Chapter 4

Diseases of Date Palm

4 Diseases of Date Palm

4.1. Fungal Diseases of Date Palm

4.1.1. Inflorescence Rot

***Mauginiella scaettae* Cavara**
(Monilliales: Monilliaceae)

Distribution and Economic Importance

Inflorescence rot disease is one of the most important and serious diseases affecting date palm in most countries growing the crop. It is a common disease in North Africa (Morocco, Algeria, Tunisia, Libya and Egypt) and is also recorded in Mauritania, Palestine, Iraq, Iran, Syria, Italy, Bahrain, Saudi Arabia, United Arab Emirates and the Sultanate of Oman. Inflorescence rot disease is known as khayas (Ar.) in Iraq and khamedj (Ar.) in Libya, Tunisia and Morocco. The disease spreads and causes serious damage to date palm groves in hot and high humid areas, especially in neglected groves, but is unable to spread in dry areas. In Oman for example, inflorescence rot is more common in coastal regions because of high humidity relative to interior areas. Usually, inflorescence rot infects male spadices more severely than female ones. This may be due, in many places to the practice of planting male date palms at the edges of groves where sanitation is generally less rigorous. Infested inflorescences contain mycelia of *Mauginiella scaettae*, which remain in the same tree for several years, resulting in the annual reappearance of symptoms and regular spread to neighbouring palms. Hussain (1985) has estimated that the losses attributable to inflorescence rot may reach 20- 30 kg of dates each year per infested date palm, depending on the annual yield of the affected palms.

Symptoms of Infection

The first symptoms of infection by inflorescence rot appear in early spring with the appearance of dark brown spots on the outer surface of the emerging, unopened spathes in the axils of the fronds. The spots are most clear at the edge of the spathe where the fungus starts to infect the inflorescence. Later the lesions spread to cover the entire outer surface of the infected spathe while the inner surface becomes yellow with black spots. Generally, heavy infected spathes remain closed and regularly wither and die. If the infected spathe does split, the infected areas usually dry and appear covered with the powdery fructifications of the fungus. The symptoms also appear on the spikelets and the tiny flowers. Symptoms of infestation with inflorescence rot usually appear on the same palm each year and with the same intensity, more rarely, symptoms may appear once every few years.

Sources of Infection

The pathogen is present in mycelial form and is primarily transferred from infected to healthy palms during the pollination period through the use of infected male inflorescences. The mycelium of the fungus can be found in infected palms in the remaining spikelets, flowers and or the petiole bases [carb, (Ar.)]. Symptoms of infection

appear early on the young spadix when it is still hidden within the leaf bases at the top of the palm. During February and March white mycelium is easily visible on the infested tissues. The mycelium penetrates directly into the spathe reaching the inflorescence where spore are then formed. The spores of *Mauginiella scaettae* are short-lived; fungal survival is achieved through the mycelial stage.

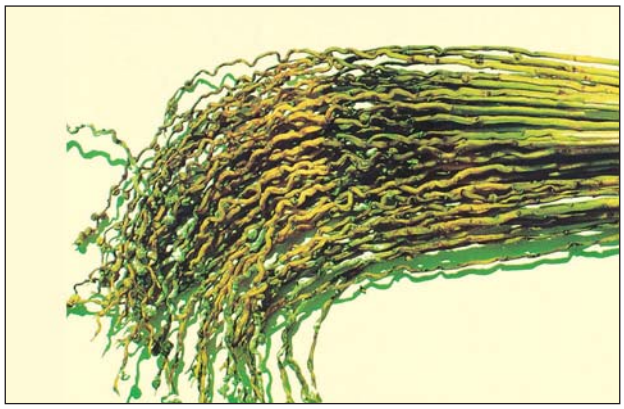


Fig. 4.1. Visible signs of infection on the inflorescence caused by *Mauginiella scaettae*.

Prevention and Control Measures

Various prevention and curative measures are available for inflorescence rot control. The most important measure is to avoid the use of infected male spathes during pollination. Infected spathes from affected date palms should be collected and burnt. After harvest, all bunch stalks, infected leaflets and dried spikelets should also be collected and burnt. Keeping the heart of the palm cleans through proper sanitation and efficient husbandries are essential to prevent infection, inflorescence rot is most common in neglected groves.

The use of resistant varieties, especially in heavily infested areas, is the most viable, long-term control measure for inflorescence rot management. Laville (1973) has reported that the varieties Medjool, Ghars, Khadrawy and Sayer are susceptible to inflorescence rot while Hallawi, Zahdi, Hamrain and Takermest appear to have resistance to the disease.

Spraying with recommended fungicides can be effective in reducing disease levels in the infested groves. Applications of fungicides should concentrate on the infested palms after the removal of infected tissue. At least two successive sprays per year should be applied, the first during December, the second in January. Copper oxychloride or Tri-miltox Forte WP ® at the rate of 300 g/hl. water or Bavistin FL ® (Carbendazim) at 100 ml/hl. water have all been reported in the management of inflorescence rot.

4.1.2. Thielaviopsis Bud Rot

Ceratocystis paradoxa (Dade)
(Ceratobasidiales: Ceratobasidiaceae)

The asexual state of the pathogen is referred to *Chalara paradoxa* (De Seynes) Sacc., previously known by the synonym *Thielaviopsis paradoxa* (De Seynes) Höhn. Paulin-Mahady *et al*. (2002) consider the currently accepted name for *Chalara paradoxa* to be *Thielaviopsis paradoxa* (De Seynes) Höhn., Figs. 4.2 and 4.3.

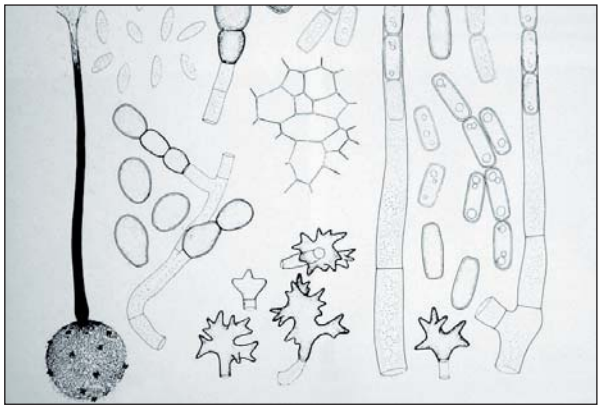
The fungus produce two different types of "asexual" spores, endoconidia and chlamydospores. The latter will surviv for long periods in the soil. The fungus also has a "sexual" stage name of *Ceratocystis paradoxa*, which is rarely observed in natural settings, Elliott (2006). While this fungus is found throughout the world, its host range is primarily restricted to monocot plants grown in warm climates. All palm species are considered potential hosts for this fungus and besides palms, the fungus causes diseases of banana, mango, pineapple and sugarcane.

Distribution and Economic Importance

Chalara (*Thielaviopsis*) *paradoxa* causes a range of symptoms on date palms. Thielaviopsis bud rot is also known as bitten leaf, heart rot or dry basal rot disease. It is widespread in many countries including Algeria, Tunisia, Egypt, Mauritania, Iraq, Saudi Arabia, Brazil, Mexico and the USA, especially in Arizona, California and Florida. In Oman, Hammouda (1985) recorded the pathogen for the first time on coconut palm in the southern region of Oman, which causing stem bleeding disease.

Symptoms of Infection

The fungus causes a bud rot, which may be accompanied by tears or lacerations on the leaves. It enters the tissues of the bud through infected leaves or their bases, causing damage and necrosis to the bud. Later, other lateral buds may appear as a result of infection. The most prominent



(Source: Snowdon, 1990)

Fig. 4.2. *Ceratocystis paradoxa*
1. perithecium. 2. ascospores. 3. chlamydospores.
4. perithecial appendages. 5. surface of perithecium wall.
6. conidiophores. 7. conidia

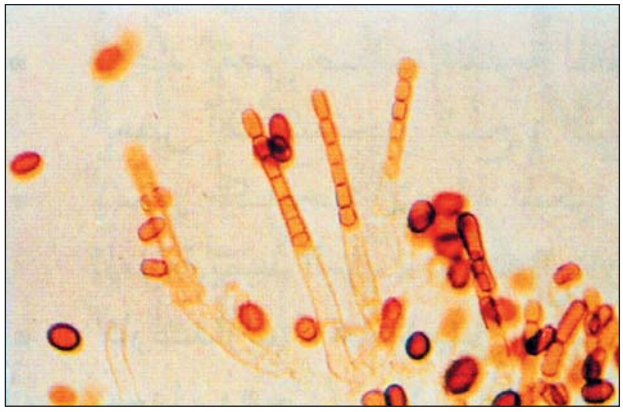


Fig. 4.3. *Chalara* (*Thielaviopsis*) *paradoxa*
Notice the Conidia and Chlamydospores

signs of infection are the appearance of elongated black spots, lengthwise along the rachis, and the dryness of the infected leaves. Infection usually begins with the old, outer leaves, spreading to the younger, inner leaves. These symptoms may remain for 6 to 8 years or even more. The visual symptoms appear on one side of the frond with a dark or black coloured line running lengthwise along the frond, Fig. 4.4.

(Source: Abdul Qader and Al-Husseini, 1997)

Fig. 4.4. Symptoms of infestation by *T. paradoxa*. Note the one-sided yellowing and the presence of a dark line, lengthwise along the frond.

The pathogen also infects roots and stems and is considered one of the most important vascular wilt diseases of date palm. The signs of decay and rot appear on the roots and in the trunk followed by the characteristic blackening and drying of leaves. Inspection of infected leaves reveals the mycelium of the fungus and its black coloured spores. The heart of the palm also rots and eventually, the diseased palm dies. *T. paradoxa* can also infect many species of ornamental palms including *Washingtonia filifir*, *Sabal palmetto*, *Rhapis* sp., *Caryota* spp. and *Phoenix canariensis,* Fig. 4.5.

Elliott (2006) mentioned that "Stem bleeding" is a common symptom of *Thielaviopsis* trunk rot, which observed on coconut palm (*Cocos nucifera*). This stem bleeding is a reddish-brown stain that runs down the trunk from the point of infection. He also added that since any trunk wound may result in stem bleeding, close examination of the point of infection is required, and if the stem bleeding is due to *Thielaviopsis paradoxa* and the disease has progressed significantly, the tissue immediately surrounding the wound, i.e. infection point, will be quite soft in comparison to surrounding trunk tissue. Palms other than coconuts, especially those with a smooth trunk, may also exhibit stem bleeding, but it seems to be most common in coconut, Fig. 4.6.

(Source: Chase and Broschat, 1991)

Fig. 4.5. *Thielaviopsis* trunk decay of Canary palm, *Phoenix canariensis*, showing masses of black chlamydospores.

Fig. 4.6. Stem bleeding on a coconut trunk due to infection of *Thielaviopsis paradoxa.*

Prevention and Control Measures

Some date palm varieties appear to show some degree of resistance to infection by *Ceratocystis paradoxa*. However, such varieties require more extensive assessment to determine the degree and nature of this resistance and to determine the quality of their yield, their growth characteristics and the economic feasibility of production. For existing palm groves, practices causing injury to the palms either in the nursery or in the field after transplanting should be avoided to reduce the chance of infection.

Fungicide should be applied during pruning either by spraying or locally treating the sites of injury with an anti-fungal paste, e.g. Valsa wax ® (thiophanate-methyl). Early infections to the buds, leaves or root tissues can be treated by using Bavistin FL ® (carbendazim) at the rate of 100 ml/hl. water, Ridomil Gold Plus WP ® (copper oxychloride+metalaxyl-M) at the rate of 200 g/hl. water or by treating the soil with Banrot ® fungicide (thiophanate-methyl + etridiazole).

4.1.3. Black Scorch (Medjnoon)

Ceratocystis paradoxa (Dade) (Ceratobasidiales: Ceratobasidiaceae)

Asexual state: *Chalara paradoxa* (De Seynes) Sacc.
Synonym = *Thielaviopsis paradoxa* (De Seynes) Höhn.

Distribution and Economic Importance

Black scorch disease, also known as medjnoon (Ar.) or Fool's disease, is widespread in Iran, Iraq, Saudi Arabia, Egypt, Tunisia, Algeria, Morocco, Mauritania and the USA. In Oman, the disease has been observed in areas where excessive rain or irrigation water accumulates under the palms, especially during periods of high temperature. This leads to increased relative humidity within the grove aiding disease spread.

Although black scorch disease is usually of minor economic importance on date palms in most countries, occasionally it causes greater levels of damage when the disease causes death of palms, especially in neglected groves or places with high soil salinity or poor drainage. It is probable that palms become predisposed to infection because of soil salinity stress or excessive soil saturation. Djerbi (1983) reported that the varieties Thoory, Hayani, Amhat, Saidy and Halawy are highly susceptible to black scorch disease. Klotz and Fawcett (1932) had previously reported the disease on Zahdi, Menakher, Baklany, Gantar, Halooa, Sukkar Nabat, Horra, Besser and Koroch varieties. In Iraq it was found that Deglet Nour is resistant. Black scorch disease can also affect coconut palms, many ornamental palms, sugar cane and pineapple.

Symptoms of Infection

Four distinct types of symptoms appear on infected date palms. These are black scorch on the leaves, inflorescence blight, trunk rot and terminal bud rot. The infection starts with pathogen entry via wounds on the palm. Hard black spots appear on the infected parts giving a scorched appearance. The edges of young frond leaflets are discoloured by scattered, irregularly shaped black spots, which coalesce to cover large areas of the leaflets, leading to desiccation of the frond. Severe infection causes a rot in the lower parts of the fronds; lighter infection may lead to frond dwarfing.

Infected spikelets die quickly with blackening and rot of the spadix. These symptoms resemble inflorescence rot disease. The two diseases can be differentiated by splitting the spathe; mycelial growth and black spores indicate black scorch while white fungal growth indicates inflorescence rot disease, Figs. 4.7, 4.8 and 4.9.

Black scorch disease affects date palm at all ages, attacking young offshoots as well as mature palms. Infection leads to rotting of the terminal bud and the frond bases accompanied by dryness and blackening of the infected plant tissues.

After the death of the terminal bud, some infected palms may develop a lateral bud from the uninjured portions of the meristematic tissue. This grows vertically as a new crown. However, the new crown will appear bent at the point of infection, hence the term medjnoon (meaning crazy palm in Arabic). These palms are retarded in their growth and production will be affected for several years. Generally, severe attacks of medjnoon disease lead to death of the terminal bud and death of the palm itself especially in neglected groves or groves planted in poorly drained or saline soil.

Prevention and Control Measures

Sanitation of severely diseased fronds is usually adequate for black scorch disease control. All affected fronds, leaf bases and inflorescences should be pruned, collected and immediately burned to prevent disease spread. Fronds surrounding the infected terminal bud should also be cut and burnt. Because fungal growth, spore germination, infection and subsequent disease development are highly dependent on moisture, any reduction in humidity will help to limit disease levels. Thus, regular irrigation and avoiding the accumulation of water under the palms by improving drainage will help to reduce disease development. Eradicating weeds at the stem base will

Fig. 4.7. Symptoms of black scorch disease on palm fronds:
1. Black scorch on young fronds.
2. Note the dwarfing of the one year old medjool variety palm infected by black scorch disease.

(Source: FAO, 1999)

Fig. 4.8. A Date palm infected by *C. paradoxa*, showing complete deterioration due to death of the terminal bud.

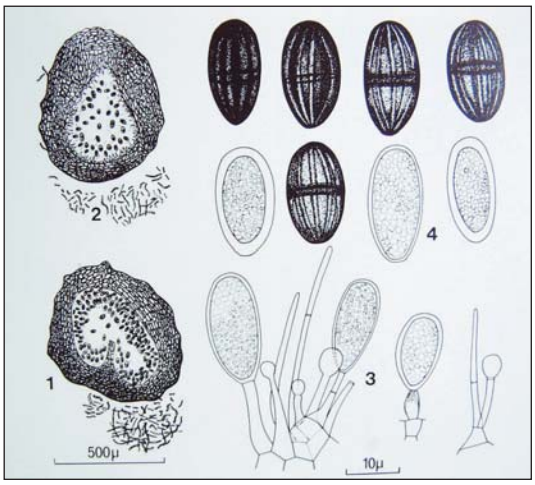
Fig. 4.9. Late stage infection with *C. paradoxa* causing black scorch disease.

also reduce local humidity levels. Pruning sites should be treated with an antifungal paste such as Valsa Wax PA ® (thiophanate-methyl). Spraying the crown and other affected parts of the palm with a fungicide can provide effective control of the disease. Tri-miltox Forte WP ® at the rate of 300 g/hl. water, Bavistin FL ® (carbendazim) at 100 ml/hl. or Topsin M70 WP ® (thiophanate-methyl) at 150 - 200 g/hl. water is effective against black scorch disease. The first application must be done after removing and burning all infected parts.

4.1.4. Bending Head

***Ceratocystis paradoxa* (Dade)**
= *Thielaviopsis paradoxa* (De Seynes) Höhn.

***Lasiodiplodia theobromae* (Pat.) Grifon & Maubl**
= *Botrydiplodia theobromae* (Pat.)



Lasiodiplodia theobromae
1, 2. pycnidia. 3. conidiogenous cells and conidia. 4. conidia

Distribution and Economic Importance

In most date growing areas, bending head disease is considered of limited distribution, although, according to Djerbi (1980) it is considered a serious disease in Tunisia, Algeria, Mauritania and Egypt. In Oman, bending head disease appears to accompany black scorch disease and has been recorded in neglected groves or where drought stress occurs. It has also been observed in areas where stress has resulted from water accumulation under the palms especially during the summer.

