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Red ring and other diseases of the oil palm in Central and South America

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Abstract

The red ring disease caused by the nematode *Bursaphelenchus* (*Rhadinaphelenchus*) *cocophilus* and transmitted by the American palm weevil, *Rhynchophorus palmarum* used to be the most important disease of the coconut and oil palms in tropical America, and it is still prevalent in some plantations. Symptoms progression may be very fast (acute form) and the affected palm may die within a few months after first symptoms are noticed (progressive yellowing starting from lower leaves). On the other extreme of a continuous of symptoms, the youngest leaves emerge short and with several types of malformations (chronic form). The palms so affected usually do not die, but may remain showing symptoms for several years.

Disease incidence can be kept at a low level if an integrated management approach is followed, which includes elimination of sources of inocula (diseased palms), destruction of the weevil's breeding places, and lowering the adult population of the weevil by mass trapping.

Besides the red ring, other less-important diseases also occur in tropical America: *Pestalotiopsis* leaf blight, sudden wither (*Phytomonas* sp.), charcoal base rot (*Ustulina deusta*), wet basal rot (possibly *Erwinia* sp), and upper stem rot (possibly *Phellinus* sp., but its etiology is not clear).

Fusarium wilt probably came to America in contaminated seeds from Africa, and is only present in Brazil, and probably Ecuador. Finally, *Ganoderma* spp., of the most importance in Southeast Asia, is considered a secondary pathogen in America, but its importance could increase as old plantations are renewed.

Colletotrichum gloeosporioides (*Glomerella* sp. and other associated secondary pathogens) is the only disease of importance in nurseries in most American countries, but can be easily kept under control by managing watering, fertilization and plant spacing. Symptoms of chlorotic ring spot (probably a potyvirus) have been found only in Ecuador and probably Colombia.

Different types of spear rot of the oil palm are not diseases in the traditional sense, but can be described, understood and managed by considering them as particular cases of a decline-type of growth disorders. This approach has been effective, and many thousands of hectares of affected oil palms have been recovered both in terms of vegetative growth and productivity. The key aspect has been to improve agronomic management, particularly soil aeration and plant nutrition.

This paper gives general information on causal agents of each disease, its epidemiology and known commercial control methods, as well as, an evaluation of its potential to become a more important threat in the future, particularly in its quarantine aspects.

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Introduction

Different types of rotting, desiccation and yellowing in the spears and the whorl region, are the most threatening phytosanitary problems in some oil palm plantations in tropical America. Since no primary pathogens are known to be associated with these problems, much confusion has been generated in the literature, when different local names are given in different places, to what could be variations of the same condition.

Even though, the real etiology of such problems is still not completely understood, most evidence accumulated so far indicates that they much resemble to what is known as a decline of a community of plants, which are incapable to sustain a high productivity of biomass under unfavorable environmental conditions (Manion and Lachance, 1992; Chinchilla and Durán, 1998, 1999; de Franqueville, 2001). Successful management of such problems can be obtained following an approach that mainly considers an improvement of agronomic practices.

The red ring disease has been the most important disease in several countries in South and Central America. In Costa Rica, it reached very high levels until a successful integrated management was developed in the early nineties. Since then, the disease has been reduced to a secondary importance (Oehlschlager et al. 1993, 2002; Chinchilla et al. 1995; Chinchilla, 2003).

Other diseases pose some threat in some countries or specific plantations; this is the case of sudden wither (Marchitez sorpresiva), *Ustulina* charcoal base rot, *Pestalotiopsis* leaf blight and *Fusarium* wilt. Causal agents of these diseases and management possibilities are discussed briefly in this paper.

The red ring/little leaf disease

Introduction

This has been historically the most important disease of the oil palm in Central America and some other countries in South America (Malaguti, 1953; Schuiling and Dinther, 1981; Chinchilla and Richardson, 1988; Chinchilla, 1991). The nematode *Bursaphelenchus cocophilus* (*Radinaphelenchus cocophilus*) (Cobb) Baujard, (Nematoda, Aphelenchoidea) is the causal agent (Fig. 1), and is transmitted by the American palm weevil *Rhynchophorus palmarum* L. (Curculionidae) (Fig. 2). The importance of other possible vectors is not clear, such as *Metamasius hemipterus* (Curculionidae), which role as a vector could not be demonstrated, at least in Costa Rica (Perez et al. 1997, Bulgarelli et al. 1998).

