintained. To allow gas exchange, a 5-mm diam. hole had been made in two opposite walls of each container. Closed chambers containing

the fruit were incubated at 20ºC. For each season and cultivar, six replicate humid chambers, each containing nine date fruit, were prepared. The number of diseased fruit in the chambers was recorded each week for time periods that depended on the amount of diseased fruit; the evaluation period was 7 weeks for 'Boufeggous' fruit and 3 weeks for 'Medjool'. All fungal diseases observed on each single fruit were recorded. Frequently, the same fruit was infected by more than one pathogen. Pathogens that caused distinctive symptoms were directly recorded or, otherwise, isolated and further identified as described below. In general, fungi were annotated at the genus level, although uncertain but common organisms were further identified at the species level and tested for pathogenicity as described below.

Assessment of disease caused by wound pathogens

Non-disinfected 'Boufeggous' and 'Medjool' date fruit were each wounded at two equidistant points in the equator with a sterilized stainless steel probe, 1 mm wide and 2 mm in length. Each wounded fruit was placed on the base or lid of a sterile 55 mm diam. Petri dish. As previously described, Petri dishes containing wounded fruit were set inside humid chambers, incubated at 20ºC for 7 or 3 weeks for 'Boufeggous' or 'Medjool' dates, and the number of fungal infections on each fruit was recorded. For each season and cultivar, six replicate humid chambers, each containing nine date fruit, were prepared. Isolation, identification, and pathogenicity tests with uncertain organisms were conducted as described below.

Isolation and identification of fungi

The putative pathogens most frequently observed in the previous incidence studies were identified following the procedures described by Palou *et al.* (2013c). Briefly, causal agents were isolated from decayed fruit by plating portions of infected fruit tissue onto potato dextrose agar (PDA) in Petri dishes and incubating at 25ºC. If needed, the fungi were subcultured on PDA and identified at the genus level based on macroscopic and/or microscopic morphology. For identification at the species level, selected isolates were submitted to the "Colección Española de Cultivos Tipo" (CECT, Spanish Type Culture Collection, University of València (UV), València, Spain) for identification on the basis of morphology of colonies growing on Czapek yeast extract agar, malt extract agar, 25% glycerol nitrate agar, or oatmeal agar. Identification was confirmed by amplification and sequencing of the ribosomal DNA intragenic spacer regions ITS1 and ITS2 along with the 5.8S rRNA gene (White *et al*., 1990), and in some cases, the D1/D2 region of the 28S rDNA gene (Peterson, 2000).

Pathogenicity tests and characterization of disease development

Penicillium expansum, *Cladosporium cladosporioides*, *Alternaria alternata*, and *A. niger* (clade) were isolated from decayed dates and, after identification at the species or clade (for *A. niger*) levels, their capability to cause disease was tested on 'Medjool' dates. The isolates were grown on PDA at 25ºC for 7 to 10 d prior to inoculation. Dates were surface-disinfected by immersion in 0.5% sodium hypochlorite for 2 min, then rinsed thoroughly with deionized water, and allowed to air dry at room temperature. Inoculation of these fruit was performed by pipetting 20 µL of spore suspension of *P. expansum*, *A. niger* (clade), or *C. cladosporioides* at 1×10^6 spores mL^{-1} or *A. alternata* at 1×10^5 spores mL^{-1}, onto fresh skin wounds made with a stainless steel rod with a probe tip 1 mm wide and 2 mm long. Inoculated fruit were placed in humid chambers as previously described and incubated at 20ºC for up to 10 d, or cold stored at 5ºC for up to 42 d. Three chambers each containing nine dates were used for each fungus and temperature. Additional chambers with nine wounded but with uninoculated dates were used as experimental controls. Disease incidence (percentage of infected fruit relative to the total number of fruit) and the diameter of the lesions (disease severity) were determined every 3 d on fruit stored at 20ºC, and every 7 d on cold stored fruit. To fulfill Koch's postulates, re-isolations from inoculated dates showing disease symptoms were performed in aseptic conditions onto PDA plates after 7 d of incubation at 20ºC. Each experiment was conducted twice.