Symptoms of Infection

The most important symptoms are the whitening and drying of the middle leaflets of the frond; the fronds themselves also bend and become dry. The central cluster of young fronds in the crown remains erect with a bend at the tip of each frond. Infected young fronds die and fall from the palm while the older fronds die but remain attached to the palm, drooping vertically. After the death of the palm, the trunk bends and may eventually break, Fig. 4.10.

Brun and Laville (1965) reported that *Thielaviopsis paradoxa* and *Botrydiplodia theobromae* are capable of infecting palms weakened by severe thirst, prolonged drought or neglect through poor management. The disease may appear concurrently with black scorch disease. *Thielaviopsis paradoxa* can also cause terminal bud rot, the most important symptoms of which are the white appearance and dryness of the fronds with rotting of the terminal bud.

Fig. 4.10. Date palm affected by bending head disease.

Prevention and Control Measures

Following proper sanitation and cultural practices, especially regular irrigation and avoidance of water stress, will help to prevent the occurrence of bending head disease. Removal and immediate burning of all affected palm parts will limit the spread of disease. Spraying with one of the fungicides recommended for black scorch disease will also help to manage the disease and reduce pathogen dispersal.

4.1.5. Leaf Spots

Leaf spots diseases are widely distributed around the world and caused by a variety of pathogens. They are more intense in regions with warm, humid climates. Identification of the pathogen associated with a particular leaf spot is difficult without isolating the fungus; a single leaf spot lesion may harbour several pathogen species. In some cases identification is relatively easy, as in the case of Graphiola leaf spot where the fruiting structures are readily seen. Similarly, in the case of Diplodia leaf spot, pycnidia produced by the pathogen can be seen using a hand lens.

In Oman, Saaidi (1992) reported three severe leaf spot diseases on date palms in the Batinah coastal area: false smut caused by *Graphiola phoenicis* (Moug.) Poit., brown leaf spot caused by *Mycosphaerella tassiana* (DeNot.) Johans and Diplodia leaf spot caused by *Diplodia phoenicum* (Sacc.) H.Fawc. & Klotz. The diseases had local incidence levels of 75, 47 and 41%, respectively. Other fungi were also detected including *Alternaria alternata* (Fr) Keissler, *Drechslera* sp. and *Phoma* sp. In Saudi Arabia, Abdel Qader and Al-Husseini (1997) isolated *Alternaria alternata* (Fr) Keissler, *Cladosporium cladosporioides* (Fresen.) de Vries, *Drechslera australiensis* (Bugnicourt), *Helminthosporium* spp., *Periconia* sp., *Phoma glomerata* (Corda) Wollenw. & Hochapfel, *Scytalidium* sp., *Stemphylium bottryosum* Wallr, *Ulocadium atrum* Preuss and *Xylohypha nigrescens* (Pers.) E.W. Mason from leaf spots.

The most important sources of infection by the leaf spot causing fungi are infected fronds left from the previous season and insects and other pests, especially those with piercing or sucking mouthparts that cause leaf injuries through which the fungi enter. Tools used in pruning can also spread infection. Intercrops or neighbouring trees may act as alternate hosts or symptomless carriers of leaf spot pathogens. For the management of leaf spot diseases, copper based fungicides such as copper oxychloride (3Cu $(OH)_2$ Cu Cl_2) can be used as protection, applied after pruning. Where symptoms are already present, systemic fungicides such as Bavistin® FL (carbendazim) at the rate of 100 ml/hl. can be used.

4.1.5.1. False Smut (Graphiola Leaf Spot)

Graphiola phoenicis (Moug.) Poit. (Graphiolales: Graphiolaceae)

Distribution and Economic Importance

Since the first description of *Graphiola phoenicis* from palm in 1823 by Mougeot, it has been classified both as a slim mould and a true fungus, Chase and Broschat (1991). It is now considered to belong in its own order (Graphiolales) within the class Heterobasidiomycetes, being related to the smut fungi.

False smut, Graphiola leaf spot or false rust disease is one of the most widespread diseases in all date growing areas. The incidence of the disease is correlated with the occurrence of continuous high humidity or heavy rains. It is common in Oman, United Arab Emirates, Bahrain, Saudi Arabia (Eastern Province) and Egypt (Delta and Fayoum). It is also present in Libya, Tunisia, Algeria, Morocco, Mauritania, Niger, Senegal, Pakistan, India, USA and Argentina.

Martinez (1966) recorded *G. phoenicis* on 11 species of palms in Florida: *Acoelorrhaphe wrightii* (Grisebach et Wendland), *Arecastrum romanzoffianum* (Chamisso) Beccari, *Butia capitata* (Martius) Beccari, *Coccothrinax argentata* (Jacquin) Bailey, *Phoenix canariensis* Hortorum ex Chabaud, *P. dactylifera* Linnaeus, *P. reclinata* Jacquin, *P. roebelenlii* O'Brien, *Roystonea oleracea* (Jacquin) Cook, *Sabal palmetto* (Walter) Loddiges ex J.A. et Schultes, and *Washingtonia robusta* Wendland.

The disease leads to the premature death of infected fronds, reducing the productive life from around 5 years to 3-4 years. Consequently, palm growth and date production are affected.

Symptoms of Infection

Graphiola leaf spot disease is most common in areas of continuously high humidity and in plantations with dense or closely spaced palms or in coastal areas, near seas or rivers. The fungus mainly affects old fronds. Infection is completely absent on young pinnae, rarely appears on younger fronds but gradually increases on 2-3 years old fronds.

Signs of infection appear on both sides of the pinnae as small yellow to brown spots, round in shape and slightly elevated from the surface of the pinnae. The diameter of each is between 1-3 mm. The outer layer is hard in texture and dark in colour, the inner layer produces the spores, it is fragile and easily disintegrates. These sori are initially cream in colour, changing to dark brown later. When disease intensity is high, the total damaged area of the fronds ranges between 2-7%, Figs. 4.11 and 4.12.

The general symptoms of false smut disease include overall weakness of the palm, yellowing of leaves and premature death of fronds with a consequent reduction in date production. Infection is frequently more severe in short palms where fronds are touching or approaching the ground thereby increasing the local humidity.

Sources of Infection

The main sources of infection are previously affected fronds containing spore-producing sori. At maturity, each sorus will exude a column of spores arising from fertile hyphae. This filament appears yellowish, containing numerous spores, which are released to infect healthy

tissue. The disease cycle may take as long as 10 months to complete one generation.

Fig. 4.11. Graphiola leaf spot disease caused by *Graphiola phoenicis*.

Fig. 4.12. Emerging fruiting structures (sori) of *Graphiola phoenicis*.

Resistant Varieties to False Smut Disease

Hussain (1985) reported that the varieties Barhee, Adbad, Rahman, Gizaz, Iteema, Khastawy and Kazaz are among the less susceptible varieties in Iraq. In Oman, differences were found in the level of varietal susceptibility (Anonymous, 1992c), Table 4.1.

Table 4.1. The susceptibility of some Omani date palm varieties to Graphiola leaf spot disease.

Susceptibility	Variety	Severity*
Very high	Fardh	11.53
	Meznag	11.48
High	Madlouky	8.96
	Bounarinja	7.76
	Khamri	7.40
Moderate	Khalas	5.93
Low	Um el Sala	2.33
	Damos	2.16
	Khasab	1.47

* Severity as average number of sori /4 cm^2.

Prevention and Control Measures

Cultural measures should be strictly applied to reduce disease intensity including:

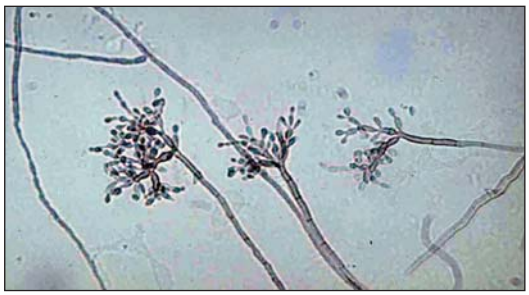
- Removal and immediate burning of heavily infected fronds.
- Regular irrigation and removal of weeds to decrease humidity under the palms.
- Correct spacing at planting.
- Removal of some palms from dense plantations to increase ventilation.
- Preferential cultivation of highly or moderately resistant varieties in areas where the disease is common.
- Use of sterilized tools during pruning operations. Avoid the use of chain saws that are difficult to sterilize. Sterilization can be achieved by 5-minute immersion in 2.5% sodium hydrochloride.

Fungicides can be used to decrease the incidence of infection. Infected palms should be repeat sprayed at one to two weeks intervals according to the severity of infection to protect the emerging foliage. Tri-miltox Forte WP ®, Copper Oxychloride at 300 g/hl. water or Bravo ® (Chlorothalonil) at 200 g/hl. water have proved useful in the management of false smut.

4.1.5.2. Brown Leaf Spot

***Mycosphaerella tassiana* (De Not.) Johans**
(Dothideales: Mycosphaerellaceae)

Asexual state = *Cladosporium herbarium* (Pers.Fr.) Link



Conidia and conidiophores of *Cladosporium herbarium*
cause of brown leaf spot

Distribution and Economic Importance

Brown leaf spot has been recorded across North Africa and the Middle East (Rieuf, 1968). It is common in Tunisia, Algeria and Morocco, but is generally considered of minor economic importance. In Oman, the disease is widespread in the Batinah coastal area with recording an area-wise incidence of around 47% apparently due to the prevalent high relative humidity (Saaidi, 1992).

Symptoms of Infection

Symptoms appear on all parts of the frond: leaflets, pinnae, spines and rachis and affect both old and young fronds. The leaf spots vary in shape and size; they are dark coloured, sometimes black. Later the spots turn pale while the edges of the lesions remain reddish brown. On the rachis, lesions vary in length from one to a few centimetres, Fig. 4. 13.

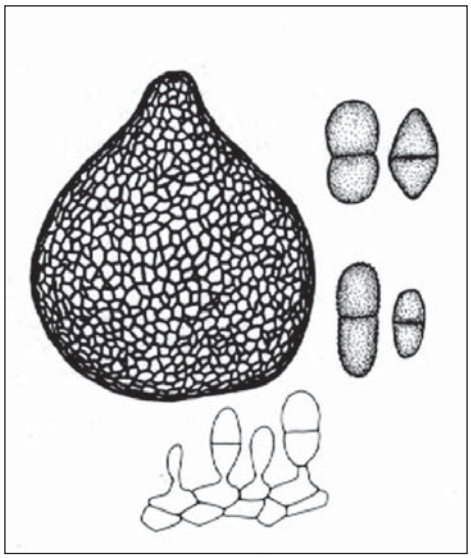
Prevention and Control Measures

Brown leaf spot disease is considered to be of a minor economic importance and so management measures are not normally recommended. However, annual pruning and burning of old infected fronds is helpful to prevent disease spread. In case of severe infection, fungicides such as: Dithane M-45 ® or Bravo® (Chlorothalonil) can be used.

Fig. 4.13. Symptoms of brown leaf spot caused by *Mycosphaerella tassiana* on date palm fronds.

4.1.5.3. Diplodia Disease (Offshoots and Frond Stems Disease)

***Diplodia phoenicum* (Sacc.) H Fawc. & Klotz**
(Botryosphaeriales: Botryosphaeriaceae)



Conidiophores of *D. phoenicum*

Distribution and Economic Importance

Diplodia disease is widespread, especially in date growing areas with warm and humid climates. It is common in Oman, Saudi Arabia, the United Arab Emirates, Bahrain, Iraq, Palestine, Egypt, Tunisia, and Morocco and in California and Arizona in the USA (Fawcett, 1930).

Diplodia disease is usually considered to be of minor economic importance, however, it may cause serious damage in some years resulting in the death of large numbers of palms and their surrounding offshoots. The pathogen can also cause fruit rot.

Symptoms of Infection

Diplodia phoenicum infects both old and young palms as well as their offshoots. The signs of infection first appear on old fronds then spread to younger ones occasionally causing frond death. The disease can also reach the terminal bud. A common symptom of the disease is the appearance of yellowish-brown streaks on the ventral mid-portion of the frond extending 15-120 cm along the leaf base and the rachis. The colour of these lesions becomes dark brown with age. The disease can readily spread from one leaf base to an adjacent leaf base, Fig. 4.14.

Symptom development on offshoots around the infected mother palms can follow one of two distinct patterns. In some cases the outer (older) fronds of the offshoot die and the disease spreads to the other parts of the frond reaching the terminal bud leading to the death of the offshoot. Alternatively, symptoms appear on the central cluster of young fronds, first at the apex of the offshoot followed by the death of the outer, older leaflets.

(Source: FAO, 1999)

Fig. 4.14. Signs of early infection by *D. phoenicum.*

Sources of Infection

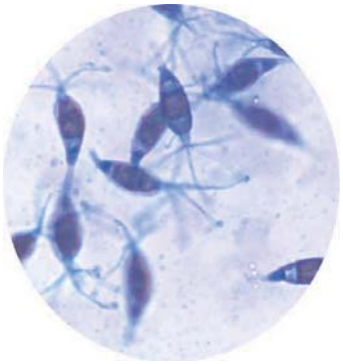
The pathogen enters the palm through wounds made during pruning, accidental wounds or during the process of separating the offshoots from the mother palms. Irregular or excessive irrigation also increases the severity of the disease, especially under warm, humid weather conditions. The disease is also most severe in neglected groves.

Prevention and Control Measures

As *Diplodia phoenicum* is most commonly a wound pathogen, the most important management practices relate to care during pruning and general sanitation. Infected fronds should be removed and burned; saws and other tools should be sterilized using a 5 minute immersion in 2.5% sodium hypochlorite. Wounds should be treated with an antifungal paste, e.g. Valsa-Wax, and freshly cut offshoots should be dipped in a fungicidal solution and sprayed with a fungicide such as Thiram or Tri-Miltox Forte ® at 300 ml/hl. water every two weeks. Immersing offshoots in a copper-based solution may protect against infection and may also help in the rapid generation of new fronds. Regulation of irrigation is important as is avoiding subjecting the palms to drought, especially in the hot season.

4.1.5.4. Pestalotiopsis Leaf Spot (Leaf Blight)

***Pestalotiopsis palmarum* (Cook) Steyaert**
(Xylariales: Amphisphaeriaceae)



Distribution and Economic Importance

Pestalotiopsis palmarum infects date palms and several ornamental palms and occurs in most countries where these plants are grown. Table 4.2. shows the host ranges of *Pestalotiopsis palmarum* and *Graphiola phoenicis* in California, USA.

Symptoms of Infection

Symptoms of Pestalotiopsis leaf spot start as tiny black spots, which enlarge in size and form approximately circular lesions with a diameter up to 2 mm, Fig. 4.15. The lesions later become almost white in colour with a dark to black border and with a black zone at the centre. Such lesions are present on all the parts on the frond including the spines, Chase and Broschat (1991).

Sources of Infection

The most important sources of infection are lesion-containing, unpruned fronds. Pestalotiopsis leaf spot is more intense in areas of high humidity or during the rainfall. Disease is also more frequent in areas using sprinkler irrigation, especially with date palms planted in gardens, as this aids the spread of infection in short-trunk date palm with crowns are near to the ground.

Prevention and Control Measures

In new groves, dense planting should be avoided to allow for good air circulation so that frond surfaces can dry, preventing the build-up of conditions suitable for infection. Infected fronds should always be pruned, collected and burned. Sprinkler irrigation methods should not be used, especially for low growing types; rather bubbler systems should be employed. The timing of irrigation should also be managed to prevent excessive humidity build-up. Use of preventive applications of broad-spectrum fungicides can help in disease control; effective products include Topsin M70 WP ® (thiophanate-methyl) at the rate of 150-200 g/hl. water.

Table 4.2. Host range of *Pestalotiopsis palmarum* and *Graphiola phoenicis.*

Species infected by *Pestalotiopsis palmarum*	Species infected by *Graphiola phoenicis*
1. *Acoelorrhaphe wrightii*	1. *Bismarckia nobilis*
2. *Arenga pinnata*	2. *Butia capitata*
3. *Butia capitata*	3. *Caryota mitis*
4. *Chamaerops humilis*	4. *Caryota urens*
5. *Chrysalidocarpus lutescens*	5. *Chamaedorea elegans*
6. *Cocos nucifera*	6. *Chrysalidocarpus lutescens*
7. *Coccothrinax argentata*	7. *Cocos nucifera*
8. *Phoenix canariensis*	8. *Elaeis guineensis*
9. Phoenix dactylifera	9. *Phoenix canariensis*
10. *Phoenix reclinata*	*10. Phoenix dactylifera*
11. *Phoenix roebelenii*	11. *Phoenix reclinata*
12. *Phoenix sylvestris*	12. *Phoenix roebelenii*
13. *Phoenix theophrasti*	13. *Rhapis excelsa*
14. *Roystonea elata*	14. *Roystonea elata*
15. *Sabal minor*	15. *Sabal palmetto*
16. *Sabal palmetto*	16. *Veitchia merrillii*
17. *Syagrus romanzoffiana*	17. *Washingtonia* spp.
18. *Washingtonia robusta*	

(Source: Chase and Broschat, 1991).

