Diseases of the Date Palm: Present Status and Future Prospects

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أمراض نخلة التمر الحاضر والتوقعات المستقبلية

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الخلاصة: هنالك العديد من الأمراض التي تصيب نخلة التمر ولكن يظل البيوض أشدها خطورة، يسبب هذا المرض الفطر فيرزيريوم أوكسيسبروم، وهذا الفطر من الأنواع التي تعيش في التربة وقد تأثرت به كل زراعات النخيل في المغرب وفي غرب ووسط الصحراء الجزائرية. تسبب البيوض في موت ١٢ مليون نخلة في المغرب وثلاثة ملايين في الجزائر مما أدى إلى الاسراع في إنتشار ظاهرة التصحر. تناقش هذه الدراسة الأعراض الظاهرة والداخلية، بالاضافة إلى الطرق المتبعة في التعرف على هذا الفيوزيريوم مثل إختيار كيفية تسبب المرض ، مواصفات الاستزراع ، والتناسق الجسدي .....الخ. تحدث العدوى من قرب حيث ينتقل المرض من جذور النخيل المصابة إلى الصحيحة أما من بعد فتنتقل العدوى بواسطة الفصائل المصابة والتي لا تظهر عليها أعراض المرض كذلك ينتقل المرض بواسطة التربة المنقولة ومياه الري. كما تمت مراجعة طرق المكافحة المختلفة من الوسائل الوقائية والكيميائية والزراعية والحيوية والوراثية. ويبدو من الدراسة أن أفضل وسيلة ترتكز على البحث عن الاصناف المقاومة. لقد اختيرت مائة تركيبة جينية وتم اكثارها عن طريق الزراعة النسيجية وزرعت في المناطق المتأثرة بالمرض لاعادة تأهيل واحات النخيل التي دمرها مرض البيوض. من بين الأمراض الأخرى التي تصيب نخلة التمر مرض الخامج، عفن الثمار الذي تسببه العديد من أنواع الفطر، اللفح الأسود ومرض بلعات. تعتبر هذه الأمراض ذات أهمية محدودة وغير منتظمة الحدوث، لكنها تشكل خطورة عظيمة وتتسبب في خسارات بالغة تحت الظروف الملائمة إذا لم تتبع الطرق الصحية السليمة. كذلك تمت مناقشة مرضين خطيرين يفتكان بالنخيل غير معروفي العوامل المسببة لهما (الوجام ومرض الورقة المتكسرة) هذا بالاضافة إلى أمراض أخرى عديدة وتداعيات فسيولوجية أقل أهمية.

ABSTRACT: While date palm is affected by many diseases, bayoud remains the most serious one. It is caused by a soil born pathogen, *Fusarium oxysporum f.sp. albedinis*. It has affected practically all Moroccan palm groves as well as those of western and central Algerian sahara, where it has respectively killed more than 12 million in Morocco and three million in Algeria and has accelerated the desertification phenomenon. External and internal symptoms as well as identification methods of *F.o.* f. sp. *albedinis* by pathogenicity test, cultural characteristics, and vegetative compatibility were reviewed and discussed. Small distance contamination occurs by root contact between diseased trees and healthy ones, and at large distances through the movement of contaminated planting material (offshoots, symptomless carriers) and infested soil and irrigation water. Prophylactic measures as well as chemical, cultural, biological and genetic controls were reviewed. It appears that the most productive mean lies in research into resistant cultivars. Hundreds of genotypes have been selected and introduced for micro-propagation and planted in infested areas to rehabilitate date palm oasis ravaged by bayoud. Among other date palm diseases Khamedj *(Mauginiella scaettae)*, fruit rot (due to numerous fungi), Black scorch (*Thielaviopsis paradoxa*), Belaat (*Phytophtora sp.*) are of minor importance and of sporadic occurrence. However, they become serious and cause heavy losses under favourable conditions and when proper sanitation is not applied. Two serious and fatal diseases of unknown causes (Al Wijam and the Brittle leaf disease) as well as many other diseases and physiological disorders of minor importance were also reviewed.

Except for bayoud disease, a relatively limited number of research studies have been carried out on diseases and physiological disorders of the date palm. Despite their importance and common occurrence, there is a lack of information due to the difficulties encountered in the study and the control of these diseases. These difficulties are inherent in the slow growth, height and nature of the palm tree, as well as its broad geographical distribution. These difficulties are aggravated by the socio-economic environment in many date-producing countries where elementary control measures are often expensive or not feasible.

Despite the absence of precise statistical data on losses, the economic importance of date diseases is recognized and estimates are reported wherever available. Distribution, symptoms, causal agent and control of these diseases are also discussed.

Bayoud Disease

DISTRIBUTION AND IMPORTANCE OF BAYOUD: Bayoud

is incontestably the most serious fungal disease of the date palm (*Phoenix dactylifera L.*) It constitutes a real plague in the date growing areas of parts of North Africa and a threat to those countries still unharmed by it. Bayoud is an epiphytotic disease for which there is no known cure at the present time (Djerbi,1982).

Bayoud most probably had its origin in the Draà valley of Morocco from which it has advanced both westward and eastward, affecting most of Morocco's palm groves. In this country the spread of the disease was particularly rapid and spectacular; it advanced from oasis to another following the strings of palm groves that are more or less continuous along the valleys: Draà, Ziz, Gheris; (Bulit et al. 1967 and Toutain, 1965).

The disease entered northwestern Algeria and affected Beni Ounif in 1898 and Bechar in 1900. The palm groves in the vicinity of these centres were in turn affected (Beni Abbes, 1098; Fatis and Tabelbala, 1912; Taghit, 1923). Since these oases were close to Morocco and easily accessible, their contamination seems "natural". However, it is surprising that the disease appeared at the same time (1920) at Foggaret Ezzoua (Tidikelt) in the heart of the Algerian central Sahara, a thousand kilometers from Bechar.

Between 1920 and 1940 the map of bayoud foci expanded modestly. However, the last 30 years have been particularly favourable to the spread of bayoud. Due to the disorganized nature of services during World War II and the Algerian War for Independence, research activities, as well as elementary protective measures to check the spread of the disease were lacking in continuity. Many foci thus appeared: e.g. Igli, Aoulef, Reggane, etc. Bayoud has now reached the barrier of the Great Western Erg and the Tadmait plateau. Bayoud reached Metlili in 1950, crossing a distance of 700n kms in a single bound; the Ghardaia and El Golea palm groves were in turn affected more recently in 1965 and 1978 (Brochard and Dubost. 1970a., Djerbi, 1982.).