Statistical analyses

Total disease incidence, i.e. percentage of fruit infected by any pathogen (referred as 'all pathogens'), incidence of decay caused by each commonly identified pathogen, and incidence of decay caused by unidentified or sporadic pathogens (referred as 'other

pathogens') were considered as dependent variables. Disease incidence data were arcsine transformed before analysis. Depending on the experiment and the existence of significant interactions, 2-way or 1-way analyses of variance (ANOVA) were performed using Statgraphics Centurion XVI (Statpoint Technologies, Inc.). When appropriate, means were separated by Fisher's Protected LSD test ($P<0.05$). For each type of disease assessment, i.e. disease caused by latent and wound pathogens, the average relative frequency of pathogens causing decay at the end of each evaluation period was also calculated.

Results

Incidence of latent pathogens

In spite of working with dates that had been surface-disinfected, the most frequent fungi responsible for decay on both 'Boufeggous' (Figure 1A) and 'Medjool' (Figure 2A) dates were *Penicillium* spp., and *Aspergillus* spp. belonging to the *Aspergillus* section *Nigri* (black aspergilli). *Penicillium* spp. caused blue or green molds and *Aspergillus* spp. caused black rot. *Alternaria* spp., causing small black lesions irregularly distributed throughout the fruit skin, and *Cladosporium* spp. were also observed. Some other pathogens causing minor decay were identified as *Rhizopus* spp. and other *Aspergillus* spp. (usually species forming yellow fungal bodies).

Although the etiology of latent postharvest diseases was similar in both date varieties, there were some differences in their relative frequency depending on cultivar and season. Total decay in 'Boufeggous' dates (disease caused by 'all pathogens') during the entire incubation period was less in growing season 1 than in season 2. While only decay caused by *Penicillium* spp., *Aspergillus* spp. section *Nigri*, and *Alternaria* spp. was observed in season 1, *Cladosporium* spp. and other minor pathogens were also isolated from decayed fruit in season 2 (Figure 1A). On 'Medjool' dates, latent decay was only assessed for one season. The most frequently isolated fungi were *Penicillium* spp. (95% incidence at the end of the incubation period), *Aspergillus* spp. section *Nigri* (90%), and *Alternaria* spp. (80%). *Cladosporium* ssp. and other pathogens were found in approx. 15% of the infected fruit during the 3 weeks of incubation at 20ºC (Figure 2A).

The study of the relative frequency of latent infections at the end of the incubation period (7 weeks for 'Boufeggous' and 3 weeks for 'Medjool' dates) confirmed that there were three major pathogens causing fungal decay on both date cultivars; i.e., *Penicillium* spp., *Aspergillus* spp. section *Nigri*, and *Alternaria* spp. (Figure 3). However, while the differences in the percentage of fruit infected by these three fungi where negligible on 'Medjool' fruit, *Penicillium* spp. were more frequently isolated than *Aspergillus* spp. section *Nigri* and *Alternaria* spp. on 'Boufeggous' dates, regardless of the season.

Incidence of wound pathogens

The etiology of postharvest disease on wounded 'Boufeggous' and 'Medjool' dates was similar to that observed on surface disinfected dates (Figures 1B and 2B). For 'Boufeggous' dates, total incidence of wound infections (caused by 'all pathogens') was similar in seasons 1 and 2. *Penicillium* spp. were among the most frequently isolated pathogens from infected wounds, with an incidence after 5 weeks of incubation at 20ºC of 55% for season 1 and 65% for season 2. However, the main fungi causing wound infections in season 1 were *Aspergillus* spp. section *Nigri*, and the number of wounds infected by *Alternaria* spp., *Cladosporium* spp., or 'other pathogens' was low during the whole incubation period. In season 2, in contrast, the incidence of *Cladosporium* spp. was similar to that of *Penicillium* spp., and *Aspergillus* spp. section *Nigri* were the third most frequently isolated fungi from infected wounds, with an incidence of 55% after 7 weeks of incubation (Figure 1B). For 'Medjool' dates, the percentage of infected fruit was 100% after 1 week of incubation in humid chambers at 20ºC. The main pathogens isolated from infected wounds were *Penicillium* spp. followed by *Aspergillus* spp. section *Nigri* and *Cladosporium* spp. After 2 weeks of incubation at 20ºC, half of the wounds were infected by *Aspergillus* spp. section *Nigri* and *Cladosporium* spp. while 80% were infected by *Penicillium* spp. At the end of the incubation period, the incidence of disease caused by *Penicillium* spp. was 90%, by *Aspergillus* spp. section *Nigri* was 70%, and by *Cladosporium* spp. was 55% (Figure 2B).