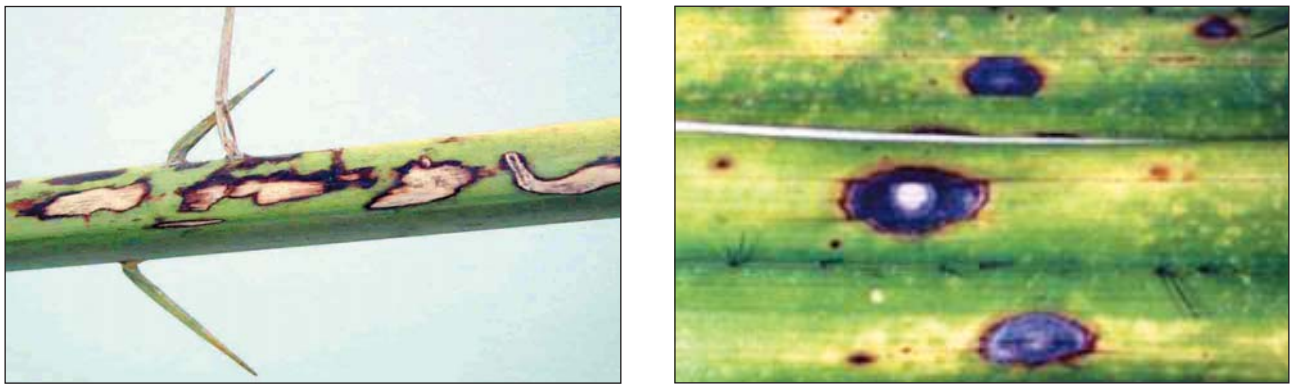
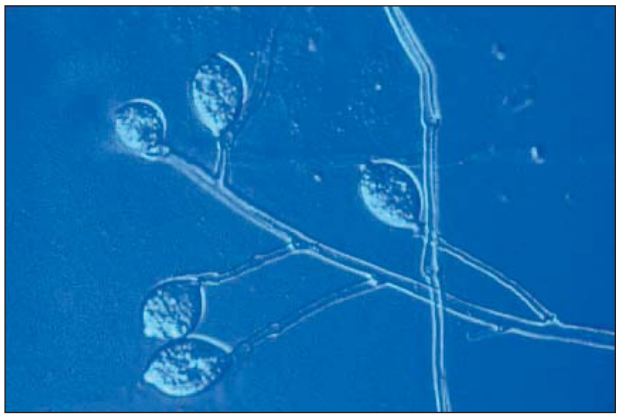


Fig. 4.15. Pestalotiopsis leaf spot infection showing large lesions with black borders.

4.1.6. Belâat Disease

Phytophthora* sp. nr. *palmivora
(Peronosporales: Pythiaceae)



Phytophthora sp. nr. *palmivora,*
showing sporangiophores and the sporangia.

Distribution and Economic Importance

Belâat Disease is generally considered of minor economic importance with limited distribution on date palms. It was recorded by Monciero (1947), Calcat (1959) and Toutain (1976) in Tunisia, Algeria and Morocco. In Oman, symptoms of the disease have been reported on a limited number of palms in some groves in the Batinah coastal area.

Symptoms of Infection

The pathogen infects weak palms, starting with the growing apex and a wet rot forms on the inner tissues of the young frond. Usually, infection occurs near the terminal bud causing bud decay and leading to the death of young fronds and the growing apex. Before dying, the young fronds rapidly change colour from green to white, giving rise to the most characteristic symptom of the disease, the rapid whitening of the heart of the palm. In some palms the infection may stop just under the growing apex, in others it may continue downwards through the trunk and in severe cases infected trunks release an unpleasant odour reminiscent of fermenting organic matter.

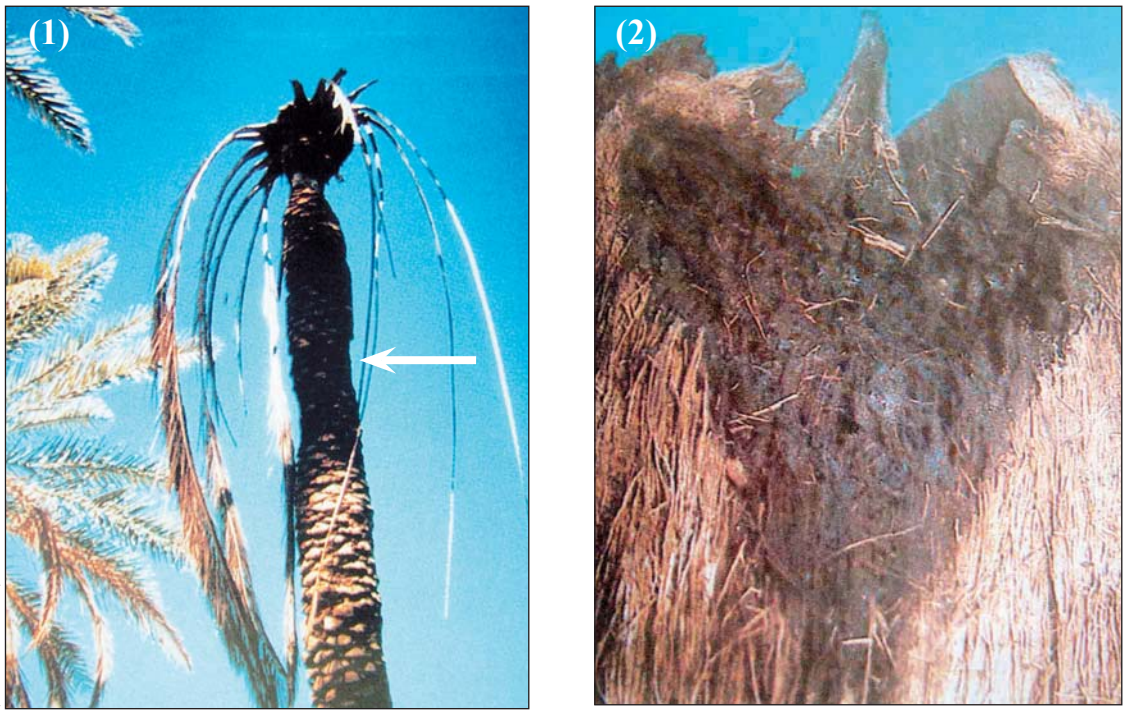
As a result of trunk infection, the palm becomes suffocated at the site of infection. This is the origin of the name Belâat, meaning "not swallowing" in North African dialect of Arabic. Some palms can overcome this condition by producing a lateral bud and continuing away from the disease. Usually, offshoots from affected palms remain healthy, Fig. 4.16.

Sources of Infection

Belâat disease usually appears in neglected palm plantations and the infection is not transmitted palms to offshoots.

Prevention and Control Measures

The most important Belâat disease preventive measures include avoidance of the excessive soil moisture by regular, moderate irrigation; balanced fertilization; regular ploughing to improve aeration and drainage, especially during the high rainfall period. Curative foliar fungicides can limit disease incidence and spread. Crowns should be



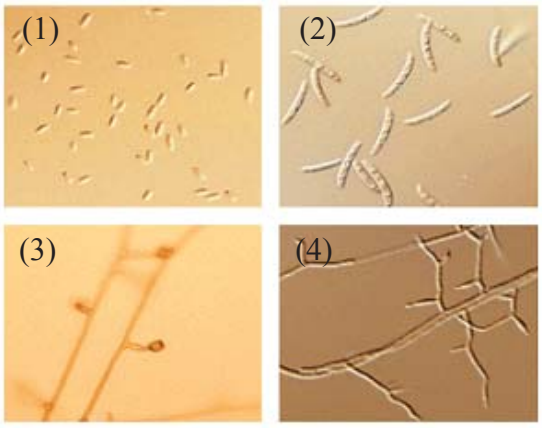
(Source: FAO, 1999)

Fig. 4.16. Symptoms of Belâat disease caused by *Phytophthora* sp. nr. *palmivora.*
(1) Death of the terminal bud caused by Belâat disease, followed by whole palm death. (Note the characteristic constrictions on the trunk "Belâat").
(2) Conical wet heart rots of the terminal bud.

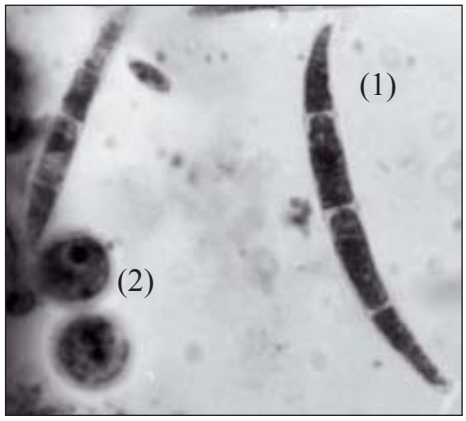
treated with a systemic fungicide such as Ridomil Gold ® (metalaxyl) or Previcur N ® (propamocarb) at the rate of 250 g or ml/hl. water. The use of copper oxychloride can also provide a protective layer on leaf bases and around the terminal bud. However, once the disease occurs, severely affected palms should be removed and burned.

4.1.7. Fusarium Wilt

***Fusarium oxysporum* Schlechtendahl**
(Hypocreales: Nectriaceae)



Fusarium oxysporum
1. Microconidia 2. Macroconidia
3. Microphialides 4. Macrophialides



Fusarium oxysporum
1. Enlarged Macroconidia.
2. Clamydospores.

Distribution and Economic Importance

Fusarium wilt has been recorded in California, USA on palms showing symptoms similar to those of Bayoud disease in Morocco and Algeria and is one of the most destructive palm diseases affecting California landscapes. The disease was first identified and characterized in California by Feather *et al*. (1979, 1989). The pathogen is easily spread by pruning practices, through the soil or irrigation water and causes the gradual death of affected palms.

Symptoms of Infection

Diseased palms show marked retardation of growth, wilting and yellowing of the fronds. The yellowing is more pronounced on the leaflets on one side of the fronds. Fronds on one side of the palm may die more rapidly than the others producing a lopsided appearance. Fronds may die more rapidly from the lower fronds upwards or a ring of fronds may die with green, living fronds above and below. On a single infected frond, necrosis begins from the basal leaflets, spreading toward the frond tip. A dark brown streak often appears at the bottom of the rachis and when the infected frond is split, the vascular vessels show a marked brown colouration due to pathogen-induced blocking of the vascular tissue. The pathogen is capable of surviving in the soil until conditions are favourable for infection. The pathogen enters the roots and spreads to the trunk and the rest of the palm through the vascular system. Offshoots from affected palms are liable to carry the infection (Chase and Broschat, 1991).

Sources of Infection

Fusarium oxysporum grows and multiplies in soil at temperatures between 21-33°C. Beyond this range the pathogen can survive as chlamydospores. The pathogen is frequently transported from infected to healthy palms through soil movement, during irrigation or through cuts or wounds caused by pruning tools.

Prevention and Control Measures

Fusarium oxysporum is soil- and water-borne fungi. In addition, the pathogen is transmitted through pruning tools such as chain or hand saws. As there are no treatments for the control of the disease, prevention of infecting is paramount. Transmission can be minimised by using clean pruning tools, which should be thoroughly sterilized between operations by soaking in 2.5 % sodium hypochlorite solution for 5 minutes. Household bleach can be used by preparing a 25 % solution (1 part bleach + 3 parts water). Before sterilization, tools should be cleaned of any debris. For chain saws it is recommended that they be taken apart and the chain and bar soaked separately. The disinfectant solution should be replaced at least every ten palms or every two hours, whichever is shorter. Tools should be rinsed with clean water before resuming pruning operations. Other potential disinfectants include tri-sodium phosphate or quaternary ammonium salts. The latter is recommended as a 5% solution, soaking tools for 5 minutes (Smith *et al*. 2003).

4.1.8. Bayoud Disease (Fusariose)

Fusarium oxysporum F. sp. *albedinis* Malencon (Hypocreales: Nectriaceae)

Distribution and Economic Importance

The Bayoud disease is one of the most dangerous diseases of date palm. By 1958, in Morocco, around ten million palms of the finest varieties including Medjool and Bou Fegouss had been destroyed (Pereau-Leroy, 1958). Toutain (1970 and 1973) showed that 90-100% of palms of varieties sensitive to the disease would be destroyed in a period of about 15-20 years with an annual mortality rate of around 6%. In the case of moderately resistant varieties losses could amount to 1.5% per year. Both Toutain and Louvet (1972) and Saaidi (1979) estimated that the annual average rate of loss of date palms in Morocco due to the Bayoud disease was about 3-5%. Losses due to Bayoud disease are not limited to the date palm crop as the disease indirectly affects the intercrops especially Lucerne (*Medicago sativa*), Henna (*Lawsonia inermis*), wheat, barley and many vegetables. These intercrops utilise the shade provided by date palms; once the palms are destroyed, farmers are often unable to cultivate these crops.

The name Bayoud comes from the Arabic word "Abiadh", meaning white and refers to the whitening of the fronds of diseased palms. The disease was probably first reported in Morocco sometime before 1890. It subsequently spread eastward and by 1898 had reached the borders of the Algerian Sahara and elsewhere. Although there are no confirmed records of the disease spreading beyond Morocco and Algeria, there are some reports of the presence of Bayoud disease on ornamental *Phoenix canariensis* palms in the South of France and Italy. The optimal temperature for *Fusarium oxysporum* f. sp. *albedinis* growth is 21-27°C; fungal growth is weak at 37°C. Hamouda *et al*. (1998) attributed the absence of Bayoud disease in Oman to the resistance of the Omani date palm varieties and to the high temperatures prevalent in Oman for long periods during the year.

Symptoms of Infection

1. The External Symptoms

The symptoms appear on initially one or more of the newly emerged fronds Fig. 4.17. The first symptom is the white appearance of some spines or some pinnae near the frond base. Subsequently, whitening and death spreads upward to adjacent pinnae toward the tip of the frond, but only

on one side of the midrib. At the apex, the direction of symptom spread reverses moving from tip to base until all leaflets have died. The complete destruction of the frond may take from a few days to several weeks. On the dorsal side of the dead pinnae a brown coloured stain appears and the tissue surface becomes sunken. Adjacent fronds also begin to show the same symptoms and as they die the dead fronds hang down, still attached to the trunk of the palm. Eventually the disease reaches the terminal bud and the whole palm wilts and dies. The period between the onset of symptoms and death of the palm varies from 6 months to 2 years. Carpenter and Elmer (1978) reported that in some cases the palm may die after only one month of infection while in other cases it may take up to 10 years for the palm to die. The rapid evaluation of symptoms depends mainly on the general health of the palm and on variety, Figs. 4.17 and 4.18. According to Saaidi (1979) Bayoud disease attacks both mature and young palms, as well as offshoots at their bases.

2. Internal Symptoms

When a cross section is made in the infected parts of the midrib of the frond, reddish-brown necrotic areas are seen. Toutain (1965) mentioned that when a longitudinal section is taken from the trunk of an infected palm, long fascicles of infected tissue, reddish-brown in colour, are observed ranging in length from 1 to 2 centimetres. Pale vascular vessels can be also seen distributed from the top to the base of the palm. Both Malencon (1950) and Pereau-Leroy (1958) indicate that the vascular tissues are less affected by the infection than the other tissue, suggesting that the cause of death may be due to toxins secreted by the fungus rather than vascular congestion. This may explain why some infected offshoots remain apparently healthy for up to 10 years after the death of the mother palm.

Sources of Infection

Fusarium oxysporum f. sp. *albedinis* is present in the soil, infected offshoots or other parts of the palm including the rachis, trunk and dead roots remaining in the soil. The pathogen can also survive as chlamydospores which can remain viable for prolonged periods of time. Bersi (1983) noted that the spread of Bayoud disease into isolated oases was primarily due to the transplantation of offshoots from infected palms or by the importation of baskets, ropes or other implements made from infected palm materials. The pathogen can survive at unfavourable conditions on infected fronds for several weeks. When suitable conditions are restored the pathogen regains activity in the soil multiplies and spreads to infect healthy date palms.

Intercrops cultivated among the palm trees such as Henna (*Lawsonia inermis*) and Lucerne (*Medicago sativa*) can harbour *Fusarium oxysporum* f. sp. *albedinis* and remain symptomless. These crops are considered primary sources of infection and contribute to the spread of the disease when transported from infected to noninfected areas. The disease is more serious and spreads faster when susceptible rather than resistant varieties are cultivated. Copious surface irrigation and inter-cropping also lead to the spread of the disease.

(Source: FAO, 1999)

Fig. 4.17. Bayoud disease, notice white appearance of fronds.

(Source: FAO, 1999)

Fig. 4.18. Advanced stages of Bayoud disease.

Prevention and Control Measures

The spread of Bayoud disease may be restricted by adopting the following measures:

1. The Cultivation of Resistant Varieties

Louvet *et al*. (1970) stated that the cultivation of the resistant varieties is the ultimate measure that can be taken to restrict the spread of the Bayoud disease. Bersi (1983) has listed the resistant varieties cultivated in Morocco as Boskami, Tadment, Al Kami and Taker Bosht, while the varieties Bou Fegouss, Boskari, Medjool and Deglet Nour were susceptible to the disease.