The continuous spread of bayoud highlights the dangerous problem threatening particularly the important plantations of Deglet Nour in Oued Rhir and the Zibans (Algeria) and even in Tunisia as well as in all date growing area of the world. Bayoud has killed 12 million palms in Morocco and more than 3 million in Algeria, including the best renowned, vigorous and productive palms (Djerbi, 1983). Bayoud has not only caused the loss of the best varieties, but also accelerated the desertification phenomenon with an influx of farmers to large urban centers.

Because of the considerable damage that bayoud has caused to Moroccan and Algerian palm groves and the threat that it constitutes to other countries, the disease has become the greatest enemy to date growing areas of the world.

SYMPTOMS: This disease attacks mature and young palm tree alike, as well as their basal offshoots (Bulit et al. 1967; Carpenter,1971).

Symptoms of Bayoud appear first on one or more leaves of the middle crown; some pinnae or spines located on one side of the leaf become white and the disease progresses from the base upward to the apex. After one side has been affected, the whitening and dying process appears on the other side of the leaf, progressing from the top of the palm to the base until the leaf is destroyed. As the pinnae die, a brown stain appears on the dorsal side of the rachis. Then the adjacent or opposite leaves are affected in the same manner until the terminal bud is finally affected, leading to the death of the tree.

The palm may die from six months to two years after the appearance of the first symptom. The rather rapid evolution of the symptoms essentially depends on the variety and the planting conditions.The disease appears on offshoots rapidly or may develop lately after the death of the parent palm.When affected trees are uprooted, only a small number of diseased roots, reddish in colour are revealed. When cut, the stipe shows large numbers of reddish spots, at the base; as they advance in the upper parts of the trunk, the coloured spots corresponding to the conducting fascicles separate and their complicated path, inside the healthy tissues can be followed. A transverse cut through affected leaves reveals reddish brown parenchyma with highly coloured conducting fascicles. Therefore, there is a continuity of vascular symptoms from the roots to the top of the leaves of the affected date palm.

PATHOGEN AND DISEASE DEVELOPMENT: The causal organism responsible for bayoud disease is a soil borne fungus named *Fusarium oxysporum* forma specialis *albedinis* (Killian et Maire), Malencon and Gordon. It belongs to the group Fungi Imperfecti, the Order Moniliales and the Family Tuberculariaceae. Its growth begins at 7°C, remain slow until 12°C, becomes rapid between 21°C and 27.5°C, and stops at 37°C (Bounagan, 1975).

In culture, *Fusarium oxysporum* f. sp. *albedinis* forms a fine, clear and curly mycelium on which small orange -pink sporodochia are produced. Sometimes, blue to black sclerotia are born on the medium. They are either distributed over the mycelium or form groups.

The fungus produces three kinds of asexual spores namely microconidia, macroconidia and chlamydospores. Microconidia which are one or two celled (3 x 15 μ x 3-5 μ), are the most frequently and

abundantly produced spores either in culture or in diseased date palm vessels. Macroconidia are rare, and they have pediform bases, short pointed tips and three to five cells, they measure 20 - 25 x 3-5 μ. Chlamydospores are globular with a smooth thick wall, produced terminally or intercalary, varying from 6 to 20 μ. They are single or grouped in two or four, in short chains.

Substantial differences were found in pathogenicity among strains of the fungus and among the isolates from various parts of the same diseased palm.

Fusarium oxysporum f. sp. *albedinis* can be identified and characterized by different methods: (i) pathogenicity test (Djerbi,1982; Djerbi and Sedra, 1986; Djerbi, 1990; Nash-Smith, 1972; Oihabi, 1984), (ii) morphological characteristics (Cherrab; Chettab et al., 1978; Djerbi et al., 1985) or (iii) vegetative compatibility (Djerbi, 1990b; Djerbi et al.,1990).

Typical wild type colonies of the *F.o.* f. sp. *albedinis* isolates can be conserved or regenerated by single spores cultures. They are characterized by an arborescent and fine mycelium, a greasy appearance, a pink salmon color and a slow growth on PDA (colony diameter 3.2 cm / 4 days / at 20°C).

Pathogenicity tests are realized on date palm seedlings at two leaf stage with an inoculum obtained through a shaken culture. Seedlings can be inoculated by two methods as follows; the soil is cleared away from the stem base of the plants as to expose the adventitious roots and 2 ml of inoculum are poured on roots previously rinsed by water. The soil is then filled, so that the roots are not left bare for too long. In the second method, seedlings are grown in polyethylene bags and inoculum is brought on the roots which become visible through the polyethylene bag, without clearing the soil.

In both cases, the first wilt symptoms appeared after one month and the seedling mortality is recorded during three months. The identification of *F.o.* f. sp. *albedinis* by pathogenicity test, although time consuming, should be always used to confirm the forma specialis *albedinis*.

The vegetative compatibility is based on crossing complementary "nit mutants" obtained on minimal medium containing potassium chlorate. All forma specialis of *F.o.* f. sp. *albedinis* can be put together to form a vegetative compatibility group (VCG).

SURVIVAL, INFECTION AND DISEASE CYCLE: *Fusarium oxysporum* f. sp. *albedinis* is preserved in the form of chlamydospores in the dead tissues of diseased palm trees, especially in the contaminated roots. With the subsequent disintegration of such organs, chlamydospores are released into the soil where they remain dormant. Chlamydospores are found at a depth of 30 to 50 cm and sometimes deeper, they can survive in this form for a long period of time, even when the palm trees have long since disappeared (eight years or more); (Louvet,1977).

Upon the return of suitable conditions the chlamydospore germinates and invades a root, entering the vascular tissues as a parasite. Once the pathogen is inside the vascular element, it grows rapidly and the cycelium advances up the root into the stem. In the vessels, the mycelium produces microconidia that are carried upwards by the sap stream. This process continues upward, internally through the tree which dies when the fungus and its toxins reach the terminal bud.