The vector

The adults of *R. palmarum* present a wide variation in size, ranging from 20 mm to 41 mm in length (*rostrum* excluded). Mean body length in males is larger than in females. The sexes are usually differentiated, the male bearing a pubescent tuft over its *rostrum*. However, this characteristic is normally absent on the smallest individuals. The *rostrum* of the female is longer, thinner and more curved than that of the male (Mexzón and Chinchilla, 1994).

Fig. 1. *Bursaphelenchus cocophilus* (anterior end)

Fig. 2. *Rhynchophoros palmarum,* American palm weevil

The life cycle, from egg to adult, occurs within 80-160 days and the adult may live for three months. A female may lay 10 to 48 eggs daily within a period of 8-11 days. Some females may lay up to 60 eggs within the first three days. Both the mating period and the egg-laying period occur within 14 days, but mating may occur between adults recently emerged from the pupae. The mating period is about three minutes. Eggs' hatching occurs in three days, and then follow nine larval stages (60 days), a pre-pupal stage, and finally the pupal stage. Adults are more active early in the morning and late in the afternoon (Griffith 1968, Mexzón et al. (1994).

Symptomatology

The presence of *B. cocophilus* has been associated with a complex of symptoms in oil palm. One manifestation is known as the acute or classical form of the disease, where the most striking symptom is a progressive yellowing that starts on the lower leaves and advances toward the youngest ones, which may be reduced in size. A palm so affected may die within a few months.

In other circumstances, an infected palm somehow seems to restrict the systemic establishment of the nematode in the whole plant, and restrict its activities to a region in the whorl where the leaves are in the active elongation stage. As a result of the feeding of huge numbers of nematodes in this region, the new leaves emerging from the whorl look deformed and much shorter than normal (little leaf symptoms). The palm eventually takes a funnel appearance where all young leaves are short and deformed. A palm so affected normally does not die (chronic form of the disease), but may remain producing short leaves for several years until it takes the appearance of a gigantic duster (Fig.).

Fig. 3. Acute symptoms of the red ring disease

Fig. 4. Chronic symptoms of the red ring disease

Internally, the stem shows in a transversal cut, a series of necrotic lesions which may form a ring around the central part of the stem (Fig. 5). The color of the affected tissue may have different tones of brown, that may vary from almost black to rose. The presence of a discrete ring tends to be more frequent in palms showing the classical symptoms. The discolored tissue not always form a continuous ring, and lesions may appearing dispersed in the stem, forming several discontinuous or continuous concentric rings or simply appear as a central necrotic area, that may even disintegrate leaving a hollow center. This last condition is sometimes found in palms that have been affected for a long time showing chronic symptoms.

The classical and chronic symptoms are the extremes of a continuous, and almost any combination of symptoms may be found in individual palms in commercial plantations (Chinchilla and Richardson, 1987; Chinchilla, 1991).

Fig. 5. Red ring disease in oil palm: stem symptoms

Epidemiology

Incidence of the red ring disease has decreased significantly where modern control practices have been taken. In palms less than six years old incidence was normally very low, but 20 % or more of the palms could be affected in plantations of intermediate age (around 12-15 years). An accumulation of 50 % or more of affected palms was reached in some particular areas of plantations in Honduras, where no active control practices had been taken.

Incidence may vary a lot even within a particular plantation. Incidence reached by a particular area depended mainly on age of the palms, sources of inocula of the nematode (infected palms), and the population of infected vector weevils (Chinchilla, 2003). There is no evidence that the nematode could be seed transmitted (Griffith, 1987).

Adults of *R. palmarum* are readily attracted by volatiles from physically wounded palms or those affected by different diseases, including red ring and different types of spear rot. Laying of eggs may readily occur in these sites, and a high population of larvae can develop even in young palms. If the attacked palm is infected with the red ring nematodes, larvae may take and keep them through the molts until they reach the adult stage (Hagley, 1965; Griffith, 1987).

