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Onset of spear rot symptoms in oil palm and prior (and contemporary) events

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Abstract

The sequence of events prior and contemporary to the onset of visible and characteristic symptoms of spear rot was followed in four groups of oil palms (*Elaeis guineensis* Jacq.) that were initially healthy. Spear rot corresponds to a disorder known as PC (pudrición del cogollo) in South America. Those palms that eventually developed characteristic PC symptoms (yellowing of some leaflets at the base of a few of the youngest leaves, plus desiccation and/or rotting of some of the spears) previously showed a period of rapid vegetative development followed by a sudden drop in growth. Just before the onset of the characteristic symptoms, the plants showed a reduction in leaf length, leaf area and leaf emission rate. These variables maintained steady positive growth rates in palms that remained healthy. This sequence of previous events in palms that later developed symptoms (vigorous growth followed by an obvious retardation in growth) may indicate that plants with a more vigorous growth were exposed to some sort of stress that made them more susceptible to PC. It was determined that the stress period that could have caused the susceptibility response occurred from 8 to 9 months before growth measurements detected a growth reduction. Such stress then occurred during the fast growing phase of the organs affected.

Inflorescence abortion was the main factor associated with a reduction in bunch numbers in diseased palms, which is also in accord with the stress hypothesis as an important cause for disease appearance. Bunch weight was not reduced until six months after symptom appearance.

The frequency distribution of the density of the fine root system in young diseased palms tended toward lower values (less than 0.75 g/l). This behavior may also occur prior to the onset of the characteristic symptoms, and was evident from 2 to 5 months earlier.

Introduction

Spear rots in oil palm are common disorders in all places where this palm has been planted commercially. A particular form, known in tropical America as “pudrición del cogollo” (PC) has been particularly damaging in many plantations in Panama, Nicaragua, Colombia, Ecuador, Surinam and Brazil (Ruinard et al. 1990; Mariau et al. 1992; Swinburne 1993; Franqueville 2001). In Costa Rica, and some other countries these “spear rots” are not lethal, but they still cause important losses in productivity, because a long period of time is normally required for a palm to recover both its vegetative growth and yield potential. Recovery, however, may be speed up by improving agronomic practices (Chinchilla and Durán 1998, 1999).

The variety of local names given to these disorders in different countries may reflect the lack of knowledge on its causes. In Brazil, the local name given to the condition was translated as “lethal yellowing”, which initially caused great confusion with a completely different problem: coconut

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lethal yellowing. In some areas of Ecuador and Colombia, the name given is “pudrición del cogollo” (whorl rot), or even “lethal whorl rot”, but death of the affected palm does not always occur, and in some regions recovery is the norm. In Costa Rica, a similar disorder is better known as “dry spear”, since the most common symptom is not rotting of the spears but their desiccation accompanied sometimes by yellowing of young leaves. This disorder is not lethal (Chinchilla and Durán 1998, 1999; Chinchilla and Escobar 2004).

Symptoms similar to ‘pudrición del cogollo’ as they occur in tropical America are not unknown in Asia, but incidence has never reached the levels observed in the second continent (Turner 1981; National Research Center for Oil Palm 1996). The second author has observed identical symptoms in Thailand in a small, poorly drained plantation.

The participation of pathogens as the primary cause of spear rots has not been established beyond doubt (Chinchilla and Durán 1999; Franqueville 2001), and these problems are usually interpreted as a growth disorder associated with one or more types of stresses that trigger a susceptibility response. Pathogens associated with symptoms are considered opportunistic.

Incidence, severity and the ability to recover from spear rots in oil palm are associated with agronomic management, soil, nutritional and climatic factors that affect proper plant performance, particularly the root system. The most common problems found in affected areas are poor soil aeration, unbalanced nutrition (particularly the ratio between bases, and normally low K contents), a biologically impoverished soil and an altered water balance (Turner 1981; Monge et al. 1993; Alvarado et al. 1997; Chinchilla and Durán 1998, 1999, Franqueville 2001). However, the etiology of the problem remains open to discussion, as is the case for so many of the so-called declines that affect many other plant species (Lima 1982; Manion y Lachance 1992; Melakeberhan 1993; Tu 1994; Grimm et al. 1997).

Studying disease progression symptoms, in particular those events that occur prior to the presence of actual visible symptoms may help us understand the causes behind spear rots in oil palm. For spear rot (PC), the characteristic initial symptoms are considered to be yellowing of a few leaflets of the youngest leaves and localized spear desiccation and/or rotting.

To achieve this, a group of palms, originally considered healthy, must be systematically monitored over time in an area where the disease is expected to appear. Repeated growth measurements can be taken (both aerial and root systems), as well as physiological data (photosynthesis, stomata behavior, assimilated portioning etc.), so that when the typical symptoms appear in one of more of these plants, all measurements can be studied in retrospect and compared with data from plants that remain healthy. This study reports on several of these kinds of trials conducted in a commercial oil palm plantation in Costa Rica (Central Pacific region), where the disorder known as “dry spear” is common.

For practical purposes, we consider the typical (or the very early symptoms of the disease) to be the yellowing of a few basal leaflets of some of the youngest leaves. At the same time or soon afterwards, some spears develop areas where the tissue desiccates and/or rots. In the text these symptoms are referred to as the “first symptoms”.

Materials and methods

All observations and experiments were done in a commercial oil palm plantation that had been affected by a ”dry spear” condition since 1992, and which had symptoms very similar to the South American “pudrición del cogollo” or PC (Chinchilla and Durán 1999). This area has soils derived from alluvial deposits, some of them very shallow, with large deposits of sand and gravel. The rainy season normally extends from April to November, with a well marked dry season (Fig. 1).