With the exception of *Penicillium* spp., which were found to infect an average of about 32% of wounded fruit from both cultivars and both seasons, the relative frequency of each pathogen at the end of the incubation periods (7 weeks for 'Boufeggous' and 3 weeks for 'Medjool' dates) varied depending on cultivar and season (Figure 3). The relative frequency

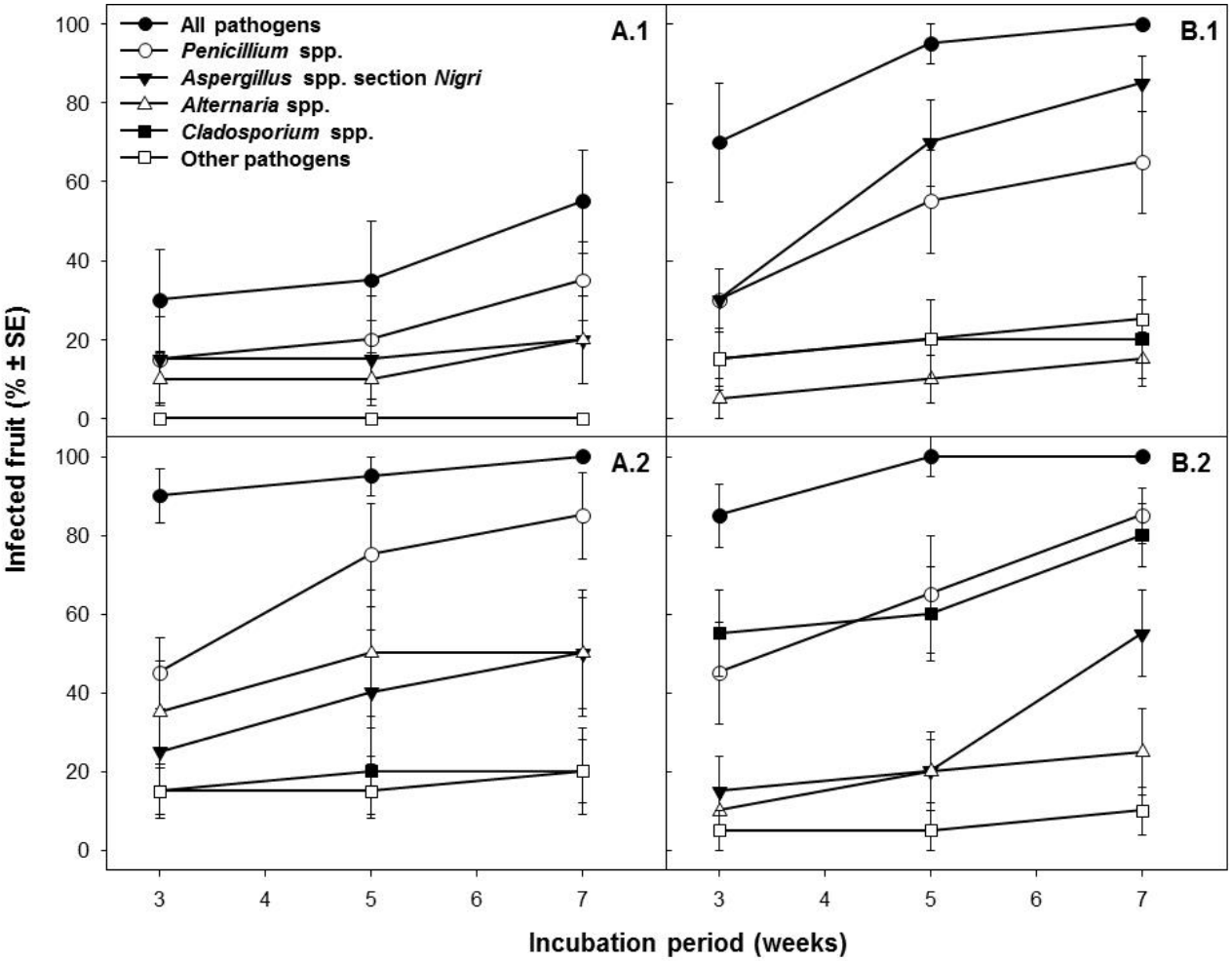

Figure 1. Incidence of postharvest fungal diseases from latent (A) and wound (B) infections on 'Boufeggous' dates from Elx (Spain), from two consecutive seasons, 2006 (1) and 2007 (2). Dates were surface-disinfected (A) or artificially wounded (B) and incubated at 20ºC in humid chambers for 7 weeks.

of disease caused by *Aspergillus* spp. section *Nigri* was 42% from season 1 and 22% from season 2 on 'Boufeggous' dates, while it was 26% on 'Medjool' dates. Similarly, the average percentage of infections caused by *Cladosporium* spp. at the end of the incubation period was 10% from season 1 and 31% from season 2 on 'Boufeggous' fruit, while it was 20% on 'Medjool' dates (Figure 3).

