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Research Article

Inflorescence Rot of Date Palms in the Mزاب Valley (Northern Algerian Sahara)

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Abstract

The date palm heritage of the Mزاب region is renowned for its remarkable biodiversity and the presence of numerous cultivars. However, the palm groves in this area create an environment that is highly conducive to the spread of fungal diseases. This study investigates inflorescence rot in date palms (*Phoenix dactylifera* L.) within the Mزاب Valley, a condition predominantly caused by the fungus *Mauginiella scaetiae* Cavarra. This pathogen may pose a significant socio-economic threat to oasis agriculture in Algeria. Field surveys were conducted at three sites in the Mزاب Valley: Laâdira and El-Ghabet (Ghardaïa commune), and Ahbas (El-Atteuf commune). The study focused on six predominant cultivars of the region: Tamdjouhert, Tdalt, Tazerzayt, Ighes n Wutchidhen, Ut Qbala, and Deglet-Nour. These cultivars were monitored to assess their response to inflorescence rot, commonly referred to as El-Khamedj. Laboratory investigations included fungal isolation and detailed macro- and micro-morphological analyses. The findings highlighted notable differences in the resistance and susceptibility of the cultivars to the disease. Deglet-Nour, Ighes n Wutchidhen, and Ut Qbala were identified as the most affected cultivars, while Tazerzayt and Tdalt exhibited greater resistance. Among the studied cultivars, Deglet-Nour from the Ahbas site was found to be the most vulnerable to inflorescence rot.

Keywords: fungal diseases, *Mauginiella scaetiae*, El-Khamedj, survey, varietal behavior, isolation, identification.

Introduction

Algeria produces a wide variety of crops, but many of these, as is the case worldwide, are susceptible to plant diseases. For instance, citrus trees have been impacted by viroids [1] and viruses [2], while date palms suffer from significant infestations by fungi [3, 4] or parasites [5]. In this context, several research programs

have been launched to better understand the nature of these pests and develop effective strategies to combat these phytopathogens [6-12]. The date palm (*Phoenix dactylifera* L.) holds a pivotal role in the agriculture and economy of Saharan and oasis regions. Dates are not only a staple food for oasis populations but also a vital export commodity for Algeria. Beyond their fruit, date palms provide byproducts used as livestock feed, windbreaks, and raw materials for construction and artisanal crafts. In Algerian oases, their importance extends beyond economics, playing a critical ecological and cultural role. These palms create microclimates

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conductive to diverse crop cultivation and support biodiversity in fragile ecosystems [3, 13].

Currently, Algeria cultivates approximately 18 million date palms across 169,380 hectares, producing an annual yield of around 500,000 metric tons of dates [13]. These trees also serve as a vital genetic reservoir, supporting sustainable agricultural practices and strengthening the socio-economic fabric of Saharan communities. Furthermore, they enhance soil health and provide habitats for various species, thereby preserving biodiversity in arid conditions [13, 14]. Over the past century, the doubling of date palm cultivation illustrates their resilience to climate changes [15]. Date palms carry significant cultural value, deeply rooted in local traditions and symbolizing sustenance and heritage. Their presence in festivals and rituals underscores their integral role in community life [16]. However, challenges such as diseases and market constraints threaten their viability, necessitating urgent measures to preserve their ecological and economic contributions.

Date palms form the backbone of oasis ecosystems, fostering favorable conditions for human and livestock life. Their canopy mitigates the harsh effects of dry air and hot winds, increases humidity, and reduces evaporation. This microclimate supports the cultivation of understory crops, including fruit trees, vegetables, and fodder plants. Despite their ecological importance, date palms are threatened by diseases such as inflorescence rot, primarily caused by the fungus *Mauginiella scaettae* Cavara, also known as *Geotrichum scaettae* (Cavara) Maire. This disease, reported in several North African countries [4], can result in significant economic losses, affecting both local farmers and the national economy. The pathogen, an imperfect fungus belonging to the class *Ascomycetes*, is consistently isolated from infected tissues. Other fungi, such as *Fusarium oxysporum* Sheldl. emend. Snyder & Hansen, *Fusarium moniliforme* Sheld. (aggregate), *Fusarium solani* (Mart.) Appel & Wollenw. (aggregate) Snyder & Hansen, *Fusarium proliferatum* (Matsush.) Nirenberg ex. Gerlach & Nirenberg, *Thielaviopsis paradoxa* (Dade) C. Moreau, *Ceratocystis paradoxa*, and *Trichothecium roseum* (Pers.) Link, have also been associated with rotting date palm inflorescences, though they are less common [4, 17, 18].