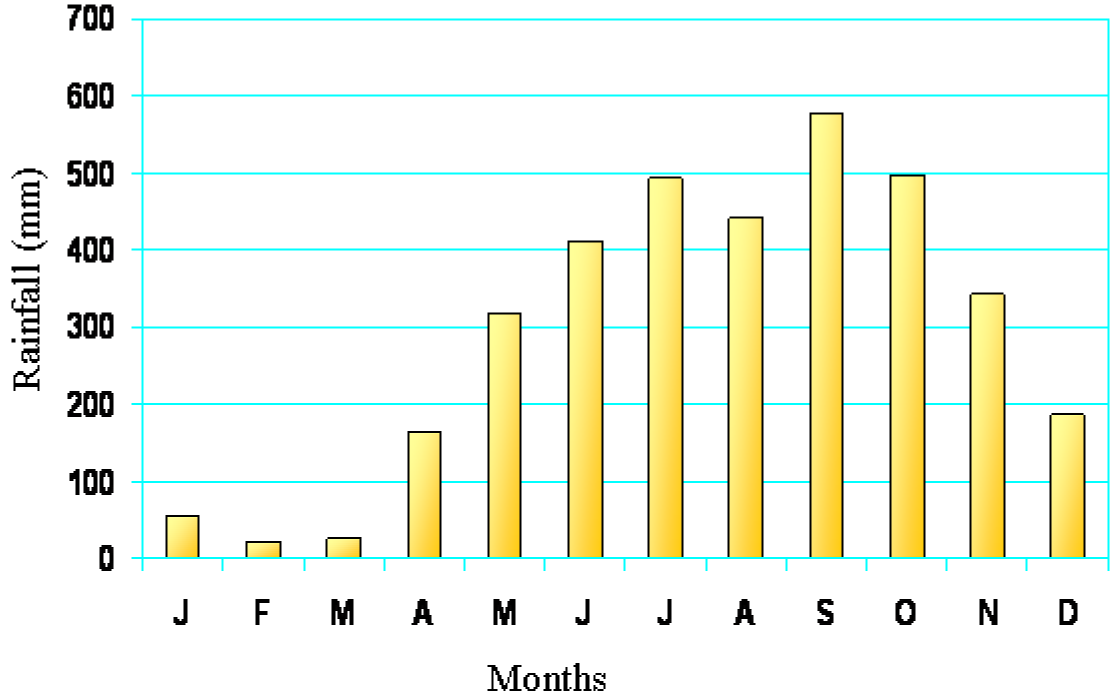

Fig. 1. *Monthly rainfall distribution in the Quepos area, Costa Rica (1992-200)*

Study 1. One hundred apparently healthy palms of a Deli x AVROS cross planted in 1990, were selected to take vegetative monthly growth measurements on leaf one. The area was being affected by “dry spear” and so the date when each palm showed the 'first symptom' was recorded. To facilitate the interpretation of the results, all palms showing symptoms within a period of two months were analyzed together.

Study 2. Palms of the Deli/Kigoma x Ekona variety (304 palms) planted in 1997 were used in this study. The area formed part of a fertilization experiment where data on growth measurements and disease incidence were routinely recorded. As in the previous study, those palms showing the first symptoms within a few days of each other were grouped to facilitate data interpretation.

Study 3. A group of 78 healthy palms and 48 affected ones (Deli/Kigoma x Ekona planted in 1998) were used in this study. Root density was determined during the early part of the rainy season (June, 2001), and later in December (end of the rainy season). During the second sampling of the root system, some of the originally healthy palms had developed the "dry spear" symptoms. Sampling was done with an Eijkelkamp auger that extracts a soil volume of 730 cm^3. Roots were washed with water and dried at 70 °C for 24 hours in an oven with forced air. Roots were then classified into two categories according to size: first and second orders and third and fourth orders together.

Study 4. Twenty-five 8-month old healthy palms of the Deli/Kigoma x Ekona variety were selected for biweekly growth measurements. Nutrient content in leaves 1, 2 and 6 was measured once at the start of the study. Roots were sampled with a Eijkelkamp auger (15 cm deep at 30 cm from the stem). Soluble sugar concentration was estimated using a portable refractometer (Leica) using sap from the bulb, large roots and leaf rachis.

Results and discussion

Study 1

Leaf one growth measurements reflect prevailing conditions several months prior to actual emergence of that leaf from the whorl. Rachis length and petiole cross section of an open leaf are measurements that express the effect of stress occurring several months earlier, when these organs were in a rapid growth phase (approximate positions -10 to -6 in the phyllotaxy, Corley and Tinker 2003). Assuming a leaf emission rate of two leaves per month (for an adult palm), any stress occurring from 5 to 3 months earlier could be reflected in growth data for leaf one.

The group of palms that developed visible symptoms in January and February 1996 had shown much longer rachis lengths in previous measurements (November-December, 1995), but by the time symptoms appeared rachis lengths had declined considerably. This observation may be the expression of the effect of a prior stress that had occurred about five months earlier.

A second group of palms that developed symptoms later (March-April 1996) had maintained a steady growth rate (until the first group showed symptoms), but when the symptoms eventually appeared, rachis lengths had also declined (Fig. 2).

The fact that plants with symptoms showed a slight increase in rachis length for some time after symptom appearance, may indicate that the prior stress event was of comparatively short duration; however, the low values for rachis length and PxS following symptom development are just a consequence of the severity of the attack. The phase after the appearance of the first symptoms is not considered here, but the negative effects of this disorder on yield are well known and may extend for more than two years.

