ASD Oil Palm Papers, No. 32: 1-10, 2008

The many faces of spear rots in oil palm and the need for an integrated management approach

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Abstract

The use of arbitrary names to describe some 'diseases' affecting spears and young leaves in oil palm, and the lack of convincing evidence to associate these symptoms with a given pathogen, has caused much confusion in the literature dealing with diseases of this palm in tropical America. We sustain the thesis that most of these disorders (assumed elsewhere to have a pathogen or group of pathogens as a primary cause) may all be variations of similar underlying causes, where pathogens and other organisms associated play an opportunistic role.

Most of these disorders, that manifest themselves as rots, discolorations and drying of the whorl and young leaves in oil palms, could be better understood, explained and managed if considered as particular cases of a progressive deterioration (decline) of a plant population. This approach has been used in many places to recover many hundreds of hectares affected, particularly, where more benign forms of the condition were present.

The most relevant aspects considered have been improving soil aeration, water, nutrition and agronomic management in general. However, some more severe forms of spear rots still occur and cause severe damage and even death of palms in some regions in tropical America; indicating gaps in our knowledge. These gaps have to be filled through research using a multidisciplinary effort. The final solution to these problems, probably, will only come from a combination of good agronomic practices, starting from the choice of the planting site, and the use of varieties that are tolerant or resistant. The sources of resistance/tolerance seem to be present in both species, *Elaeis guineensis* and *E. oleifera*.

Introduction

The oil palm (*Elaeis guineensis* Jacq.) suffers from relatively few important diseases in each one of the different environments where it has been planted commercially. In Southeast Asia, basal stem rot caused by *Ganoderma* spp. is the only disease really causing some threat to the industry; and in several African countries, *Fusarium* wilt (*Fusarium oxysporum* f.sp. *elaeidis*) is the only one causing economical problems in some plantations. In tropical America, there are two phytosanitary problems of real importance in many plantations: the red ring disease (caused by *Bursaphelenchus cocophilus*) and spear rots, of yet, unknown causes.

"Diseases" affecting young tissues of the oil palm in many countries include disorders known as common spear rot, crown disease, PC (pudrición del cogollo: whorl rot), 'pudrición letal del

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cogollo' (lethal spear rot), spear rot, 'amarillamiento' fatal (fatal yellowing), 'amarillamiento' letal (lethal yellowing), pudrición seca de la flecha (dry spear rot), pudrición severa del cogollo (severe whorl rot), pudrición húmeda del meristemo (meristem wet rot), etc. (Turner 1981, van de Lande 1986, Renard and Franqueville 1989, Swinburne 1993, Chinchilla and Durán 1999). Chinchilla 2008. Confusion has increased when a name already used for another disease (of better known etiology) has been used to describe one of these disorders; an example being the use of the name "lethal yellowing" which is an accepted name for a coconut disease (fitoplasma).

The terms 'whorl rot' and similar, refer to a group of symptoms in oil palm, where the young leaves normally develop partial yellowing and the spears show partial rotting or drying of portions of the leaflets, rachis and petioles. Yellowing of leaves is associated with the presence of rotting of portions of rachis and petioles. Old leaves are never affected initially. No pathogen has so far been identified as the sole cause of these symptoms, but both a high incidence and severity is consistently preceded by environmental factors causing stress on the plant (predisposing factors). However, there are also some clear differences in susceptibility, being the popular variety Deli x AVROS particularly vulnerable.

Spear and whorl rots in oil palm, including those that seem to cause palm death are not endemic to tropical America, but more or less severe forms have been described elsewhere. Even 'common spear rot' may in some cases lead to palm death. In general terms, the literature on oil palm diseases from most countries includes references to different disorders affecting young tissues that resemble what is known in America as PC. The final result of some of these symptoms may be plant death (Duff 1963, Kovachich 1957, Turner 1981, Watanavanich 1982, Mariau et al. 1992, Swinburne 1993, Chinchilla and Durán 1998). The author has seen identical symptoms of PC in countries like Thailand and Honduras, where PC is not ´known´ to occur; but since incidence has been very low, this situation never attracted attention. This is an indication that the rapid increase of the 'disease' in other places is mainly dependent on the prevalence of particular environmental conditions and management, and not on the presence of an aggressive primary pathogen.