Recent studies have explored various control measures for managing *M. scaettae*. Biocontrol

agents, fungicides, and plant-derived phytochemicals have shown promising results. For example, *Aspergillus niger* demonstrated an 85.33% inhibition of *M. scaettae* growth *in vitro*, presenting an environmentally friendly alternative to chemical fungicides [19]. Similarly, fungicides such as difenoconazole and a boscalid-pyraclostrobin combination effectively controlled the pathogen at reduced doses [20]. Additionally, plant extracts from *Eucalyptus torquata* and *Cupressus atlantica* exhibited potent antifungal properties, attributed to their phenolic and flavonoid content [21]. While these approaches hold promise, concerns about fungicide resistance and environmental impacts underscore the importance of integrated pest management strategies.

This study focuses on diagnosing inflorescence rot in date palms within the Mزاب Valley. It examines symptoms, infection rates, and the resistance or susceptibility of major date palm cultivars. Fieldwork was supplemented with laboratory analyses, including the isolation and macro- and microscopic identification of the pathogen.

Material and methods

In the Field

Field surveys were conducted at three locations within the Mزاب Valley, specifically in three distinct regions: Laâdira and El-Ghabet (both in the Ghardaïa commune) and Ahbas (in the El-Atteuf commune) (**Figure 1**). Our methodological approach combines surveys conducted through questionnaires across multiple farms in the study area, alongside a series of interviews and discussions with farmers specializing in date palms. These farmers, who are active members of agricultural associations, provided responses to a variety of questions. Several walking transects were conducted both between and within palm groves to gather as much information as possible. Preliminary surveys were initially carried out at the study sites to locate diseases affecting date palms. The survey forms were filled out in collaboration with the farmers. In addition to general information about the farms, these forms included data on the date palm varieties present, the phytosanitary status of the gardens, the identification and extent of the studied disease, and monitoring their progression. A total of seventy survey forms were completed in the study area.