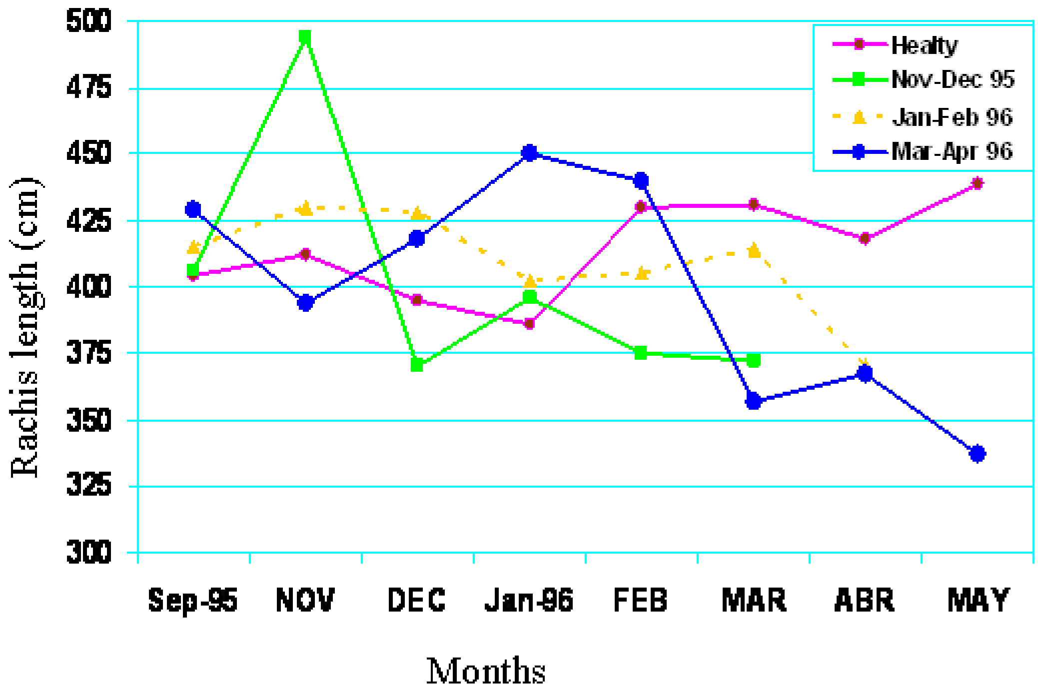

Fig. 2. *Rachis length in four groups of palms planted in 1990. Growth was monitored before, at, and after the characteristic symptoms of PC (spear rot) appeared. Palms that were still healthy were compared with three groups of palms that developed symptoms in the months of November-December 95. January-February 96, and March-April 96*

The behavior of the PxS value, also very sensitive to stress, closely followed rachis length tendencies (Fig. 3). Similar results were also obtained when growth was measured on a group of palms that eventually developed the common spear rot/crown disease. In this case, the palms again showed a rapid growth rate phase, followed by a reduced growth rate phase and eventual symptom development (Chinchilla et al. 1997).

Study 2

Vegetative growth. A group of palms that developed symptoms in December 1999 was used to document the negative effects following symptoms onset. These palms were part of a fertilization experiment where growth measurements on leaf 17 were taken every six months. Due to the long period between measurements, it was not possible to establish clear relationships between symptoms onset in particular plants and growth patterns prior to this event. Nevertheless, an attempt was made assuming a leaf emission rate of nearly three leaves per month for young palms. According to this, the PxS and rachis length values on leaf 17 reflected a situation (of stressful or good conditions for growth) that occurred around 8-9 months earlier. Then, these organs were negatively affected during its active growth phase approximately one or two months before symptoms developed in the different groups of palms. Study 4 was done to better understand this observation, by taking monthly growth measurements.

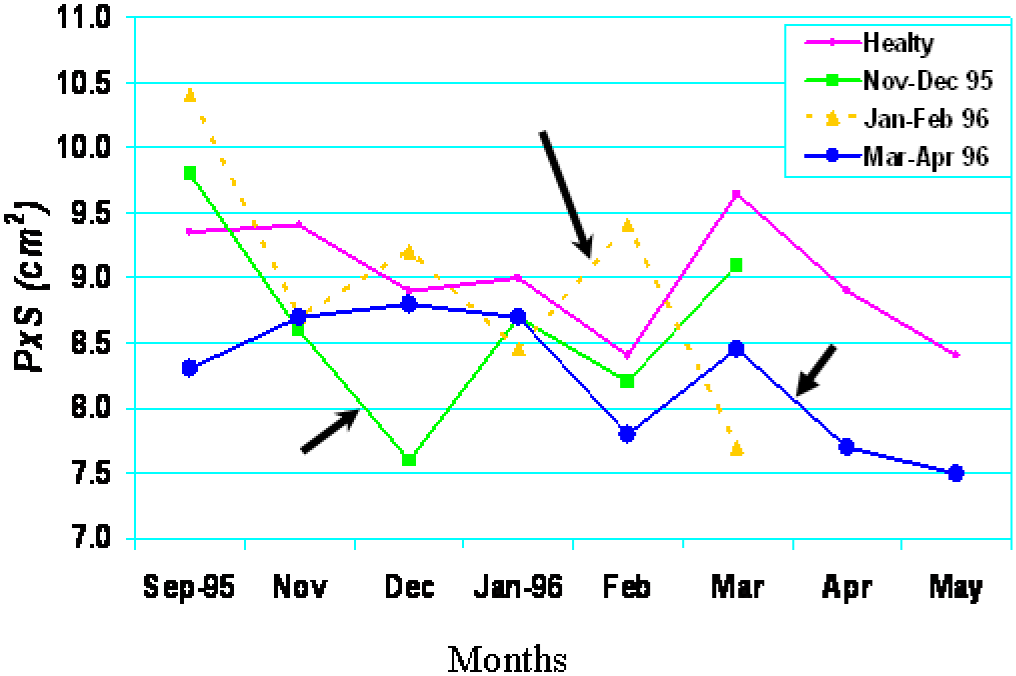

Fig. 3. *Petiole cross section in four groups of palms planted in 1990. Vegetative growth was followed prior to spear rot symptom development. A group of healthy palms was compared with other groups that developed symptoms in Nov-Dec. 95, Jan-Feb, and March-April 96 (indicated by arrows).*

Growth measurements, before the onset of symptoms (October 1999) and posterior to this event, (August 2000) were similar when healthy palms were compared with diseased ones (Table 1). However, the negative effects of the severity of the disease were quite obvious on data collected one year after the first symptoms were noticed.

Table 1. Growth measurements in a group of palms that remained healthy and another that showed symptoms in an intermediate date (December 1999). Palms planted in 1997

Category	October 1999				March 2001			
	n	PxS	RL	LA	n	PxS	RL	LA
Healtthy	35	4.7	302	3.2	33	9.3	438	5.7
Diseased	20	4.7	302	3.2	7	6.3	328	3.7

PxS = petiole cross section (cm²), RL = rachis length (cm), LA = leaf area (m²)

Production. Palms with heavy bunch loads could be more predisposed to suffer spear rot. However, there is no apparent reason to expect differences in numbers of bunches due to changes in sex ratio between palms that remain healthy and those that will eventually show symptoms. Total number of bunches produced per palm can be affected at the time of floral differentiation, which occurs at least 19 months before the anthesis event. However, any difference in bunch number between palms that remain healthy, and those with the first symptoms could be the effect of different abortion or bunch failure rates. Considering this, it is not probable that floral differentiation (or any stress affecting it) could be related in some way with the subsequent development of symptoms. Two facts can be pointed out here: spear rot symptoms may appear during the first year in the field and growth measurements have not detected any difference between palms that remained healthy and those that developed symptoms two years later.