In adult oil palm plantings, a red ring infected palm may provide the inoculum for 3-5 neighbor palms, which are not necessarily contiguous, but may be within a distance of 30 or so meters (Chinchilla, 1991; Oehlschlager et al. 2002).

The adult population of *R. palmarum* tended to be aggregated (Oehlschlager et al. 1995), and this is also a factor that contributed to the epidemiological behavior of the disease caused by *Bursaphelenchus cocophillus*. The results of the analysis using geostatistics confirmed the aggregated distribution of palms showing the red ring disease (Barboza and Chinchilla 2003).

Total adult population of the insect fluctuates during the year. The highest captures in traps were obtained during the dry season, but the percentage of insects carrying the nematode (potential vectors) was the lowest during this part of the year, and started to increase toward the end of the rainy season (Chinchilla et al. 1990; Morales and Chinchilla, 1991).

Disease progress curves help to understand the epidemiological behavior of a pathogen in a population of plants, since such curves combine the effects of the pathogen, the environment and the host. There are two basic disease progress curves: that followed by the so-called polycyclic pathogens, and that followed by monocyclic pathogens. The monomolecular and Gompertz equations are normally used to describe these types of epidemiological behavior. Surprisingly, the epidemiological behavior of the red ring disease was quite different depending on the type of symptom present (chronic vs. acute)

In the Atlantic coast of Honduras, where the little leaf condition was prevalent, the equation that better fitted the data on changes of disease incidence in time was the monomolecular (simple-interest type of growth). On the other hand, in Costa Rica, where the prevalent symptom was the classical manifestation of the disease (acute form), the equation that better fitted the data was Gompertz's (polyciyclic type of increase) (Barboza and Chinchilla, 2003).

The specific interactions (genotype/pathogen/environment) that explain the differences in symptoms (chronic vs. acute forms of the disease) are not well understood. Salazar and Chinchilla, 1989 failed to associate the differences in symptoms (and epidemiology) to races of the nematode, which could be differentiated by morphometric differences. There is then, the possibility that some unknown environmental conditions may determine the prevalence of either symptom.

The differences in the epidemiological behavior (simple vs. compound interest models), can be partially explained considering the behavior of the vector insect, and the ability of the plant to "regulate" the multiplication and movement of the nematode within the different tissues.

When a plant shows the little leaf symptoms (chronic form), the systemic movement of the nematode is somehow restricted, and the highest populations occur only in the developing young leaves within the whorl. Those palms showing typical little leaf symptoms, commonly do not present signs of nematode activity in the stem (no ring and sometimes just some stains randomly distributed), and nematodes, if present, nematodes do not look very healthy. The little leaf symptom was practically the only symptom present in most palms affected by the nematode in Honduras, but was less frequent in Costa Rica in the Pacific coast, where the classical form of the disease was prevalent.

Rotting of the tissue is very limited or absent in the little leaf condition. This makes the plant less attractive to the insect vector, which responds to volatiles coming from wounded or rotting tissues. The presence of larvae and adults of the vector were uncommon in palms affected by typical little leaf symptoms, and this was one of the reasons why these palms did not die, but remained showing symptoms for years. The final result was a slow disease-increase rate, where incidence depended mainly on the initial population of the vector already infected with the nematode. It was known that the proportion of vector insects infected with the nematode was particularly high in Honduras (Chinchilla et al. 1991). The epidemiological behavior under such conditions followed the monomolecular equation.

The opposite happened in palms showing the classical or acute form of the disease, where the most common situation was to find larvae and adults of the vector in the rotting tissue of the whorl, which in turn brought more insects until the palm died. A high proportion of the insects breed in the affected tissues could acquire the nematode and vectored it to neighbor plants, determining an epidemiological behavior that can be described as a more typical compound interest disease (described with the Gompertz equation).

Disease Management

Disease management must follow an integrated approach which considers the plantation itself and all surrounding areas. Through research and experience, the following five principles are considered essential in order to reduce and maintain the red ring disease at a low level.