During the course of its upward progression, *Fusarium oxysporum* f. sp. *albedinis* breaks up the xylem and colonizes the surrounding parenchyma tissues of the tree by an inter - and intracellular mycelium. This gives the reddish brown colour characteristic of a diseased tree.

After the death of a tree, the mycelium continues to develop in the dead tissues and forms numerous chlamydospores in the sclerenchyma cells. These constitute very favourable conditions for survival of the fungus (Louvet,1977).

Within the palm groves, Bayoud spreads regularly from one tree to another and more rapidly as the level of irrigation increases; contamination occurs by means of root contact. In this situation, the disease takes on an epidemic aspect. The number of affected trees increases rapidly and the life span of the diseased trees decreases (Brochard and Dubost, 1970a; Malencon, 1950).

A survey realized during the 1980 - 1981 period by the author in the palm groves of the Draa valley (Morocco) which include 2 million date palms showed that 165, 574 date palms were killed by Bayoud with a rate of destruction of 5 to 12% per year. The intensive cultivation of traditional palm groves may explain the spectacular expansion of bayoud (Djerbi 1988).

The spread of bayoud between oases with the appearance of foci in locations far from the original focus is primarily caused by the transport of infected offshoots or palm tree fragments harbouring the fungus.

HOST PLANTS: Many plant species are often grown as intercrops in palm groves, notably alfalfa, henna, etc. To date, *Fusarium oxysporum* f. sp. *albedinis* has only been isolated from henna and clover. These plants harbour the bayoud organism without manifesting any symptoms (Djerbi, et al. 1985; Elgharfi and Djerbi,1985.), (symptomless carriers). Since these crops require copious amounts of irrigation during hot seasons, these crops favour the rapid spread of the

disease mainly when the plantations include susceptible varieties.

Bayoud Control

CHEMICAL CONTROL AND ERADICATION: A vascular disease is often thought to be controlled by the use of systemic fungicides. Unfortunately, the repeated applications of these products lead to the formation of resistant strains of the parasite. There are other reasons why soil treatments of this type are distined *a priori* to fail. The distribution of chlamydospores occurs at great depths and over vast areas, the cost of the operation is very high, and protection of palm tree roots during the course of their life span is impossible.

Chemical control or eradication can, however, be feasible in the event of the early discovery of primary sources of infection in a healthy area. In this case, rigourous methods may be used for eradication. After demarcation with a large security margin the bayoud focus, the trees are then uprooted and incinerated on the spot. Cartidges of Methyl bromide of 620 g each are placed at a depth of 0.50 m and at 3 m distance soil is then covered by a plastic (saranex type, not permeable to fumigants); and methyl bromide is realized by piercing the cartidges. The plastic cover is removed after three days, Eradication should be conducted during warm period, when the temperature of soil exceeds 20°C.

This technique was successfully applied in 1978 on a Bayoud focus in El Golea (Algeria), since then the disease has not appeared.

CULTURAL CONTROL: Some cultural techniques which place pathogenic organisms in unfavourable conditions sometimes reduce the damage caused by this disease. Unfortunately, the factors that favour high yield in palm trees (irrigation, fertilization, etc.) are the very same which favour the growth of the parasite (Djerbi,1982; Louvet and Toutain, 1973; Saaidi, 1979). A significant reduction in the amount of irrigation can retard the advance of infection.

PROPHYLATIC MEASURES: Some prophylactic measures are applicable to areas or countries which have not yet been affected by the bayoud disease. They have, however, no value for date growing regions that are already affected, as in Morocco.

The essential task is to prevent the movement of contaminated plant material from an infected palm grove to a healthy one. This material, as has been previously mentioned, consists mainly of offshoots, palm tree fragments, artifacts made from these materials, manure and infested soil. Legislation preventing the conveyance of contaminated plant material from one country to another has been adopted by various countries (Algeria, Saudi Arabia, U.S.A., Tunisia, Mauritania, Iraq, Egypt, Libya, etc.). However, the problem is not in promulgating legislation, but rather in implementing it. A minimal control system should also be set up at the airports of the principal date growing countries. But, this would necessitate a large number of qualified personnel who do not yet exist in areas threatened by the bayoud. In any case, even though prophylactic measures accompanied by periodic efforts at eradication of primary bayoud foci can lessen the spread of the disease, they cannot definitely stop it (Dubost and Kellour).

EXTENSION WORK AND INFORMATION: Information dissemination is necessary to the success of all other actions taken in the control of the bayoud spread. In Tunisia, coloured pictures on bayoud were distributed in all departments of the Ministry of Agriculture.

Many extension aids on bayoud, as well as a book on this subject in Arabic, French and English were distributed in North African countries. In addition, two films and a set of slides on bayoud have been produced. They focus on date palm production and protection including the bayoud problem.

BIOLOGICAL CONTROL BY USING RESISTANT SOILS: As mentioned above, it was observed that bayoud affected all Moroccan palm groves except Marrakech. Investigations carried out on Marrakech soils showed that they are highly suppressive to bayoud disease, consequently the search of suppressive soils in Moroccan and Algerian palm groves constituted an important and complementary way which was explored by many investigators in order to valorize susceptible cultivars characterized by a good commercial value but rapidly destroyed by bayoud. These investigations may also help to select suitable antagonists for biological control of this disease.

The evaluation of soil receptivity of oasis was undertaken on a large scale in Morocco, Algeria and Tunisia; the criteria used to compare these soils were based on soil capacity (i) to express the disease (ii) to decrease the spore germination of *F.o.* f. sp. *albedinis* and (iii) to host or receive the pathogen and to favour its evolution. Many soils were found resistant to bayoud. It was shown that the observed suppressiveness of the soils are related principally to the presence of a high density of microorganisms and also to the soil texture. The investigations carried out on some of these resistant soils (Marrakech) allowed the detection of several antagonistic microorganisms including 4 bacteria, a fungus (*Stachybotrys sp*) and an actinomycetae.

These microorganisms have the capacity of inhibiting in vitro spore germination, mycelial growth and sporulation of *F.o.* f. sp. *albedinis*. It is evident that this approach combined to genetic control will contribute to a better perspective of bayoud control.

