ROOT ROT DISEASES IN THE FORESTS AND PLANTATIONS OF THE IVORY COAST

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INTRODUCTION

These results were produced in a collaboration between the phytopathology laboratories of O.R.S.T.O.M. and C.T.F.T. The aim of this collaboration was to survey the plant-health problems caused by root rots in the main species of commercially grown ligneous trees in the Ivory Coast.

The first part of this work describes the various field surveys in the Ivory Coast and the most serious parasitic fungi that were found, laying particular emphasis on the economic impact of each disease. The second part will deal only with the particular case of rubber trees, *Hevea brasiliensis*, and the epidemiology of these root diseases.

IDENTIFICATION AND ECONOMIC IMPACT OF THE MAIN ROOT ROT DISEASES

The table 1 shows the main commercially grown ligneous trees and the surface areas covered by the plantations. The main crop is *Hevea brasiliensis*, followed by teak and species of *Terminalia*. Nearly sixty per cent of these planted areas in the forest zone were established after mechanical clearing, and thirty per cent in poisoned forest. After several field trips , four major parasites were isolated and characterized from the root systems.

- *Rigidoporus lignosus* (Polyporaceae), formerly called *Fomes lignosus*, the agent of white root rot. This fungus can aggregate its hyphae into rhizomorphs, which then constitute an excellent structure for propagation. In the tap root, this parasite cause a dry white rot.

- *Phellinus noxius*, (Polyporacae) formerly called *Fomes noxius*, the agent of brown root rot. *In vivo*, on the roots of infected plants, this parasite forms a blackish mycelial sleeve with sand and gravel encrusted. The presence of brown areas in the necrosed root tissues is characteristic of the white pitted rot caused by this fungus.

- One Agaricacea, of the genus *Armillaria*, the agent of agaric root rot ; as sporocarps were never observed, it is imposible for the moment to identify this species more completely. - *Sphaerostilbe repens* (Hypocreala) which cause a collar canker. On Hevea this parasite is detectable by its coremia and by the patches of coagulated latex all around the collar of diseased trees. Finally, the genus *Ganoderma* is very common in the Ivory Coast. However, its behavior is mainly saprophytic.

Owing to its geographical positions between four and eleven degrees of latitude north, in the heart of the forest zone of West Africa, the Ivory Coast has a tropical vegetation. Nevertheless, two zones can be distinguished : one is a zone of dense rain forest in the southern half of the country, subdivided into an evergreen and a semi-deciduous forest ; the other is a zone of wooded savannah in the north. The distribution of the parasites within the areas surveyed is shown in figure 1. The main foci of endemic parasitism lie in the rain-forest zone.

The economic impacts of each of these parasites on the various trees is variable (table 2). *Armillaria* and *Ganoderma* were found only in localized spots and at present they are still only minor parasites. The ascomycete *S. repens* was reported only on Hevea. In some plantations it causes heavy infestations. However, despite the serious disturbances that it causes to the non-lignified tissues of the collar, only very rarely does it cause the death of an infected tree. This table shows, finally, that *R. lignosus* and *P. noxius* are the most serious parasites, especially on *Tectona grandis*, *Cedrela odorata*, and *Hevea brasiliensis* (rubber tree).

EPIDEMIOLOGY OF RUBBER ROOT DISEASES

Given this disturbing situation and considering the projected development of 100.000 hectares of rubber plantations in the Ivory Coast by the year 2.000, it seemed necessary to estimate the potential dangers represented by these fungi, by studying the dynamics of development of their centers of infection. Experiments were carried out, first, in the primary forest before clearing and in the new plantation established subsequently ; and, secondly, in a four-year-old commercial plantation.

FOREST EXPERIMENTS

The aim of the study was first to catalogue the initial density of primary centers of infection and second, after clearance and planting, to follow the explosion of these centers of infection due to the disturbance of the natural equilibrium. Over about 20 hectares surveyed in this forest it was estimate on average, but by default, that there was about two centers of parasitic infection per hectare. A minute examination of the collars of all the trees over an area of one hectare revealed in addition that 9 % of trees were contaminated or infected. After clearing, as early as the first year, the activity of these centers of infection resulted in the deaths of 1,5 % of the Hevea trees planted within the areas studied. At present, after four years, the explosion of infestation has resulted in 8 % of the rubber trees being stricken, more than half of which have died as a result of the fungal infection. This study shows that, despite good preparation of the ground, i.e. mechanical clearing of the forest, formation of windrows and burning of the debris, more than 75 % of the centers of infection found in the forest, were found again in Hevea.