Organization, training of field personnel and surveillance: All areas of the plantation must be visited at least once a month to detect and take fast action on any phytosanitary problem found. The position of any affected palm must be annotated so a particular action can be taken later

(eradication, or appropriate treatment). Surveillance work is done by trained personnel, but all regular plantation workers must be instructed to inform the phytosanitary squad about any abnormal situation found.

Eradication of palms with symptoms: Nematicide treatment of red ring affected palms is not recommended: response on little leaf affected palms is erratic, and palms with the classical symptoms die anyway. Preventive treatment with nematicides is not effective and environmentally unacceptable.

B. cocophilus is an obligated parasite and will not survive in rotting tissue beyond a few weeks, and will die within a few days in the soil. The eradication of all affected palms is essential, including other palm species (mainly coconuts) in areas surrounding the plantation. Infected palms are eliminated by trunk injection with an appropriate herbicide, that must produce a rapid death of the palm and not allow breeding of larvae of *R. palmarum* in dying tissue. Daconate (MSMA) is a product with such characteristics.

Reduction of breeding sites of *R. palmarum*: The palm weevil is attracted and breeds on palms physically wounded or those with diverse types of rotting. In young palms, weevils are attracted by volatiles coming from spear rots and wounds caused by rats and *Strategus aloeus*. Faulty pruning and harvesting practices can cause wounds in adult palms, and strong winds and lightning can seriously damage palms attracting the weevils. All these situations must be properly treated to avoid the formation of breeding sites for the weevil.

The way a red ring infected palm is eliminated may have a profound effect on disease incidence. Palms felled with a chain saw may become the source of several generations of infected weevils, which will propagate the disease. Treatment of cuts with an insecticide does not necessarily prevents females laying eggs, since rains may wash the product, and because the ability of the insect to crawl through areas difficult to protect with the insecticide (lower parts of the trunk facing the ground). The residually of the product is also an important factor to consider. The best option to avoid these problems is the poisoning of the infected palms.

Reduction of the adult population of the weevil. The attraction of adults by certain plant volatiles has been used to capture them in diverse types of traps. Pieces of stem of several palm species have been used, but costs involved are high since they must be normally replaced every week. When red ring incidence and weevil population are both high, these traps may not be enough to control the disease.

The use of *'rhynchophorol'* (6-methyl-2-hept-2-en-4-ol), the aggregation pheromone produced by the male of the species, allows to improve captures by a factor between 6 and 30 in traps with sugar cane as a food source. The red ring disease has been effectively controlled in tropical America using an strategy that consider the use of *rhyncophorol* as an essential element (Chinchilla and Oehlschlager, 1992; Chinchilla et al. 1993; Oehlschlager et al. 1993 a,b; Giblin-Davis et al. 1996; Oehlschlager et al. 2002).

Agronomic management. Excessive shade within the plantation and poor superficial drainage are conditions favorable for *R. palmarum* activities, then, proper disease management must

consider good drainage practices, timely pruning of old palm leaves and the choice of the most appropriate palm density according to environmental conditions (light) and vegetative growth (leaf length) of varieties to be planted.

The use of the principles outlined above allows to lower significantly disease incidence regardless of initial level of inoculum. An initial period of about nine months may be needed to observe a drastic change in incidence, since the incubation period must be considered and the total population of the weevil must be critically hit.

Enforcement of the phytosanitary law: An important element for the success reached in Costa Rica to control the red ring disease was the enforcement of the law that makes the control of the disease mandatory. This has permitted to extend to large areas the work of elimination of sources of inoculum of the nematode and the trapping of the vector weevil.

Sudden wither (Marchitez sorpresiva)

Introduction. This disease, also known with the names of Cedros Wilt and Hart Rot, is associated with the presence in the phloem of flagellates of the genus *Phytomonas* sp. (Dollet, 1984). In Central America, it has been found infecting oil palm only along the Northern Caribbean coast of Honduras, scattered in a few very small and concentrated areas. The presence of sudden wither has not been documented in oil palm in Costa Rica.

Symptoms and epidemiology. The symptoms of this disease have been described elsewhere (Turner, 1981; Chinchilla and Richardson, 1988), and little is known on disease epidemiology. The causal agent seems to be transmitted by some insects in the Pentatomidae family (*Lincus* sp. and possibly others), and these insect are normally found in leaf axils of infected palms.

