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Factors Involved in the Development of Nutfall Due to *Phytophthora katsurae* in Ivory-Coast

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Summary

Nut rot on coconut can be spread simply by contact or by spreading agents which maintain isolated infections within a bunch on a given tree and at plot level. The disease generally spreads horizontally from one bunch to another and vertically, particularly vertically downwards, from one nut to another in a given bunch. The positive effect of water and insects in disease spread has been demonstrated.

Résumé

Facteurs impliqués dans l'accroissement des chutes de noix causées par *Phytophthora katsurae* en Côte-d'Ivoire

La propagation du parasite responsable de la pourriture des noix immatures du cocotier se fait soit horizontalement par des contacts entre régimes soit verticalement, entre noix à l'intérieur d'une même grappe. Le rôle de la pluie et des insectes dans la propagation est démontré. L'épidémie dans cette affection est caractérisée par deux phases: une phase agrégative, au cours de laquelle la contamination interviendrait de proche en proche et une phase régulière pendant laquelle les nouveaux cas apparaissent éloignés des foyers initiaux.

Introduction

Pathogen dissemination is generally an important factor in disease development. It contributes to the establishment, development and maintenance of epidemics, since it results in parasite propagules spreading from so-called conservation sites or primary foci to healthy organs. In certain cases simple contact between diseased and healthy organs can result in contamination; in other situations, a dispersion agent is required (2). Water, wind, insects, rodents and man are all potential agents for spreading infection.

The diversity of propagules capable of spreading infection (sporocysts, zoospores, hypha fragments, etc.) means *Phytophthora* can spread in several ways (4,5). For a given disease, the role played by each dissemination factor has to be determined if the development of epidemics is to be understood. This approach was not previously taken with bud rot and immature nutfall on coconut. This is the topic of the present paper.

Material and methods

As soon as the first diseased nuts were observed, the bunches and the trees on which they occur were marked to enable counting and locating new diseased nuts. This enabled us to monitor disease evolution in space, both on individual trees and in whole plots. To determine how the disease spread, the position of a new diseased nut was recorded. The design was in square block with ten rows and ten coconut palms per row.

In addition to these observations the pathogen was trapped from insects and rainwater.

Insects living under and on the floral parts were inventoried. The nuts on trees were inoculated via wounds, with liquidized insects for which an increase in population levels coincided with an increase in the disease according to previous observations (3). Whole insects or insects with their legs and mandibles removed were rinsed in sterile water or disinfected with bleach, then liquidized and inoculated to nuts via wounds. Controle nuts were only wounded. Inoculation with rainwater was carried out by using cotton wool soaked in water collected in a container placed under the coconut palms.

Results

Dissemination

Rotten nuts were found to be either in contact with other nuts or isolated in the bunches on a given tree or on different trees. Although in the former case, infected nuts were always in contact with another already diseased nut, in the latter there was no apparent contact between either diseased nuts or bunches. Depending on the situation, we discuss contact dissemination or isolated dissemination.

A detailed analysis of results shows that isolated dissemination was significantly more frequent, with 53.50% (50.33 - 56.60%) of the diseased nuts observed (table 2) and 72.36% (65.25 - 79.46%) of the bunches bearing diseased nuts (table 1).

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Table 1
Spread of nut rot due to *Phytophthora katsurae* from bunch to bunch as a percentage of the total number of bunches, irrespective of the type of dissemination.

Diseased nuts	Dissemination			
	Horizontal	Vertical		All types
		Upward	Downward	
Number of isolated diseased bunches, % and range	55 36.18%(28.34-43.82)	41 26.97%(19.9-34.02)	14 9.2%(4.6-13.8)	110 72.36%(65.25-79.46)
Number of grouped diseased bunches, % and range	29 19%(12.76-25.23)	9 5.9%(1.3-10.5)	4 2.6%(0.07-5.12)	42 27.64%(20.5-34.7)
Total bunches % and range	84 55%(47.09-62.9)	50 32.9%(25.43-40.36)	18 11.8%(6.67-16.9)	152 100%

Table 2
Spread of *Phytophthora katsurae* rot from nut to nut as a percentage of the total number of nuts observed irrespective of the type of dissemination.