GENETIC CONTROL: Resistance to bayoud can be obtained from three sources: Selection of bayoud resistant varieties from those already existing (local and introduced); selection of high quality resistant Khalts from natural date palm populations; and creation of resistant and high quality varieties through hybridization programs.

SELECTION FOR RESISTANCE AMONG EXISTING VARIETIES: Following, the survey carried out in all Moroccan date palm plantations, 32 varieties were selected and field tested toward *F.o.* f. sp. *albedinis,* among these varieties, seven were found highly resistant; however, among these selected varieties only Takerboucht, Boo Ijjou Bankhanni and Sair Laylet were of acceptable quality certainly not equal to Deglet Noor or Medjool. In Morocco, extensive data are available on the bayoud resistance of many varieties (Saaidi, 1979).

The evaluation of field resistance of six Iraqi cultivars (Barhri, Hallaoui, Khastaoui, Khadraoui, Sair and Zahdi) and six Tunisian cultivars (Boufeggous, Besser Lahlou, Gondi, Horra, Kenta, Kentichi) showed that none of them is resistant to bayoud (Djerbi and Sedra, 1982; Pereaw - Leroy, 1954; Saaidi, 1979; Toutain, 1965; Watson, 1972)

SELECTION OF RESISTANT KHALTS FROM THE NATURAL DATE PALM POPULATION: In the course of work dealing with the epidemiological study of the disease and the search for resistant varieties, very high quality Khalts were often found in active bayoud foci. Subsequent prospecting campaigns indicated that Khats constitute more than 50% of Morocco palm groves (i.e. approximately 2 million trees). The importance of Khalts is related to the damage caused by Bayoud disease which led to the substitution of the destroyed high quality varieties by palm trees of seedling origin. During 1979-1983, advantage was taken of this genetic potential by a systematic survey in the principal Moroccan palm groves (Djerbi et al., 1986; Sedra, 1985). The criteria for selection of Khalts is based mainly on the quality of the dates and their location in relation to the bayoud foci. In nurseries, these clones are inoculated in order to accelerate the selection process. Thus, during the survey in the Draa Valley and the Iafilatet area, 1,608 clones derived from good quality khalts were selected, planted and inoculated. This program which began in 1979, allowed already the selection of resistant and high quality clones (clones 3014, 3002 and male NP3) which are actually vegetatively propagated and planted in order to restore the bayoud infested palm groves, and to create new date growing areas in Morocco and Algeria.

CREATION OF RESISTANT HIGH QUALITY VARIETIES: Another program for breeding and selection of superior, bayoud resistant date varieties was began in Morocco by Pereau Leroy (Pereau-Leroy, 1954) and Toutain (Toutain, 1965). After a period of inactivity, an intensive program has been renewed in Morocco and Algeria in collaboration with the UNDP/FAO Regional Projects (GCPN/REM/021/MUL; RAB/84/018; RAB/88/024; TCP/RAB/2254 etc..) (Brochard, 1973; Djerbi and Sedra, 1986). Nearly 500,000 hybrid seeds have been produced with the aim of linking resistant characteristics with the highest fruit quality and yield. The crosses realized include: high quality susceptible females x bayoud resistant males; bayoud-resistant females x advanced backcrossed "varietal" males from Indio, (California, U.S.A.); and high quality susceptible females x advanced backcrossed "varietal" males; more than 20 000 date palm progenies resistant to Bayoud have been selected and under screening for quality in Morocco and Algeria. Among this material, more than hundred clones resistant to Bayoud and of high quality were selected and are vegetatively propagated by tissue culture.

Khamedj Disease

Khamedj disease, or inflorescence rot, is a serious disease affecting all date growing areas (Chabrolin, 1928; Fawcelt, 1931; Trabut, 1912), where it has reached epidemic proportions in Iraq (Al Hassan and Waleed, 1977; Al-Hassan et al. 1977; Allison, 1952; Hussein and Al-Baldawi, 1977), in Mauritania (Munier, 1955), United Arab Emirates, Saudi Arabia (Djerbi 1983) and Bahrain (Djerbi 1982 b).

Khamedj disease is the most serious diseases affecting date palm inflorescence in neglected palm groves in hot and humid regions. The disease can reappear each year on the same tree with the same intensity. Losses might average 30-40 kg of fruit per year in severely affected palms.

Male trees which frequently grow in marginal areas and are communal property, may be heavily infected because they receive little attention and the old inflorescences, source of inoculum, remain many years on the trees.

Inflorescence rot is the only date disease of economic importance among the 22 million palm trees in the Tigris and Euphrates Valleys, mainly in Basrah. Nevertheless, important outbreaks are sporadic and

occur only after prolonged cold, humid weather in winter. These conditions cause the disease to reach epidemic proportions. During 1948-49 and 1977-78 severe outbreaks occurred in Basrah, affecting both male and female trees and destroying 80% of the production (Al Hassan and Waleed,1977; Al Hassan et al.,1977). Serious damages were recorded in Katif in Saudi Arabia in 1983 with losses ranging from 50 to 70% (Djerbi, 1983). Conversely, under normal conditions, outbreaks are localized and the extent of damage varies between 3 and 10%.

PATHOGEN AND SYMPTOMS: Kamedj disease is mainly caused by *Mauginiella scaettae* Cav., however, *Fusarium moniliforme* and *Thielaviopsis paradoxa* may also cause, more rarely, the inflorescence rot.

Sporulation occurs in the form of chains of hyaline conidia which fragment into mono-or bicellular units and more rarely, into pluri-cellular units. These fragments are 10-30 μ in width.

The first visible symptoms of the disease appear on the external surface of unopened spathes as they begin to emerge in late winter or early spring. Brownish or rusty areas develop and spread slowly. Symptoms are most apparent on the internal face of the spathe where the diseased tissue are oily yellow and translucent in appearance. Small drops of water form on the surface and the central part of the affected area which is often covered with whitish brown dots. The inflorescences become dry and are covered by a felt-like mycelium which is soon replaced with the powdery fructifications of the fungus. When the infected spathes split, they reveal partial or complete destruction of the flowers and strands. Severely damaged spathes may remain closed and their internal contents may be totally infected.