Bunch abortion (before anthesis) and bunch failure (post-anthesis) both affect bunch number per palm. As with the case for sex ratio, these events are affected by stress, but contrary to sex ratio, we would expect this stress to be related to the subsequent presence of spear rot symptoms. The first yield peak in this experiment occurred in 2001, from March to July. During this period, the closer the time to peak yield, the lower the effect on bunch numbers in palms that developed symptoms (Fig. 4). The difference in bunch numbers between healthy palms and those that developed symptoms in May 2000 (approximately nine months before the onset of peak yield), was clearly larger than that found between palms developing symptoms in August and September (approximately 6-7 months before the peak yield).

In general, when healthy and diseased palms were compared, bunch number was lower in those groups of palms that showed the first spear rot symptoms from 8 to 12 months before the peak yield. No clear differences were observed between palms that showed symptoms only seven months before. This may indicate that events associated with a reduction in bunch number per palm occurred during a period very close to the one that had caused abortion (9-11 months before harvesting). According to this, it is highly probable that abortion of female inflorescences is the main reason for a reduction in bunch number in palms that eventually present spear rot symptoms. As such, this situation may be reflecting a stress that occurred before the onset of such symptoms.

Bunch weight in diseased palms decreased approximately six months after symptom initiation (Fig. 5). In a previous study, it was determined that both bunch and individual fruit weights from healthy palms were larger than in palms with the first symptoms of spear rot. The average difference in bunch weight was 2.7 kg, and the weight of individual fruitlets from diseased palms was down by 56%. The reduction in bunch weight was also associated with a decrease in total fruit set (increment in the proportion of parthenocarpic and vane fruits).

Another study found that fruit set was larger in bunches from healthy palms, when compared to palms with the initial spear rot symptoms. However, in some period prior to symptom onset, the percentage of parthenocarpic fruits in palms that remained healthy was similar (or even lower) than that for palms that eventually developed symptoms. Considering that fruit set is defined in a period shortly after pollination, it can be concluded that a particular event (stress) occurred during a period before symptom onset, and those palms that had better fruit set (and possibly larger bunch loads) were those more exposed to any particular stress.

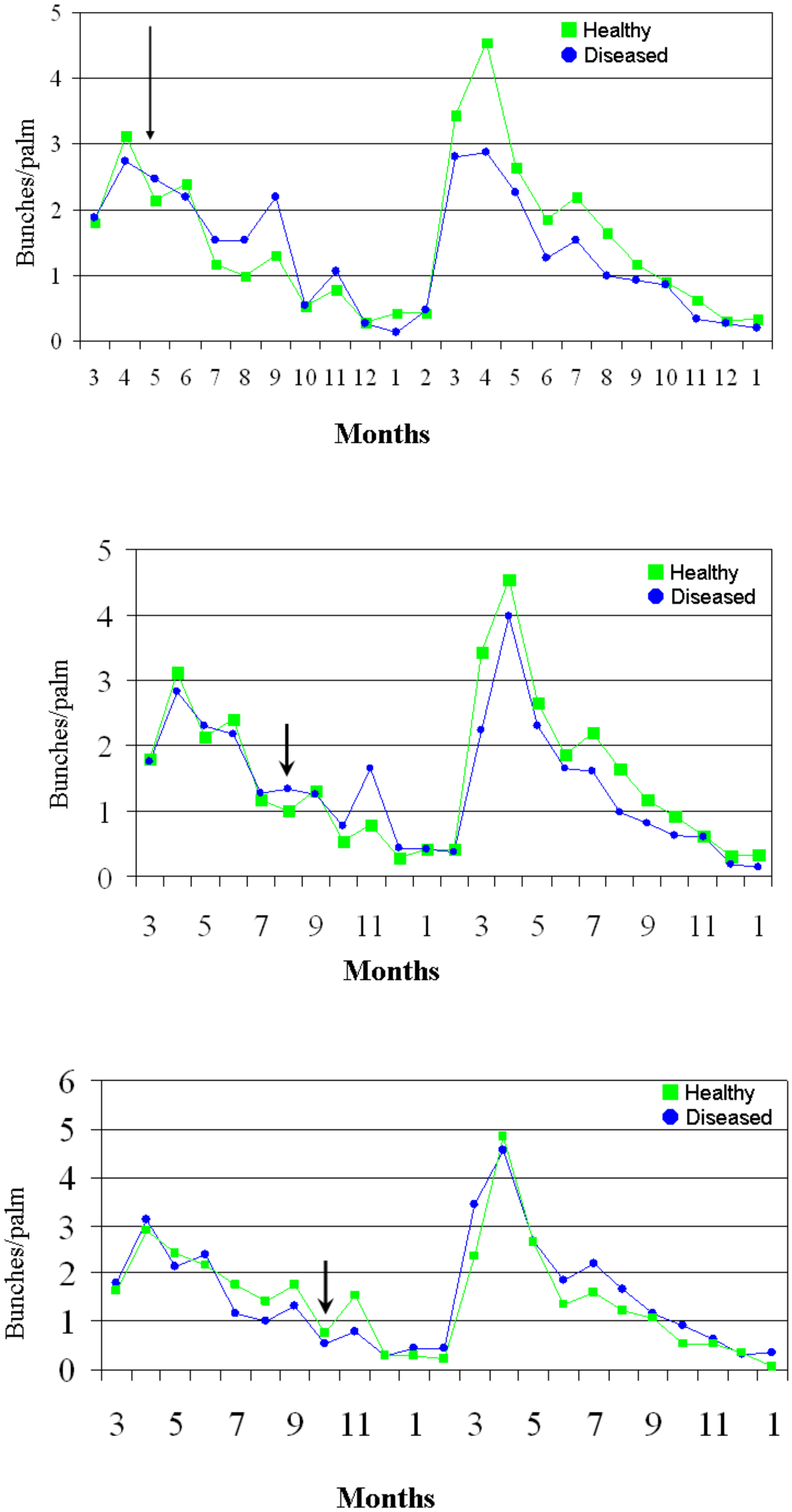

Fig. 4. *Number of bunches in healthy palms and three groups of palms that developed spear rot symptoms: the arrows indicate the dates when symptoms were noticed.*

The reduction in weight of the individual fruits was associated with events that may have occurred during the first two months after anthesis, since at that time the fruit reaches about 80% of its total weight (Corley 1977). This indicates the inability of these palms to support the development of such fruits.