RUBBER PLANTATION EXPERIMENTS

The second set of epidemiological experiments was performed on twenty parcels of mature plantation totalling 8.000 rubber trees. These sections were chosen for their high level of fungal infestation. Therefore, the quantitative aspect of these results cannot be directly extrapolated to the whole of the plantation or even, of course, to the whole of the Ivory Coast rubber-growing zone. These experiments, which have so far lasted five years, consist in practice of observing the sanitary state of each of the 8.000 trees every 6 months. The end of this study is planned for October 1983 but already some striking facts about the parasitic behavior of *R. lignosus*, *P. noxius*, and *S. repens* can be seen.

* Fungi detection methods

Usually the planter's technique to characterize the sanitary state of each tree is to briefly expose the collar and look for the presence of mycelia on the root plateau. This method is obviously laborious, so it was looked for a means of earlier and more rapid detection. With this aim, the techniques of aerial infrared photography now used in plant-health surveys of forests in temperate countries were tried on rubber tree. For two years, many aerial missions were carried out below heavily infested sections which were photographed simultaneously on infra-red film and a control color film. Various sophisticated methods as microdensitometry were used to interpret the photos obtained.
Apart from the way the two types of emulsion show up withering trees with leaf symptoms, no other earlier indication of the pathological state of the many diseased trees is observable on the infra-red photos. In other words, the rotting of the root system does not significantly affect the spectral properties of the foliage during the most part of the pathological cycle. Therefore it was conclude that these techniques are ineffective in the tropical environment on rubber.

* Pathogenesis evolution

First of all, the overall infestation by the three agents of root rot declined noticeably after the strong advance recorded during the first year of the study (figure 2). In addition, during the five years of the study the level of mortality underwent an even more marked decline. This figure also shows the parasitic development with time i.e. the annual percentages of trees newly contaminated plus the percentage that had died. With *R. lignosus*, the most dangerous parasite, the extent of the centers of infection decreased greatly. This phenomenon is less perceptible with *P. noxius*. On the other hand, the decrease in annual levels of mortality was quite similar for these two fungi. Finally, the first deaths of trees cankered by *S. repens* were observed only in the fourth year.

The sharp increase observed in 1981, after four years of the study, was due to tornadoes at the end of the dry season that blew down many trees that had been infected for several years. Examination of these fallen trees showed that they survived the fungal attack by means of the hypertrophy of their lateral roots thus compensating for the necrosis and loss of the taproot. However, the consequent loss of anchorage in the ground made these trees particularly vulnerable to wind action.

A more specific study of the behavior of each of these parasites shows that the phases of contamination and colonization of the roots were each related to climatic conditions (figure 3). In fact, and especially for *P. noxius*, the rainy season from May to October coincided clearly with the extension of the centers of infection by contamination of neighbouring trees, whereas in the dry season this progression slowed down greatly. On the other hand, the colonization and death of infected trees was observed preferentially during this latter period. With *R. lignosus* this behavior was altered by year three of the study, after which the annual levels of contamination and mortality changed little.

* Parasites agressiveness

These observations led to compare the respective aggressiveness of *R. lignosus* and *P. noxius* as a function of time, or more specifically as a function of the age of the Hevea trees at the time of contamination (figure 4). One may consider that Hevea trees newly contaminated by one or other parasite make up a distinct population whose mortality can be observed each year. On these bases, each of the curves in this figure represents the cumulative mortality observed every six months. These data show first that the attack by *P. noxius* was more severe than that by *R. lignosus*. For example, after five years, 98,5 % of the trees attacked by *P. noxius* were dead whereas *R. lignosus* left 30 % of diseased trees still living. These intrinsic differences in aggressiveness between these two parasites almost certainly reflect the level of intensity of the mechanisms that come into play in a infection. This result is also confirmed by our laboratory, first on young plants inoculated in a greenhouse and secondly by *in vitro* experiments on degradation of wood.