BIOLOGY AND EPIDEMIOLOGY: The fungus is mainly preserved as a mycelium (Al Ani et al. 1971a; Al Ani et al. 1971 b; Michael and Sabet, 1970) in infected inflorescences remaining on palms from the previous season mainly in the thick tissues of the fruit stalk. In infected leaf bases, which appear to be of particular importance since they ensheath the developing spathes during their most susceptible stage. The spores, on the other hand, do not play an important role in disease perpetuation because of their short life span. Transmission of the disease from one tree to another occurs through contaminated pollen.

The infection of a young inflorescence occurs early when the spathe is still hidden in the leaf base. The infection is of external origin and does not need a preliminary lesion. The fungus penetrates directly into the spathe, resulting in an intercellular mycelium which most often remains localized in the parenchyma and rarely enters the vascular tissue. The mycelium then reaches the inflorescences and the fungus sporulates abundantly.

The disease is particularly serious in areas characterized by high humidity or with prolonged periods of heavy rain in winter and spring. Wet, cold winters seem to favour the spread of the disease (Al Hassan and Waleed, 1977). In the spring (February - March), temperatures ranging from 15 to 20°C are necessary for the appearance and development of Khamedj disease (Al Hassan et al.1977). Therefore, certain varieties of date palms are not affected by the disease since their spathes emerge either too early or too late, during a period when the fungus cannot grow due to temperatures that are too low or too high. Overgrown or neglected palm groves and heavily waterlogged land are conducive to the spread of the disease.

CONTROL: Good sanitation and efficient maintenance of date growing areas is the first step in the control of Khamedj disease. The collection and burning of all infected inflorescence and spathes is a good beginning (Chabrol,1928). Palms with diseased inflorescences should be treated after the harvest and in early spring before the spathes emerge with one of the following fungicides: Bordeaux mixture, lime-sulfur solution, copper sulphate-lime mixture (Chabrol,1928). Dichlone 3%, Thiram 4%, Benomyl and Tuzet at the rate of 125 g/hl (Al Hassan et al., 1977; Hassan and Al Baldawi 1977).

Some varieties are particularly susceptible to khamedj: Medjool, Ghars, Khadrawy, Sayer, et.; while Halawy, Zahdi, Hamrain and Takermest varieties show good resistance (Al Ani et al. 1971a; Hussein and Al-Baldawi, 1977; Laville, 1973).

Fruit Rot

DISTRIBUTION AND ECONOMIC IMPORTANCE: Fruit spoilage due to microorganisms constitutes a major problem wherever date palms are grown. The economic importance of fruit rots varies greatly from year to year since their incidence is governed by climatic conditions, particularly high humidity and rain, from the Khalal stage until fruit maturation. Estimates of losses have been reported from different countries as follows:

- In the United States, losses in some areas are estimated to lie between 10 and 40%;annually 5% losses occur from fungus spoilage even though bunches were covered with paper wraps or dusted with fungicides. Economically, fruit rots can be considered the most important disease of dates in

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The first visible symptoms of the disease appear on the external surface of unopened spathes as they begin to emerge in late winter or early spring. Brownish or rusty areas develop and spread slowly. Symptoms are most apparent on the internal face of the spathe where the diseased tissue are oily yellow and translucent in appearance. Small drops of water form on the surface and the central part of the affected area which is often covered with whitish brown dots. The inflorescences become dry and are covered by a felt-like mycelium which is soon replaced with the powdery fructifications of the fungus. When the infected spathes split, they reveal partial or complete destruction of the flowers and strands. Severely damaged spathes may remain closed and their internal contents may be totally infected.

BIOLOGY AND EPIDEMIOLOGY: The fungus is mainly preserved as a mycelium (Al Ani et al. 1971a; Al Ani et al. 1971 b; Michael and Sabet, 1970) in infected inflorescences remaining on palms from the previous season mainly in the thick tissues of the fruit stalk. In infected leaf bases, which appear to be of particular importance since they ensheath the developing spathes during their most susceptible stage. The spores, on the other hand, do not play an important role in disease perpetuation because of their short life span. Transmission of the disease from one tree to another occurs through contaminated pollen.

The infection of a young inflorescence occurs early when the spathe is still hidden in the leaf base. The infection is of external origin and does not need a preliminary lesion. The fungus penetrates directly into the spathe, resulting in an intercellular mycelium which most often remains localized in the parenchyma and rarely enters the vascular tissue. The mycelium then reaches the inflorescences and the fungus sporulates abundantly.

The disease is particularly serious in areas characterized by high humidity or with prolonged periods of heavy rain in winter and spring. Wet, cold winters seem to favour the spread of the disease (Al Hassan and Waleed, 1977). In the spring (February - March), temperatures ranging from 15 to 20°C are necessary for the appearance and development of Khamedj disease (Al Hassan et al.1977). Therefore, certain varieties of date palms are not affected by the disease since their spathes emerge either too early or too late, during a period when the fungus cannot grow due to temperatures that are too low or too high. Overgrown or neglected palm groves and heavily waterlogged land are conducive to the spread of the disease.

CONTROL: Good sanitation and efficient maintenance of date growing areas is the first step in the control of Khamedj disease. The collection and burning of all infected inflorescence and spathes is a good beginning (Chabrol,1928). Palms with diseased inflorescences should be treated after the harvest and in early spring before the spathes emerge with one of the following fungicides: Bordeaux mixture, lime-sulfur solution, copper sulphate-lime mixture (Chabrol,1928). Dichlone 3%, Thiram 4%, Benomyl and Tuzet at the rate of 125 g/hl (Al Hassan et al., 1977; Hassan and Al Baldawi 1977).

Some varieties are particularly susceptible to khamedj: Medjool, Ghars, Khadrawy, Sayer, et.; while Halawy, Zahdi, Hamrain and Takermest varieties show good resistance (Al Ani et al. 1971a; Hussein and Al-Baldawi, 1977; Laville, 1973).

Fruit Rot

DISTRIBUTION AND ECONOMIC IMPORTANCE: Fruit spoilage due to microorganisms constitutes a major problem wherever date palms are grown. The economic importance of fruit rots varies greatly from year to year since their incidence is governed by climatic conditions, particularly high humidity and rain, from the Khalal stage until fruit maturation. Estimates of losses have been reported from different countries as follows:

- In the United States, losses in some areas are estimated to lie between 10 and 40%;annually 5% losses occur from fungus spoilage even though bunches were covered with paper wraps or dusted with fungicides. Economically, fruit rots can be considered the most important disease of dates in

California because of the cost of control measures and the losses from damaged fruit (Bliss et al., 1950; Brown, 1957; Calcat, 1959; Lindogren et al., 1948).