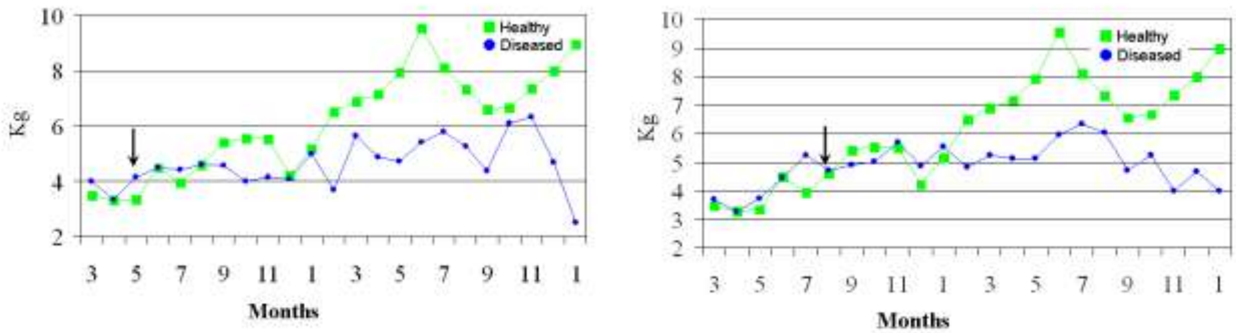

Fig. 5. *Mean bunch weight in healthy palms and three groups affected by spear rot. Arrows indicate dates when symptoms were noticed.*

Most of the events described so far occur before or contemporaneous to symptom onset, and it seems evident that later, and depending on symptom severity, the affected palms may lose most of their yield potential for the next two or more years.

Study 3

The frequency distribution of fine roots (third and fourth orders) in diseased palms tended to be at the lower end values (less than 0.75 grams of roots per liter). During the first root sampling in healthy palms, two peaks in density of fine roots were found at 1.5 and 3 g/l, containing about 70% of the samples taken (Fig. 6). In diseased palms, data near 1.5 g/l represented only about 33% of the samples. A second peak (density from 0.25 to 0.50 g/l) contained only around 24% of the samples taken from diseased palms. An increase in weight corresponding to larger roots (primary and secondary) can be considered normal according to an increase in palm age.

All palms (those that remained asymptomatic and the affected ones) showed a reduction in the amount of fine roots during the second sampling done six months later (Fig. 7), which indicates that even healthy looking palms could be going through a predisposing period, which eventually caused most plants to show symptoms in that particular area. This reduction in the density of fine roots was probably due to poor soil aeration that affected the area after several months of rains. However, during the first sampling, only 36% of the healthy plants (which eventually showed symptoms) had root densities higher than 1 g/l. In those palms that remained healthy up to the second sampling, the corresponding percentage was 82%. These observations may indicate that a reduction in the fine root system is a condition that precedes the onset of spear rot symptoms.

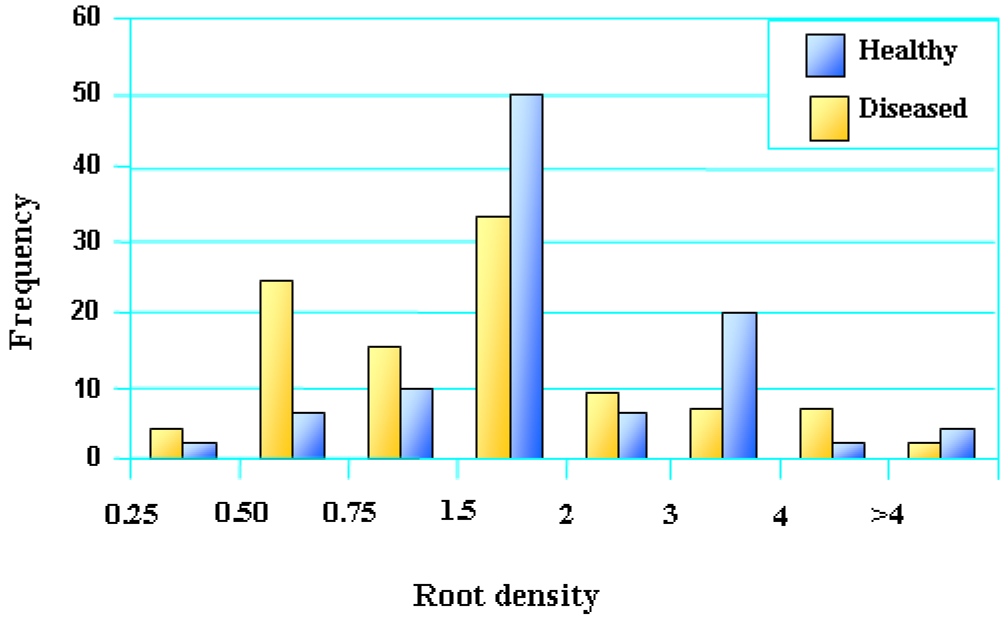

Fig. 6. *Frequency distribution of fine roots (third and fourth orders) in healthy palms and with initial spear rot symptoms. Palms were approximately three years old.*

For both sampling periods, statistical differences were found in total amount of fine roots between healthy palms and those with the first symptoms (Table 2). Some apparent inconsistencies could be the result of the inability to separate palms that started to show symptoms between the actual sampling days. Symptom severity may also introduce differences among plants difficult to quantify.

Table 2. Mean concentration of roots (g/l) in healthy palms, those with initial spear rot symptoms, and those recovered from the diseased, on two sampling dates. Palms planted in 1998.