Identification, pathogenicity, and disease development

The most frequently isolated species of the genera *Alternaria*, *Penicillium*, and *Cladosporium* were identified, using morphological and molecular tools, as *Alternaria alternata* (Fr.) Keissler, *Penicillium expansum* Link, and *Cladosporium cladosporioides* (Fresen.) G. A. de Vries. Disease notes acknowledging the first report in Spain of black spot caused by *A. alternata* and blue mold caused by *P. expansum* on fresh date palm fruit have been published (Palou *et al*., 2013a; b). In the case of *Aspergillus* section *Nigri* (black aspergilli), the used molecular identification procedures did not allow the identification at the species level and it could only be concluded that the isolates belonged to the *Aspergillus niger* clade (Varga *et al*., 2011). Therefore, the denomination *A. niger* (clade) has been used in this report.

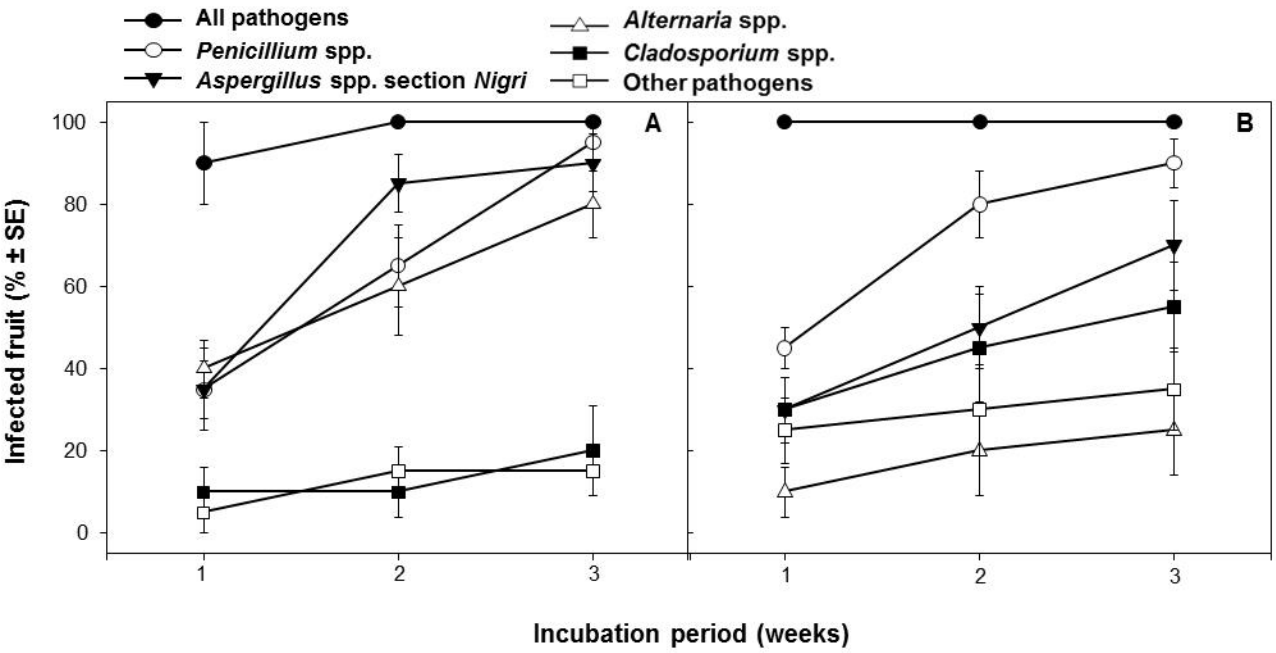

Figure 2. Incidence of postharvest fungal diseases from latent (A) and wound (B) infections on 'Medjool' dates from Elx (Spain). Date fruits were surface-disinfected (A) or artificially wounded (B) and incubated at 20ºC in humid chambers for 3 weeks.