- In Tunisia, rain or high humidity conditions, at harvest time, cause heavy losses sometimes reaching 50% (Zambettakis and Nicot, 1973); these losses were observed by the author in 1982 and 1984 (Djerbi, 1988).

- In Algeria, Deglet Noor is particularly susceptible to fruit rots and may be damaged in unfavourable years, with losses exceeding 25% (Calcat, 1959; Carpenter and Klotz, 1973).

- In Palestine, fruit rots occur in late maturing varieties like Deglet Noor and Barhee.

PATHOGENS AND DISEASE DEVELOPMENT: Microorganisms involved in preharvest fruit rots are numerous: Molds: Species of *Alternaria*, *Stemphylium*, *Helminthosporium*, *Cladosporium*, *Macrosporium*, *Citromyces ramosus* and *Phomopsis diospyri* etc. may infect fruit directly in the Khalal stage. Other species of *Aspergillus* (e.g. *A. niger* and *A. phoenicis*; may cause the calyx-end rot of fruit (Zambettakis et al., 1948). These molds are of a little importance at the Tamar stage since they are inhibited by high sugar concentrations.

Several other species of saprohytic fungi and bacteria, among which yeasts and *Penicillium spp.* are important, also invade fruit through wounds during maturation and storage (*Acetobacter, Saccharomyces, Torula, Mauginiella scaettae*).

However, the most common types of fungus fruit spoilage are the calyx end rot caused by *Aspergillus niger* (Bliss 1938) and the side spot decay caused by *Alternaria sp.*

Dates are susceptible to *Aspergillus spp.* in the Khalal and Rutab stages and are resistant in later Tamar stage. The factors governing resistance of fruit to fungus attack appear to be related to both structural and chemical types of protective mechanisms. During these susceptible periods, the fruit is subject to attacks through wounds at any point on the surface. However, in the absence of wounds, the fungus only gains entrance to fruit in the region of the calyx where the cuticle is absent and the outer epidermal walls are not thickened; however, it does not attack unwounded surfaces where the cuticle and epidermis are thickened.

Alternaria sp., the causal agent of the side spot decay attacks wounded fruits in the Khalal and Rutab stages, but direct penetration of unwounded fruits occurs only in the Rutab stage.

CONTROL: Preharvest fruit rots may be reduced by several means. Prior to the Khalal stage, wire rings may be inserted in the bunches to avoid conditions that tend to increase humidity and to facilitate ventilation and drying of wet fruit. Even in the absence of rain, dew may form on hanging fruit (Bliss and Bream 1940). Aeration can also be obtained by the removal of fruit strands from the centre of the bunch (Meremadi, 1971; Nixon 1936; Nixon 1940).

In the early Khalal stage, bunches of high quality varieties may be covered with paper wraps to protect them from rain (Bliss, 1938; Bliss and Lindgren, 1949; Bliss et al., 1950). During the Khalal stage, a dust consisting of 5% ferbam, 5% malathion, 50% sulphur and an inert carrier (40%) may be applied to bunches to limit fungus spoilage and to control insects (Bliss, 1946; Carpenter and Klotz, 1966). Thiomate "19" was also recommended (Bliss and Lindgren, 1947).

Conditions that increase humidity such as standing water, excessive soil moisture and presence of intercrops or weeds should be avoided, especially during the Khalal stage.

Graphiola Leaf Spot

DISTRIBUTION AND ECONOMIC IMPORTANCE: *Graphiola* leaf spot is a widespread disease of date palms and likely to occur wherever the palm is cultivated under humid conditions which prevail in many suboptimal to marginal date growing areas. Crop yield may be reduced by the premature death of *Graphiola* infected fronds.

Graphiola leaf spot is the most common date disease in Egypt; it is widely distributed in the Delta region and at Fayum, but absent in the less humid oases (Fawcett and Klotz, 1932). Severe infections seen near the Mediterranean coast interfere considerably with production. *Graphiola* also causes serious damage to palms in several of the south humid date growing regions of Mali, Mauritania, Niger, and Senegal (Laville, 1973). It also occurs in the humid coastal areas of North Africa and the Near East, but the disease is of little importance in the principal interior date growing regions (Killian, 1924). *Graphiola* also occurs in Argentina, the United States, Pakistan and India (Djerbi, 1980; Fawcett and Klotz, 1932; Laville, 1973; Sinha et al. 1970).

PATHOGEN AND DISEASE DEVELOPMENT: Graphiola leaf spot, one of the smut fungi, is caused by *Graphiola phoenicis* (Moug.) Poit. The fungus develops sub-epidermally in small spots on both sides of the pinnae and on the rachis. Finally, the fruiting structures emerge as small, black, covered sori which are absent or infrequent on one year-old leaves, conspicuous on

two year-old leaves and continuing to increase during the third year. Sori are most abundant on apical pinnae, less abundant on the middle section and even fewer on the basal section (Killian, 1924; Nixon 1957). The sori are 1-3 mm. in diameter and consist of two layers; the outer peridium is hard, dark and persistent, while the inner hyaline peridium is thin and degenerates after spores reach maturity.

Spores are produced in the fertile areas of the sori and are interspersed with groups of sterile filaments. At maturity the sori open to liberate masses of yellow spores. Individual spores are spherical to ellipsoidal, 3-6μ in diameter and have a thick, smooth hyaline wall. After the spores disseminate, only the rough black craters of the sori remain. Heavily infected leaves die prematurely.