2. Cultural Control Measures

Some cultural measures can limit the spread of Bayoud disease including:

- Management of irrigation; as irrigation has a marked effect on the spread and development of Bayoud disease, irrigation frequency and amount should be decreased.
- Restrict the importation of seeds and unprocessed products of symptomless carriers such as Henna and Lucerne from Bayoud-infected countries or regions.
- Avoid the movement of contaminated offshoots or tools made from palm parts from infected areas into disease-free areas.
- Cultivate palms on soil with a natural high water content to decrease the need for repeated irrigation.
- Cultivate disease-resistant offshoots.

However, Bult *et al*. (1967) have stated that a decrease in irrigation and the removal of intercrops are ineffective in the control of Bayoud disease.

3. Quarantine

Some countries, such as the Sultanate of Oman have intensified control measures and banned the entry of palm offshoots or palm products from countries that have reported Bayoud disease. In Oman, the Ministry of Agriculture and Fisheries issued decree 26/81 that banned entry into the Sultanate of offshoots and date fruits coming from or passing through Morocco, Algeria or their neighbouring countries.

4.1.9. Omphalia Root Rot

1. *Omphalia pigmentata* Bliss
2. *Omphalia tralucida* Bliss
(Agaricales: Tricholomataceae)

Omphalia pigmentata spores.

Distribution and Economic Importance

Omphalia root rot is considered of minor economic importance. It was recorded in the Coacell valley, California, USA (Fawcett and Klotz, 1932) and in Kankossa, Mauritania (Bliss, 1944).The disease affects palm roots and their offshoots or palms grown from seed. Although root rot is considered of minor importance in the USA it may cause relatively large losses in susceptible varieties.

Symptoms of Infection

The disease causes deterioration in the condition of the palm hence the alternate name of "decline disease". It is distinct from Rapid Decline Disease (Section 4.3.1). Symptoms start with the death of older, green fronds. Subsequently, new fronds are smaller in size and fruit bunches are smaller than normal, bearing commercially undesirable dates. These initial symptoms are followed by retardation in growth and ultimately complete arrest of growth leading to a marked decline in the quantity and quality of fruits. A severely affected palm will fail to bare fruit. The disease also affects the rate of growth of the trunk. Over a period of nine years healthy Khadrawy date palms had an average circumference of 181 cm compared to 129 cm in diseased palms. The variation was even greater in Deglet Nour where average trunk growth in 9 years for healthy palms was 339 cm compared to 68 cm for infected palms (Hussain, 1985).

Omphalia root rot disease reduces the average number of fruit bunches. The average number of bunches in infected Khadrawy ranged from 0.5 to 8.8 whilst in diseased palms of the same variety the range was from 0 to 6.8 bunches per palm. In Deglet Nour the effect of the disease was more intense with the average number of bunches per palm decreased from 0.9-11.3 bunches in healthy palms to 0-2.9 in diseased palms (Hussain, 1985).

Root rot disease is often difficult to diagnose. However, infected roots show spotting and frequently the signs of

pathogen growth. Most affected roots are brown with blackened areas on some small roots. Hussain *et al*. (1979) stated that symptoms of the disease may be confused with those of water stress. Therefore pathogen isolation and identification should always be confirmed.

Sources of Infection

The causal pathogens have been isolated from diseased and neglected palms. The pathogen can viable in dead palm roots in the soil for up to two years. They are found in the soil as mycelium around infected palms at depths up to 60-120 cm. The pathogen enters the roots of healthy palms, penetrating the cell walls and ultimately colonising the vascular tissues.

Prevention and Control Measures

The most important measures include:

- Transplanting only noninfected offshoots of known origin.
- Cultivating resistant varieties. The varieties of Deglet Nour, Haiani, Sayer, Ahmar and Hilali appear to be susceptible to the disease, while Khidrawy, Khalas, Halawi and Medjool appear resistant.
- Maintaining good cultural practices, especially with regard to irrigation and fertilization.
- Sachs (1967) recommended spraying infected palms with Brestan® (fentin + maneb) at 2-week intervals over a period of two months to control the disease.

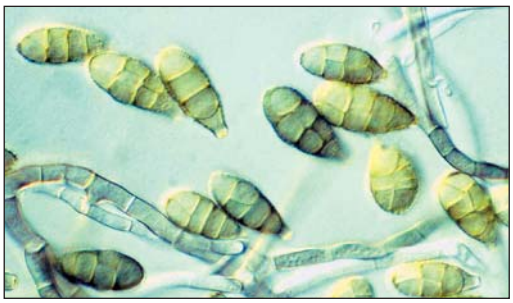
4.1.10. Fruit Rot

Many fungi infect and attack date palm fruit causing damage, rotting and economical losses to fruits. It is already known that the fungal diseases intensify in regions having high relative humidity during the fruit ripening season, or in those areas when the period of fruit ripening coincides with the rainfall season. Generally, fruit rot diseases are common worldwide in all date growing areas, even though the economic importance varies between the different geographical areas, the date palm varieties and also the stage of fruit growth, i.e., Hababouk stage (size is about that of a pea), Kimri stage (green stage), Khalal stage (colour stage), Rutab stage (soft ripe stage) and Tamar stage (full ripe stage). Djerbi (1983) reported that the most common fungi causing fruit spoilage are the Caly-xend rot by *Aspergillus niger* and the Side Spot Decay caused by *Alternaria* sp.

The following are the most important and common fruit rot diseases, which known to attack date palm fruit and causing serious damage and losses to date fruits production; these are: Side Spot Decay, Calyx-end Rot, Penicillium Rot, Soft Rot, Date Blight, Phompsis and Stemphylium Rot.

4.1.10.1. Side Spot Decay

Alternaria alternata (Fr) Keissler
(Pleosporales: Pleosporaceae)



Alternaria alternata conidia and conidiophores.

Distribution and Economic Importance

Side spot disease is common in Oman, UAE, Saudi Arabia, Yemen, Qatar, Bahrain, Egypt, Libya, Tunisia, Algeria and USA. This disease and other fruit rot diseases cause economic damages in many parts of the world characterised by high levels of relative humidity during the fruit ripening season.

Fruit rot diseases result in 25-50 % loss in harvest in both Algeria and Tunisia, Djerbi (1983). Many of the causal pathogens can infect the fruits of date palm as well as many other fruit tree species.

Symptoms of Infection

The pathogen infects injured date fruits in late Khalal stage and intact dates in Rutab stage. The infected fruits show small black translucent spots with clearly marked edges. These spots widen and coalesce to form large dark-coloured, oval or circular necroses.

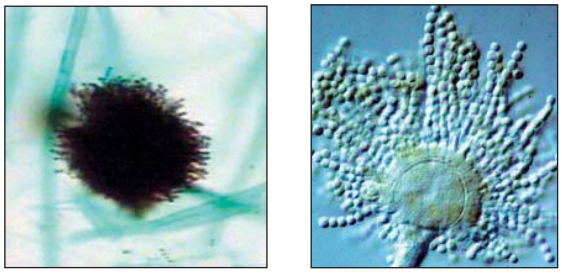
The pathogen, Alternaria sp., has dark coloured mycelium, which produces short, simple, erect conidiophores that bear single or branched chains of conidia. The conidia are large, dark, long, or pear shaped and multicellular with both transverse and longitudinal cross walls. These conidia are easily detached and carried by air currents.

Sources of Infection

The pathogen disseminates through infected dropped fruits and also survives on the spikelet and calyx after fruit fall. It can survive in the soil in the form of resting bodies (microsclerotia) or resting spores (chlamydospores). The fungus enters the fruit by a germ tube through the intact epicarp or via mechanical cuts on the fruit surface. Spores can remain quiescent on the surface of the fruit. Spores may germinate during Kimri, Khalal or Rutab stages of fruit ripening but not during Tamar (fully ripe) because of the high sugar content.

4.1.10.2. Calyx- End Rot or Black Rot

Aspergillus niger Van Tieghem
(Eurotiales: Trichocomaceae)



Conidia and conidiophores of *A. niger*

Distribution and Economic Importance

Aspergillus niger is distributed in all date growing areas; common in Oman, Saudi Arabia, Bahrain, Libya, Tunisia, Algeria and USA. Also called black mould rot, the pathogen infects a wide range of fruits and vegetables, especially in areas of high humidity. The seriousness of the damage increases in areas with rainfall during Khalal, Rutab or Tamar stages of development.

Calyx-end rot or black rot disease is considered one of the most serious diseases attacking the date palm fruits in the state of California, USA. In some seasons, the infection rate is as high as 25% which can be decreased to 5% if control measures are followed strictly. It is also important to note that the black rot disease continues to affect the dates even after harvesting the dates and during storage. The water content of the dates is the determining factor in the economic damages incurred; if the water content in the stored dates is 21%, the rot starts to appear. The incidence of infection increases with the increase in water content up to 29% at a water content of 26%.

Symptoms of Infection

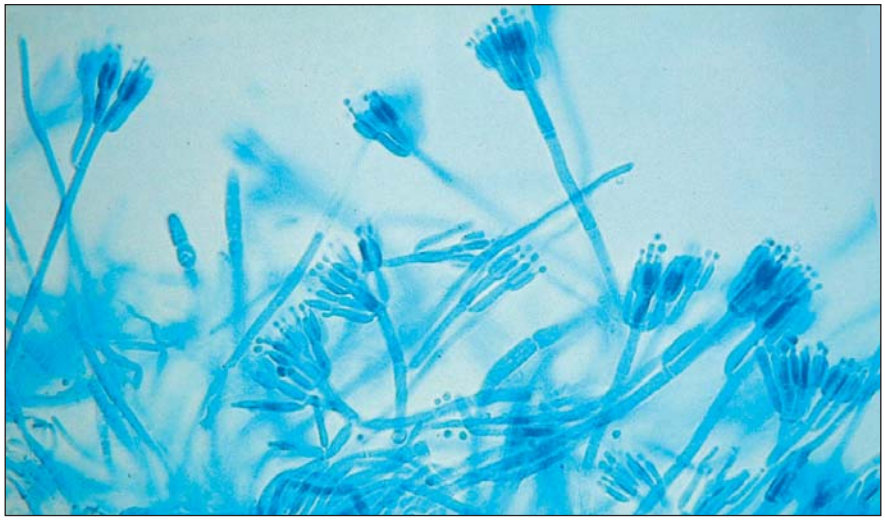
This disease affects the date fruits in Khalal and Rutab stages only and rarely shows on the fruits in Kimri stage. Usually, fully ripened dates with low water content are not affected. The fungus causes putrefaction near the calyx of the fruit which shows a dark coloured ring near the calyx end, especially in Rutab stage. The rottenness and decay near the calyx lead to fruit drop.

Sources of Infection

The fungus survives on already or nearly dead plant matter. Thus, it can multiply all the year either on plant debris or in the soil. The spores spread in the air or in the soil, and when they reach the fruits under favourable conditions of high humidity and moderate temperature, they start to germinate and penetrate the fruit causing fruit rotting.

4.1.10.3. Penicillium Rot

***Penicillium* spp.**
(Eurotiales: Trichocomaceae)



Penicillium spp.,

Distribution and Economic Importance

Penicillium rot is caused by different species, *Penicillium italicum*, which causes "blue mould rots" and *Penicillium digitatum*, which causes "green mould rots". *Penicillium* spp. cause soft rot on the date fruits especially the fruits injured near the tips. It is widespread in Oman, Saudi Arabia, Bahrain, and Yemen, North African countries, USA and other countries.

Symptoms of Infection

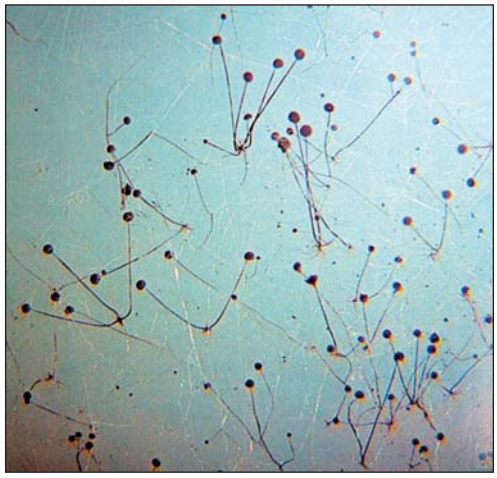
The name *Penicillium* comes from the word "brush" referring to the appearance of spores. *Penicillium italicum* and *Penicillium digitatum* are the most common species attacking date fruits. *P. digitatum* works by producing ethylene to accelerate ripening. *Penicillium digitatum* is a widespread fungus, attacking date fruits as well as many other fruits. It causes green mould rot and the earliest symptom is a soft water-soaked area on the surface of the fruits. Soon the white mycelium or mould will appear and the green-olive spores form at the centre of the lesion. In *Penicillium italicum* the infected fruits appear with blue-green spores. The sporulating area in *P. digitatum* is usually surrounded by a broad band of white mycelium, whereas in *P. italicum* the white margin is narrow and generally not more than about 2 mm wide.

Sources of Infection

P. digitatum infect the date fruits and enters the fruit tissues through any mechanical injuries or breaks on the fruit surface. Whereas, *P. italicum* can spread from infected date fruit to healthy ones in contact with the infected through the uninjured skin.

4.1.10.4. Soft Rot

Rhizopus nigricans Ehrenberg
(Mucorales: Mucoraceae)



Sporangia of *Rhizopus*

Distribution and Economic Importance

The disease is widespread in many countries around the world especially those characterised by high relative humidity or rain during the period of fruit maturity. It is common in the date growing areas in the coastal regions of the Arabian Gulf countries, North Africa as well as in Iraq and the USA. Like most of the fruit rot fungi, *Rhizopus nigricans* also infects the fruits of many vegetables and fruit trees.

Symptoms of Infection

This fungus infects the date fruits with high water content, during Khalal and Rutab stages. Black or grey spots appear on the infected date fruit. The fungus may cause soft rot to some fruits and dry rot to others. Wounds present on the surface of the date fruits help in the spread of the disease.

Sources of Infection

The optimal temperature for *Rhizopus nigricans* growth is between 23°C and 26°C. Infected date fruits carry the sporangia and mycelium of the fungus. The mycelium of the fungus has no cross walls and produces long aerial sporangiophores at the tips of which minute black spherical sporangia develop. The sporangium consists of a thin membrane containing thousands of small spherical sporangiospores. When the mycelium grows on a fruit surface, it produce stolons, i.e., hypha which arch over the surface and at the next point of contact with the surface produce root-like hyphae, called rhizoids, inside the fruit tissue. The spores are dispersed in the air.

4.1.10.5. Date Blight

Helminthosporium spp.
(Pleosporales: Pleosporaceae)

Distribution and Economic Importance

Many species of *Helminthosporium* occur throughout the world and are very common and severe on many important crop plants. Helminthosporium rot is widespread and infects the date fruits in most countries including Oman, United Arab Emirates, Yemen, USA and North African countries. In addition, it can infect most of the intercropped plant species.

Symptoms of Infection

The fungus produces large, cylindrical, dark three to many celled conidia that have thick walls and sometimes are slightly curved. The conidia are produced successively on new growing tips of dark, septate and irregular conidiophores (Agrios, 1978). It infects date fruits during Khalal and Rutab stages of ripening. In addition, the date palm fronds may also get infected with brown spots appearing on the leaflets. In that case, the spots widen to cover most of the leaflets and the rachis. Initially, each spot is circular or semi-oval in shape with marked edges, later the spots coalesce to cover larger areas on the fronds. The infection by date blight disease is high in coastal areas having high relative humidity and moderate temperatures.

Sources of Infection

The fungus is found in the remaining parts of the infected date palms and the spores are in the soil. Usually, infection occurs through wounds and breaks found on the fruit surfaces.

4.1.10.6. Phomopsis Rot

Phomopsis sp.
(Diaporthales: Diaporthaceae)

Distribution and Economic Importance

The fungus infects the date fruits during the Khalal and Rutab stages in many date growing countries worldwide. The rot is soft and pale at first in the form of a spot on the fruit surface. Later the spot becomes black and somewhat drier.

4.1.10.7. Stemphylium Rot

Stemphylium sp.
(Pleosporales: Pleosporaceae)

Distribution and Economic Importance

Like most fruit rot fungi, *Stemphylium* infects the date fruits during Khalal and Rutab stages but may infect the pinnae and rachis of the fronds as well. It is distributed worldwide.

Symptoms of Infection

The infected fruits show the usual signs of rot while on the pinnae and rachis the infection is manifested as small, round spots. Each spot is yellow in colour and has a red dot in the centre. The spots coalesce in severe infection

to form larger lesions. A suitable fungicide, like Dithane M45 (mancozeb) can be used to control the disease, but only on the fronds.

The percentage loss related to the fruit rot diseases can range between 10 % and 50 % of the harvest fruits (Darley and Wilbur, 1955; Calcat, 1959; Djerbi *et al.* 1980). Table 4.3 summarises yield loss percentages in date palm fruits in selected countries and attributable to fruit rot diseases mainly side spot decay (*Alternaria alternata*) and calyx-end rot (*Aspergillus niger*).