In plantation, these differences were reflected particularly in the duration of the pathological cycle, in other words in the average time taken by each of these parasites to kill a just-contaminated tree. Thus a calculation for all the trees dying during these five years shows that the average duration of the infectious cycle was 17 months for *R. lignosus* and only 12 months for *P. noxius*. These two averages reflect the relative speeds with which the two parasites attack. However, these data are only approximate indications since there are two underlying sources of variability :

- first, there was the observed heterogeneity in duration of the fungal attack. On this point the death of the infested tree can come after six months or after several years, depending on each tree-parasite interactions,

- secondly, the aggressiveness of the two parasites decreased with time ; a comparison of the slopes of the curves reveals a progressive decrease in fungal aggressiveness with time ; in other words, each year more and more trees took longer and longer to succumb to the fungal attack. This phenomenon is clearly shown in table 3 that show the rate of mortality in populations of Hevea contaminated for two years. The decrease in these aggressiveness is related mainly to the Hevea trees' ability to resist infection, which increases with age. The falling-off of aggressiveness of *R. lignosus* compared with *P. noxius* is also particularly noticeable on this table.

* Incidence of clearing on pathogenesis

It should nevertheless be emphasized that these parasitic activities are also strongly conditioned by the previous cultural history, in other words by how the soil is prepared before planting. Two techniques are currently used by the planters : one consists in clearing the forest with the aid of mechanical engines to uproot all stumps deep down and gather them into windrows before burning. The other, and less expensive method, manual clearing, leaves a large proportion of woody debris in the soil. Figure 5 show the double effect of the type of clearing : first, on the initial level of infestation ; then on the final development of the disease. In mechanically cleared parcels the level of infestation at the start of the study was low and subsequently changed little. On the other hand, in parcels cleared manually the percentage of diseased trees was already clearly higher in year one and continued to increase each year afterwards. Thus woody debris present in the soil and between the rows of trees represents a trophic base that helps to keep the parasite vigorous enought to overcome the defenses of the host and to progress from tree to tree.

CONCLUSION

This review of the pathological problems of the root system of commercial ligneous trees planted in the Ivory Coast shows that *Rigidoporus lignosus* and *Phellinus noxius* are at present the most serious. None of the methods of combatting them used at present -- shallow basins around the collars of trees, uprooting of infected trees, and fungicidal treatment of neighboring trees -- can really stop the spread of these diseases.

Given this situation it is necessary to continue the biological studies and to reinforce the plant-health surveillance both in young plantations where the first secondary centers of infection become apparent and in the industrial forests where a resurgence of existing centers of infection is still to fear.

SLOW GROWING TIMBER SPECIES :

TEAK	MAKORE	SIPO	AFRICAN MAHOGANY (ACAJOU)	NIANGON	DIVERS
16000 ha	530 ha	2300 ha	2120 ha	1400 ha	300 ha

MEDIUM GROWING TIMBER SPECIES :

IDIGBO (FRAMIRE)	AFARA (FRAKE)	OBECHE (SAMBA)	CEDRELA	OKOUME	GMELINA
5300 ha	12700 ha	1800 ha	8000 ha	900 ha	1000 ha

SPECIES FOR PAPER PULP :

EUCALYPTUS	PINUS
200 ha	300 ha

LATEX EXPLOITATION:

