Bayoud and Belaat diseases of date palm (*Phoenix dactylifera* L.) in Figuig oasis of Morocco

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**Abstract.** From 2016 to 2017, a survey was carried out during four vegetative cycles of date palm tree (*Phoenix dactylifera* L.) in Figuig oasis of Morocco. Two types of date palm culture were surveyed, that is traditional and modern plantations. The aim of the survey was mainly to explore date palm diseases, their incidence and geographic distribution in Figuig oasis. Results revealed the presence of two major diseases: the harmful Bayoud disease and Belaat disease. The rate of contamination of each disease reached respectively 3.38% and 3.31%. Spatial distribution of each disease varies for each one both in traditional and modern plantations, as shown in kernel density maps of diseases infestation. Bayoud disease spread more in traditional oasis. In fact, 60.96% of infested date palm trees by Bayoud disease were recorded in traditional plantations. On the contrary, in modern ones, Belaat disease was the main disease and the rate of infestation reached 67.13%. The survey also focuses on the influence of occurred farming practices in infested plantations which are often characterized by a lack of phytosanitary treatment, fertilization and weeding. Furthermore, pruning, gravity irrigation and the presence of underlying culture were also identified as increasing factors for pathogens dissemination.

**1. Introduction**

The date-producing area in Morocco covers 1,741 ha with a production of 111,701 tons in 2018 which represents 1.31% of world production [1]. The main date palm plantations in Morocco are located in pre-Saharan and Saharan areas such as Errachidia, Figuig, Goulmim, Tata, Tiznit, Marrakech and Ouarzazat. The oasis of Figuig is the south-eastern oasis of Morocco but is located in the South-West of the Saharians oasis and date palm plantations. Currently, the date palm growth area occupies more than 1,741 ha with a production of 4,683 tons in 2016 [2]. In Figuig, such as in others date palm culture areas, traditional and modern plantations constitute the two types of cultivation system. According to Carpenter [3], the traditional ones are characterized by a high planting density, genetic diversity of trees, poor management of irrigation and farm practices and a lack of control against pests and diseases. On the contrary, the modern ones are characterized by monoculture, organized planting and low density.

Bayoud disease has destroyed in one century more than two-thirds of Moroccan palm groves, that is around 12 million palm trees. Moreover, more than 150,000 palm trees were eliminated in 1981 in the Draa Valley in Morocco [4]. Over 3 millions palm trees were eradicated in three regions in Algeria [5] because of a soil-borne fungus, *Fusarium oxysporum* f.sp. *albedinis* which was first discovered more than a century ago in Moroccan oasis [6]. The spread of this plague reached Figuig oasis in 1898 [7], then reached southern Algeria between 1920-1950 [8] and reached Mauritania in 1995 [9]. According to [10], Bayoud diseases' attacks were recorded early in Figuig oasis at the beginning of the 20th century.
and destroyed over a half of the good cultivars and eradicated 12 local cultivars. The death rate caused by this disease has recently decreased to 4.3% despite the presence of good quality cultivars [11]. No effective control strategy exists against these diseases and the strategy adopted in Morocco is to plant more palm trees than the Bayoud disease kills.

Belaat disease caused by *Phytophthora* spp. Similar to *Phytophthora palmivirra* [4] is mainly present in Nord African country and is also recorded in the United Arab Emirate [9, 12-15]. Belaat disease usually occurred in abandoned farms. It’s sporadic and sometimes mini-epidemic for young date palm plantations: moreover, the incidence is related to location and the adopted farming practices [16].

Nevertheless, GIS makes easier the control and management of diseases and pests and is really helpful to localize and predict the geographic spreading of these different threat [17]. It’s used recently for processing and modelling dataset rapidly by researchers of agronomy and natural resources [18].

The aim of this study, which will be focused on Bayoud and Belaat diseases in Figuig oasis, was to compare the incidence rates of infestation in different systems of culture, with different farming practices. To reach that goal, the first steps are the identification of these date palm diseases and the mapping of their spatial distribution.

2. Materials and methods

2.1. Study site and plant material

From 2016 to 2017, over 4320 date palm trees were prospected in Figuig oasis. They were located in all oasis among 113 farms using one of the two following types of culture system: the traditional plantations or the modern ones as shown in Figure 1. 78 of those farms were using traditional plantation type of culture and 35 farms were using modern ones. The number of prospected date palm trees was respectively 1170 and 3150 trees. We focused in this survey on the abundant local cultivars in Figuig oasis and especially ‘Assian’, ‘Aziza bouzid’ and ‘Boufeggouss’.

![Figure 1. Date palm plantations in Figuig oasis.](image-url)
Table 1. Prospect regions on date palm cultures in Figuig oasis.

| Type of plantation       | Farms number | Prospected date palms trees | Percentage of infested trees |
|-------------------------|--------------|-----------------------------|------------------------------|
| Traditional plantations | 78           | 1170                        | 12.99%                       |
| Modern plantations      | 35           | 3150                        | 15.65%                       |
| Total                   | 113          | 4320                        | 28.64%                       |

2.2. Data analysis

In this survey, only the contaminated trees that show typical symptoms of disease during different vegetative periods was recorded. Data of diseases was also collected through face-to-face interviews with farmers.

A survey sheet was made of each case of infestation and contains diseases' and cultivar's name, GPS localization, the infested part (root, stem, leaves, inflorescences and fruits) including farm’s information such as its type of culture system (traditional or modern plantations), the presence of underlying culture (fodder, cereal, vegetable crops, arboreal), the farming practices (Tillage, weeding, phytosanitary treatment, fertilization, leaf pruning, bunch thinning and bagging) and the type of irrigation system (gravity and drip irrigation).