On the other hand, ´lethal spear rots´, as known in most countries in tropical America, are not necessarily lethal, but a proportion of palms (that may reach almost 100% in some places) may recover from symptoms. Symptom severity, speed of recovery, and the proportion of recovered palms normally depend on the total agronomic history of the plantation, even from land preparation and planting practices (Chinchilla and Durán 1988, 1999).

The many faces (symptoms) of spear and bud rots in oil palm

Rots and drying of tissues in the bud region of the palms, normally accompanied by yellowing of portions of the younger leaves is the most important and prevalent phytosanitary problem in many oil palm plantations in tropical America. Despite extensive research during several decades, no primary pathogen has been identified as the sole cause of these problems. As a consequence, many different local names have been given to what could be mere variations (in symptoms) of the same basic condition.

Some elements in common to all these disorders are:

a. Young leaves and the region close to the meristem are affected.
b. Root system development is being altered (particularly fine roots) even before aerial symptoms appear.
c. Not a particular causal agent has been identified despite several decades of research in this direction.
d. Incidence, severity and recovery ability are all associated with stress, particularly that affecting root formation, its development, sanity and longevity.
e. They are associated with a poor and unbalanced nutrition.
f. A percentage of palms recover 'spontaneously' (even in places where most plants eventually may die).
g. Improvement of agronomic practices (soil aeration, nutrition, water management…) are associated with a reduction in incidence, symptom severity and ability to recover.

The most benign form is normally called 'common spear rot' (Fig. 1)) which is commonly (or always, depending on criteria) associated with the so-called 'crown disease' or 'juvenile disease', since it is prevalent in very young palms (1-3 years old, but can also occur on nursery and adult plants). The palms affected by these disorders normally recover 'spontaneously' after a few weeks or months (occasionally, even years) of showing symptoms. CSR/CD (common spear rot/crown disease) occurs in all regions where the oil palm has been grown (Duff 1963, Turner 1981, Corley and Tinker 2003). A common symptom sequence in young palms is:

1. Shortening of young leaves.
2. Limited rotting of some leaflets on some of the spears.
3. Rachis bending and breaking.
4. Some spears and youngest leaves show partial rotting and drying of some sections.
5. Production of short and somewhat distorted young leaves during the recovery phase.

Fig. 1. Common spear rot/ crown disease in a nursery plant (*left*) and a young plant in the field (right). Leaflets on bent portion of the rachis rot and are missing (*right*).

A variation of this condition is known as 'wither tip' (Turner 1981) (Fig. 2a), which symptoms (rotting of tissues located at tips of youngest leaves) tend to be recurrent during several years in some plants. It is common that spear accumulation precedes the development of several of these disorders (Fig. 2b).

Fig. 2a. Extensive yellowing of young leaves and 'wither tip' symptoms (rotting/desiccation located at the tip of leaves only)

Fig. 2a. Spear accumulation (even in wet soils) sometimes precedes development of spear rots in oil palms

Rotting of tissues in CSR/CD normally does not progress much toward the main meristem which facilitates recovery. However, in other forms of spear rots and bud rots, rotting can be quite extensive and may eventually affect the meristem, in which case the palm dies.

There is normally agreement (some persons may disagree though) that 'common spear rot' and 'crown disease' are essentially the same thing. However, apart from this disorder, there is not much agreement on names, symptoms and causal agents of the many other forms of spear rot in oil palm. Spear rots or bud rots have received different names in different regions and countries, but symptoms always include limited or extensive drying and/or rotting of young leaves (including spears) and yellowing of already open young leaves.

The most infamous of these disorder is called in several Spanish speaking countries as 'pudrición del cogollo' or PC (Fig. 3a) , and symptom description may vary a little or much, according to the person describing the problem and the region where he observes the affected plant. The main point of discrepancy seems to be if the affected plant will or will not have a chance to recover. Similar symptoms have been described in Colombia, Ecuador, Brazil, Surinam, Nicaragua, Panama, affecting palms of any age. The condition known in Costa Rica as 'flecha seca' (dry spear: Fig. 3b) can be considered a mild form of 'bud rot' or PC, as described in other regions in tropical America. The 'disease' may affect palms of any age, including occasionally, nursery palms. Most palms affected by 'flecha seca', normally recover 'spontaneously' after several months or even years from symptoms onset. When the recovery period is very long, yields can be severely affected during 2-4 years. Affected palms may die if invaded by the American weevil, *Rhynchophorus palmarum*. This is also true for all forms of spear rots, even 'common spear rot'.