Diseased nuts	Dissemination			
	Horizontal	Vertical		All types
		Upward	Downward	
Number of isolated diseased nuts, % and range	111 11.46%(9.45-13.46)	96 9.9%(8.11-78)	311 32.12%(29.17-35.06)	518 53.5%(50.35-56.61)
Number of grouped diseased nuts, % and range	190 19.6%(17.09-22.10)	95 9.8%(7.92-11.62)	165 17%(14.63-19.36)	450 46.48%(43.3-49.62)
Total diseased nuts observed, % and range	301 31.1%(28.18-34.01)	191 19.73(17.22-22.23)	476 49.17%(46.2-52.3)	968 100%

Direction of dissemination

The next nuts to be attacked were either close to or under the first rotten fruits. This phenomenon, at the tree level, led us to distinguish between horizontal dissemination and downward (or upward) vertical dissemination.

Assessment of these different dissemination directions, comparing the percentages of nuts or bunches considered, shows that vertical dissemination, particularly downward, is predominant for nuts, i.e. from one nut to another within the same bunch, with 49.12% (46.02 - 52.3%) for downward vertical dissemination and 19.7% (17.22 - 22.23%) for upward vertical dissemination as opposed to 31% (28.18 - 34.01%) for horizontal dissemination (table 2). In the case of bunches, horizontal dissemination, with 55.1% (47.07 - 62.9%) was significantly more frequent than vertical dissemination, which accounted for 32.9% (25.43 - 40.8%) for upward vertical dissemination and 11.8% (6.67 - 16.9%) for downward vertical dissemination (table 1). It was also seen that horizontal dissemination between bunches (table 1) and downward vertical dissemination on nuts (table 2) were the most frequent, and that they concerned isolated dissemination. The fact that the disease spread in these ways had major impact on our observation, and suggests that dissemination agent were involved.

Occurrence of coconut palms bearing rotten nuts

Figure 1 shows the experimental design, comprising one hundred coconut palms in rows of ten trees. The numbers marked in the squares correspond to the number of the round when we observed that the tree was contaminated. There were fifteen rounds in all. Although certain trees marked 0 during the first observation round are in a line, either along the row or across several rows, the disease spread observed subsequently did not follow this pattern.

This observation backs up the hypothesis of the existence of external dissemination agents.

11	0	0	6	13	0	0	0	0	0
0	0	11	11	0	0	11	0	0	13
0	7	0	3	11	0	10	3	12	13
11	8	11	0	11	0	4	6	0	12
9	0	8	13	11	0	11	10	12	11
13	0	11	11	15	0	0	0	11	9
0	0	6	11	10	0	0	0	10	12
0	0	0	0	2	0	0	1	0	14
0	11	0	11	12	0	7	7	11	3
12	0	13	12	0	0	0	9	0	6

Figure 1. Position of trees with diseased nuts in order of appearance.

Table 3
Nut infection on coconut by inoculation with liquidized insects

Inoculum source		No. of nuts		
		Total nuts inoculated	Total nuts infected	% success and range
Temnoschoita quadrimaculata	Whole	100	20	20(12-28)
	Mutilated washed in sterile water	100	2	2(0.8-4.8)
	Mutilated, washed in water-bleach mixture	100	0	0
Carpophilus hemipterus	Whole	100	14	14(7-21)
	Mutilated, water in sterile water	100	1	1(0.9-2.9)
	Mutilated, washed in water-bleach mixture	100	0	0
Oecophila longinoda	Whole	100	10	9(3.5-14.5)
	Mutilated, washed in water	100	0	0
	Mutilated, washed in water-bleach mixture	100	0	0
Control		100	1*	1(0.9-2.9)

* Proximal infection outside wound zone.

Insects in coconut plantations

The insects gathered on and under the sepals of diseased nuts were identified by the ESA entomology laboratory as *Temnoschoita quadrimaculata, Diocalandra* sp., *Carpophillus hemipterus* and *Oecophila longinoda*, an ant are very often found in coconut plantations.