Seed transmission of the pathogen would be very difficult indeed; since a palm infected with *Phytomonas* will stop bunch development and rot all already formed bunches rather quickly, before other symptoms appear (Fig. 6).

Disease management. When this disease first appeared in South America in the 60's, it did apparently cause serious losses in some countries, mainly because inappropriate agronomic management of plantations at that time. Even today, the disease is more common in those areas where weed control and drainage are deficient. Actually, if very basic control practices are used (such as an early eradication of infected plants, insecticide treatment of affected and neighbor palms, and above all, a better agronomic management -weed control, drainage and palm nutrition), sudden wither becomes a disease of secondary importance, as has been observed in Honduras.

Vascular wilt

Introduction. *Fusarium* wilt is caused by the vascular pathogen *Fusarium oxysporum* f. sp. *elaeidis*. In the Americas, this disease has only been found on two plantations, one in the state of Pará in Brazil and the other in Quinindé, Ecuador (van de Lande, 1985; Renard and de Franqueville, 1989b, Corley and Tinker, 2003). However, it could be also present in Colombia. Up to 1989, vascular wilt was reported in the Ivory Coast, Benin, Nigeria, Cameroon, Zaire, Ghana and Congo, besides the two mentioned spots in America (Renard and de Franqueville, 1989b; Corley and Tinker, 2003).

Symptoms and epidemiology. Symptoms of this disease have been described extensively (Turner, 1981; van de Lande, 1985; Renard and de Franqueville, 1989b), and there are no important differences between Africa and America (Fig. 7).

F. oxysporum f.sp. *elaeidis* may persist in the soil without the presence of susceptible oil palm varieties, and gets access to a palm through root contact. Superficial draught-damaged roots are particularly susceptible to fungal colonization, and foci of infected palms may develop with time.

Fig. 6. Marchitez sorpresiva (sudden wither)

Fig. 7. *Fusarium* wilt

Disease management. *F. oxysporum* f. sp. *elaeidis* is a real seed-borne pathogen (de Franqueville and Renard, 1990), and it has been demonstrated that under poor seed management, the pathogen can be carried along with the seed and pollen (Flood et al. 1990). Due to its broad occurrence in West Africa and very rare presence in America, along with close genetic relationships between the American isolates of *F. oxysporum* f. sp. *elaeidis* and those of West Africa, some workers consider that this disease was introduced to Ecuador and Brazil from West Africa. The risks of seed imports from areas where *Fusarium* wilt is present should be taken seriously, and all precautions should be taken to guarantee the production of pathogen-free seeds, which include an appropriate fungicide treatment.

In a replanting, the site previously occupied by infected palms constitutes the main source of inoculum. However, early eradication of diseased palms is still a practice that may help to reduce disease incidence in future plantations. In areas where the disease is prevalent tolerant varieties can be planted. Partial or (apparently) total recovery in many of these tolerant plants is common. In general, good agronomic practices help to reduce disease incidence. A well balanced nutrition (particularly the supply of potassium) also helps, as well as all measurements taken to reduce water deficit, which includes the choice of soils with good water-holding capacity.

Charcoal basal rot (corky basal rot)

This disease, caused by a cosmopolitan fungus, is mostly of secondary importance in America (Turner, 1981). The fungus *Ustulina deusta* (Sphaeriales, Xylariaceae) is primarily a saprophyte (wood decomposer) and probably only attacks palms that have been previously stressed (flooding, lightning etc.).

Symptoms in Central America differ somewhat of those described in the literature (Turner 1981). Usually the infected palms do not show any external symptoms until there is a very extensive rotting at the base of the palm, and the fruiting bodies of the fungus appear at the base of the palm (Fig. 8). The lesion is light brown with many narrow black stripes (pseudo-sclerotia), often associated with a white mycelium. The affected tissue is spongy (corky consistency) and very light with total destruction of fibers. The advancing edge of the lesion is diffuse or well limited by a thin, dark brown band. The lesion is normally very well confined to the basal portion of the trunk only. No characteristic symptoms appear on the canopy of the plant. When symptoms are well advanced, leaves of several orders bend at the base of the petioles and remain hanging still green for some time.