Fig.3a. Typical symptoms of 'pudrición del cogollo' (PC) including rotting and/or yellowing of young open leaves and spears

Fig.3b. 'Flecha seca' (dry spear rot). The group of spears appears desiccated but rotting or chlorosis (yellowing) may be absent. This symptom seems to be a severe variation of 'wither tip'

Symptom severity of PC may vary greatly even in palms growing in close vicinity. In some cases, the attack is so light that it is difficult from the distance to tell if a given plant suffered or not an attack. It could be said that some plants that look as if never were affected (when judged after several years from the initial attack) were affected so lightly that no permanent signs were left. These plants may be taken even as resistant.

Plants suffering mild attacks are sometimes observed in areas where most other palms show severe symptoms. These palms may show a few young leaves with clhorosis (yellowing), but there might be no rotting of tissues (or only limited to a relatively small lateral portion of the petiole) (Fig. 4). These palms normally are able to recover easily from the condition without suffering apparently much. Yellowing may even partially disappear after some time.

Fig. 4. Palms showing yellowing of some young leaves but no rotting (or limited). The palm on the left belongs to the Bamenda x Ekona variety.

Another known variation of the same theme (yellowing and drying of portions of the young leaves, with or without rotting of tissues) is a condition that was known as 'dwarf leaves' in Costa Rica (Fig. 5). These symptoms (normally occurring in palms of 2-3 years in the field) may occur in absence of any rotting on the spears or bud region. New leaves on these palms are much shorter than old ones and are pale yellow in color. The symptoms were common on palms planted in areas previously affected by other more severe conditions, such as the 'flecha seca', on the central Pacific coast of Costa Rica. All plants so affected, recovered within a few weeks or months, apparently without affecting yields severely.

Fig. 5. The condition known as ‘dwarf leaves’ may or may not progress to PC-like symptoms. The palm on the right shows short young leaves and chlorosis

The PC in tropical America has been described in several regions as always 'lethal'; but this is a position that can be easily challenged. Even in some plantations where it was assured in the past that all affected palms eventually would die, it is possible today (after many years that a given plantation was abandoned total or partially) to observe groups of palms that never suffered an attack or they somehow survived to one. This is the case in some plantings in Ecuador (Eastern), Brazil (Para) and Nicaragua (Atlantic coast) (Fig. 6).

Fig. 6. *Left*. All palms in this area on the Pacific coast of Costa Rica were affected by PC-like problems and recovered after sometime. *Right*. Palms going through the recovery phase in a plantation on the Atlantic coast of Nicaragua.

Even though, the 'true' bud rot (PC) has been described by some as the main phytosanitary threat to the oil palm industry, it is forgotten that other forms of 'whorl rots' could be more lethal. The case of what we will call here 'severe bud rot' (pudrición severa del cogollo) is particularly interesting, since this disorder will kill the plant in a matter of weeks or may be even days. It can be argued that 'severe bud rot' is the same as PC (it actually is one more in the list of variations of this theme), but it shows some important differences with the 'classical' PC (Figs. 7-8).

Fig. 7. *Left above*. 'Severe bud rot'; 'sudden drying of all spears and young leaves with no previous yellowing. There is a generalized destruction (liquefaction) of the internal tissue close to the meristem (*Right above*). These symptoms different from 'amarelamento fatal' as known in Para, Brasil. *Left below*. Palm with PC-like symptoms ('amarelamento fatal') where rotting did not reach the meristem (*Right*).

'Severe bud rot' affects young palms mainly (first 3-4 years in the field), but it also occurs in older palms; where incidence has been abnormally high in a plantation in the state of Para in Brazil. Normally, the first symptom observed is a rather sudden drying and desiccation (with no previous yellowing) of the whole package of spears and some of the youngest leaves. These severe symptoms are the result of a rapid liquefaction of all tissues above the meristematic

region. Rotting soon reaches the meristem and kills the plant. Symptom progression is so fast that initially, a plant may look apparently healthy from some distance. There is no evidence of spread of this disorder and the appearance of new cases normally diminishes with age.