Nut infection

All of these insects except for *Diocalandra* sp., made up the basic inoculum for nut infection; the inoculum was made of liquidized insects and was applied to a wound on the pericarp.

The inoculation success rates, varied depending on the inoculum preparation: 20% with *Temnoschoita*, 14% with *Carpophilus* and 9% with *Oecophila* (Table 3). The success rates were virtually nil when the insects had their legs and mandibles removed. Insects disinfected with bleach did not produce any symptoms whatsoever.

Rainfall and nutfall

The weekly nutfall rates were calculated (percentage

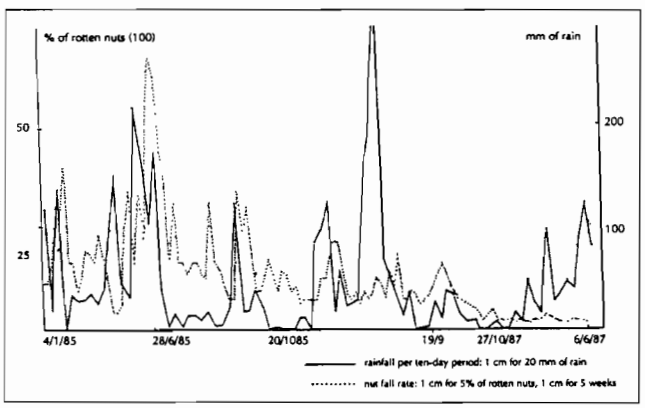

Figure 2. - Time-course of nutfall relation to rainfall.

of rotten nuts compared to the total nuts observed all nutfall combined, during the trial). These rates were used to plot the curves for rot evolution and establish a relationship with the rainfall curves (Fig.2).

The fit of these two curves (curves for nutfall rate evolution and rainfall per tenday period) revealed a relationship between rainfall peaks and disease peaks, slightly staggered during the main rainy season. The disease regressed during the dry season.

Rainwater and nut infection

The rainwater collected under fronds and in leaf axils was also infectious, even if there were no diseased fruits on the tree. Of 150 nuts inoculated with rainwater collected under a tree with diseased nuts 24 (16%) showed symptoms. This percentage fell to 6% with rainwater collected under trees without diseased nuts (Table 4). These results clearly confirm the importance of water in epidemic development. Its role in dissemination was one of the reasons the high rate nutfall observed during the rainy season.

Table 4
Inoculum detection in rainwater

Inoculum source	No. of nuts		
	No. of inoculated	No. of rotten nuts	%successfull infections
Rainwater under trees with diseased nuts	150	24	16
Rainwater under trees without diseased nuts	150	9	6
Sterile water	150	0	0

Discussion and conclusion

Our results showed that nut rot on coconut may be spread either by simple contact between fruits or via dissemination agents that maintain isolated infections on coconut palms.

Of the different dissemination agents, insects and water play a major role. The importance of rainwater is due to its dual effect on phycomycetes, to which *Phytophthora* belongs. In effect it ensures sporocyst germination, hence the release of zoospores, and also transports propagules (1,6,7). In this water-borne dissemination, splashing phenomena may occur when drops fall directly on sites bearing parasite elements. However, this work suggest that rainwater plays a role in downward vertical dissemination. As it runs over dis-

eased nuts or *Phytophthora* preservation sites, it picks up fungus propagules, transporting various amount depending on the distance covered. Rainwater collected under coconuts 1 m from the ground can still contaminate.
As for insects, their importance is due to their mobility, which enables them to extend their effect over large distances. This means not only single coconut palms but from one coconut palm to another and from one plot to another. Propagule transfer on the legs and mandibles seems to be the most effective mode of dissemination. As regards the mode and direction of parasite propagule dissemination, our results lead us to conclude that their transfer to healthy parts of the plant via dissemination agents is one likely factor in the propagation of nut disease caused by *Phytophthora*.

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