RUBBER TREE
45000 ha

TABLE 1 IDENTITY AND AREA OF PROSPECTED TREES

FIG. 1

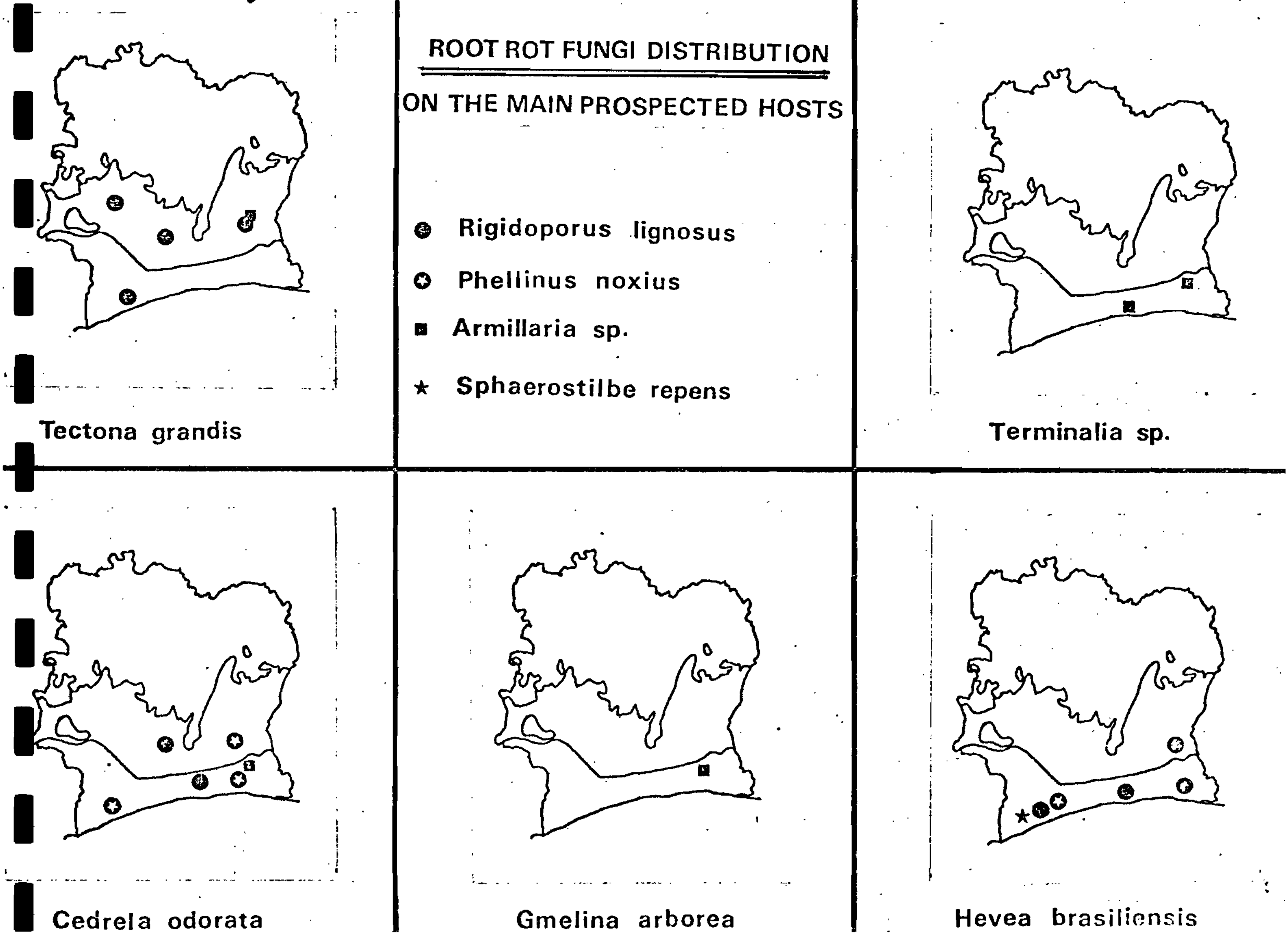


TABLE 2

Economic incidence of root rot fungi

	TECTONA GRANDIS	*GMELINA ARBOREA*	*CEDRELA ODORATA*	*TERMINALIA sp.*	*HEVEA BRASILIENSIS*
Area (ha.)	-15900	1007	8056	18000	45000
RIGIDOPORUS LIGNOSUS	✪✪✪		✪		✪✪✪✪
PHELLINUS NOXIUS			✪✪		✪✪✪
SPHAEROSTILBE REPENS					✪✪
ARMILLARIA sp.	✪	✪	✪✪	✪	
GANODERMA sp.		✪			✪