Fig. 8. Young leaves cut from palms with PC-like symptoms (*left*) and 'severe bud rot' (*right*)

The associated organisms

Many decades of more or less continuous efforts to identify a primary pathogen as the sole cause of most spear rots in oil palm have failed. Common spear rot is an interesting case, since efforts to identify the cause in America date back at least from 1928, when the very first oil palms were brought to America and some of them showed symptoms. Several opportunistic microorganisms of cosmopolitan occurrence are associated with rotting of spears, such as *Fusarium* spp. and *Erwinia* spp. Bending of rachises is due in part to an abnormal lignification, which causes bending as they grow and weight increases (Monge et al. 1993, 1994).

Many people have tried to associate PC to almost any imaginable pathogen that has been or not present in diseased palms. Accordingly, many different pesticides (fungicides, nematicides, insecticides, bactericides, etc.) have been used on such affected palms in an attempt of protecting them from infection or recovering from symptoms. By the time being, it seems that this via will not take anywhere. Almost all microorganisms commonly associated with spear rots in oil palm belong to a group that share some characteristics, which in turn are also also shared by those microorganisms associated with the so-called ´declines´ as described in many forest species, citrus, avocado, prunes, etc.

1. They are common weak (ubiquitous) pathogens present in practically any ecosystem.
2. Only prosper in tissues previously weakened due a single stress or a combination of several types of stress.
3. Attack actively growing (young) tissues near the meristem in the whorl or roots.

Even if a particular pathogen is ever identified as causing most of the symptoms that characterize spear rots in oil palm (PC in particular) this would not necessarily lead to the development of a successful control strategy by attacking the pathogen directly. It was already mentioned the impossibility of prevent (cure) affected palms by using a whole battery of agrochemicals. The

examples of ‘lethal yellowing of coconut’ in commercial coconut groves and ´*Fusarium* wilt´ in oil palm further illustrate the point. For this last disease, the problem seems to have an agronomic origin, since it is closely associated with conditions that are clearly adverse for an acceptable plant performance; including poor soil physical and chemical properties (poor aeration and fertility: particularly low K), poor water management (water deficit in soils with low water retention capacity), drainage problems, etc. (Turner 1981, Renard and Franqueville 1989). Disease tolerance, and of course, better agronomic practices, are the logical solutions.

In the case of PC, any new tissues (roots and whorl) under stress can be attacked by many opportunistic microorganisms such as (*Pythium* spp., *Phytophthora* spp., *Fusarium* spp., *Thielaviopsis* spp., *Erwinia* spp. etc.) and any other taking advantage of the situation of a debilitated organ, such as some arthropods (sinphylids) that further destroy the fine root system and open new doors for the invasion of the opportunistic. There are, however, other organisms that really can aggravate the condition of an affected plant. In Ecuador and other countries, for example, the attack of the root miner, *Sagalassa valida*, can cause massive death of roots, debilitating even further the plants and contributing to its death. The presence of *Cyparisius daedalus* (*Castnia daedalus*) in Para, Brazil is definitely linked to a more severe damage to affected palms, and in most countries, *Rhynchophorus palmarum* can not be separated as an important factor leading to death of PC-affected palms.

Predisposing factors

If we consider the scarce evidence in favor of the existence of a primary pathogen as the sole cause of spear rots in oil palm, and the difficulties of getting an economical viable approach to control the disease by a direct attack to such hypothetical pathogen; then it results appropriate to study and develop alternative ways of managing the problem. One such approach is to study, define and understand all factors associated with incidence, severity and the ability of some plants to recover from symptoms.

All disorders described above share many characteristic with what is known in forest scientific literature as 'declines'. These disorders may all be caused by the inability of a population of plants to sustain a particular biomass under marginal or drastically changing conditions (Manion and Lachance 1992, Chinchilla and Durán 1998, 1999, Bergamin et al. 1997, de Franqueville 2001).

Some of the characteristics shared by spear and bud rots in oil palm and forest declines are:

a. Increment of incidence in time follows a lineal or near lineal tendency in time (at least in many situations).
b. Total or partial recovery of a proportion of plants affected.
c. Strong 'site effect' on incidence and severity of symptoms.
d. There is no known single pathogen associated with all symptoms observed.
e. All organisms so far identified associated with symptoms are normal, ubiquitous, secondary pathogens.