All four pathogens tested for pathogenicity in this research were able to grow and cause disease during incubation at 20ºC, and both the number of infected fruit and lesion diameter increased throughout the incubation periods (Figures 4A, 4B). After 7 d of incubation, disease incidence on inoculated 'Medjool' dates caused by *A. niger* (clade) was 100%, and by *P. expansum* was 92%. After 10 d of incubation at 20ºC, average values of the percentages of infected fruit and lesion diameters on dates inoculated with *A. niger* (clade) were 100% and 12 mm, for *P. expansum*, 92% and 22 mm, for *A. alternata*, 69% and 12 mm, and for *C. cladosporioides*, 47% and 2 mm. Symptoms of diseases caused by these pathogens are shown in Figure 5.

With the exception of *A. niger* (clade), all the pathogens were able to grow on artificially inoculated and cold stored date fruit (Figures 4C, 4D). After 21 d of storage at 5ºC, disease developed on every fruit inoculated with *P. expansum*, with an average lesion size of 10 mm. Disease severity increased to 28 mm a week later, and the fruit were discarded. Fruit inoculated with *A. niger* (clade), *A. alternata*, and *C. cladosporioides* were kept at 5ºC until up to 42 d of cold storage. Incidence and severity of disease at that time were 0% and 0 mm diameter for *A. niger* (clade), 100% and 23 mm for *A. alternata*, and 90% and 9 mm for *C. cladosporioides*.

Discussion

The most important fungal pathogens causing postharvest decay in two different date palm fruit varieties cultivated in Elx (Spain) were *P. expansum*, *A. niger* (clade), *A. alternata*, and *C. cladosporioides*. Although the data obtained in this study were collected some years ago, the fact that cultivar and date palm orchard distribution in the area, production systems, climatic conditions, yields, postharvest handling, and destination markets have not substantially changed indicates that our results are currently valid and applicable.

Early research work by Fawcett and Klotz (1932) reported that *A. niger* and *Alternaria* spp. were important pathogens of date fruit, causing, respectively, calyx-end rot and brown rot. Since then, other authors have confirmed this etiology, although

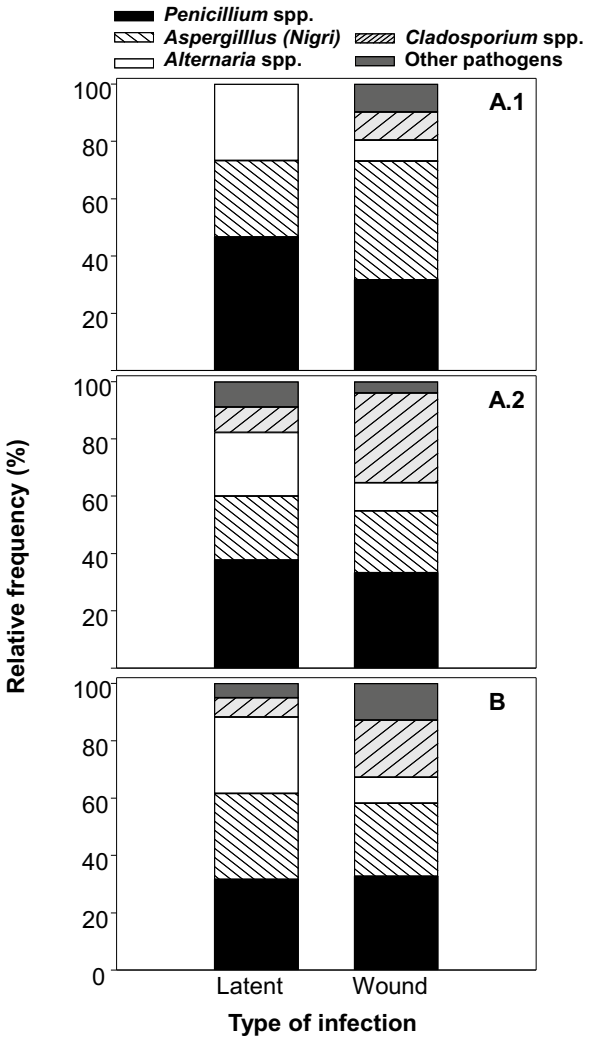

Figure 3. Relative frequency of pathogens causing postharvest diseases on date palm fruit 'Boufeggous' (A) for two consecutive seasons, 2006 (1) and 2007 (2) and 'Medjool' for one season, 2007 (B). Date fruits were surface-disinfected (Latent) or artificially wounded (Wound) and incubated at 20ºC in humid chambers for 7 (A) or 3 weeks (B).