Disease progress curves are of the monocyclic type (Barboza and Chinchilla, 2003) indicating a strong influence of the initial amount of inoculum (probably infected-buried stems of previous forest species or oil palms). In Central America, a peak of incidence is commonly seen when palms reach 9-11 years of age, and up to 2.5 % incidence was observed in some particular harvesting lots in Honduras. The disease has not been found in palms less than six years of age (Umaña and Chinchilla, 1991).

Basal stem rot (*Ganoderma* spp.)

At least two species of this fungus cause the most serious disease of the oil palm in Southeast Asia, but it is of no importance in America so far, where its occurrence is rare. Symptoms are similar in America (Fig. 9), and there are no serious studies conducted to understand the causes of such large differences in incidence, but part of the answer could be related to soils suppressive to the fungus.

Some cases of the disease reported in Central America in the 80s created some concern on the possibility that the fungus could repeat the history of destruction found in Southeast Asia (Chinchilla and Richardson, 1988), but after 15 years or so, and many thousands of hectares replanted, the disease is still of rare occurrence.

Fig. 8. Corky basal rot **(***Utulina deusta)*

Fig. 9. Basal stem rot (*Ganoderma* spp.*)*

Nursery diseases

Anthracnosis

Glomerella sp. (*Colletotrichum gloeosporioides* and other associated opportunistic pathogens) is the fungus most commonly associated with anthracnose-type of symptoms in tropical America. Symptoms have been described elsewhere (Turner, 1981) (Fig. 10).

In Costa Rica, anthracnose is successfully managed by using an integrated management approach, that includes a balanced nutrition (avoiding excess of nitrogen), proper water management (avoiding excess or water deficit), proper plant spacing (wide bag spacing), and the use of fungicides when necessary.

Chlorotic Ring Spot

Diseases caused by virus are rare in palms (Chase and Broschat, 1993), but in 1995 some virus-like symptoms appeared in many nurseries in the North Occident of Ecuador (Chinchilla, 2001). Symptoms were associated with the presence of flexuous filamentous, rod-shaped viral particles and cytoplasmatic inclusions (pinwheel, scrolls), that place the virus within the group of the

Potyviridae, and makes aphids the possible vectors. The virus is not seed-borne (Chinchilla, 2001; Genty, 1996).

Disease incidence was quite high in some nurseries (25-80%), but since this first outbreak in 1995, incidence has steadily decreased, and the problem is thought to be under control now, even though nobody knows the exact reasons for the outbreak and subsequent decrease of this particular problem.

Symptoms of the disease (Fig.10) include a combination of chlorotic streaking, mosaic and ring spots. This last symptom consists of irregular rings (halos) of chlorotic tissue surrounding a central clear green area. The shape of the rings ranges from almost circular to oval, and continuous rings may merge to form a pattern of concentric rings. The halo has a pale-whitish appearance in the youngest leaves, but as the leaf ages, it takes a yellow-orange coloration. No rotting or desiccation occurs and affected palms keep an otherwise apparent normal vegetative growth. The decrease in disease incidence in nurseries in Ecuador has been associated with rigorous early-rouging practices, a better use of shade, and control of weeds (particularly grasses) and insects, in and around nurseries.

Fig. 10. Anthracnose (*left*) and ring spot symptoms in nursery palms

Spear rots

Common spear rot/crown disease (CSR/CD)

This condition occurs in all regions and countries of the world where oil palms have been planted (Duff, 1963; Turner, 1981; Corley and Tinker, 2003). A common sequence of symptoms in young oil palms with this condition is: spear rot, bending of rachises and the appearance of little leaves (recovery phase).

CSR/CD typically appears in palms between one and three years old, but it can also appear in plants up to seven years old and in young nursery palms. The symptoms may persist for a few weeks, months or even years, but generally the affected plants recover without any particular treatment.