For the (normally) mildest form of spear rots (CSR/CD) susceptibility seems to be genetically controlled (Blaak 1970), but there are some predisposition factors that have been identified: the disorder is associated with all elements that affect root development such as poor soil aeration, (weak or no structure, poor drainage, soil compaction…), unbalanced nutrition, particularly nitrogen excess in presence of potassium shortage (Turner 1981, Breure and Soebagjo 1991, Sterling and Alvarado 1996, Alvarado et al. 1997, Chinchilla et al. 1997).

Two peaks of high incidence of CSR/CD are common in young plantings in areas with a clear dry season: the first coincides with the onset of the second rainy period after planting. During the preceding dry season many of the superficial fine roots die and not many new roots are expected to form in dry conditions. Later, after rains are initiated, it is a common practice to use fertilizers high in nitrogen to stimulate a vigorous new aerial growth, in detriment of a poor root development. The second peak of incidence occurs toward the end of that rainy season (second year in the field) when the soil is saturated with water in poorly drained soils, which also affects negatively root growth.

CSR/CD is normally managed by using sound agronomic practices, in particular those tending to maintain good soil aeration and promoting root development. Incidence is also decreasing in commercial plantations as the breeding programs identify and discard progenitors conferring susceptibility.

Spear and bud rots in general are then associated with factors such as low soil aeration, unbalanced nutrition and an uneven water supply (altered water balance). In general, any factor that affects negatively root formation and its longevity would predispose a plant to an attack of PC. Low soil aeration may be caused by impeded drainage through the soil profile, the presence of impermeable layers, very fine or contrasting textures in soil profile, compaction, etc. On the other hand, a draught period may cause substantial root death, particularly fine roots. The final result of all this could be the formation of few new roots and the deterioration of the already formed root system. A severe drought will contribute to the deterioration of the fine rot system, which will be aggravated in soils with low water retention capacity and low potassium content.

From a nutritional point of view, it is common in soils where PC appears that potassium and phosphorus are in a deficiency condition or unbalance with other elements, such as magnesium and/or calcium (Chinchilla and Durán 1999, Cristancho et al. 2007). A potentially dangerous combination could be the use of excess of nitrogen where potassium is deficient in soils with low water retention capacity and under conditions where periods of water deficit are fallowed by soils saturated with water. All these factors cause severe loss of the fine root system and induce an important stress on the plant. The presence of PC has also been associated with low zinc and copper content and the ratio between iron and manganese in both the soil and the plant; but these last relations are not always clear. When soils are saturated with water, some forms of iron tend to accumulate in the roots (causing toxicity) and the element becomes deficient in the young aerial tissues.

The characterization of what could be considered a predisposed palm would be a key step toward the understanding and managing of oil palm spear rots. For the time being, we know of some characteristics that seem to be present in a predisposed (stressed) palm:

a. A poor development of the root system and the persistence of conditions that are unfavorable for root health.
b. Reduced rate of petiole and rachis elongation.
c. A heavy load of bunches under conditions unfavorable to sustain them.
d. Low potassium availability.
e. Changes in nutrient gradient along some tissues such as leaves, stem and roots; particularly K and Ca and a high N/K ratio.
f. Accumulation of low-molecular weight metabolites (soluble sugars, nitrogen compounds and other degradation products in the leaves).
g. Altered water balance (stomata regulation and water potential altered).
h. Possible unfavorable rations Fe/Mg and other elements (low levels of Cu).
i. Possible induced Ca deficiency (altered transpiration).

However, not all of the above elements are always present in a plant that will eventually develop symptoms, and sure there are others that we still do not identify or understand; but this lack of knowledge have to be tackle through more research in this area. In general, it looks like there is a malfunction of phloem tissues that become incapable of bringing badly needed essential metabolites (sugars) to tissues in active expansion. Whatever causes this phloem-apparent malfunction could well explain the catastrophic symptoms observed in the whole whorl region.