CONTROL: Leaf pruning is the usual practice for reducing damage from *Graphiola* leaf spot. Light to moderate infections could be satisfactorily controlled by Bordeaux mixture (Wood and Mortensen, 1938). Nixon (Nixon, 1957) studied the relative susceptibility of date varieties in Texas, (U.S.A.). He concluded that Kustawy, Jouzi (Iraq) and Tadala (Algeria) developing only a light infection are tolerant to *Graphiola phoenicis*. Amir Hajj, Khadrawy, Sayer, Ammary, Fursi (Iraq) were found to develop a moderate degree of infection. Ashrasi, Bahrab, Dubayni, Halawy, Khisab, Khadrawy, Maktoom, Zahdi (Iraq); Deglet Noor, Tazizoot, Thoory (Algeria); Hayany, Saidy (Egypt); Badrayah, Braim (Iraq); and Koroch (Baluchistan) were all found to develop severe infections. Sinha et al (Sinha et al. 1970) studied the *G. phoenicis*, tolerance of 25 varieties of date palm. The seven resistant cultivars include Barhee, Abbad Rahman, Gizaz, Iteema and three Egyptinan selections. Tolerant varieties may be useful either directly or in breeding programs.

Diplodia Disease

DISTRIBUTION AND PATHOGEN: Diplodia is a minor disease of palms reported by Fawcett (Fawcett, 1930) in the California, U.S.A. and in Egypt, Morocco, U.A.E. Bahrain and Tunisia (Djerbi, 1982; Fawcett, 193; Fawcett and Klotz, 1932; Toutain, 1967).

Diplodia disease is caused by *Diplodia phoenicum* (Sacc.) Fawc. and Klotz.

In culture or in diseased tissues the fungus form black pycnidia which extrude unicellular and hyaline spores which later become dark and bicellular and measure 22-24 μ x 10-12 μ. Dark intercalary chlamydospores are produced abundantly in culture. Pycnidia may develop inside protected leaves of dying offshoots or on the surface of dead tissues.

SYMPTOMS AND DISEASE DEVELOPMENT: *Diplodia* disease is characterized by the death of offshoots, either while they are still attached to the parent or after they have been detached and transplanted. The disease also causes premature death of fronds in older palms. In offshoots the disease may be expressed in two distinct ways: The fungus may infect and kill the outside fronds, leaving the younger shoots and buds alive for some time before finally causing their death as well; The central leaf cluster and terminal bud may die before the older fronds.

On the fronds of older palms, the ventral mid-portion of the stalks is the most commonly affected part and shows yellowish brown streaks 15 cm, to over one meter in length extending along the leaf base and rachis. The upper part of the fronds, however may still appear green and unaffected. The lesions gradually become brown; internal infection and necrosis may be extensive in leaf tissues.

In offshoots, the infection may take place at its base, near the joint of the mother palm, the disease causes the death of the bud and young fronds, apparently by preventing sufficient water from reaching them. When the infection takes place in the outer fronds, the disease later spreads to the young fronds, to the heart and finally kills the offshoot. The fungus usually enters the palm through wounds made during pruning or cuts made when removing the offshoot. The form of the disease which begins in the outer fronds also appear to be aided by wounds. Faulty irrigation, causing some roots to die back to the base of the palm, may also contribute to the infection.

CONTROL: As infection readily enters wounds made by tools during pruning, one precaution to take is to disinfect all tools and cut places. The cut surface made by removing offshoots should be disinfected and, as far as possible, the dead functionless tissues removed, disinfected or burned. Dipping or spraying the offshoots with various chemicals has been found effective against the fungus. These chemicals include: Potassium permanganate, Copper sulphate, Copper carbonate, Bordeaux mixture (Klotz, 1967), Benomyl (Carpenter, 1975), Methylthiophanate and Thiram. In addition, the offshoots dipped in copper solutions were the first to produce new fronds, suggesting a stimulating effect.

Black Scorch

DISTRIBUTION: Black scorch, a fungus disease called "medjnoon", or "fool's disease", has been found occurring naturally on all parts of the date palm tree. While the Black scorch is apparently a minor disease of sporadic occurrence, the severity of its attack in some instances indicates that it may become so important as

to require special attention.

Black scorch has been observed on date palms in Egypt, Tunisia, Algeria, Saudi Arabia, Iraq, Mauritania and the U.S.A. In addition to the date palm this fungus is a parasite of a number of plants including areca, oil palms, sugar cane, coconut and pineapple (Djerbi, 1982).

SYMPTOMS: The fungus attacks all organs of the date palm. Symptoms are usually expressed in four fairly distinct forms: Black scorch on the fronds, inflorescence blight, heart or trunk rot and bud rot on palms of all ages. Infections are all characterized by partial to complete death of the tissues. Typical lesions are dark brown to black, hard, carbonaceous and give the petioles, fruit strands and fruit stalks a scorched charcoal like appearance. Many of the fruit strands may be completely rotted by the disease and the yield substantially decreased. Dark conidia may develop abundantly on the lesions.

Decay is most serious when it attacks the terminal bud. The pathogen enters through a wound and progresses rapidly toward the bud. The entire terminal bud and adjacent leaf bases may decay, presenting a dried, dull and blackened appearance. Some palms recover, probably by development of a lateral bud from the uninjured portions of meristematic tissue and such palms show a characteristic bend in the region of infection. This is, why it is called the "medjnoon" or "fool's disease". It sets back normal growth by several years.

PATHOGEN: *Thielaviopsis paradoxa*, the imperfect form of *Ceratocystis paradoxa*, is the causal agent of Black scorch. It develops rapidly on host tissues or in culture producing long chains of endospores which fragment readily giving two types of spores; hyaline, cylindrical microconidia formed endogenously in uniseriate chains, measuring 5-15 x 3-7 μ; phialospores and dark egg-shaped macroconidia also extruded in chains from the tips of short lateral hyphae, measuring 11-17 x 7-15 μ: aleuriospores. Between the two types of spores, all graduations of size, colour and shape may be found.

The optimum temperature for the fungus development in culture ranges between 24 and 27°C; it grows very little at 32°C. Mildly warm, moist weather accompanying or alternating with windy weather favours distribution and infection of the inflorescences. The manner in which the conidia are borne, in long chains which break up into small groups and single conidia, favours wind distribution.

CONTROL: Good sanitation is the first step in the control of Black scorch disease. The affected fronds, leaf bases and inflorescnces should be pruned, collected and immediately burned. The pruning cuts and surrounding tissues should be protected by spraying with one of the following fungicides: Bordeaux mixture, Lime-sulfur solution, Dichlone, Thiram, etc.