In GIS map, each contaminated tree was mapped and represented by a data point. Then, polygons were drawn to delimit date palm plantations. A kernel density map of the studied event was create using GIS density (Arcgis; ESRI 2010). Kernel density tool was performed to generate a spatial distribution of infested trees in study site and represented in red for the highest density of diseases infestations and in green for the lowest.

3. Results and discussion

3.1. Bayoud disease

Fusarium oxysporum f.sp. albedenis is causing a serious problem in date palm plantations in Morocco. Infection by vascular Fusarium wilt starts generally with the roots and spreads in the vessels of trunk up to the apical part. The first typical symptoms are internal, showing a browning vascular of roots, trunk and leaves. Then appears the external symptoms with the hemiplegic dryness of the leaves which characterizes the Bayoud disease [16] and causes death of trees at the last stage.

Survey’s results in Figuig oasis revealed that 3.38% of trees were infested by Bayoud disease which can be considered as the major’s. Spreading of Bayoud disease varies on traditional and modern plantations. The geographical distribution of Bayoud disease in Figuig oasis is mainly concentrated in the traditional plantations and the nearby areas with the modern plantations as shown in Kernel density map of Bayoud disease Figure 2. Among infested date palm trees, the rate of infestation in traditional plantations reached 60.96 % and 39.04 % in the modern ones Figure 3. The lowest rate observed in the modern ones seems to be attributed to the monoculture and low density of plantations which characterize this type of culture system and decrease the dissemination of pathogen.

Furthermore, various modes of dissemination were presented for the pathogen and the sources can be the infected plants and parts of trees, soil, irrigation and farmer material [16], which makes it difficult to propose only prophylactic acts as measures to control diseases. In case of Figuig oasis, many farms practices seem to increase in case of contamination: for example as shown in Figure 3. Pruning process, as the main process of dissemination reached 83.56% of infested trees. Pruning seems to increase dissemination of diseases by infected pruning tools and removed leaves. According to Salah [19], regular pruning prevent diseases and pests infestation by removing dead leaves and should be accompanied by treatment of trees. Furthermore, pruning tools should be disinfected and falling leaves should be removing to stop dissemination of pathogen during pruning. Underlying crops, such as Alfalfa, Henna (Lawsonia inermis) and Lucerne (Medicago sativa), are healthy carriers and may occur problem of contamination to date palm trees. Otherwise, a few of them can inhibit growth of Fungus in the soil such as vetiver (Chrysopogon zizanioides) [20]. In Figuig, 85.18% of attacked trees were cultivated with
underlying crops, whereas 39.04% of cases were recorded in farms where weeding is practiced Figure 3.

Disease attacks vary from one farm to another in Figuig oasis depending on water quality, temperature and the frequency of irrigation [21]. In addition, gravity irrigation increases the dissemination of Bayoud disease: it seems to be better to use drip irrigation especially for young plants [16]. Results indicate indeed the high rate of infestations adopting gravity irrigation contrary to drip irrigation which reached respectively 66.43% and 10.27% as shown in Figure 3. In addition, a lack of fertilization was recorded and only 13.01% of infested date palm trees were fertilized. In fact, the fertilization, especially fertigation, fortify growth of date palm trees [16].
3.2. Belaat disease

The infected trees by *Phytophthora* were characterized by whitening and death of young frond at the crown of date palm tree and causing death of the terminal bud. The infection progress downwards in the trunk, as a wet heart rot form [16]. According to Zaid et al [22], acetic and butyric fermentation odours were releasing from the heart of infested tree.

Figure 4 presents spatial distribution of Belaat disease in Figuig oasis. Severity of infestation of Belaat disease in Figuig oasis reached higher rate in modern plantations with 67.13% of contaminated trees, than in traditional plantations which reached 32.56% Figure 5.

![Figure 4](image)

**Figure 4.** Density of infested trees by Belaat disease in Figuig oasis.

![Figure 5](image)

**Figure 5.** Percent of farming factors of infested trees by Belaat disease.

Sedra [23] recommended many farming practice such as pruning, fertilization and irrigation as cultural controls against Belaat disease. The results confirm the importance of fertilization: indeed,
among the contaminated trees by Belaat disease, 78.33% were not fertilized trees. According to Salah [19], regular pruning prevent diseases and pests infestation by removing dead leaves and should be accompanied by treatment of tree. Furthermore, pruning tools should be disinfected to stop dissemination of pathogen during pruning. As shown in Figure 5, over 72% of infested trees were pruned. Moreover, the presence of underlying crops with the infested date palm trees reached 83.21% of the recorded cases. The drainage system protects trees from Belaat attacks [15] and, in the case of Figuig’s farms, only 20.27% occurred tillage.

Gravity irrigation must be avoid in order to stop the dissemination of Belaat disease [16]. According to the system of irrigation adopted in Figuig oasis, rate of contaminated trees was higher for gravity irrigation than for drop irrigation and reached 58.74% and 29.37% respectively, as shown in Figure 5.

4. Conclusions
The results presented in this study reveal the variation of diseases distribution in Figuig oasis, which require a safety model of date palm plantation to control and management diseases, especially Bayoud disease. The spatial distribution of Bayoud was mainly concentrate in traditional plantations and seems to be disseminated in the nearby areas of the modern ones. On the contrary, Belaat disease was manly recorded in the modern ones.

Results present farming practices such as measure to control spreading of diseases and to maintain the cultivars safety. Preventive measures must be taken into consideration during pruning and by getting rid of leaves and infested parts from the plantations. Furthermore, pruning tools must be disinfected after each use. The presence of underlying crops exposes date palm trees to infestations due to healthy care of cultivated crops. Drip irrigation is most safety as system of irrigation. Tillage and weeding seem to be suitable for trees protection.

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