The onset of symptoms of the so-called ‘flecha seca’ (dry spear) in Costa Rica seems to be preceded by a sequence of events that indicate the presence of one or more types of stresses that had been affecting the palms for some time before typical symptoms appear. The adverse effects seemed to be more negative on those palms that had being growing vigorously and had a heavy bunch load. The sequence of events (previous, contemporaneous and posterior) in symptom development in young palms were:

1. Inflorescence abortion.
2. Reduction in fruit set.
3. A period of variable length were both aerial and root growth increased over the mean of other plants followed by another period characterized by diminishing petiole cross section and rachis length.
4. Reduction in the amount of fine roots.
5. Onset of 'first typical symptoms (yellowing in the base of some leaflets located at the base of some of the youngest leaves, with or without rotting or desiccation of spears).
6. Reduction of bunch weight and oil bunch content (Albertazzi and Chinchilla 2005).

Some of these tendencies had already been observed in plants that had developed common spear rot symptoms (Chinchilla et al. 1997).

The first events that were considered to be previous to the onset of 'typical symptoms' were observed at least 5-6 months before (i.e. a reduction in fruit set), but if we consider inflorescence abortion, this will conduct us to an event that took place well before; for example a severe drought or prolonged soil water saturation.

A more vigorous growth preceding a posterior decline and the eventual presence of PC symptoms, tends to evocate the image of a variant of the Democles sword that claims a price to those plants that seem to need more of the already available limited resources.

These situations (certain events preceding the onset of symptoms) are not easily conciliated with the idea of a primary pathogen as the sole cause of spear rots. Of course, none of the previous symptoms would necessarily conduct to a spear rot problem, but would indicate a clear predisposition for that.

The type and severity of symptoms (yellowing, desiccation and rotting) and the speed of recovery of affected palms were related with the degree at which the root system had been previously deteriorated and the ability of the plants to form new roots (Albertazzi and Chinchilla 2005).

Genetic resistance and tolerance

The species *E. oleifera* is an important source of resistance to the different spear (bud) rots, and this resistance can be combined with the species *E. guineensis* to obtain the traditional OxG hybrids, that have been planted in some areas affected by these disorders with a varied degree of success. The main problem with these hybrids is that they present some agronomic disadvantages, such as vegetative desuniformity, excessive vegetative growth, very thick stems, long leaves (less plants can be planted per area unit), thick petioles (making harvesting more difficult), less oil content and pollination problems (assisted pollination is rather expensive). The more obvious advantages are its resistance to spear (bud) rots and less saturated oil.

OxG hybrids can be genetically improved so they retain desirable characteristics (PC tolerance and oil quality from *oleifera*, for example) but at the same time incorporating the economical advantages of *E. guineensis*, such a higher oil content, less vigorous vegetative growth and no need of assisted pollination. Such an effort is being conducted at ASD's breeding program (ASD 2007).

The search for resistance/tolerance to spear rots can also be conducted within the species *Elaeis guineensis*. It is well known that Deli palms (mother palms) confer susceptibility toward these disorders and that one of the most popular varieties, Deli x AVROS can be severely affected. So far, all known *guineensis* varieties are susceptible, but some may carry genes of tolerance. The characteristics that are present in these tolerant varieties are:

1. The disorder appears later in time with respect to more susceptible varieties like Deli x AVROS.
2. A reduced rate of disease increase over time.
3. Less severe symptoms.
4. A faster recovery from symptoms.
5. Less final incidence and,
6. Less negative effects on yields (Chinchilla et al. 2006).

Some Ekona genes seem to confer higher tolerance and so do some pollen sources also having stress tolerance (particularly water stress: Mobai and Malawi (experimental), and La Mé (commercial). On the other side, the maternal sources, Bamenda and Tanzania (commercials) and Angola and Entebbe (experimental) also seem to confer tolerance. These maternal origins also are stress tolerant.

The performance of the commercial variety Bamenda x Ekona has been consistent in several localities where it presented the tolerance characteristics mentioned above. Other commercial and experimental crosses with potential are Tanzania x Ekona, Deli x La Mé, Angola x Ekona, Deli/Angola x La Mé and Tanzania x Ghana. The commercial varieties Deli x Ghana and Deli x Nigeria are susceptible, but in less degree than Deli x AVROS (less severe symptoms and a faster vegetative and productive recovery). So far, there is not enough experience with the different compact clones and seed varieties, but some clones seem to be tolerant.