Susceptibility to these disorders is genetically determined (Blaak, 1970), but there is also a clear predisposition due to several environmental factors, that adversely affect plant physiology bringing about the susceptibility response. Some factors commonly associated with the disorders are those that adversely affect root development, such as poor soil aeration (poor drainage, water deficit, soil compaction…) and nutritional imbalances, particularly excess of nitrogen with respect to potassium (Turner, 1981; Breure and Soebagjo, 1991; Sterling and Alvarado, 1996; Alvarado et al. 1997; Chinchilla et al. 1997).

In young plantations, two peaks of high incidence are common. The first one coincides with the establishment of the following rainy season after field planting: during the previous dry season not many new roots are formed and superficial roots may die. Later, with the onset of the rainy season plants are fertilized (mainly N), which induces a high rate of aerial growth, not according with a modest root development. The second peak of disease incidence occurs the same year (second in the field) during the rainiest months when the soil gets water saturated, which also causes problems for proper root functioning.

Symptoms of the condition in Central America are identical to those described in other countries (Turner, 1981; Chinchilla and Durán, 1998). Rotting of young tissues is associated with the activities of several weak ubiquitous pathogens, such as *Fusarium* spp. and *Erwinia* sp., and the bending of the rachis is due, at least in part, to an abnormal lignification, which causes the bending of the spear as it grows and its weight increases (Monge et al. 1993, 1994).

Management is achieved by proper agronomic practices. A balanced nutrition (avoiding excess of nitrogen with respect to potassium), proper weed control, improving soil aeration (drainage, reducing soil compaction and avoiding the deterioration of soil physical characteristics) must be specially emphasized. The condition is less prevalent nowadays due the identification and elimination of susceptible genotypes in most breeding programs.

Bud Rots

The use of local names to describe diseases, and the lack of scientific evidence to associate the condition with a known pathogen, may cause much confusion, particularly when expressed using elements of the local folklore. The case of oil palm bud rot in tropical America has been particularly confusing, where similar conditions in different countries have received many different names such as spear rot, dry spear rot, lethal bud rot, fatal yellowing etc. (Turner, 1981; van de Lande, 1986; Renard and Franqueville, 1989; Swinburne, 1993; Chinchilla and Durán, 1999). The confusion has been increased when names already recognized for other diseases have been used such as lethal yellowing and sudden wither.

All these names have been used freely to refer to disorders in which the youngest leaves partially or completely rot or desiccate, and outer leaves remain green. No pathogen has been identified as the sole cause of these problems, but there are always environmental factors that have been determined as predisposing the plant to such disorders. Some previous studies attempted to show epidemiological evidence in favor of the presence of a transmissible agent (van de Lande, 1983), but the same data can be interpreted quite differently using conventional epidemiological tools

(Bergamin et al. 1997). In Costa Rica, the epidemiological studies done indicated that initial disease increase over time normally followed a clear linear tendency.

Spear rots (Fig. 11) are by no means endemic to America, not even those that could cause the death of the palm, since this sometimes occurs even with the most familiar of these rots, the common spear rot. Different types of severe bud rots have been described wherever the oil palm has been grown (Duff, 1963; Kovachich, 1957; Turner, 1981; Watanavanich, 1982; Mariau et al., 1992; Swinburne, 1993; Chinchilla and Durán, 1998).

The first author of this paper has seen bud rots causing death of oil palms in countries like Thailand and Honduras, where symptoms and particular conditions associated with the problem were identical to those found in areas where the disorder was prevalent in other countries of America. After many years there has been no indication whatsoever that the condition has 'spread' in those countries, indicating, once again, that the rapid increase of the problem is mainly dependent on the prevalence of particular environmental conditions, and not on the presence of an aggressive primary pathogen.

Furthermore, 'lethal' bud rots as known in most areas of Tropical America is not necessarily lethal, but more and more hectares have recovered from the condition, where the managing approach has shifted from a pathological orientation to one that considers plants needs according to the environment and yield potential (Chinchilla and Durán, 1988, 1999).

As it is the case for CSR/CD, microorganisms associated with most bud rots are weak-opportunistic pathogens. On the other hand, these conditions are almost always associated with similar predisposing factors, and one is tempted to think that they can be better understood if seen as a continuum, where CSR/CD is a relatively mild condition, and "lethal" bud rot is on the opposite end. Between these essentially artificial extremes, there exists a lot of variation in the severity of symptoms.