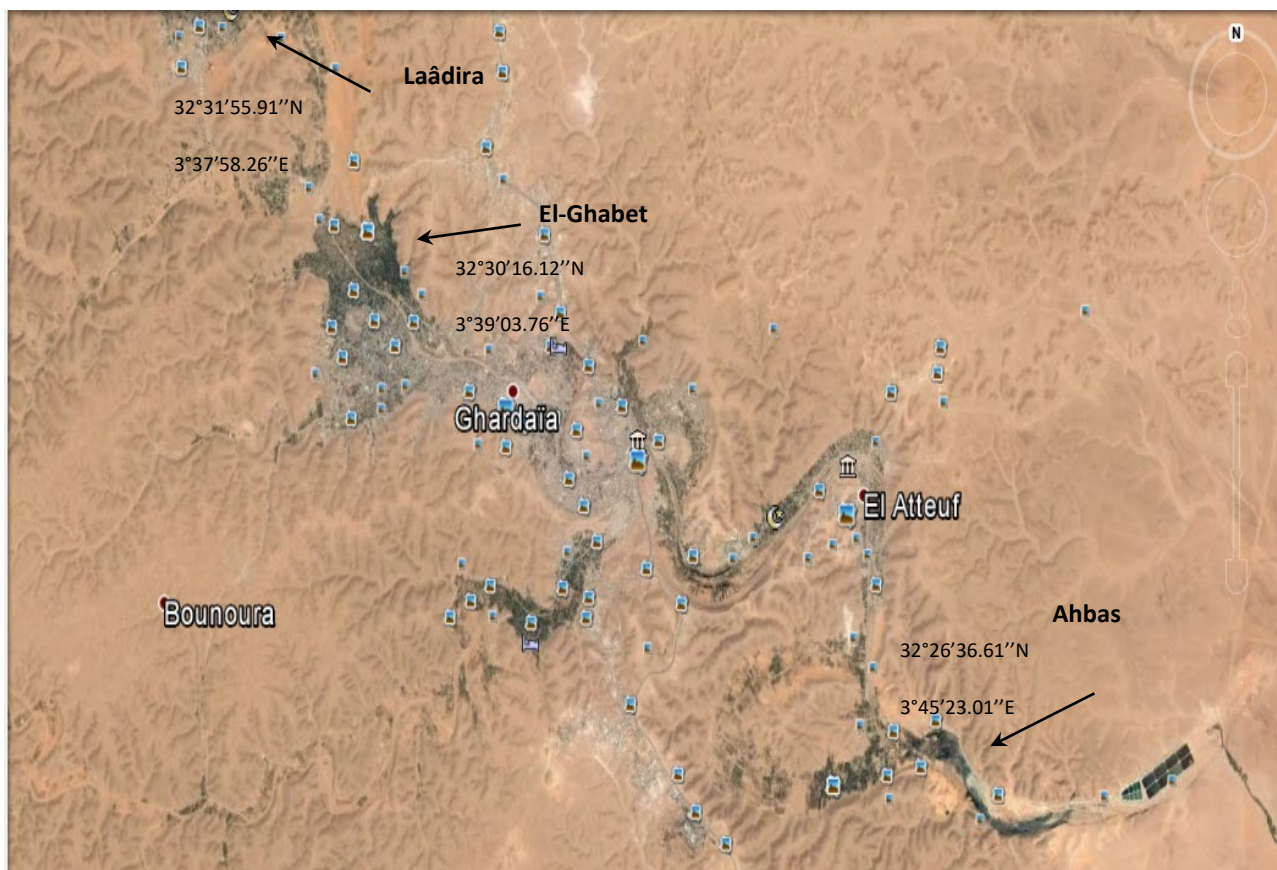


Figure 1. Geographic location of the study sites in the Mzab Valley (Google Earth)

The disease infestation rate was calculated by comparing the number of infected date palms to the total number of surveyed palms for each studied variety, resulting in a percentage derived from the following formula:

$$TI (\%) = (NPI / NPT) \times 100$$

TI: Infestation rate.

NPI: Number of infected palms.

NPT: Total number of surveyed palms.

For El-Khamedj, we observed rust- or brown-colored spots on the spathes, which gradually spread, leading to the rotting of the inflorescences (commonly known as El-Khamedj).

Sampling

Six dominant cultivars from the Mzab Valley, Tamdjouhert (Timjouhert), Tdalt (Dalt), Tazerzayt, Ighes n Wutchidhen (Ghars), Ut Qbala (Bent Qbala) and Deglet-Nour, were monitored for their response to inflorescence rot. Sample collection should be carried out from diseased palms, specifically from infected spathes and inflorescences affected by El-Khamedj. It is worth noting that symptoms of Bayoud (caused by *Fusarium oxysporum* f. sp. *albedinis*) and black rot (caused by *Thielaviopsis paradoxa*) are present year-round, whereas the symptoms of El-Khamedj appear only when the spathes emerge (late January to early February).

Each collected sample will be labeled with a unique code indicating the number and date of collection, accompanied by a data sheet. During the transport of samples to the laboratory, special care must be taken to avoid secondary contamination within the agricultural sites.

Culture Medium

The selection of a culture medium is based on its suitability for optimal development of the phytopathogen. The medium used is PDA (Potato Dextrose Agar), which promotes both good mycelial growth and significant sporulation of fungi. In the presence of light, it also ensures the typical pigmentation of the isolated fungi. The composition of PDA is as follows: 200 g of potato, 15 g of dextrose (D-glucose), 20 g of agar, and 1000 ml of distilled water. Other standard media, such as Malt and Czapek media, can also be used.

Isolation of *Maugiella scaetiae*

Portions of rachises and inflorescences showing symptoms are cut into small fragments (3 to 5 mm) and disinfected by soaking in a 10% sodium hypochlorite solution (or 70% ethanol) for 5 minutes. They are then rinsed for 10 minutes in three successive baths of sterile distilled water, dried with filter paper, and placed in Petri dishes containing PDA medium, with 5 fragments per

dish. The dishes are incubated at $25 \pm 2^{\circ}\text{C}$ for a sufficient period to allow fungal fructification.