The idea of the need of some predisposing factors (stress) as necessary elements that may conduct to symptom development (affecting both incidence and severity) becomes strengthened by the fact that stress tolerance and spear rot tolerance seem to be associated. In this respect, some crosses tolerant to water deficit have also shown tolerance to PC and related disorders (Alvarado and Sterling 2005, Chinchilla et al. 2006). This line of research is now actively followed.

Conclusions

The search for the causes and solutions for the different phytosanitary problems of the oil palm in tropical America has been particularly fruitful during the last 15 years or so. For most of these problems, a solution has been achieved when an integrated management approach have been followed. This has been the case for diseases such as the red ring, sudden wither and now for some the many forms of bud and spear rots. A central idea of this approach is that prevention is the first barrier against phytosanitary problems. Some important elements that should be a constant in the industry are the utilization of planting materials from known sources, optimum land preparation (causing minimum negative effects on soil physics and fertility, including the preservation and enrichment of a diverse soil biology), improving the quality of nursery plants, effective soil water management, better agronomic practices during the unproductive period and a permanent monitoring of plantations among others. Behind many of these practices is the realization that a healthy root system guaranties a healthy plant, and that many problems arise from a weak and underdeveloped root system.

Some forms of spear and bud rots still represent a very important problem in some plantations in tropical America, but most evidence accumulated so far indicate there is not a sole pathogen as the sole cause of these disorders. However, they share similar symptoms and normally are clearly associated with similar environmental and management conditions. This is an indication that a general management strategy can be devised for all of them.

The characterization of what constitute a predisposed plant (or plantation) is an essential knowledge badly needed to get a better understanding of these disorders and will help, no doubt, to work a more sound agronomic management aimed to prevention. Within this scheme, it is

important to define all previous physiological events that conduct to symptom development. The stresses (predisposing) factors must be characterized, and timely identified and removed to anticipate the problem. Corrective measures must be taken well in advance in an attempt to reduce incidence and severity and increase the probabilities of plants recovering from symptoms in a shorter period of time.

Besides this, all aggravating elements, such as the attacks by *Rhynchophorus palmarum*, *Sagalassa valida* or *Cyparisius daedalus* have to be detected opportunely and removed from the equation also.

Disease resistance/tolerance can also be an important part of disease management, but no genotype will perform well from a commercial point of view if it is not given an appropriate agronomic management. This is particularly true if stress tolerance and disease tolerance are related, since it would be expected that some energy is always used to maintain and use physiological mechanisms for protection from stress. Within this scheme, it is important to define all previous physiological events that conduct to symptom development.

A final solution to all these disorders will only be obtained through research, and with the cooperation of people from different disciplines. A team work is needed with the participation of both soil and plant scientists. The problem is surely complicated and incidence, symptom severity and the ability of a plant to recover seem to be closely associated with previous and actual factors of the environment affecting negatively palm growth, the historical agronomic management of the plantation, and probably the kind of opportunistic organisms present.

The final solution will also surely imply the use of better agronomic practices adapted to the place where the plant is growing (considering its yield potential), and the development of tolerant varieties, where the desired traits of *E. oleifera* could be used, but considering that such tolerance could also be found within *E. guineensis*.

Literature

Alvarado, A; Chinchilla, C; Bulgarelli, J; Sterling F (1997). Agronomic factors associated with common spear rot in oil palm. ASD Oil Palm Papers, 15: 8-28.

Alvarado, A. y Sterling, F. 2005. Variedades de palma aceitera tolerantes al estrés. ASD Oil Palm Papers, 28: 5-20.

ASD de Costa Rica. 2007. Nuevo híbrido OxG Compacto (características varietales). 7p.

Bergami A., Amorin L., Laranjeira F., Berger R., Hau B. (1998). Análise temporal do amarelecimento fatal do dendezeiro como ferramenta para elucide sua etiología, Fitopatol. Bras. 23: 391-396.

Blaak, G (1970). Epistasis for crown disease in the oil palm. Euphytica, 19:22-24.

Breure, C and Soebagjo, F (1991). Factors associated with the occurrence of crown disease in oil palm and its effects on growth and yield. Euphytica, 54:55-64.

Chase, A and Broschat, T (1991). Diseases and disorders of ornamental palms. American Phytopathological Society, U.S.A. 56 p.