	Fine roots		**Large roots**	
	June 2001	December 2001	June 2001	December 2001
Healthy on both dates	1.53	0.53	0.21	1.11
Symptoms on date 2	0.78**	0.38**	0.15	0.58*
Symptoms since date 1	1.08*	0.25	0.46	0.53*
Recovered by date 2	2.08	0.26	0.19	0.34**

Statistical comparisons against the group of healthy palms within the same column (t-test).

Study 4

Out of the 25 palms originally selected as healthy, a total of 18 (70%) developed spear rot symptoms. The increase in disease incidence from April 2002 (which coincided with the onset of the rainy season) was related to a previous reduction in the amount and weight of both fine and larger roots, which was partially a consequence of the previous dry season. Once the rainy season started (and the first cases of spear rot were detected), it was also noticed that the root system was reactivated in those palms that remained healthy, but this did not happen for those palms showing symptoms, or the response was comparatively weak. Before the onset of symptoms, the amount of roots (both fine and large roots) decreased to nearly half in most palms (94%) (Table 3). This reduction in root density was evident between from 2 to 5 months before the first symptoms were detected.

Table 3. Percentage of palms (8-months old) that showed spear rot symptoms (18 of the originally healthy 25), where the amount of fine roots decreased, increased or did not change, before and after symptoms were detected

	Fine roots			**Large roots**		
	Decreased	Similar	Increased	Decreased	Similar	Increased
Before symptom detection	94%	6%	-	89%	11%	-
After symptom detection	39%	17%	44%	44%	12%	44%

The growth of the root system did not follow a defined pattern in all plants after symptoms developed: in approximately the same percentage of plants (39-40%), root density increased or decreased, and no clear change was detected in 17% of the plants. In some of these plants root density was lower than 0.5% g/l. These different responses between palms were probably the result of differences in the severity of the attack, and the ability of the plants to start an early recovery process.

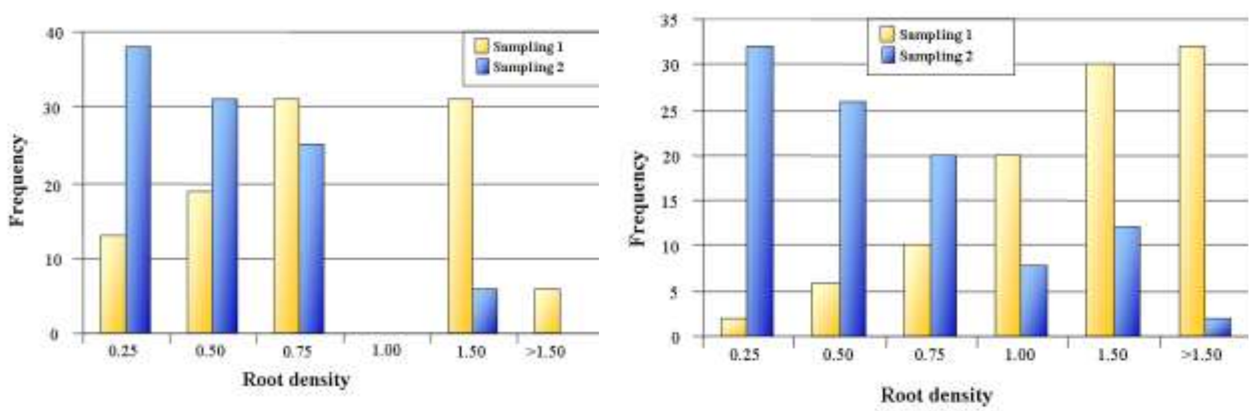

Fig. 7. *Frequency distribution of the fine root system (third and fourth orders) at two sampling dates 6 months apart. Left: Palms that showed spear rot symptoms during the second sampling. Right: Palms that remained healthy. Palms were about three years old.*

Other variables also affected before the onset of the spear rot symptoms were the PxS value and rachis length: the growth rate of the PxS value decreased or did not change in 66% of the palms that eventually showed symptoms. The PxS growth rate maintained a steady increase in 85% of the plants that had not shown symptoms up to that date.

Rachis length growth-rate decreased or was maintained in 88% of the plants that later developed symptoms. In healthy palms, as expected for palms of this age, a steady increase in the value of this variable was maintained in 86% of the plants. In general, the PxS value increased from 2.0 to 2.8 cm^2, and rachis length changed from 2 to 3 m in palms that remained healthy during the period of study.

In those palms that became diseased, a reduction in PxS and rachis length values for leaf one was observed about 2-3 months before symptom onset, which means that any stress event causing this reduction actually occurred sometime before, considering the time needed by the leaf to reach position one in the phyllotaxy. Leaf emission rate (less than two leaves/month) was considered low for palms this age.

Symptom severity seemed to be closely related to the magnitude of the stress that caused a reduction in root density, and in PxS and rachis length values. Those palms that presented low severity (little yellowing accompanied by limited rotting or desiccation of spears) had a smaller reduction in the magnitude of these variables before symptoms actually appeared (Table 4). For palms with mild attacks, it was observed that the root systems reactivated their growth in 50% of the cases, and in some palms it was also observed that rachis and PxS growth rates increased.

Table 4. Weekly changes in growth rates of PxS and rachis length (leaf one), and leaf emission rate in healthy and diseased palms, according to spear rot symptom severity and the speed of recovery (8-months old palms)

Category	Severity	Recovery rate	Change rate PxS (cm^2/week)	Change rate RL (cm/week)	Leaves/month
Healthy			0.012 ± 0.07	0.86 ± 1.3	1.54 ± 0.09
	low	high	-0.030 ± 0.04	-3.8 ± 2.4*	1.47 ± 0.05
Affected	low	slow	-0.040 ± 0.07	-1.18 ± 5.5	1.39 ± 0.10*
	high	slow	-0.142 ± 0.09	-1.63 ± 8.5	1.45 ± 0.07

* t-test (P = 0.05) compared against healthy palms
** Diseased palms were separated into three categories according to symptom severity and speed of recovery. PxS = petiole cross section; RL = rachis length

Under a severe attack (generalized yellowing and more than one third of the affected leaves desiccated) the reduction in rachis length and PxS values and in root density prior to the observation of the first visible symptoms was very clear. Following a severe attack, most palms (66%) also showed a continued reduction in all these variables.