Purification and Preservation of *Maugiella scaetiae*

If contamination or multiple types of mycelium appear in the same dish, subculturing is performed on PDA medium to avoid mixtures and obtain pure cultures. After the culture is purified, a small piece of mycelium is taken from the purified culture using a sterilized loop and inoculated into a Petri dish or test tube containing a solidified medium. These are then stored in an incubator at 6°C to prolong their viability.

Results and discussion

Young spathes, enveloped by the bases of infected palm fronds, become contaminated by latent mycelium during their emergence. Spores, however, do not play a significant role in disease persistence due to their short lifespan. Transmission of the disease from one tree to another occurs through contaminated male inflorescences during the pollination process. On a tree showing symptoms of El-Khamedj, contamination of the young inflorescence occurs very early, while the spathe is still hidden among the sheaths of infected palm fronds. This contamination is external and does not require prior injury; the fungus actively penetrates the spathes, developing intercellular mycelium that often remains localized in the parenchyma and rarely invades vascular tissues. The mycelium then spreads to the floral buds, where the fungus sporulates abundantly [22].

This disease is particularly severe in regions characterized by high humidity or significant rainfall extending into winter and spring. A

temperature of 15 to 20°C in spring (February-March) is necessary for the onset and development of El-Khamedj. The fungus primarily persists as latent mycelium in male or female inflorescences and in the leaf bases and petioles of palm fronds [23]. This explains why certain date palm varieties escape the disease; their spathes emerge either early or late, during a period when the fungus cannot grow due to temperatures being either too low or too high. Dense, poorly maintained palm groves and heavy, waterlogged soils exacerbate the disease [22].

Most epidemic plant diseases are transmissible, which explains their relative suddenness. Transmission occurs passively through soil, the atmosphere, runoff water, or irrigation water, or actively via a vector, which may itself be passive or active (rain, agricultural equipment, humans or insects). For the host plant to be infected, it must be receptive to the pathogen. This receptivity can be modulated by resistance genes that are expressed either during the juvenile stage or the adult stage [24].

The first visible symptoms of the disease appear on the external surface of the still-closed spathes as soon as they emerge, either at the end of winter or the beginning of spring. One or two rust-colored or brown spots are observed, gradually spreading (**Figure 2**). These spots are much more noticeable on the inner side of the spathe, where the fungus has already invaded the inflorescences, causing their rot. When the affected spathes burst open, they reveal a more or less complete destruction of the flowers and pedicels. In cases of severe infection, the spathe does not open due to the total rot of its contents, leaving only the base of the inflorescence alive.



Figure 2. Development of inflorescence rot (El-Khamedj) symptoms

The inner surface of the spathes, which appears translucent yellow, shows brown punctuations corresponding to the contact points of the infected inflorescences. The infected tissues have an oily, translucent appearance; small droplets of water bead on their surface, and the central part of the spot is often covered with a white downy growth. The inflorescences dry out and become covered with a mycelial felt, which is soon replaced by powdery fructifications of the fungus [22].

Mauginiella scaettae survives from one year to the next on the debris of inflorescences and palm

fronds, and it can attack new flowers when the season is favorable. The partial or total rot of inflorescences, with their varying colors, allows identification of the dominant causal agent. This fungus causes white to cream-colored rot, *Fusarium moniliforme* results in pinkish rot, while *Thielaviopsis paradoxa* leads to dry, brownish rot [25]. The results of infestation by inflorescence rot disease (El-Khamedj) at the study sites are summarized in **Table 1**.