Chinchilla, C (2003). Integrated management of phytosanitary problems in oil palm in Central America. Manejo Integrado de Plagas y Agroecología, 67: 69-82.

Chinchilla, C and Durán, N (1998). Management of phytosanitary problems in oil palm: an agronomic perspective. Palmas, 19 (número especial): 242-256.

Chinchilla, C and Durán, N (1999). Nature and management of spear rot-like problems in oil palm: a case study in Costa Rica. Proc. of the 1999 PORIM Int. Palm Oil Congress (Agriculture), Kuala Lumpur, Malaysia. 1-6 February 1999. p. 97-126.

Chinchilla, C; Salas, A; Castrillo, G (1997). Common spear rot/crown disease in oil palm: effects on growth and initial yields. ASD Oil Palm Papers, 16: 1-17.

Chinchilla, C.; Alvarado, A.; Albertazzi, H; Torres, R. 2006. Tolerancia y resistencia a las pudriciones del cogollo en fuentes de diferente origen de *Elaeis guineensis*. Conferencia Internacional sobre Palma de Aceite, Cartagena. Septiembre, 2006. 23 p.

Chinchilla, C. 2007. Experiencias y estrategias de Costa Rica en el manejo de la PC y mejoramiento genético para la obtención de nuevas variedades. Taller sobre pudrición del cogollo en Tumaco, Colombia. Octubre 2007. 12 p.

Cristancho, J., Castilla, C., Mojas, M., Munevar, F. Silva, J. 2007. Relación entre la saturación de Al, Mg, K y la tasa de crecimiento de la pudrición del cogollo de la palma de aceite en la zona oriental de Colombia. Palmas, 28(2): 25-35

de Franqueville, H (2001). Oil palm bud rot in Latin America: preliminary review of established facts and achievements. CIRAD/BUROTROP, France. 33 p.

Duff, A (1963). The bud rot-little leaf disease of the oil palm. J. West Inst. Oil Palm Res. 4 (14): 176 190.

Kovachich, W (1957). Some diseases of the oil palm in the Belgian Congo. J. West Afr. Inst. Oil Palm Res. 2: 221 229.

Malaguti, G (1953). Pudrición del cogollo de la palma aceitera Africana en Venezuela. Agronomía Tropical, 3: 13-31.

Manion, T and Lachance, D (1992). Forest Decline Concepts. APS Press. Minnesota. 249 p.

Mariau, D; van de Lande, H; Renard, J; Dollet, M; Rocha, L; Rios, R; Orellana, F; Corrado, F (1992). Pudriciones del cogollo en palma aceitera, en América Latina. Sintomatología, epidemiología e incidencia. Oléaginéux, 47(11): 605-618.

Monge, J; Chinchilla, C; Woung, A (1993). Studies on the etiology of the crown disease/common spear rot in oil palm. ASD Oil Palm Papers, 7:1-16.

Monge, J; Vásquez, N; Chinchilla, C (1994). Common spear rot/crown disease in oil palm: anatomy of the affected tissue. Elaeis, 62(2): 102-108.

Renard, J and de Franqueville, H (1989). Oil palm bud rot. Oléagineux 44 (2):87-92.

Renard, J., Franqueville, H (1989). La fusariose du palmier á huile. Oléaginéux, 44(7):341-349.

Sterling, F and Alvarado, A (1996). Crown disease\common spear rot: genetic differences and effect on initial production. ASD Technical Papers, 12: 18-32.

Swinburne, T (1993). Fatal yellows, bud rot and spear rot of African Oil Palm. A comparison of the symptoms of these diseases. The Planter, 69(802): 15-23.

Turner, P (1981). Oil Palm Diseases and Disorders. Oxford University Press. New York.

van de Lande, H (1983). Studies on the epidemiology of spear rot in oil palm in Suriname. Thesis. Wageningen Univ., Wageningen.

van de Lande, H (1986). Diseases of fatal character to the oil palm in Surinam and in North Brasil. De Surin. Landb. 34 (1,2,3,): 1 12.

Watanavanich, P (1982). Oil palm diseases in Thailand. The Oil Palm in the Eighties (Pushparajah and Soon eds.). The Incorporated. Society of Planters. Kuala Lumpur, Malaysia. p 457-460.