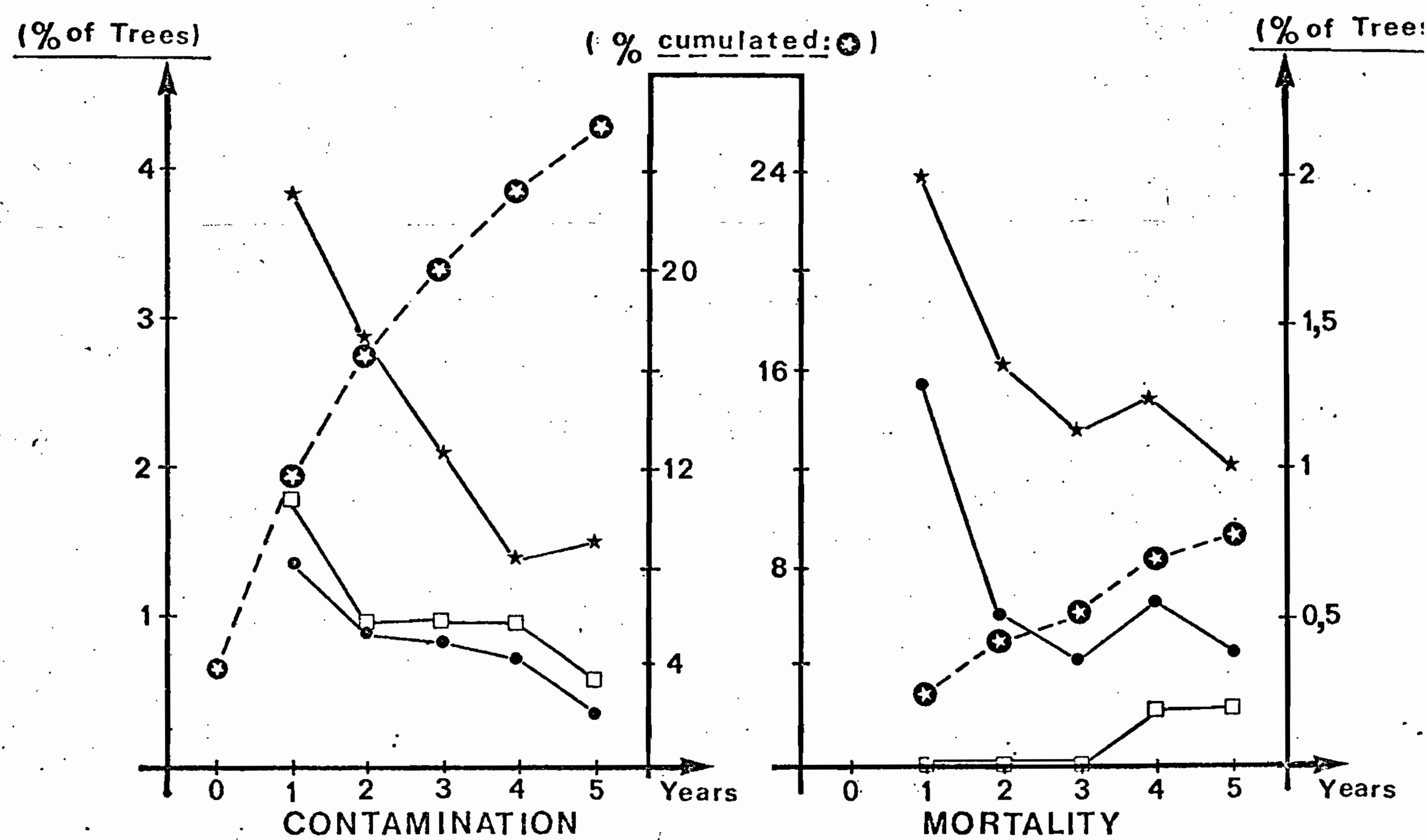
✪ ponctual localization

✪✪ low economic incidence

✪✪✪ noticeable economic incidence

✪✪✪✪ important economic problem

FIG. 2



PATHOGENESIS EVOLUTION

★ R. LIGNOSUS • P. NOXIUS □ S. REPENS ✪ R.L.+P.N.+S.R.