they identified *Alternaria* spp. as the causal agent of side-spot decay rather than brown rot (Zaid *et al*., 2002; Ploetz *et al*., 2003). Several species of the genera *Penicillium* and *Cladosporium* have also been reported as fungi causing fruit rots in dates in Saudi Arabia (Al-Sheikh, 2009) or Nigeria (Omamor and Hamza, 2007). In the present study, different species of *Penicillium* causing distinctive symptoms (multi-coloured sporulating bodies) were observed on decayed dates. The most predominant species caused blue mold and was identified by morphological and molecular traits as *P. expansum*. In the case of *Cladosporium* spp., *Alternaria* spp., and *Aspergillus* spp. section *Nigri*, all the observed isolates had the same external aspect and caused very similar symptoms on date fruit. The samples subjected to molecular identification were identified as *C. cladosporioides*, *A. alternata*, and *A. niger* (clade). Pathogenicity of these four major fungal species was proved by fulfilling Koch's postulates using 'Medjool' dates from Elx's palm grove. The best adapted species to grow on dates at 20ºC was *P. expansum*, which also showed the greatest growth rate at 5ºC. Only *A. niger* (clade) did not grow on dates stored at 5ºC. This was not surprising since it has been reported that mycelium of *A. niger* is highly sensitive to low temperatures, with a minimum growth temperature of approx. 10ºC (Barkai-Golan, 2001).

As expected, since *Penicillium* spp. are typically wound pathogens, blue and green molds caused by these fungi were very frequently observed in wounds inflicted to 'Medjool' and 'Boufeggous' dates. Nevertheless, there was an unexpected generally high incidence of *Penicillium* spp. on surface-disinfected dates. Typical wound pathogens such as *Aspergillus* spp. or *Penicillium* spp. may occasionally develop under high humidity conditions on the surfaces of fresh dates through infested dirt or debris that can be later inoculum sources for wound contamination and infection (Ploetz *et al*., 2003). In addition, it is possible that intact fruit used for assessment of latent pathogens had invisible microcracks contaminated by *Penicillium* spp. or *Aspergillus* spp. near the time of harvest. In this case, disease could also develop after harvest because spores in wounds are protected from the oxidizing activity of the sodium hypochlorite used for surface disinfection. Date rots caused by different species of *Penicillium* have been previously reported in different date growing regions. In Saudi Arabia, *Penicillium* was identified as one of the most prevalent genera causing decay on stored dates (Aba-Alkhail *et al*., 2004). In a broader study with thirteen locally grown date varieties, Al-Sheikh (2009) isolated four different *Penicillium* spp. *Penicillium chrysogenum* and *P. expansum* were found on all thirteen varieties. *Penicillium citrinum* and *P. purpuragenum* were also reported among the twenty most frequent fungal species causing fruit rot on