Prevention and control of fruit rot diseases

Several measures and procedures should be taken to prevent and/or control fruit rot diseases:

- Proper ventilation of the fruits by removing some central fruit stalks in each bunch before entering the Khalal stage of ripening.
- Protecting the date fruits from rain or dew by covering the fruit bunches with paper wraps or cloth bags during fruit ripening especially in areas with rain during ripening.
- When collecting the date fruits, great care should be exerted to avoid causing unnecessary mechanical injuries or wounds to the fruits.
- Store the date fruits in well ventilated places after collection.
- Proper drainage of irrigation water to avoid ponds forming and so to prevent a rise in humidity among the date palms during the ripening season.
- It may be beneficial to collect the date fruits immediately before complete ripening and artificially ripening in warm rooms (ripening rooms), especially during periods of high humidity.
- Dusting the fruit bunches in the beginning of khalal stage with a Malathion-fermate mixture (5% malathion and 5% fermate mixed with 45% powdered sulfur and 45% inert carrier). The fermate component is fungicidal while Malathion is used against saprophytic insects usually associated with fruit rots, insects that spread fungal spores to healthy palms. The dusting process should be stopped 7-10 days before collecting the fruits.

Table 4.3. Percentage yield losses of selected varieties due to fruit rot diseases.

Country	% Yield Loss	Main Varieties	Control Measures
USA	10 - 40	Medjool Deglet Nour	1. Covering bunches with paper wraps. 2. Dusting with fungicides
Tunisia	50	Deglet Nour	paper wraps
Algeria	25	Deglet Nour	None
Morocco	40	Medjool	None
Palestine	45	Medjool Barhee	None

Source: Djerbi, 1983.

4.2. Diseases caused by Phytoplasma

Mycoplasma-Like Organisms (MLOs)

Phytoplasmas are micro-organisms which cause diseases in many plants. They are smaller than bacteria but larger than viruses. Phytoplasmas are nonnucleated microorganism lacking a true cell wall. The diameter of phytoplasmas is ranging from 175-250 µm. They are either spherical (slightly ovoid) or filamentous (thread-shaped). Occasionally, they produce branched semi-mycelia structures. The size of spherical Phytoplasmas is range from one to a few microns while the branched structure can range in length from a few to 150 microns. Most phytoplasmas are penicillin-resistant, but are sensitive to tetracycline and chloramphenicol; some are sensitive to erythromycin and other newer antibiotics.

4.2.1. Lethal Yellowing Disease

Lethal Yellowing (LY) is considered one of the most dangerous diseases affecting palm trees worldwide especially the coconut (Cocos nucifera). In the early of 1970's, Mycoplasma Like Organisms (MLOs, later renamed phytoplasmas) were found associated with Jamaican Tall coconut palm symptomatic of LY. McCoy (1976) reported that LY disease destroyed around 300,000 coconut palm trees in Miami, Florida in the USA, in less than five years. Thomas (1974) and Chase & Broschat (1991) prepared a list of palm species susceptible to LY disease, which included also the date palm (*Phoenix dactylifera* L.), Canary Island date palm (*P. canariensis* Hort.) and Senegal date palm (*P. reclinata* Jacq). Table 4.4 shows the palm species known to be susceptible to lethal yellowing disease and the species known to be non-susceptible to the disease.

Geographically, the LY disease is spread in the Caribbean countries (Cuba, Jamaica, Bahamas and Cayman Islands), the USA (Florida and Texas states), West Africa (Ghana, Togo, Cameroon and Nigeria) and in East Africa (Tanzania). In Oman, no case of LY disease has been recorded, either on coconut palms in the south or on date palms in the north.

It is believed that a plant-hopper *Myndus crudus* Van Duzee (Hemiptera: Auchenorrhyncha: Cixiidae) is the vector of the pathogen causing LY disease, Fig. 4.19.

Clearly, *Myndus crudus* should by placed on the quarantine list of prohibited insects to enter Oman. It is even more prudent to place all the members of the family Coxiidae on the list. In addition, all LY disease-susceptible palm species, listed in Table 4.4, should be banned from entering Oman or any country free from the disease.

Fig. 4.19. *Myndus crudus*, vector of the LY pathogen.

Symptoms of the Disease

The initial symptoms of LY disease on coconut begin with nut fall or "shelling" on mature palms. Nuts fall first from the mid-crown (water nuts), followed by younger nuts and lastly mature nuts (Chase and Broschat, 1991). Fallen nuts exhibit a dark-brown to black, water-soaked zone at the stem end. In addition, the new inflorescence formed after the initial fruit drop has black-coloured tips and most of the male flowers blacken and die hence, the fruits do not set. Later, the lower, aged leaves turn yellow and then the yellowing progresses from the aged leaves to the young ones. The aged leaves die prematurely as they wither and turn brown. The young leaves turn yellow from the base of the young frond toward the tip. The tips of the diseased, young fronds have brownish streaks and are watery in texture. Generally, the diseased palm is yellow in colour and within 3-6 months of the onset of symptoms the palm will die, Figs. 4.20 and 4.21.

In the case of the date palms, the diseased fronds become desiccated and grey to brown in colour instead of the yellow colour of the coconut palms. LY disease in date palm leads to fruit drop and rotting of the terminal bud causing the death of the palm after its crown topples, leaving a naked trunk.

(Source: FAO, 1999)

Fig. 4.20. The symptoms of LY disease on coconut palm.

Fig. 4.21. Coconut palms, completely destroyed by LY disease.

Table 4.4. Susceptibility of palm species to Lethal Yellowing Disease.

Known to be susceptible		Not known to be susceptible	
Scientific name	**Common name**	**Scientific name**	**Common name**
Aiphanes lindeniana		*Acoelorrhaphe wrightii*	Silver Saw palm
Allagoptera arenaria	Seashore palm	*Arega pinnata*	Sugar palm
Arega engleri	Formosa palm	*Bactris gasipaes*	Peach palm
Borassus flabellifer	Palmyra palm	*Carpentaria acuminate*	Carpentaria palm
Caryota mitis	Fishtail palm	*Chamaerops humilis*	European fan palm
Chysalidocarpus cabadae	Cabada palm	*Chrysalidocarpus lutescens*	Areca palm
Cocos nucifera	Coconut palm	*Coccothrinax argentea*	Silver palm
Corypha elata	Buri palm	*Elaeis guineensis*	African oil palm
Corypha taliera		*Heterospathe elata*	
Dictyosperma album	Princess palm	*Phoenix roebelenii*	Pygmy date palm
Gussia attenuate	Llume palm	*Ptychosperma macarthurii*	Macarthur palm
Howea belmoreana	Belmore sentry palm	*Rhapidophyllum hystrix*	Needle palm
Hyophorbe verschaffeltii	Spindle palm	*Roystonea elata*	Florida royal palm
Latania sp.	Latan palm	*Roystonea hispaniola*	Royal palm
Livistona chinensis	Chinese fan palm	*Roystonea regia*	Florida royal palm
Livistonia rotundifolia		*Sabal causiarum*	Puerto Rican hat palm
Nannorrhops ritchiana	Mazari palm	*Sabal palmetto*	Cabbage palm
Neodypsis decaryi	Triangle palm	*Syagrus amara*	Overtop palm
Phoenix canariensis	Canary Island date palm	*Syagrus romanzoffiana*	Queen palm
Phoenix dactylifera	**Date palm**	*Thrinax morrisii*	
Phoenix reclinata	Senegal date palm	*Thrinax parviflora*	
Phoenix sylvestris	Silver date palm	*Washingtonia filifera*	California fan palm
Pritchardia affinis		*Washingtonia robusta*	Mexican fan palm
Ravenea hildebrandtii	Dwarf majesty palm		
Syagrus schizophylla	Aricury palm		
Trachycarpus fortunei	Windmill palm		
Veitchia spp.	Christmas palm		

Source: Chase and Broschat, 1991

Chase and Broschat (1991) reported that some varieties of coconut palms are highly resistant to LY disease. Table 4.5 shows the degree of resistance of different varieties of coconut palm to LY disease. As for date palm, the resistance status of varieties is not known.

Table 4.5. The highly and moderately resistant varieties of coconut palm to Lethal Yellowing Disease.

Highly resistant varieties	Moderately resistant varieties
India Dwarf	Bougainville Tall
Ceylon Dwarf	Karkar Tall
Fiji Dwarf	Malayan Dwarf
King Coconut	Malayan Tall
	Markhan Valley Tall
	Panama Tall
	Maypan Hybrid

Prevention and Control

The most important prevention and control measures for LY disease are:

- Legislative control measures should be implemented. Issuing and bringing into force the necessary laws and decrees which ban the entry and importation of all parts of the palms of all species and genera (whether coconut palms, date palms or ornamental palms) from countries where the disease is endemic or those countries known to have cases of LY disease.

- The Ministry of Agriculture and Fisheries in Oman issued Ministerial Decree number 23/ 93, on 11 September 1993, which prohibited the entry of all offshoots of date palms, coconut palms or ornamental palms to the Sultanate of Oman from other countries.

- Upon suspecting the presence of the disease, an immediate decision should be taken to remove and burn infected palms or palms suspected of being infected to prevent the spread of infection.

- Cultivating resistant varieties is an important measure on the long run strategy.

- Using pesticides to manage the numbers of vector insects. This may decrease the rate and spread of the disease temporarily, however, it is ineffective on the long run. The costs of the chemical control against the vector insects and the harmful effects of the extensive insecticide use on the ecosystem should be considered, especially as chemical sprays need to be repeated at short time intervals.

- The plant hopper vector, *Myndus crudus*, and other members of the Coxiidae family should be placed on the quarantine list of insects prohibited to enter Oman. The date palm plant hopper, *Perindus binudatus* Emeljanov (Family: Coxiidae) was recently recorded in central Oman. All measures should be taken to eradicate this insect and prevent its spread to other areas.

- Injecting the diseased palms with the antibiotic tetracycline. Each palm should be injected every 4 months by a dose of 1-3 grams of the active ingredient. It was reported that there were no harmful side effects to the injected palms when using up to 20 grams tetracycline per palm. The antibiotic may be injected up to two inches deep into the palm. It is important to point out that the antibiotic injections should not be stopped in order to prevent the recurrence of the disease and that the palms which have disease symptoms on more than 25 % of their crowns, do not respond to the antibiotic treatment.

Even though this method is very costly, antibiotic shots are widely used in Florida, but only to treat infected palms for a limited period of time until new resistant palms are available. It is worth mentioning that, antibiotic injection treatment cannot be applied on a large scale because of the high costs involved. Four techniques have been described to administer tetracycline into the palms infected with LY disease: Gravity flow injection, Mauget injection, Minute-tree injection and self contained air-pressure injection.

4.2.2. Al Wijam Disease (Unfruiting Disease)

Causal Pathogen

Polymerase Chain Reaction (PCR) has enabled the study of tissues of leaves and roots of palms with Al Wijam disease and has supported the hypothesis that the cause of the disease is a phytoplasma. Histological studies of the leaves and roots of healthy and Al Wijam diseased palms after injection with tetracycline showed that in the cross sections of the diseased leaves, the phloem tissues contained phytoplasma particles (FAO, 1999). Al Wijam is considered a disease of limited distribution; nevertheless, it is a deadly disease. The initial symptoms are retardation of growth and no fruit production and eventually, the death of the palms. The disease was first identified by El Bakr, in 1952 in the Eastern province of Saudi Arabia. He reported that the symptoms of the disease were the slowing of growth, reduced vitality and un-fruiting followed by gradual hardening first in the lower fronds then the terminal bud. Finally, the diseased palm dies. Nixon (1954) mentioned that the name Al Wijam is indicative of the development of the pathology of the disease in the palms. The name Al Wijam is used in Al Hassa (Saudi Arabia) to describe a deterioration occurring in the palms, meaning poor or un-fruiting in the Arabic dialect of the region.

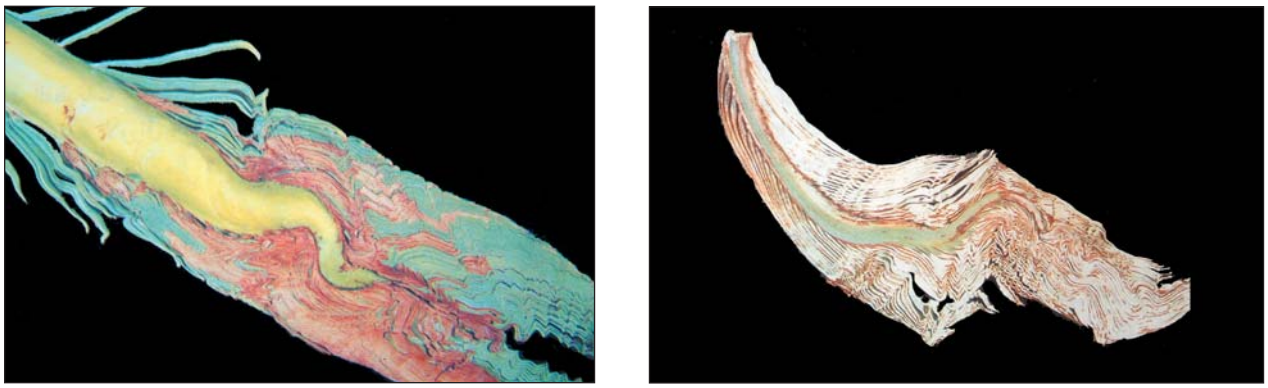
Symptoms of the Disease

Newly formed leaves on the diseased palm are reduced in size and marked by a faint, narrow, yellow longitudinal line on the midribs. Then the leaflets show green streaks on a yellow background and finally the whole leaflet becomes chloritic. The life span of the leaf is reduced and death starts from the distal end and extends towards the base. The leaflets die from the edges of the frond in the direction of the midrib. The crown leaves appear as a rosette. When a section is made through the base of the palm trunk or an infected rachis, the internal tissues show a light brown discolouration. In addition, the symptoms of the disease can be detected on the spathes, as the diseased spathes split open before complete emergence and are reduced in size. The number and size of bunches produced are also reduced year after year until the diseased palm fails to produce any bunches (FAO, 1999).

Atef and Nazeef (1998) reported that the diseased palms may produce deformed offshoots carrying dwarfed leaflets and fronds with thick bases and sharp pointed tips. The pinnae of the leaflets are clustered and entwined and take a zigzag shape after full growth. Sometimes the midribs of the fronds are thick and carry extremely short pinnae. These abnormal growth patterns may appear in healthy palms, but at much lower rates than those with Al Wijam diseased palms.Fewer strong roots are present around the bases of the diseased palms; they are brown with occasional lesions in the root structures. Generally, the growth of Al Wijam diseased palms stops within few years, Figs. 4.22 and 4.23.

Elarosi *et al*. (1983) recorded a number of fungi associated with Al Wijam disease. Fungi of the genus *Fusarium* were isolated and the most commonly present were of the species *Fusarium solani* (Mart.) sacc. They also reported that Al Wijam was accompanied by root rot and discolouration. It was also observed that the severity of the disease varied among date palm varieties. The Hatimi and Khalas varieties were the most susceptible varieties while Wasili and Khasab were the most resistant.

Great similarities were found between the symptoms of Al Wijam disease and the symptoms of the Decline Disease common in Southern California and linked to the fungal pathogen *Omphalia* spp.



(Source: Abdul Qadir and Salah El Din Al Husseini, 1997)

Fig. 4.22. Symptoms of Al Wijam disease as seen on newly emerged fronds.

Fig. 4.23. Early symptoms of Al Wijam disease showing yellow streaks on the pinnae.

Prevention and Control

It is very important to keep in mind that there are no resistant varieties to the disease at the present time and that the control of this serious disease should be done by an integrated programme, considering the following points:

- Avoiding transplantation of offshoots from infected areas to uninfected ones.
- Exerting care in the different cultural processes like balanced fertilisation, moderate irrigation, weeds control, removing and burning the old infected fronds and immediately burning the infected palm remains.
- Treating the early infections in the palm with tetracycline at a dose of 20 grams per palm by injection and repeating this two to three times at two-month intervals.
- Spraying the infected palms with a suitable fungicide such as Carbendazim (Bavistin FL at 100 ml/hl.) to eradicate accompanying fungi. Treating the soil with Banrot 400 WP® fungicide (thiophanate-methyl + etridiazole).

4.2.3. Brittle Leaves Disease

This disease was first reported in Tunisia in the areas of Nefta, Tozeur and Degashe, as well as in Algeria in the areas of Adrar, M'zab and Biskra (Djerbi, 1983). Both adult and young palms were affected as well as the offshoots.

Symptoms of the Disease

The initial symptom is the chlorotic discolouration of the pinnae with broad yellow stripes followed by the dryness of the tip of the fronds. The pinnae are short with irregular sizes. Subsequently a marked reduction in date production ensues due to the advance of the disease to many fronds on the same palm. Retardation or arrest of the growth of the terminal bud becomes evident (FAO, 1999).

Although, the pathogen causing the disease is unknown, as no fungi or other pathogens were isolated from diseased palms, PCR analyses has indicated that the causal pathogen may be a phytoplasma (FAO, 1999), Figs. 4.24 and 4.25. Djerbi (1983) conducted chemical analyses of the diseased date palm leaf tissues and found that the concentrations of all nutrients were high except for manganese, which was abnormally low. Manganese concentrations were 10 times lower in the diseased leaves compared to in samples taken from healthy palms. He also showed that the phosphorus concentration in the soil samples taken from diseased areas and the EC levels were higher than for soil of healthy areas. The high pH and conductivity in the soil may explain the lower available manganese in the soil reflected in a lower concentration in the diseased palm leaf tissues.