Spear rots in oil palm are found in association with various soil, nutritional, climatic and agronomic factors, which are adverse for the normal development of the palm. The most common among these factors are poor soil aeration, unbalanced nutrition and an altered water balance. Both potassium and phosphorus are usually in a condition of deficiency and/or imbalance in affected areas. High levels of magnesium and calcium, an over-fertilization with nitrogen associated with low soil potassium, and water deficit make a potentially dangerous combination. Low levels of zinc and copper are also associated with spear rots. Iron and manganese also seem to be associated with the disorders since these elements become available under conditions of low soil aeration. Iron may accumulate in the root system causing toxicity, but becomes unavailable in the aerial part of the plant causing deficiency

The onset of the typical symptoms of dry spear rot in Costa Rica (very similar, if not identical to bud rots described in South America (Fig. 11), seemed to be preceded by a sequence of events, that indicated the presence of one or more types of stress that affected negatively plant growth. The negative effects of such stress seemed to be worst on those plants having an apparently vigorous vegetative growth, and those with a heavy bunch load.

The sequence of events (previous, contemporary and posterior) to the onset of typical symptoms of dry spear rot in young oil palms were: inflorescence abortion, reduction in the percentage of normal fruits in the bunch, reduction in cross petiole section and rachis length, reduction in the amount of roots (mainly fine roots), onset of typical initial symptoms (yellowing on the basal portion of some leaflets of youngest leaves), presence of rotting or desiccation of spears, reduction in bunch weight and the amount of oil per bunch (Albertazzi and Chinchilla, 2005). Some of these tendencies were also observed for young palms that developed common spear rot/crown disease (Chinchilla et al. 1997).

The observed events that were anterior to the onset of what is normally considered the initial symptoms of bud rot (yellowing of the basal portion of some leaflets of a few of the youngest leaves, and limited spear rot), seemed to take place at least 5-6 months before (a reduction in fruit set in palms that were eventually affected). This situation is not easily conciliated with the pathogen theory. The type and severity of symptoms (yellowing, rotting and desiccation of spears), and the speed of recovery were related with the previous loss of the fine root system, and the ability to form new feeding roots.

Most or all of the stress factors associated with spear rots are present in all areas that have had a high incidence of these types of problems in Colombia, Nicaragua, Panama, Ecuador, Surinam, Brazil, Venezuela, Costa Rica etc (Chinchilla and Durán, 1998; Chinchilla and Durán, 1999; Franqueville, 2001). These predisposing factors have to be identified and successively removed to prevent the disorder or recover affected areas.

Fig. 11. 'Flecha seca' or dry spear rot (*left*) and PC (pudrición del cogollo) in oil palms

Conclusions

Research on causal agents and management practices for the most important diseases of the oil palm in tropical America, has been particularly productive during the last fifteen years or so. An integrated management approach has been identified as the most appropriate for important phytosanitary problems such as the red ring disease, and spear rot-like disorders. On the core of this approach lies the idea that prevention is the first step to maintain a healthy plantation. Key actions that must be taken toward this direction are the use of disease-free certified seeds (or *ramets*), appropriate agronomic practices and continuous monitoring of plantings of all ages.

Fortunately, for the oil palm industry, the main diseases present in tropical America are not known to be seed-borne, and this is true for both nursery (*Colletotrichium gloeosporioides* and chlorotic ring spot) and field diseases (red ring, sudden wither, leaf blight, *Ustulina* charcoal basal rot and *Ganoderma* basal stem rot).

Fusarium oxysporum f. sp. *elaeidis*, a real seed-borne pathogen, is only present in localized plantations in Ecuador and Brazil, and is absent in Costa Rica in Central America, where commercial hybrid seeds and oil palm clones are produced.

Spear rots are the most common phytosanitary problems in many plantations in tropical America, but most evidence accumulated thus far indicates that there are not primary pathogens associated with them. The final solution to these problems will probably come from a combination of good agronomical practices (particularly good soil aeration, a balanced nutrition and proper water management) and the development of genetic materials tolerant or with some resistance to these conditions.

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