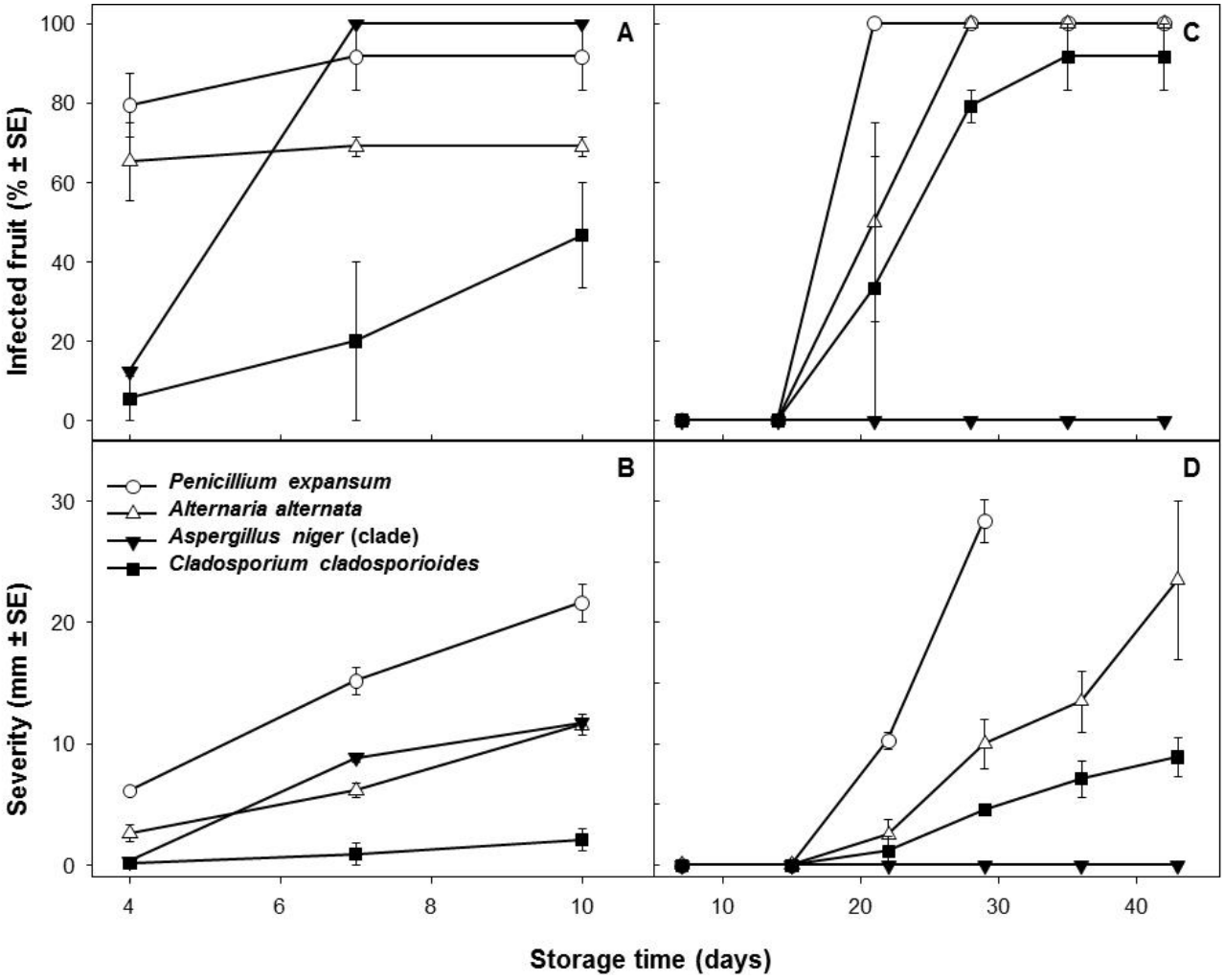

Figure 4. Pathogenicity and disease development tests. Incidence (A and C) and severity (B and D) of postharvest diseases on 'Medjool' dates artificially inoculated with fungi isolated from naturally infected fruit. Inoculated fruit were incubated at 20ºC for 10 d (A and B) or cold-stored at 5ºC for up to 42 d (C and D).

stored dates from different growing areas in Nigeria (Omamor and Hamza, 2007).

According to several reports, the fungal genera most widely distributed causing decay on stored dates are *Alternaria* and *Aspergillus* (Al-Sheikh, 2009). Many different species of *Aspergillus* have been associated with rot on dates, including *A. niger*, *A. flavus*, *A. parasiticus*, and *A. versicolor*. *Aspergillus flavus* and *A. parasiticus*, which are species known for their capabilities to produce aflatoxins, have been found on dates at all maturity stages, and date fruit extracts and tissues may support aflatoxin production (Ahmed *et al*., 1997; Aba-Alkhail *et al*., 2004). These authors suggested that special care must be taken during storage and processing of dates. In the present study, the most frequent species of *Aspergillus* observed causing decay on dates from Elx's palm grove belonged to the *A. niger* clade or aggregate. Although *A. niger* has been generally described as a wound pathogen, it has also been shown to infect date fruits without peel wounds under very high humidity conditions (Ploetz *et al*., 2003). Furthermore, similarly to *Penicillium* spp., *A. niger* also disseminates easily by air currents and can colonize microscopic peel wounds or