Prevention and Control

Quarantine is still considered the only possible measure that can be taken to control the disease and its spread on date palms from infected to noninfected areas. Djerbi (1983) stated that apparently all date palm varieties in Tunisia are susceptible to brittle leaves disease. As manganese deficiency is associated with the disease, elemental manganese can be added to the palms by spraying or injection.

(Source: FAO, 1999)

Fig. 4.24. Date palms affected by brittle leaves disease.

Fig. 4.25. Different stages of brittle leaves disease on date palm fronds.

4.3. Diseases of Unknown Causes

4.3.1. Rapid Decline or Rhizosis

Rapid decline is a minor disease in the USA and even though it is of limited occurrence, it is, nonetheless, considered a serious and devastating disease of date palm. It is also called quick death. This phenomenon was responsible for the quick death of many date palms in Coachella Valley in the USA.

The term "Rapid Decline Disease" is used collectively to describe a group of diseases of unknown causes. Bliss (1936) reported that the symptoms of this physiological disease could be termed "Rhizosis". He observed the first sign of this disease to be dropping of premature fruits in large numbers from vigorous and fruitful palms during spring and midsummer, while the fruits have completed ¼ to ¾ of their complete development. However, if the disease attacks after fruit development, they wither and shrivel on the bunch. The symptoms also include the appearance of a reddish-brown discolouration of pinnae on mature fronds, while the young fronds wilt and become pale. The disease progresses from the base and extends towards the top of the fronds causing the quick, sudden death of the mature fronds and then the younger ones. It is also noticeable that the affected fronds are shorter, smaller and upwardly erect. The diseased palm grows at a slower rate of about 25-35 centimetres each year (healthy palms grow at about 60 cm annually), while the severely affected palms may not manage to grow more than 15 cm each year.

The vegetative buds of the diseased palms stop growing or grow very slowly. The disease leads to reductions in fruiting and flowering of the palms, as the spathe is markedly weak and breakable. The symptoms of the disease are also observed on male palms.

As a general rule, rapid decline disease causes the death of 80-90 % of the green fronds on the affected palms leading to a decrease in the quantity and quality of the produced dates. According to Djerbi (1983), rapid decline disease attacks all varieties and no resistant or tolerant varieties have been observed. There are no effective control measures.

4.3.2. Bending Head

Bending head is a minor disease observed in Algeria, Egypt, Mauritania and Tunisia (Munier, 1955). The symptoms of this disease can be observed as the central cluster of fronds takes the form of an erect fascicle with a bent tip. In addition, the trunk bends and may even break. This phenomenon has no connection with the previously described bending head disease, which is a disease with a recognised fungal causal agent (*Thielaviopsis paradoxa*).

Hamouda *et al*. (1998) reported that the bending terminal bud (head) phenomenon is common in the date palm variety Qash Menouma which is widely cultivated in the Batinah coastal area of Oman. It is also appears on the Shahlee and Barhee varieties. It was observed that it affects neither the quality nor the quantity of the date yield as it does not decrease the growth or activity of the palm. Usually, the palm recovers and the growing point straightens after some time.

It was also noticed that this symptom rarely occurs in palms younger than 10 years old or shorter than 3 metres. Some researchers attribute bending head to the irregular distribution of fruits in the crowns of the palms because the bend usually occurs during fruit setting and on the

side where more fruits are concentrated. It was also found that irregularities in the bunch distribution in the crown may be the result of hot, dry winds during flowering which lead to the dryness of the stigmas of the flowers. Thus, pollination is restricted and consequently a severe reduction in fruit production occurs on the side facing the wind. Consequently, fruits are concentrated on the side of the crown away from the wind, causing the heart to bend.

Hamouda *et al*. (1998) suggested that the irregularities in fruit distribution might be due to differences in the rate of sugar synthesis based on a difference in the period of exposure to direct sunlight. The leaves on the side facing direct sunlight for longer times would have a higher rate of sugar synthesis. The increased synthesis and storage of the sugars in the fronds facing the sun for a longer period causes an increase in the number of buds in the axils of the fronds; they also develop faster than those in the opposite side. As a result, the production of flowering stalks and bunches and the growth and development of the fruits are better on the side receiving more direct sunlight. The rate of fruit ripening is higher and the percentage fruit-drop after ripening is lower in the side facing the sun. Accordingly, the increased total weight of the fruits, due to the presence of more stalks and the increased weight of individual date fruits, causes the head of the palm to bend.

Darley (1964) studied the phenomenon of the bending head on the Barhee date palm variety in the USA. Anatomical investigations done on the crowns of palms showing typical signs revealed that the heart (growing tip) tissues were normal and the terminal buds were erect. It was also observed that the bent frond bases (petiole bases) were normal and without any pathological abnormalities. To prevent or limit the spread of the problem, pruning is recommended followed by burning of removed fronds.

Fig. 4.26. The bending head phenomenon.

4.4. Physiological Disorders

4.4.1. Barhee Disorder

The Barhee variety of date palms is considered one of the finest and its dates are among the most expensive in the world. Some Barhee palms experience a sudden bending of the head without prior warning signs. This disorder is observed wherever the Barhee variety is cultivated, Fig. 4.27. The disorder, also called the Barhee disease of abnormal heads, is common in Iraq and the USA. Fortunately, it constitutes no serious threat to the palms as it affects neither the quality nor the quantity of the date production, has no effect on the growth and activity of the palms and is not contagious.

The most probable cause of this disorder is a physiological weakness in the crown area, either genetically induced or due to an imbalance in weight distribution and irregularities in the bunch arrangement on the crown of the palm (Osman and Abdel Redha, 1989).

Darley *et al*. (1960) studied Barhee disorder extensively and showed that it appeared suddenly without warning and that the central (heart) fronds bent mainly towards the South or South East, sometimes towards the East or West but never towards the North. The degree of bending ranged from 5° to 90°. When terminal buds were inspected, they were healthy, erect and the tissues were normal.

The bending occurs above the bud level. No necroses in the heart fronds bases have been found nor were any fungal infections present. Barhee disorder seldom occurs in palms younger than 15 years old or shorter than 4.57 meters in height. Barhee disorder is a transient condition and the palms regain their upright position after some time. There are some precautionary measures that can be followed to prevent or decrease the occurrence of this phenomenon, which can be summarised as follows:

- Ensuring that bunches are distributed in a balanced manner.
- Concentrating the palm bunches opposite to the bending direction. The Barhee variety is characterised by its long inflorescences which can be positioned around the crown.
- Care and attention should be given to the cultural processes especially fertilisation and regular irrigation.

Fig. 4.27. Barhee disorder.

4.4.2. Bastard Offshoots

Fig. 4.28. Bastard Offshoot Disease on a date palm.

Occasionally, twisted deformed new leaves or unusual growths of date palm vegetative buds occur especially on offshoots fronds. The growing fronds are very distinctively abnormal, corrugated and dwarfed. Mohamed and El-Haidari (1965) stated that the bastard condition is due to infestation by the date palm bud mite *Makiella phoenicis* K. It may also be due to reduction in growth caused by disequilibrium of growth regulators, Figs. 4.28 and 4.29.

Fig. 4.29. Close-up of bastard offshoots.

4.4.3. Albinism

Hamouda *et al*. (1998) described albinism as the emergence of some fronds white in colour because of the lack of chlorophyll. According to the ratio of white to green fronds, flowering and fruiting are affected. It is believed that this phenomenon is linked to recessive genetic factors or to cytoplasmicly heredity characters, Fig. 4.30.

Fig. 4.30. Albinism in date palm.

Some studies conducted on the seeds of citrus fruits have shown that albinism can be induced in some cultivars, by infecting the seeds with certain strains of the fungus *Alternaria tenuis* or by planting the seeds adjacent to fungal extracts. The effect is due to the production of a certain chemical substance that interferes with the synthesis of chlorophyll in the growing seedlings.

4.4.4. Leaf Apical Drying

The leaf apical drying phenomenon occurs in outer, i.e. older fronds, of adult palms which have been transported when mature. This is not a pathological condition but rather a physiological reaction to transplantation due to injury of the root system. It has been observed that all palms with these symptoms recover within 2 to 3 years after transplanting, Fig. 4.31.

Fig. 4.31. A recently transplanted adult palm showing leaf apical drying.

4.4.5. Black-nose

Black-nose is a physiological disorder which affects the date fruits causing deformities and lowering their quality and market value. Black-nose is induced by various factors related to high humidity. It applies to the abnormally shrivelled and darkened tip of a date fruit. The disorder is common in Tunisia, Algeria, Morocco, Egypt, Libya, Mauritania, Iraq and the USA.

It appears in abundance with excessive irrigation, rainfall or the presence of morning dew while the fruits are in the late Kimri stage of development. Excess irrigation in the summer causes checks or breaks on the epidermis especially near the style end of the date fruit. At first, small, transverse breaks appear, followed by dryness and necrosis in the layer under the checked epidermis leading to its blackening. The symptoms do not appear on the green fruits in Kimri stage, but appear at the end of the green state, late Kimri.

The fruits in Khalal stage are easily affected by increases in the humidity and checking can appear rapidly. Fruits in the early Khalal stages are distressed by rainfall or accumulation of dew during the night. Excessive thinning of fruit bunches on an individual palm can also lead to the appearance of black-nose.

Fawcett and Klotz (1932) reported that the Deglet Nour variety is the most susceptible to black-nose in the USA, while Hayani is the most susceptible variety in Egypt.

The following measures should be followed to prevent the appearance of black-nose:

- Exerting great care in regulating irrigation especially during the summer and avoiding excessive irrigation.
- Proper and moderate thinning of the fruit bunches and stalks; over thinning can increase the incidence of checking and subsequent development of black-nose.
- Good ventilation of the fruit bunches. Iron rings can be placed inside the fruit bunches to increase ventilation.
- Bagging the fruits in brown wrapping paper can inhibit the occurrence of black-nose (Nixon, 1932).
- Decreasing the moisture around the palms by controlling weeds and avoiding summer intercrops to decrease irrigation.

4.4.6. Checking

Checking occurs when the atmospheric relative humidity increases around bunches, during the change in fruits from Kimri (green stage) to Bisr (coloured stage). High relative humidity prevents evaporation from the fruit surface, while the water movement inside the palm continues, leading to swelling and enlargement of the cells under the epidermis. This shows as checks or breaks. Checking appears as horizontal or longitudinal black, fine lines and all the cells in the area around the check die. The numerous checks on the fruit lead to hardening of the epicarp and the dryness of the mesocarp, greatly diminishing the quality of the dates. Crowded fronds and over shading promote checking, Fig. 4.32.

Fig. 4.32. Symptoms checking on date fruits.

The economic importance of checking is dependent on the abundance of the checks. If the number of dates affected and/or the number of check on each date is low, no economic losses are incurred. Severe expression of checking on the dates renders them unsuitable for human consumption. Hussain (1985) report that the variety Khenaizi is resistant to checking, more so than Khalas, whereas Deglet Nour in USA and Hayani in Egypt are the most susceptible varieties. There are several measures to be taken to decrease the incidence of the checking:

- Providing enough ventilation around the fruit bunches by appropriate thinning.
- Removing the dry old fronds under the fruit bunches during the preparation process.
- Properly spacing the palm trees particularly of susceptible varieties.
- Avoid planting fruit trees densely between the palm trees.
- Collecting the summer crops and intercrops before the date fruits change into Khalal stage.
- Scheduling the irrigation and decreasing the number of irrigations during summer to decrease the relative humidity around the date palms.

4.4.7. Black Scald

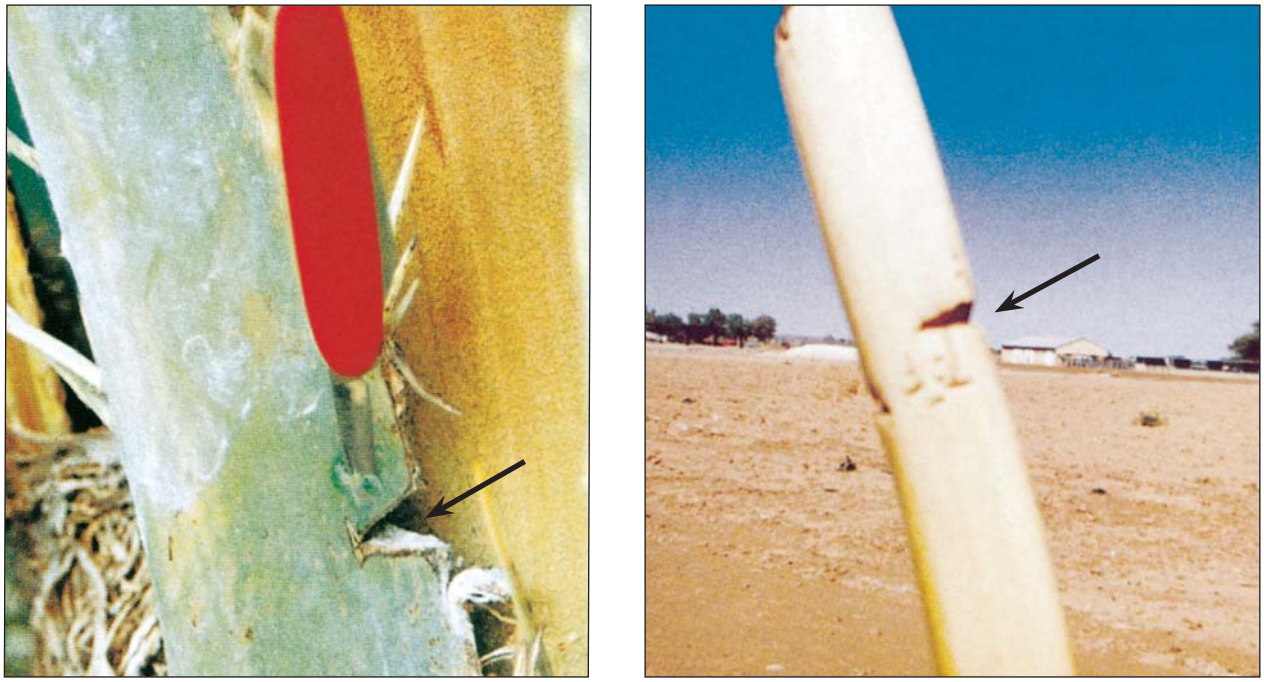
Black scald is considered a minor disorder causing little economic loss. Black spots appear on the affected palms and the involved tissues acquire a bitter taste. Nixon and Carpenter (1978) pointed out that black scald refers to the area or areas near the tip of the fruit (style end) or the fruit sides which appear black in colour, soft and sunken as if the dates were subjected to very high temperature (or burned). Usually, there is a demarcation between the healthy and affected tissues in the fruit. Black scald is present in the USA and is of unknown cause. However, it always occurs associated with checking and black-nose.

4.4.8. Crosscuts or Transverse Notches

This disease is of limited-distribution; a non-contagious, physiological disorder. It affects the fruit stalks and fronds and was recorded in the USA, Pakistan, Palestine and Iraq (Bliss, 1937; Djerbi, 1980). Crosscuts are capable of causing some economic damage. The disorder appears as clean cuts on the tissues of the lower portion of the stalk and on the fronds as if it were done artificially by a sharp knife, Fig. 4.33.

As a result, the fruits on the injured stalk may shrivel and become of low quality. Crosscuts result from anatomical defects in the fruit stalks or the fronds. Internally, sterile cavities are present that lead to mechanical breaks during elongation of the stalks or fronds during the process of fruit bunch growth.

Crosscuts disease was found to be more common in varieties having crowded leaf bases or when the palm gets older. Some varieties were reported to be resistant to the disease including Deglet Nour, Dayri and Halawi while the sensitive varieties include Sayer and Khadrawy, as reported by (Carpenter, 1975). It is understandable that the control measures for the crosscuts disease should include cultivating the resistant varieties and limiting the number of fruit bunches per palm in the sensitive varieties.



(Source: FAO, 1999)

Fig. 4.33. Symptoms of Crosscuts, appearing as sharp and clean cuts on:
1. tissues of the stalk base. 2. tissues of the frond.

4.4.9. Fruit Shrivel

Occasionally, fruits shrivel while still in Khalal stage, developing to Bisr stage, i.e. before attaining the utmost size, the maximum content of sugars and solid mass. The fruit shows crinkles and shrinkages on its surface, before it dries gradually to become Hashf (Ar.), only suitable as animal fodder, Fig. 4.34.

Fruit shrivel can be attributed to many reasons which can be grouped into the following:

- Excessive load of fruits on a single palm.
- Insufficient irrigation and improper irrigation during summer or fruit ripening period.
- Harsh arid weather conditions of high temperature and low relative humidity in the summer season.
- Exposure of the fruit bunches to sun scorch.
- Exposure of fruit stalks to mechanical damage, leading to partial or complete breaks.