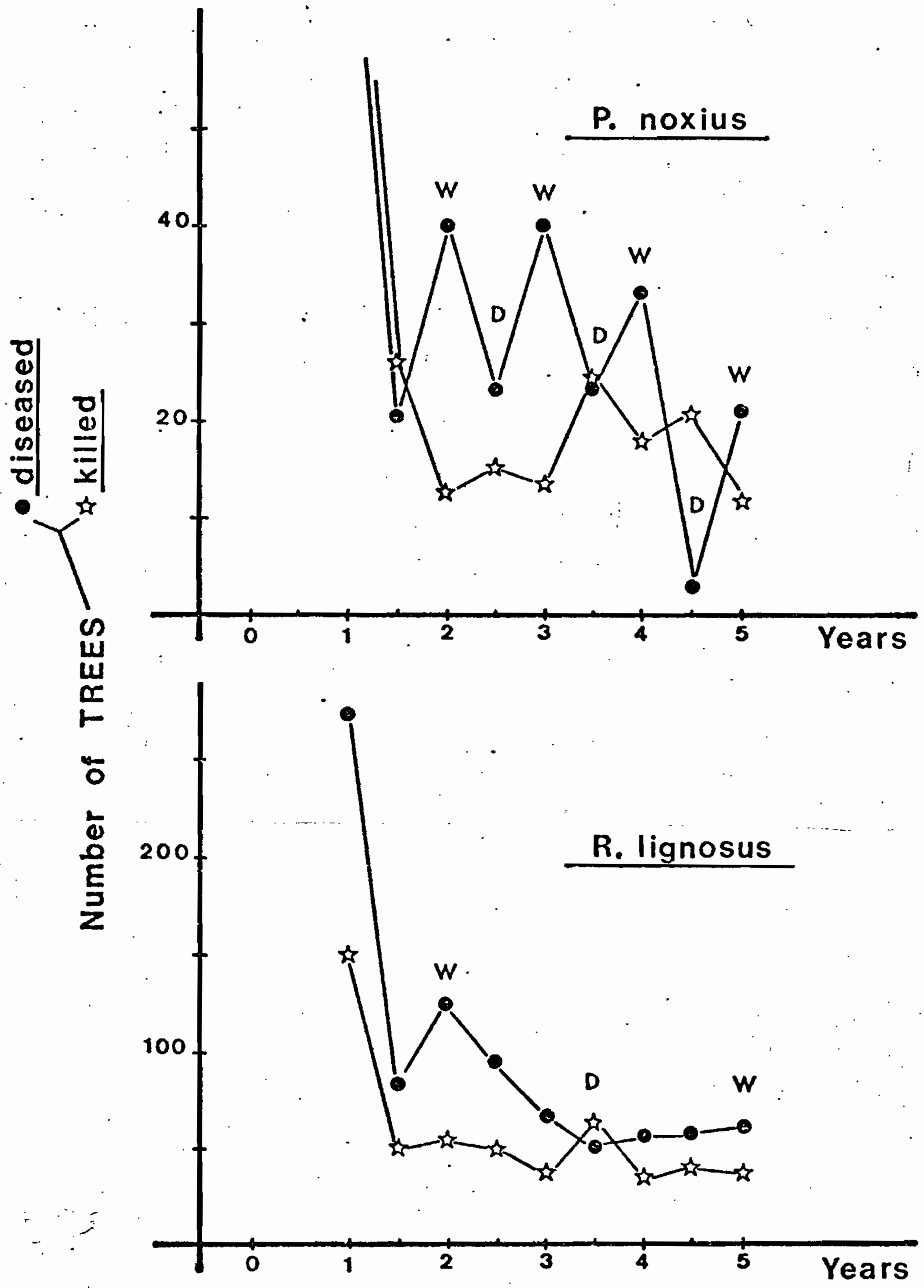


FIG 3 PARASITISM EVOLUTION

W: wet season D: dry season

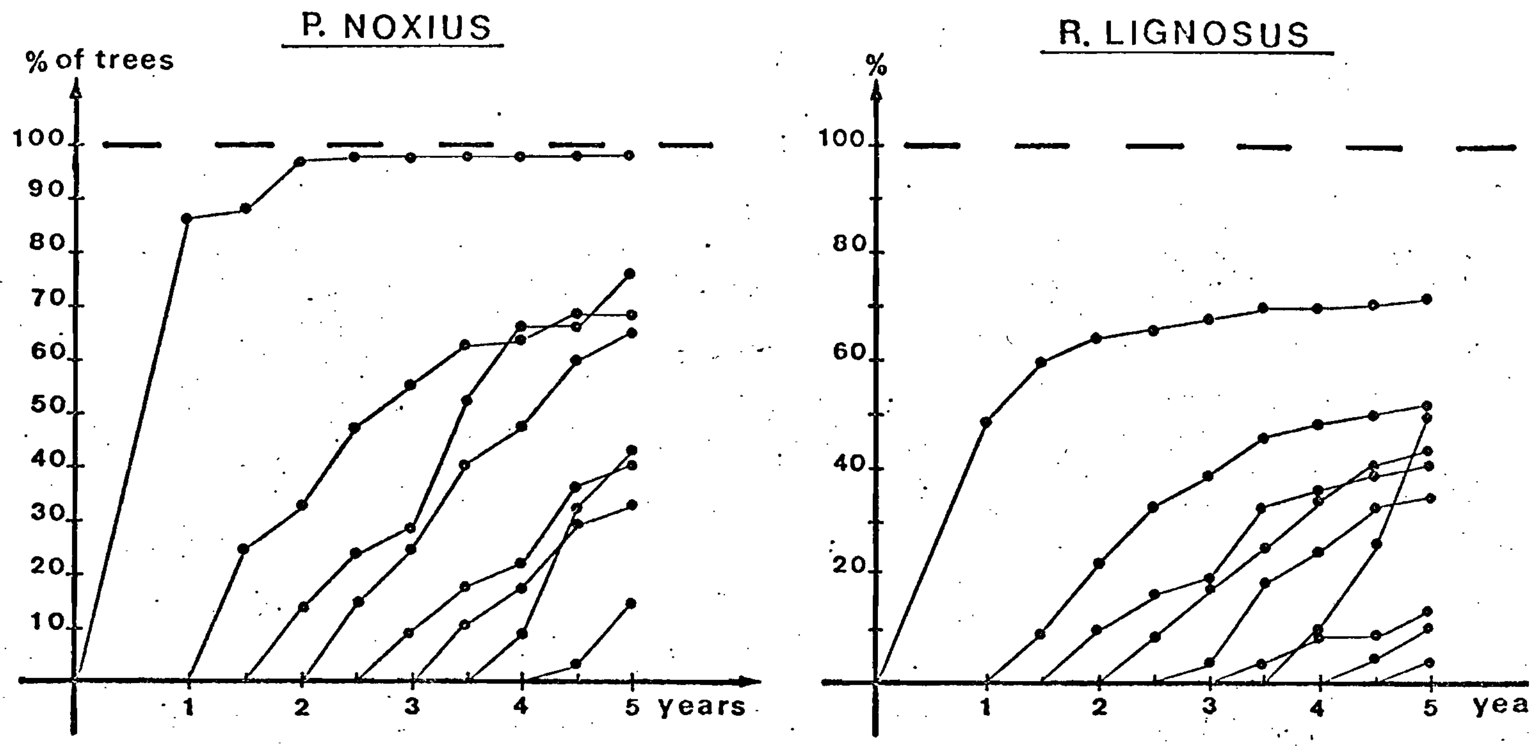
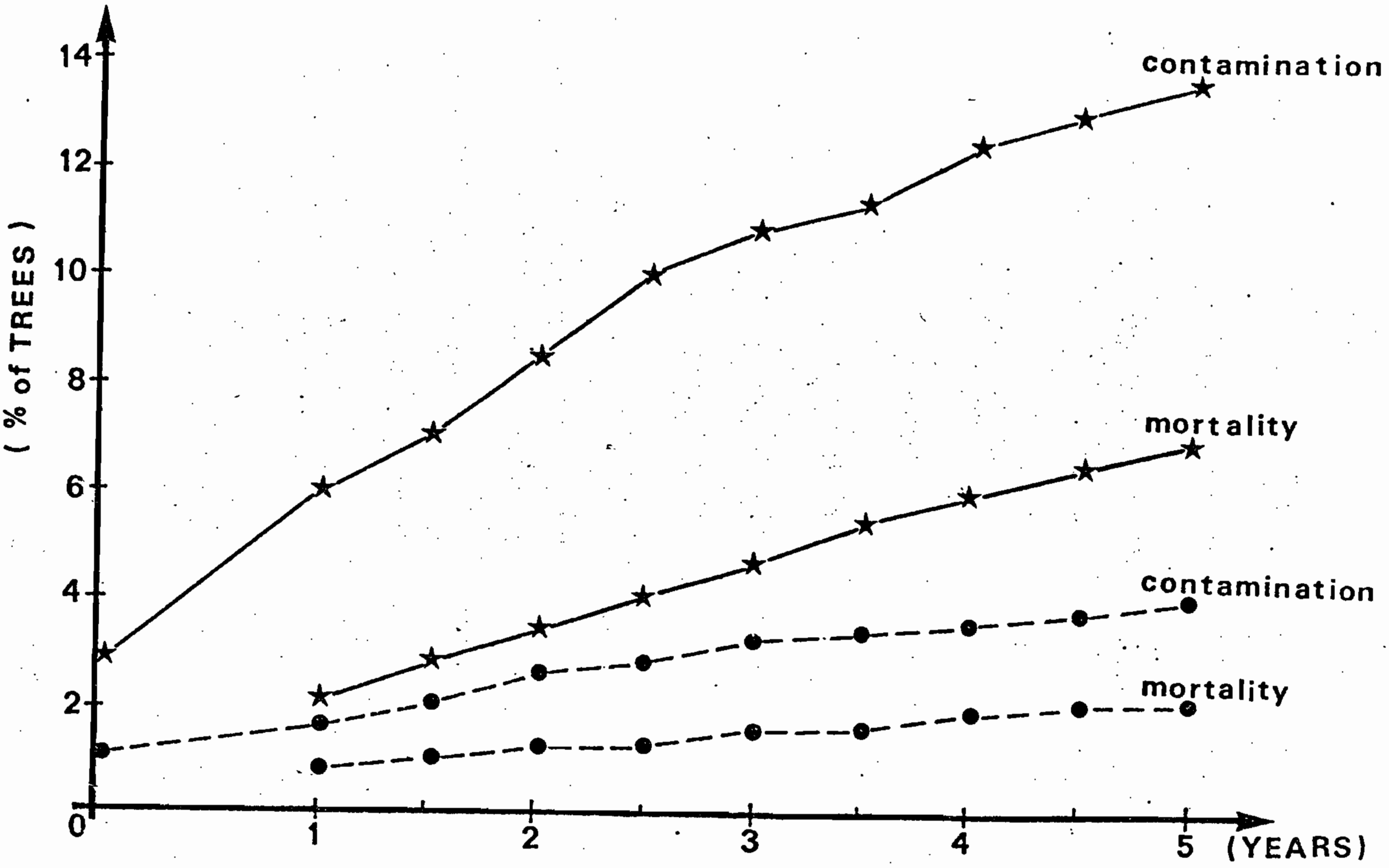


FIG. 4 EVOLUTION of MORTALITY RATE in each CONTAMINATED TREES POPULATION

JUST CONTAMINATED Trees populations	% of KILLED trees after TWO years by :	
Age of trees	*R. lignosus*	*P. noxius*
4 years	64,5 %	97 %
5 years	39,2 %	55 %
6 years	34,7 %	47,5 %
7 years	13,8 %	32,5 %

TABLE 3 DECREASE OF MORTALITY RATE ACCORDING TO THE AGE OF TREES



FOREST CLEARING METHOD: INCIDENCE ON R. Lignosus + P. Noxius PATHOGENESIS

FIG.5

★ manual clearing ● mechanical clearing