Table 1. Infestation rates of inflorescence rot disease (El-Khamedj)

Sites Varieties	Laâdira			El Ghabet			Ahbas		
	Number of palm trees surveyed	Number of infested palm trees	Infestation rate	Number of palm trees surveyed	Number of infested palm trees	Infestation rate	Number of palm trees surveyed	Number of infested palm trees	Infestation rate
Deglet-Nour	1500	5	0.33	500	4	0.80	450	4	0.90
Ighes n Wutchidhen	850	2	0.24	650	5	0.77	600	5	0.83
Ut Qbala	800	2	0.25	600	5	0.83	620	4	0.66
Tdalt	500	1	0.20	650	3	0.47	610	3	0.49
Timjouhert	450	2	0.44	700	5	0.72	520	3	0.58
Tazerzayt	600	1	0.17	650	2	0.31	750	3	0.40

Table 1 presents the infestation rates of the main date palm varieties by inflorescence rot (El-Khamedj) disease. This disease was detected in all studied varieties and sites, with a low overall infestation rate not exceeding 1%. Notably, the infestation rate was significantly lower in the agricultural perimeter of Laâdira, with values ranging from 0.17% to 0.44%. This reduced rate may reflect more meticulous agricultural practices or micro-climatic conditions less favorable to the development of the fungus responsible for El-Khamedj. By contrast, infestation rates were higher in the older palm groves of El-Ghabet (Ghardaia commune) and Ahbas (El-Atteuf commune), likely due to environmental conditions conducive to the disease and less rigorous maintenance. The rates in these sites approached 1%, with Deglet-Nour in Ahbas reaching up to 0.9%.

Varietal differences in susceptibility were observed. Deglet-Nour, Ighes n Wutchidhen, and Ut Qbala were the most affected varieties, with infestation rates close to or exceeding 0.8% at some sites. Specifically, El-Ghabet recorded peaks for Ut Qbala (0.83%) and Ighes n

Wutchidhen (0.77%), while Ahbas had the highest rates for Deglet-Nour (0.9%) and Ighes n Wutchidhen (0.83%). Conversely, Tazerzayt and Tdalt were the least affected, with infestation rates not exceeding 0.49%. Timjouhert showed moderate infestation levels, ranging from 0.44% to 0.72%.

The trend suggests that older palm groves, such as those in El-Ghabet and Ahbas, are more prone to infestation, potentially due to their proximity to Oued Mzab. The waters of the oued are considered a transmission factor for this soilborne disease. In contrast, Laâdira's better resistance highlights the impact of well-maintained palm groves and less favorable conditions for the disease.

To mitigate the spread of El-Khamedj, it is recommended to strengthen prophylactic measures in El-Ghabet and Ahbas. These measures should focus on the removal of diseased inflorescences and the application of targeted fungicide treatments. For sensitive varieties such as Deglet-Nour, Ighes n Wutchidhen, and Ut Qbala, early interventions

upon the appearance of the first symptoms are essential to limit disease propagation.

Djerbi [22] reported that this inflorescence disease affects many neglected palm groves in hot and humid regions. Under normal conditions, attacks are localized, ranging from 3% to 10%. Damage is severe only in certain years characterized by a prolonged, cold, and humid winter; when these conditions occur, the disease becomes epidemic. The same author indicated that in El Basra, Iraq, crop destruction reached 80% in 1949 and 1978, and in 1983, losses ranged from 50% to 70% in Katif (Saudi Arabia). Some varieties are more susceptible to El-Khamedj, while others show resistance. Losses can range from 5 to 65% of the crop, with some regions experiencing up to 40% loss. Severe outbreaks can result in losses of up to 70% of the crop [26].

After a few days of incubation, *in vitro*, of the cultures under favorable conditions, colony development is observed from the fragments and on the surface of the medium. The diagnosis and identification of the studied fungi are based on the examination of external and internal symptoms observed on the organs of the suspect palm, as well as the isolation of the causal agent on a culture medium in the laboratory. This is followed by macroscopic and microscopic characterization using a key for identifying pathogenic fungi [4, 27]. In pure culture, it forms a white mycelium that abundantly produces conidial fruiting bodies in the form of a white powdery coating. Its fruiting bodies consist of chains of hyaline conidia that fragment into mononucleate or binucleate cells, and less frequently multinucleate cells, measuring 10 to 30 µm in length and 5 to 10 µm in width.