The presence of generalized yellowing of young leaves (severe attack) was associated with a drastic reduction in root mass, but leaf death (dried leaflets) was observed in most palms (78%) until the amount of fine roots dropped below 0.5 g/l, which normally represented the loss of more than half of the fine root system for those palms that initially appeared healthy. The particular behavior of three individual palms is illustrated in figure eight.

The presence of the first spear rot symptoms was also associated with an increase in soluble sugar content in the young leaves, a fact that had already been observed in other studies (Chinchilla and Durán 1999). The gradients of values within leaves, roots and bulbs were similar for healthy and diseased palms (Fig. 9).

Conclusions

The presence of the first symptoms of spear rot in oil palm seems to be preceded by a series of events (of relatively short duration) that indicate the presence of one or more stress factors that negatively affected the vegetative growth of the plants and their ability to supply nutrients to the developing bunches. All these events seemed to happen several months before the actual presence of the first symptoms (partial yellowing of some leaflets of the youngest leaves and desiccation or rotting of sections of the spears). The negative effects of such stress seemed to have greater impacts on palms with vigorous growth rates and/or larger bunch loads.

A group of alterations (events) in growth pattern over time (some in sequence and others apparently simultaneous) in palms that develop spear rot symptoms was as follows: vigorous growth, inflorescence abortion, reduction in fruit set (more parthenocarpic fruits), reduction in the PxS and rachis length values, reduction in the fine root systems, onset of the so-called “first symptoms” (yellowing/rotting/desiccation of spears), reduction in bunch weight and oil content, and reduction in bunch number. Symptom severity, types of symptoms developed and speed of recovery were associated with the magnitude of the loss of the fine root system.

Changes in soluble sugar content in the young leaves of affected palms may indicate a serious alteration in carbohydrate transport and possible damage to the phloem. Such alterations would be impeding the free flow of assimilates from leaves to sinks such as the spears and roots, and eventually to the developing bunches. This is in accord with the kinds of symptoms observed, including attacks by opportunistic organisms to poorly nourished plant organs. The severity of symptoms and the speed of recovery may depend on the magnitude of blockage of the photosynthesis products and the ability of the palm to reestablish a normal flow.

From a practical point of view, palm vegetative growth (particularly PxS and rachis length) can be monitored so that any deviation from the expected tendency can be interpreted as the presence of a prior stress that could lead to negative effects on yield and even the development of a condition such as spear rot, where such disorders are expected to occur. Immediate actions that could be taken are in-depth studies and subsequent correction of the source of such stress, such as poor soil aeration, unbalanced nutrition, or any other factor that can be identified, and corrected timely.

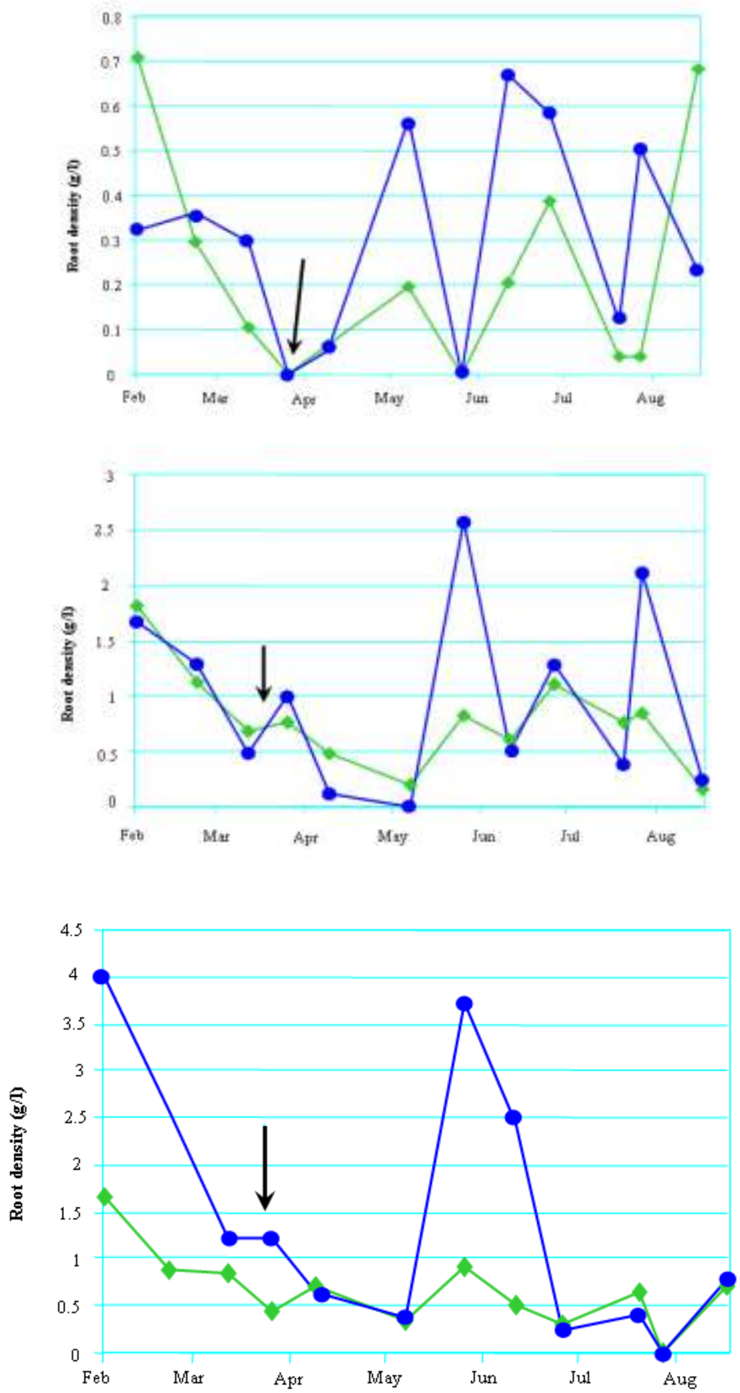

Fig. 8a. *Changes in the dynamics of the fine (♦) and large (●) root systems (g/l) in originally healthy palms, and those that developed spear rot symptoms. Arrows indicate dates when symptoms were first observed. Plants were eight months old when observations began.*