Belaat Disease

DISTRIBUTION, SYMPTOMS AND PATHOGEN: Belaat, is a minor disease of the date palm reported from Algeria, Tunisia and Morocco by Maire and Malencon (Maire,1935), Maire (Maire and Malencon, 1933), Monciero (Monciero,1947), Calcat (Calcat, 1959) and Toutain (Toutain,1967). No estimates of the losses have been published. Belaat comes from the Arabic word meaning the tree swallowed its heart.

The disease is characterized by the whitening of the entire cluster of young fronds. Infection always occurs near the terminal bud in the form of wet heart rot, leading rapidly to the death of the youngest leaves and the growing point. The infection may be stopped at a short distance below the bud. However, when conditions are favourable, the initial infection accompanied by secondary organisms progresses downward in the trunk as a conical wet rot form releasing a marked odour of acetic and butyric fermentation. Some affected palms recover by developing a lateral bud. Offshoots of affected palms usually remain healthy.

CONTROL: The frequent appearance of belaat disease in neglected plantations indicates that efficient maintenance of date growing areas in the first step of disease control. Belaat may also be controlled in the early stages with Maneb or Bordeaux mixture at the rate of 8 litres/tree.

Brown Leaf Spot

DISTRIBUTION, SYMPTOMS AND PATHOGEN: Brown leaf spot is a common disease of the date palm observed in all date growing areas (Fawcett, 1931; Rieuf, 1968). The disease is characterized by dark lesions, sometimes black, clearly delimited on green leaves. These lesions become pale and whitish and the margins remain reddish brown on dying leaves. Brown leaf spots occur irregularly on the rachis, pinnae and spines. The lesions on the rachis vary from one to several centimeters and involve only the epidermis and a thin layer of surrounding tissues which differs from *Diplodia* attack.

Brown leaf spot is caused by *Mycosphaerella tassiana* (de Not.) Johns., which is the perfect form of *Cladosporium herbarum* (Pers.) Link. Perithecia of the fungus appear on the lesions either singly or aligned

parallel to the vascular stands and measure 130-145 μ x 130-150μ. They are globose and black with ostiole and a beak. Asci measure 55-62μ and contain eight bicellular spores.

CONTROL: Since this is a minor disease, no treatments have been recommended. However, it can probably be controlled by systemic or contact surface fungicides.

Brittle Leaves Disease

DISTRIBUTION AND ECONOMIC IMPORTANCE: This disease was first observed in Tunisian oasis where it is predominant in Nefta (Takrounini et al. 1988). Although this disease was recently observed, it is well known by date growers for many years; however, this disease began to spread and became serious from 1985. The disease was also observed in Algeria (Djerbi, 1983).

Surveys realized in 1987-88 in Tunisia showed a rate of attack exceeding 10% in infested oases; the deterioration of palm groves is so serious that some date growers started to replace date palms with other fruit trees.

SYMPTOMS: The disease attacks adult and young palms alike as well as their basal offshoots; offshoots planted in replacement of destroyed trees showed rapidly the symptoms of the disease.

The first clear sign of disease is a broad chlorotic striping of the pinnae followed by a drying of the tip of the frond. The pinnae lose turgor and droop but the rachis stays erect. With the onset of chlorosis, the pinnae become very brittle and are easily broken by flexing. Many fronds on affected trees have a jagged edge appearance resulting from wind damage to weakened pinnae.

Affected palms continue to bear fruit but yields drop significantly as more fronds are affected. Symptomless trees can have affected offshoots and affected trees may apparently have healthy offshoots.

As an advanced stage leaflets twisted and show necrotic streakings on both sides. Retardation in terminal bud growth become evident, resulting in that newly formed leaves appear to be arising from the trunk at nearly the same level; the whole bunch of leaves formed after the occurrence of disease have the rosetting symptoms: leaves are shorter and of irregular size. Affected trees continue to produce spathes: flowers are apparently normal and receptive to pollination, fruit bunches become greatly reduced in size and number; fruits formed are rare, small and round and do not reach their normal maturity; rapidly the diseased palms fail to produce.

Root system of diseased trees becomes particularly reduced and presents a brown discoloration and decay.

Affected trees took varying lengths of time to die. When the symptoms first appeared close to the apex, the death of trees occurs in about two years.

CAUSAL AGENT: The causal agent remains unknown, however, symptoms look like those of *Phytoplasma* or virus diseases. Chemical analysis of date palm leaves and soils showed higher concentrations of all nutrients in tissue leaves of the unhealthy trees with the exception of concentrations of manganese, which were ten time lower. In addition, the conductivity and the phosphorus concentrations of the soil with diseased tree are higher than that of healthy one.

CONTROL: All varieties seem to be attacked. Quarantine measures are presently the main measures to limit the spread of this disease. Tunisian authorities implemented strict quarantine to prevent the movement of offshoots from affected oasis to new plantations.

Al Wijam

Al Wijam is a minor but fatal disease of unknown cause which has been observed on date palms in Al Hassa, Saudi Arabia (Al Bakr, 1952; Djerbi, 1984; Nixon, 1954). Al Wijam, in arabic means poor or unfruitful. It is characterized by the following symptoms: Newly formed leaves are reduced in size and they are marked by a faint narrow, yellow longitudinal line on the midribs. The whole leaves become chlorotic and their life span are reduced; death of leaves starts from the distal end and extends towards the base; death of pinnae begins from their tips extending towards the midrib.

Diseased palms are characterized by a retardation in terminal bud growth and the whole crown of leaves formed after the occurrence of the disease have the rosetting symptom.

Diseased spathes are also reduced in size and they split open before their complete emergence. Flowers are apparently normal and receptive to pollination; however, fruits formed are small; the number and size of bunches are reduced year after year and finally the diseased palm fails to produce, followed in few years by its death.

The decline occurs whether conditions for growth are favourable or not. No varietal resistance has been reported. Al Bakr (Al Bakr, 1952) recommended that the areas where such palms are growing must be avoided when selecting offshoots for propagation.

Other Diseases and Physiological Disorders

Many other diseases of unknown causes (Bending

head, Dry bone, Faroun, Rhizozis, Black scald etc.) and physiological disorders (Blacknose, Whitenose, Cross cuts, Internal browning, Barhee disorder, Frost damage etc.) are minor problems and of sporadic occurrence.

Distribution, economic importance, symptoms as well as control wherever available are reported in the author publication (Djerbi, 1983).

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