There are some measures that can be taken to minimise the development of fruit shrivel summarised as follows:

- Appropriate and balanced thinning of fruit bunches, with the ratio of one bunch for every 6 to 8 green fronds.
- Regular irrigation especially in the summer.
- For varieties having long fruit bunches, it is advisable to remove nearly one quarter of the fruit stalks from each bunch. The long fruit bunches have more fruit shrivel at the end of the stalks because they cannot supply the distal fruits with sufficient nutrients and water.

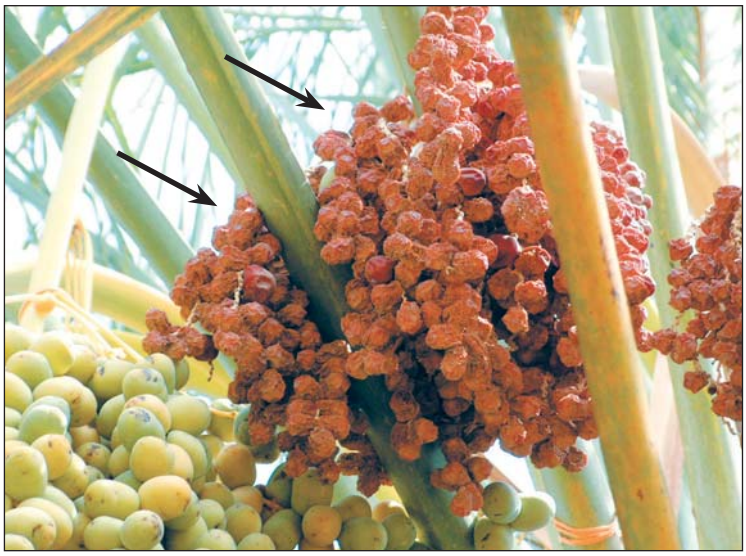


Fig. 4.34. Fruit shrivel disorder.

4.4.10. Constriction of Date Fruit

Abnormal growth patterns may be observed in the date fruits, as their tips may stop growing or slow down after exposure to some unsuitable environmental conditions, Fig. 4.35. Later on, a period of accelerated growth may follow leading to the development of a constriction around the fruit, much like a waist. The cause, in most cases, is infestation by spider mites.

Fig. 4.35. Fruit Constriction phenomenon, the presence of "waists" on the date fruits can be observed.

4.4.11. White-nose

White-nose is a physiological condition caused by hot, drying winds while the date fruits are changing from Rutab stage into Tamar stage. It is common in Iraq, Libya, Morocco, and the USA (Hussain, 1974; Djerbi, 1983). In Iraq, the disorder is called Abu Khashim (Ar.) in Basra while in Baghdad it is called Kasb (Ar.), (i.e. tough and dry).

White-nose disorder is characterised by hardening of the parts of the fruit near the calyx end. A pale coloured (whitish) ring appears on the fruit near the calyx after the rapid change from Rutab to Tamar stage as a result of the drying conditions. The affected fruit becomes very dry, hard and has high sugar content.

In Iraq, Abu Khashim disorder appears in Hilawi and Zahidi varieties and it was noticed that the incidence is usually higher in the dates of palms grown near the desert. Hussain (1985) reported that the appearance of Abu Khashim on the Hilawi and Zahidi varieties is influenced by certain factors including:

- The place of the plantation: The incidence of Abu Khashim disorder ranged from 8-13% in the date palm groves near Shat-el Arab, South of Iraq. While, it increased rapidly in plantations near the desert, reaching between 20-70%.

- The position of the fruit stalks: The incidence of Abu Khashim differed among the dates on the same fruit bunch, ranging from 1 to 9 % in the inner stalks and much higher, between 6-20% in the outer stalks.

- The number of dates on each fruit bunch: It was found that Abu Khashim incidence was lower in the fruit bunches of more than 700 dates (around 19 %). In the fruit bunches containing 300 dates or less, the incidence increased to about 62%.

From various studies it is clear that Abu Khashim disorder leads to a marked decrease in the quality of the tamar. In Hilawi and Zahidi, the disorder affects the quality and the sugar content of the tamar. Table 4.6 summarizes the studies conducted by Hussain (1985) to determine the effect of Abu Khashim disorder in decreasing the quality of dates by changing the ratios of sugar content.

Table 4.6. The effect of Abu Khashim (white-nose) on sugar contents of dates of Hilawi and Zahidi varieties.

Date Palm Variety	Fruit Condition	Sugars Percentage		
		Total	Monosaccharide	Disaccharide
Hilawi	Intact	84 - 88	81 - 88	0 - 3
	Affected	86	73	13
Zahidi	Intact	83 - 86	74 - 75	8 - 12
	Affected	85	52	33

To manage white-nose, there are several measures which should be applied, including:

- Wrapping the fruit bunches with paper bags, when the dates are in Rutab stage.
- Collecting the fruit bunches, when the dates are still in Rutab stage and leaving them to ripe artificially.
- Freezing the affected dates, and then subjecting them to a temperature of 60-75° C in relative humidity of 70% for 72 hours.
- Some studies have shown that Abu Khashim disorder can be limited by the use of growth regulators. The incidence of Abu Khashim could be reduced from 28% to 1% by treating the fruit bunches with Naphthalene Acetic Acid (NAA) at 25 part per million.

4.4.12. Effects of Drought and Salinity

A. Effect of Drought

Date palms can tolerate dryness and a decrease as well as an increase in soil moisture. However, the growth of the palm is highly affected by the amount of water applied. A decrease in the yield or complete failure to produce fruits could be a result of not getting enough water during growth and development, Fig. 4.36.

Hamouda *et al*. (1998) reported that the anatomical and morphological features of the date palm help to withstand intermittent periods of drought. This is because the palm trunk is protected by the dry frond bases and the midrib and leaflets of the fronds are covered by a thick cuticle. In addition, it is able to keep the stomata closed for long periods to limit the amount of water lost while the soil is dry.

There are several factors that determine the water needs of the date palms including: type of soil, prevailing weather conditions, ground water level, soil salinity, age of palms, irrigation method, irrigated season and the kind of intercrops cultivated under the palms. One of the most important factors when calculating the quantity of irrigation water is the amount of water lost from the soil surface due to evaporation and from the palms due to transpiration, or collectively evapotranspiration, as well as the amount of water needed for leaching i.e. washing the soil of the excess salts in the case of high salinity.

B. Effect of Salinity

Different crops vary in their capacity to tolerate and to grow normally at high salinity, whether soil or water

salinity. Arar (1975) showed that date palms are among the most tolerant to the effects of salinity, growing in soil containing up to 3 % soluble salts. However, when the soluble salts rose to 6 %, growth ceased. Arar (1975) also studied the capacity of some major crops to withstand salinity and the requirements for soil leaching.

Table 4.7 shows the expected loss in yield of some major crops under different degrees of salinity in the irrigation water and the needs of the soil for leaching. From these data, we can conclude that date palms can be irrigated with water of a salinity of up to 3.5 mmhos/cm (i.e., around 2240 ppm) without any significant decrease in their yields, provided that the requirements for soil leaching calculated at 7 % are met. When irrigating the palms with water of a salinity of 5.4 mmhos/ cm (i.e., around 3392 ppm) with soil leaching requirements of 11% the expected decrease in the yield is 10%. A 50 % reduction in expected yield is observed when the salinity of the irrigation water reaches 10 mmhos/ cm (i.e., around 6400 ppm), with a leaching requirements of 21%.

Table 4.7. Expected reductions in yields of crops due to salinity of irrigation water.

Crop	Expected Reduction in Yield (%) Highest Conc.												ECdw
	Zero %			10 %			25 %			50 %			
	ECe	ECw	LR	ECe	ECw	LR	ECe	ECw	LR	ECe	ECw	LR	
Date palm	5.3	3.5	7	8.0	5.3	11	-	-	-	16	10	21	48
Barley	8.0	5.3	12	12.0	8.0	18	16	10.7	24	18	12	27	44
Sugar Beet	6.7	4.5	11	10.0	6.7	16	13	8.7	21	16	10.7	26	42
Cotton	6.7	4.5	11	10.0	6.7	16	12	8.0	19	16	10.7	26	42
Wheat	4.7	3.1	8	7.0	4.7	12	10	6.7	17	14	9.3	23	40
Rice	3.3	2.2	12	5.0	3.3	18	6	4.0	22	7	4.7	26	18
Kidney beans	1.0	0.7	6	1.5	1.0	8	2	1.3	11	3.5	2.3	19	12
Figs & Olives	3.3	2.0	8	5.0	3.5	12	-	-	-	9	6	21	28
Citrus fruits	1.7	1.1	7	2.5	1.7	11	-	-	-	5	3.3	33	16
Strawberries	1.0	0.7	7	1.5	1.0	10	-	-	-	3	2	20	10

ECe = Electrical Conductivity of soil saturation extract in mmhos/cm.

ECw = Electrical Conductivity of irrigation water in mmhos/cm.

LR = Leaching Requirement.

ECdw = maximum concentration of salts that can occur in drainage water under crops due to ET.

N.B. For conversion to TDS as PPM multiply mmhos/cm by 640.

Fig. 4.36. Date palms suffering drought stress.

Fig. 4.37. The effect of salinity on date palm.

Ayers and Westcott (1985) report that date palms require irrigation water of an acceptable quality and in reasonable quantity to attain the maximum yield possible. To reach this goal, all cultural processes should be performed with the utmost care. In addition, the average electric conductivity of the soil (ECe) should not exceed 4 dS/m and the salinity of irrigation water (ECw) should not be more than 2.7 dS/m. Only then can maximum yields be achieved. When the previous values are exceeded, soil leaching should be performed. Table 4.8. shows the yields expected at different levels of soil and water salinities. Crop yields decline to 50 % when the soil salinity is 18 dS/m and irrigation water salinity is 12 dS/ m. However, when the soil salinity is as high as 32 dS/ m and that of water 21 dS/m no yield is achieved. Fig. 4.37. shows the effect of salinity on date palms, with a clear deterioration of the palms and whitening of fronds.

Table 4.8. ECe and ECw values with corresponding yield expectations.

Yield (%)	Soil Salinity ECe (dS/m)	Irrigation Water Salinity ECw (dS/m)
100	4.0	2.7
90	6.8	4.5
75	11.0	7.3
50	18.0	12.0
0	32.0	21.0

The quantity of water needed for leaching can be calculated as follows (FAO, 1999):

$$LR = \frac{ECw}{[5(ECe) - ECw]}$$

Where: LR = Leaching Requirement (fraction).
ECw = Electric conductivity of the water (dS/m).
ECe = Electric conductivity of the soil at % yield to be obtained (dS/m).

In addition, this quantity of water is over and above the nett irrigation requriment by the crop during the season. Accordingly, the total annual requriment of irrigation water, can be calculated from the following formula:

$$AW = \frac{ET}{[1 - LR]}$$

Where: AW = Depth of water apply (mm/yr).
ET = Total annual water demand (mm/yr).
LR = Leaching requirement.

4.5. Diseases caused by Nematodes

Although, Plant parasitic nematodes constitute only 10 % of the total number of nematode species, all species of plants are attacked by one or more species of nematode. Phytonematodes comprise either external parasites (ectoparasitism) or internal parasites (endoparasitism). Nematodes are usually not more than 5 millimetres in length with a diameter not more than 100 microns. In Oman, Waller and Bridge (1978) conducted scattered field studies in different areas of Oman and recorded species of plant parasitic nematodes on different plants. They reported the following species: *Meloidogyne* spp. on various vegetables, *Helicotylenchus multicinctus* on bananas, *Tylenchulus semipenetrans* on lemon and *Pratylenchus brachyurus* on alfalfa. In a comprehensive study conducted in 1993 by The Agricultural Research Centre in Oman, 35 different species of plant parasitic nematodes were identified and recorded infesting various crops in Oman. They included thirteen different species infesting date palms in the Batinah region (Anonymous, 1993). Table 4.9 shows the identification of these species and the severity of infestation represented by the density of nematode populations.

Table 4.9. The different species of nematodes identified and recorded on the date palms in Oman.

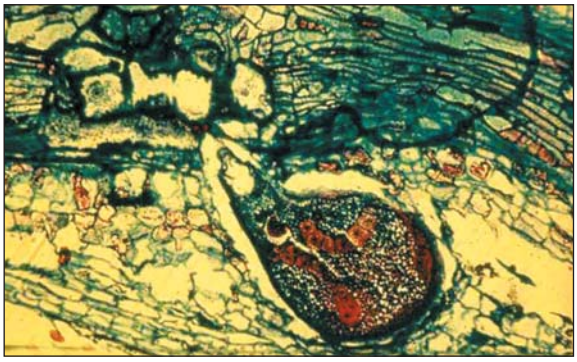
Common Name	Scientific Name	Severity of Infestation (density of population)*
Root-Knot Nematode	*Meloidogyne javanica* (Treub) Chitwood	Moderate - Very high
	Meloidogyne incognita (Kafoid & White) Chitwood	Moderate - Very high
Lesion Nematode	*Pratylenchus brachyurus* (godfrey) Filipjev & Sch. Stek	High
Ring Nematode	*Criconemoides* spp.	Low
	Hemicriconemoides mangifera Siddiqi	Moderate- High
Spiral Nematode	*Helicotylenchus dihystera* (Cobb) Sher	High
	Helicotylenchus multicinctus (Cobb) Golden	Moderate - High
Stunt Nematode	*Tylenchorhynchus* spp.	Moderate - High
Needle Nematode	*Longidorus* spp.	Moderate
	Paralongidorus citri (Siddiqi)	Low
Dagger Nematode	*Xiphinema americanum* Cobb	Moderate - High
	Xiphinema spp.	Low - Moderate

* The density of the population, (according to the number of nematodes), was estimated as follows:

Infestation	Ectoparasitic Nematodes	Endo-/semi-endoparasitic Nematodes
Low	1 - 50	1 - 250
Moderate	51 - 100	251 - 500
High	101 - 250	501 - 1000
Very High	> 250	> 1000

4.5.1. Root-Knot Nematodes

1. *Meloidogyne javanica* (Treub) Chitwood
2. *Meloidogyne incognita* (Kofoid & White) Chitwood
(Tylenchida: Meloidogynidea)



Root-knot nematode, *Meloidogyne* sp.

The *Meloidogyne* spp. attacks several crops in Oman and they are recorded for many vegetables including cabbage, cauliflower, eggplant, lettuce, okra, onion, potato, sweat potato, tomato and water melon. It is also found in many fruit trees including date palms, coconut palm, fig and grapes. Some field crops are also infested including alfalfa, peas, and green beans.

Several species of the genus *Meloidogyne* cause root knot disease in thousands of different plant species and are considered one of the most serious phytonematodes.

Four main species of *Meloidogyne* have been recorded on date palms in many countries:
1. *Meloidogyne javanica* (Treub) Chitwood
2. *Meloidogyne incognita* (Kofoid & White) Chitwood
3. *Meloidogyne hapla* (Chitwood)
4. *Meloidogyne arenaria* (Neal) Chitwood

Females of *Meloidogyne* spp. can be easily differentiated from the males and larvae which retain their worm-like form while the females are pear-shaped. The female also has slightly pointed frontal tip forming a narrow neck and a movable head with a body length approximately 541-804 µm (657 µm); with a diameter of 311-581 µm (431 µm). The male is worm-like and is 757-1297 µm (1131 µm) long; with a diameter of 17.5-42.9 µm (37.5 µm) (Orton Williams, 1972). Both the male and female nematodes live in soil where they copulate. Each mature female in roots produce up to 500 eggs into a gelatinous egg sac. The egg sac usually becomes bigger than the female which produced it. The embryo develops inside the egg till the first larval stage, and then the first moult occurs inside the egg for the second larval stage to emerge. Under favourable conditions of temperature and moisture, the second larval stage leaves the hatched egg and is capable of infesting the plant roots. There is a spear on the frontal end of the larva which is used to puncture the root tissues. This second stage larva usually penetrates the roots at the growing tips and moves through the epidermis to settle in such a way that the frontal end is in direct contact with the vascular cylinder of the root. The larva stimulates the plant to produce gigantic cells around its head from which it extracts its food supply forming at this point, the root- knots.

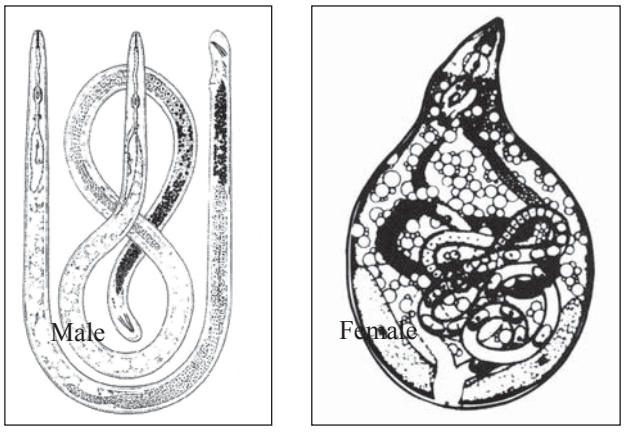


Fig. 4.38. Male and female of root-knot nematodes, *Meloidogyne* sp.