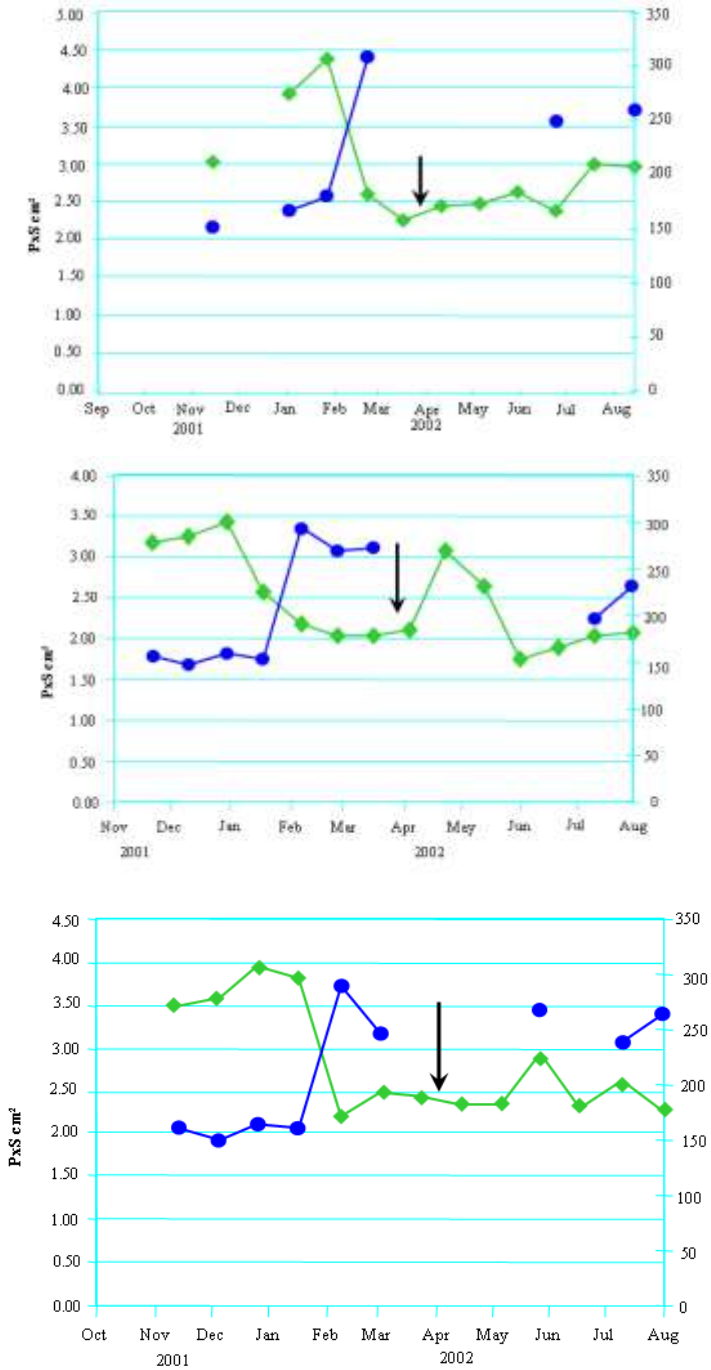

Fig. 8b. *Changes in petiole cross sections (♦) and rachis lengths (●) in originally healthy palms, and those that developed spear rot symptoms. Arrows indicate dates when symptoms were first observed. Plants were eight months old when observations began.*

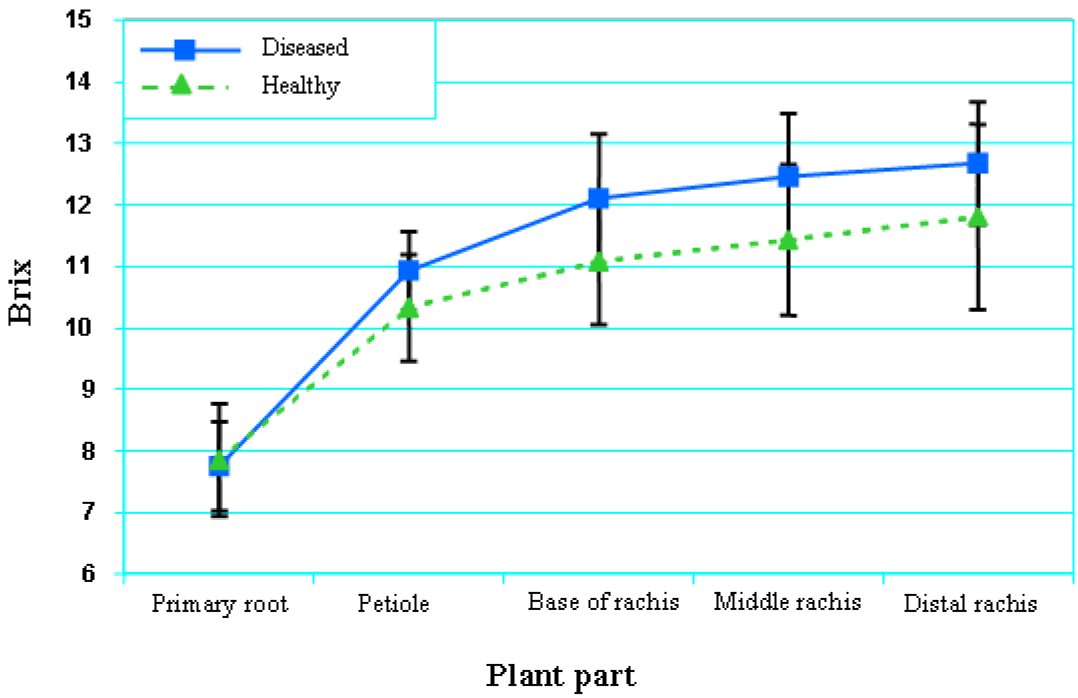

Fig. 9. *Soluble sugar concentration in leaf one in healthy palms and palms with the first symptoms of spear rot*

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