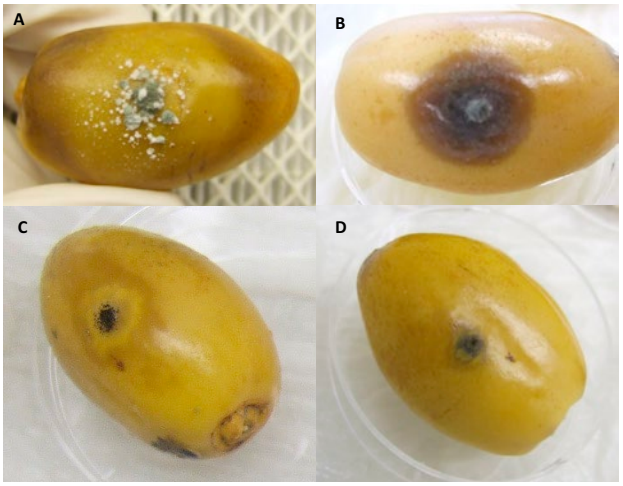

Figure 5. Symptoms of postharvest disease on 'Medjool' dates artificially inoculated with *Penicillium expan*sum (A), *Alternaria alternata* (B), *Aspergillus niger* (clade) (C) or *Cladosporium cladosporioides* (D) and incubated at 20ºC for 10 d.

cracks that could lead to postharvest infections, even on surface-disinfected fruit.

In this study, high incidence of *A. alternata* was observed on latent infections of both 'Boufeggous' and 'Medjool' dates. *Alternaria alternata* is a polyphagous fungus that attacks a large number of hosts, including many fruit trees. Conidia are profusely produced in the field and easily dispersed by wind and rain, potentially causing latent and wound infections (Rotem, 1998). Hence, it is important that appropriate fungicide field treatments are used to reduce the incidence of postharvest decay caused by *A. alternata*. In the Elx area, *A. alternata* has also been found to cause heart rot on red varieties of pomegranate (Vicent *et al*., 2016). In the present research, different species of *Cladosporium* were consistently observed causing decay on artificially wounded 'Boufeggous' and 'Medjool' dates. *Cladosporium* spp. are typical wound pathogens that have been reported as date spoilage fungi (Omamor and Hamza, 2007). In fresh fruit, decay by *Cladosporium* spp. typically starts from surface mold or 'smudge' and has often been found to be associated with *Alternaria* spp., which are the predominant causal agents of black spots (Smoot *et al*., 1983). In our case, the most frequent species on Elx dates was identified as *C. cladosporioides*.

It can be inferred from this and previous research (Palou *et al*., 2011) that the incidence and etiology of date postharvest diseases in the Elx area were more affected by local environmental conditions than by cultivar, season, or postharvest handling protocols. Nonetheless, the influence of these factors on the relative frequency of the different pathogens was also significant, and particularly, weather conditions are likely to be important. Factors such as the particular a_w in the fruit skins of each date cultivar or high soil water content that may cause skin cracks may also have important impacts on the incidence of postharvest diseases (Omamor and Hamza, 2007). These results highlight the importance of studying fungal populations and pathogenicity for a particular production area to determine the potential risks of economic losses due to postharvest decay, and to develop locally appropriate disease control strategies. One of the reasons that may account for the high incidence of date postharvest diseases in the Elx grove is the high a_w of the fruit at harvest. Under Elx conditions, and depending on the season weather and other factors, 'Medjool' dates can be harvested at the 'Khalal' stage with water contents greater than 50–52% (a_w around 0.93). This a_w value can still be greater than 0.90 on dates at the 'Rutab' stage after the application of artificial ripening treatments (Vilella-Esplá, 2004).

We conclude that, irrespective of cultivar and season, the important pathogen pressure and the environmental conditions of the Elx's date palm grove favour high incidence of postharvest decay that may result in important crop losses. Blue mold caused by *P. expansum*, black spot caused by *A. alternata*, and black rot caused by *A. niger* (clade) were major postharvest diseases of 'Boufeggous' and 'Medjool' dates. Therefore, the Spanish date palm industry should implement efficient strategies to control these particular postharvest diseases in order to reduce economic losses. Since there are no chemical fungicides at present registered in Spain for postharvest application on date palm fruit, attention should be devoted to test fungicide field treatments to reduce the incidence of latent infections. As well, preconditioning protocols should be implemented to reduce the fruit a_w, and alternative nonpolluting postharvest antifungal treatments should be evaluated to inhibit disease development.

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