When the larvae are settled inside the roots and become sedentary they thicken and take a distinctive sausage shape. The nematodes feed on the root cells by inserting their spears and secreting their salivary secretions which promote the elongation of the root cells and dissolve the cellular contents. Later, the nematodes moult for a second time and the third larval stage emerges, resembling the second stage larvae but somewhat thicker and lacking the spears. The third larval stage moults to become the fourth stage. At this stage the females can be differentiated from the males: the males are worm-like and pass through the fourth moulting, leaving the roots to live freely in the soil as mature males, retaining their vermiform appearance.

The female larvae in the fourth stage continue to grow, mostly in width less so in length and pass through the fourth moulting to become mature female nematodes with the characteristic pear shape. They continue to swell and lay eggs, which can be fertilised, or not, by the males. The females continue to feed on the giant cells and lay eggs in the gelatinous ovisacs. The eggs can be laid either inside or outside the root tissues. The complete life cycle during the summer can take from 3 to 4 weeks and is somewhat longer in the winter. Overall, the number of generations of the root-knot nematode per year ranges from 7 to 10 overlapping generations.

Signs of Infestation

The most important signs of infestation by root-knot nematode on date palms are summarized in the following points:

- Retardation in the palm growth and the appearance of swellings or galls resembling knots on the roots due an increase in both the number and size of the plant cells.
- Weak growth of the fronds of the diseased palms accompanied by yellowing, signs of malnutrition and wilting especially in the afternoons.
- Decline in the quantity and quality of the harvest date fruits.
- The anatomical feature of the diseased roots is the presence of giant cells in the vascular cylinder area around the nematode head. Such giant cells have multiple, enlarged nuclei and provide food for the nematodes.

Diagnosis should be based on the isolation of nematodes. The presence of the ovisacs on the surface of the galls, especially if dyed and identification of female nematodes and/or larvae inside the roots is indicative of the presence of an infestation.

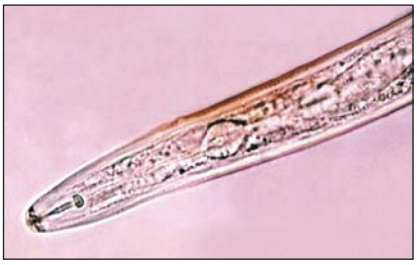
The economic importance of nematode infestation on date palms cannot be easily estimated because of lack of sufficient data. However, it is certain that the lowered yields of date palms in many countries are related to the presence of nematodes.

Some studies reported by Hussain (1985) showed the percentage of germination of date seeds to be 91% in nematode-free soil and 9 % in nematode-infested soil. He also found that the percentage death of young seedlings was only 1 % in nematode- free soil, while it was 26 % in soil infested by nematodes. It was also reported that the weight of a normal, healthy seedling grown in nematode-free soil at the age of 10 months was 15 g and 58 centimetres long, with 7 leaflets and 6 roots. Root-knot infested seedlings at the same age weighed 35 g, were 35 centimetres long and had 6 leaflets and 6 roots.

However, the roots of the infested seedlings were very heavy, constituting about 43-46 % of the total weight of the seedling, whereas the roots of healthy seedlings accounted for about 29-31 % of the total weight.

4.5.2. Lesion Nematodes

Pratylenchus brachyurus (Godfrey) Filipjev & Schuurmans Stekhoven (Tylenchida: Pratylenchidae)



Female of lesion nematode, *Pratylenchus* sp.
with a visible spear at the anterior end

Lesion nematodes are considered the most important species of migratory endo-parasites, or endo-migratory nematodes which can infest and move within the roots. They are distributed worldwide. Lesion nematodes are responsible for the decline and deterioration of the root system by retarding or stopping its growth. They form localised, necrotic lesions on the young roots, a condition followed by infection by opportunistic bacteria and secondary fungi leading to root rot. As a result of the root damage, the diseased plant grows weakly, produces low yields and may eventually die. In addition, lesion nematodes play a role in lowering the resistance of some plants to other diseases, e.g. wilt diseases. Mature male and female lesion nematodes are not differentiated morphologically; both being vermiform and cylindrical in shape. The fully grown nematode is small, less than 1 mm long (0.39-0.75 mm) and (15-29 µm) in diameter (Sher and Allen, 1953). Males are rare. When present, both females and males have the same form, but the latter is smaller, with a single outstretched testis. Phasmids located behind the mid tail and do not extend into the bursa. Simple trough shaped gubernaculum with arcuate spicules are present.

In Oman, four species of lesion nematodes of the genus *Pratylenchus* have been recorded on many vegetables, fruit trees and field crops. These are *Pratylenchus brachyurus* (Godfrey) Filipjev & Sch. Stek., *Pratylenchus coffeae* (Zimmerman) Filipjev & Sch. Stek., *Pratylenchus delattrei* Luc and *Pratylenchus pseudopratensis* Seinhoust.

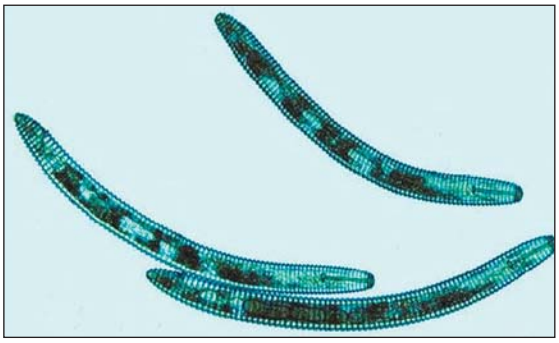
Signs of Infestation

The main sign of infestation by lesion nematodes is the presence of ulcerative, elongated spots, which coalesce to cover most of the root. The lesions are produced by the feeding of the nematode on the epidermal tissues as well as the mechanical damage caused by the movement of the different stages of the nematode inside the root. The lesions later become infected by saprophytic bacteria and fungi present in the soil leading to blackening and rottenness of the infected parts. In the final stage, the root decays and disintegrates. The complete life cycle of lesion nematodes takes from 45 to 65 days.

Lesion nematodes differ from root-knot nematodes in that the former can attack the roots in all their developmental forms and can leave the roots and migrate to the soil to live freely in the soil to return later to attack the same or adjacent roots. Lesion nematodes can be isolated from the infested roots or from the surrounding soil. In contrast, the root-knot nematodes can infest the root as second-stage larvae only.

4.5.3. Ring Nematodes

1. *Macroposthonia* spp.
2. *Hemicriconemoides mangifera* Siddiqi
(Tylenchida: Criconematidae)



Females of ring nematodes

Two species of ring nematodes have been recorded on date palms. The genus *Macroposthonia* (formerly Circonemoides) contains more than 90 different species of nematodes, all characterized by being short and thick with low motility. The body of the nematode also has deep and transverse striation in the cuticle resembling rings. The males are usually either atrophied or absent altogether; having atrophied spears and oesophagi. It is virtually impossible for adult males to feed.

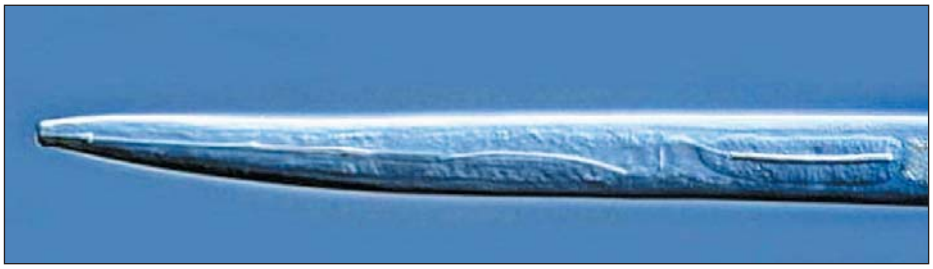
In addition, the species Hemicriconemoides mangifera Siddiqi. is recorded on date palms in Oman. The female of *H. mangifera* has a cylindrical body, tapering towards the ends, slightly arcuate when fixed, enclosed in a circular sheath which is attached at head end, excretory pore, vulva, anus and sometimes at tail end; the maximum width of body and sheath is about 27 and 30 µm, respectively. Sheath annuli are smooth but sometimes with numerous longitudinal indentations, 3-4 µm wide near mid-body; lateral fields are absent. The total number of sheath or body annuli varies from 111 to 152 in various populations.

Males of this species are generally common. Markedly different from female, they are slender and lacking a cuticular sheath. Spear and oesophagus are degenerated. Annuli are fine, about 1.5 µm wide at mid-body.

Ring nematodes can infest many plants including grapes, peach, date palms as well as ornamental and herbaceous plants. They are ecto-parasites; they live and move freely in the soil, feeding on the roots from the outside without entering the host root. With its spear inserted in the host root, the nematode remains almost motionless while feeding.

4.5.4. Needle Nematodes

1. *Longidorus* spp.
2. *Paralongidorus* spp.
(Aphelenchida: Longidoridae)



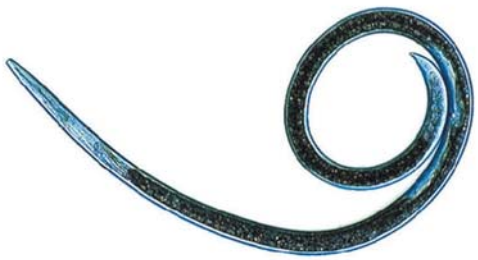
Female of needle nematode with a clear long spear inside the body

Two species of needle nematodes were recorded on the date palms. Needle nematodes are the longest species of phytonematodes as the female body length is 4.5-6.4 mm (5.5 mm) and 76-123 µm (92 µm) in width, with a long spear which may reach up to 150 µm. Males are usually very rare or absent in most populations, but in some populations they may be almost as common as females. The anterior region similar to that of the female, posterior third is curved ventrally when killed by heat. The genus *Longidorus* contains 94 different species some of which cause great damage to many plant species, while the genus *Paralongidorus* contains 34 species. The importance of needle nematode infestations is exacerbated by their capacity to transmit plant viruses, a feature they share with the dagger and root-knot nematodes.

Needle nematodes live and move freely in the soil, feeding on the roots, preferring nutritious young roots. They cause dwarfism and discolouration and destruction of the active meristematic tissues leading to stunted growth and knottiness in the roots. Needle nematodes on date palms have been recorded in Oman and some other countries. However, the extent of their economic importance is still to be determined.

4.5.5. Dagger Nematodes

Xiphinema americanum Cobb
(Aphelenchida: Longidoridae)



Female of dagger nematodes

Dagger nematodes resemble needle nematodes in their long body although they are somewhat shorter, the female body length being only 1.55-1.73 mm long and 41.5-45.5 µm wide. Males are rare and not necessary for reproduction. The body has greater curvature in the posterior region. The basal guiding ring is 51 µm from the anterior end of the body. Spicules are rather straight, cephalated, and 29 µm long. A dagger nematode has a long spear which penetrates the inside layers of root tissues feeding on the inner cells. The dagger nematode takes a characteristic curved shape, resembling a dagger, hence the name. Needle nematodes and the dagger nematodes can be easily differentiated by the position of the spear leading ring and by the presence or absence of the basal flanges of the spears. In the needle nematodes, the basal flanges are absent and the leading ring is in the frontal end of the spear, whereas in the dagger nematodes, there are noticeable basal flanges and the leading ring of the spear is just about the middle of the spear.

The life cycle of the dagger nematode can take up to one year. The genus *Xiphinema* contains more than 190 different species distributed all over the world. The species *X. americanum* Cobb has been recorded in Oman on many plants and fruit trees including citrus, grape and date palm. *X. americanum* appears to be virtually non-specific with regard to host plant, having been recorded from agricultural, horticultural, grassland and forest soils. The host plants of particular quarantine significance are those to and from which *X. americanum* transmits viruses. Hosts and distribution are listed by Siddiqi (1973) and by MacGowan (1980).

4.5.6. Spiral Nematodes

Two species were recorded on the date palms:

1. *Helicotylenchus dihystera* (Cobb) Sher.
2. *Helicotylenchus multicinctus* (Cobb) Golden
(Tylenchida: Hoplolaimidae)

Female of spiral nematodes

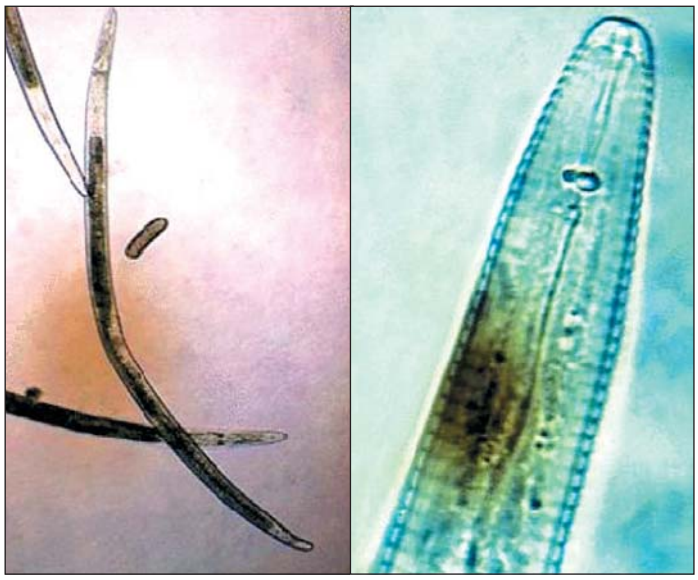
Called spiral nematodes because their bodies are usually coiled when killed by low heating. The female of *H. dihystera* has a spirally curved body, more so in posterior region after relaxation or death. The female is 610-860 µm (670 µm) long and 26-34 µm (29.5 µm) in width. Males are extremely rare, with a ventrally arcuate body. The head, stylet and oesophagus are as in the female. Bursa enveloping tail which is conoid.

H. dihystera is an almost cosmopolitan and polyphagous nematode. Sher (1966) and Siddiqi (1972) have listed a large number of hosts from many countries. It attacks banana, maize, tomato, soybean, many ornamental trees and lawn grasses. Spiral nematode species are migratory semi-endoparasitic nematodes, as they parasitize the root from the outside with part of the body inserted inside the tissues.

However, some species of spiral nematodes are either endo-parasites or ecto-parasites, and it seems that the type of parasitism of the genus Helicotylenchus varies according to the species and the plant host. Further studies are needed to determine their economic importance in relation to date palms.

4.5.7. Stunt Nematodes

Tylenchorhynchus spp.
(Tylenchida: Dolichodoridae)



Female of stunt nematodes, on the right an enlarged view of a female with the spear clearly visibly in the front.

Stunt nematodes are distributed worldwide and the genus *Tylenchorhynchus* contains more than 205 species. The length of the body varies much between 0.5 and 1.8 mm and the stylet is short, ranging from 13 to 40 µm in length, with well-developed basal knobs. These nematodes prefer dry areas and sandy soils.

Tylenchorhynchus spp. are called stunt nematodes because of the signs of stunted growth and general debilitation they inflict on diseased plants through the damage done to roots. They feed on the outer epidermal cells of the root buds and the small lateral roots; occasionally they may reach the inner epidermal areas.

As a result of their feeding activity, stunt nematodes cause necrosis and lacerations in the outer epidermal cells, and subsequently severe decline in the root system which is reflected in stunted growth. The life cycle of the stunt nematode takes, on average, one month to complete at 24°C.

Prevention and Control Measures of Nematodes

The control of nematodes in soil is considered of the most difficult and costly processes. The aim of the control process is to decrease the numbers of the primary nematodes in the soil to a low level in order to minimise damages to the plants to a level, which is economically acceptable.

Different measures, which can be taken to control the various species of nematodes infesting date palm, are summarized as follow:

- Quarantine is considered one of the most effective preventive measures employed against nematode spread in date palm plantations. It can be applied by preventing the transplantation of date palms or offshoots from areas with confirmed cases of nematode infection as a type of local quarantine.
- Proper sanitation and the removal of the weeds which are considered major sources of infestation for many species of nematodes, e.g. root-knot nematodes.
- Adding organic mulches to the soil helps in decreasing the nematode density by favouring the growth and activity of nematode natural enemies such as fungi and predatory nematodes. In addition, green mulch produces, upon decay, chemical compounds such as butyric acid which is toxic to nematodes. Organic mulches increase the strength and vigour of plants rendering them tolerant to nematode infection.
- Cultivating nematode-resistant varieties is considered one of the best and most efficient methods in controlling plant parasitic nematodes in most crops. Unfortunately, there are no detailed studies on the degree of susceptibility of different date varieties to nematode infestation.
- Although the fact that the use of chemical nematicides is the most successful and the most widely used method, it cannot completely substitute the need to use resistant varieties or crop rotation. Nematicides are considered the best option when resistant varieties are not available or when crop rotation is not applicable as in the case with perennial plants.
- In the past, the most widely used nematicide to control nematode diseases in date palms was Nemagon® 75% EC; this was removed from the approved list in 1981. Carbofuran (Furadan ® 10 G) or Oxamyl (Vydate ® 10 G) can be used in date palm offshoots nurseries to prevent spread of nematodes to new plantations.
- In the soil there are many natural enemies of nematodes including fungi and bacteria which could bring about suppression of nematode numbers under favourable conditions. Hollis and Johnston (1957) found microbiological action contributed to the reduction of numbers of *Tylenchorhynchus acutus* in soybeans growing in excessively moist soil. The endophytic fungus *Acremonium coenophialum* successfully reduced populations of *T. acutus* by 25 % in tall Fescue, thereby increasing the drought resistance of these grasses, West *et al.* (1988).