The Ghardaïa region, known for its diverse date varieties, includes highly valued cultivars like Ighes n Wutchidhen and Ut Qbala. The Mزاب region's date palm groves, surrounded by various plant species, are conducive to fungal diseases, including inflorescence rot (El-Khamedj). This disease occurs during humid and rainy periods and can reappear annually without treatment. In dry years, it regresses. The disease is less frequent in Laâdira, where good palm maintenance is practiced. Farmers, particularly climbers, manage it by removing affected parts and applying a salt solution.

Rain and high humidity trigger the projection of conidia from the latent mycelium located between the lif (leaf sheath) and the kernaф (flower spathe), leading to contamination of the spathes during their emergence. The lif refers to the fibrous material found at the base of the fronds (leaf stalks) where they attach to the trunk. This layer acts as a protective covering but can also accumulate moisture, creating favorable

conditions for fungal growth. In contrast, the kernaф refers to the sheath or outer layers surrounding the flower spathe, serving as a protective cover for the flower cluster before it fully emerges.

In the old palm groves of El-Ghabet and Ahbas, where humidity is high and maintenance poor, the disease was observed. Alternating periods of heavy rainfall and temperature increases in Ghardaïa, as observed in 2008, favored the resurgence of El-Khamedj, affecting varieties such as Deglet-Nour, Ighes n Wutchidhen, and Ut Qbala. Older, neglected palms, particularly Dokkar palms (male date palm trees), are more vulnerable and act as sources of contamination. Varieties like Tdalt and Tazerzayt showed low or no incidence of El-Khamedj, indicating resistance.

The fungus *M. scaetiae* has been identified as the causal agent of inflorescence rot, leading to significant yield losses in southeastern Algeria's date palms. This pathogen, isolated from both male and female inflorescences, prefers stomatal entry during infection [4]. El-Khamedj is also present in Iraq, Egypt, the USA, UAE, Kuwait, Bahrain, and Saudi Arabia, where it causes significant damage in certain years [4, 22]. Losses can reach 30–40 kg per tree, with complete destruction of the inflorescences in some cases. During humid years, the incidence can rise to 10% in regions such as Tunisia, with abandoned male palms being the most affected. The disease often takes on an epidemic form during cold, humid winters [18].

It seems that, if we remove or reduce the latent mycelium located between the lif (fibrous base of palm fronds) and the kernaф (sheath around the flower spathe), it could help reduce the incidence of El-Khamedj disease.

In the Mزاب region, farmers recognize cultivars based on the morphology of organs like fronds, leaflets, and fruit shape and color. Rhouma [28] notes that these traits vary depending on growing conditions, but fruit remains the primary criterion for cultivar recognition. Cultivar selection is based on adaptability to climate, earliness, taste, storage suitability, and market price. The Mزاب's date palm heritage is marked by significant biodiversity and cultivars that mature at different times, allowing for continuous harvest and fresh date supply throughout the year.

Chemical control at the onset of El-Khamedj is effective, with fungicides such as tricalcium terecuprate sulfate (76%), copper oxychloride (80%), benomyl (50%), and methylthiophanate (70%). The identified pesticides were checked on the national index of agricultural pesticides (IPPUA, edition 2015). Preventive maintenance,

including removing and incinerating affected spathes and inflorescences, is crucial.

Conclusions

The findings of this study underscore the significant impact of *M. scaetiae* on date palm cultivation in the Mزاب Valley, highlighting the urgent need for effective disease management strategies. The high susceptibility of certain cultivars to inflorescence rot (El-Khamedj) emphasizes the importance of early detection and preventive measures to mitigate potential yield losses. The comprehensive morphological characterization of the fungal isolates contributes to a deeper understanding of the pathogen's biology, which is essential for developing targeted control methods. Given the socio-economic importance of date palm farming in Algeria, future research should focus on integrated disease management approaches, including the selection of resistant cultivars, the implementation of biocontrol strategies, and the optimization of cultural practices to reduce fungal proliferation. Additionally, molecular studies could further elucidate the genetic diversity of *M. scaetiae* strains in the region, facilitating the development of more precise diagnostic tools. Overall, safeguarding the date palm heritage of the Mزاب region requires a multidisciplinary approach that combines field surveys, laboratory analyses, and sustainable agricultural practices to ensure the long-term viability of oasis agriculture.

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