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Full Length Research Paper

Alteration of post harvest diseases of mango *Mangifera indica* through production practices and climatic factors

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Mango production in Senegal takes place over the two seasons of dry and humid conditions between April and November. The increasing demand for fresh mangoes has led to an increase in land area allocated to that crop. Mango production suffers, however, from fruit rotting due to post-harvest diseases during ripening. These diseases reduce the fruit quality and cause severe losses. A survey was carried out in 2004 to detect fungi involved in post-harvest rot of mangoes (cv. Kent) produced in the Niayes area of Senegal in relation with the production practices and the climatic conditions. The results showed that at first harvest during the dry season, a broader species range of fungi including *Alternaria* sp., *Botryodiplodia theobromae*, *Dothiorella* sp., *Aspergillus niger* and non-identified fungi were responsible for mango rotting. The fruits harvested during the humid season, however, were more heavily infested but a smaller number of fungal agents were involved; *Colletotrichum gloeosporioides* and secondarily *Phoma mangiferae* played the main role. The cultural practices played an important role on mango infection whereby orchard sanitation and particularly cleaning and pruning reduced the infection rates. Orchards with no care, in contrast, yielded the most heavily infested mango samples. In addition, the harvest practice of inversion of fruits in soil for sap elimination increases contamination with pathogenic fungi.

Key words: Climatic conditions, cultural practices, interactions, mango, post harvest diseases.

INTRODUCTION

Mango (*Mangifera indica* L.) is considered one of the most popular fruits among millions of people in the tropical area and increasingly in the developed countries. Because of its delicious taste and high coloric value, it is ranked as one of the good fruits in the international market. This fruit has become an essential fruit crop in Asia, in Southern and Central America as well as in many parts of Africa. Because of diverse production conditions and the vast area grown, mango suffers from a number of diseases, some of them taking heavy toll on the crop and representing limiting factors.

In Senegal, mango production and exportation takes place from the last two months of the dry season (April and May) and goes through the rainy season (from July to September) to end in November. Export mango is essentially harvested from the Niayes area that includes land portions in the regions of Dakar, Thiès and Saint-Louis. The increasing demand for fresh mango particularly for export has led to an increase in exportation from 300 tons in 1998 to 2800 tons in 2003 (PPEA, 2003). This production is suffering, however, more and more from fruit rotting due to diseases at arrival in the export markets. Post-harvest diseases of mango reduce fruit quality and cause severe losses, because they lead to completely unmarketable fruits. Although blemished fruit can often be sold in the less demanding local market, this practice results in important economic losses due to the considerable differences between export and local prices.

The mango tree and more especially the fruit is the host of a large number of pathogens among which fungi could be major agents of fruit rot after harvest. In Senegal

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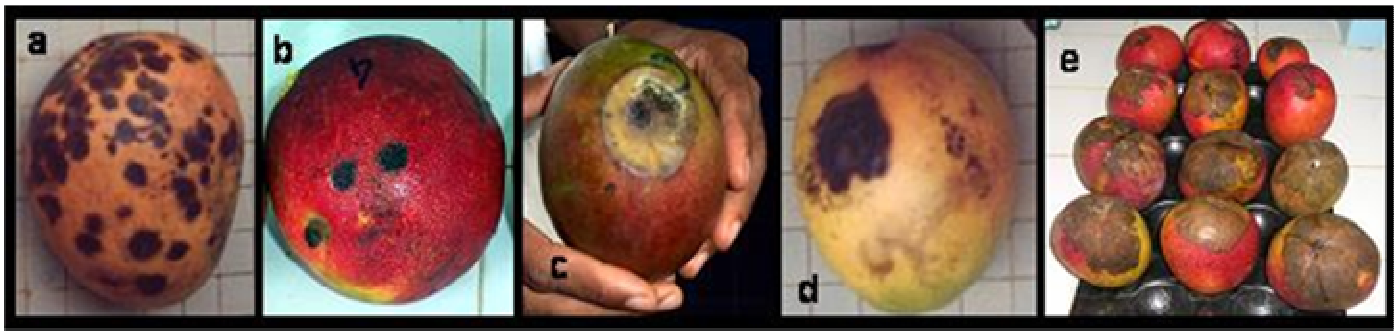

Figure 1. Mangoes cv. Kent showing rotting symptoms due to a) anthracnose caused by *C. gloeosprioides*, b) *Alternaria* sp., c) *A. niger*, d) *Phoma mangiferae* and e) stem end rot (*Botryodiplodia theobromae*).

in addition to the devastating effect of fruit flies, fungal pathogens play a major role in post harvest rotting of mangoes. Fungal pathogens involved in mango rotting after harvest include *Colletotrichum gloeosporioides* responsible for mango anthracnose, *Alternaria alternata* and *A. tenuissima* that cause alternariose, *Botryodiplodia theobromae* and *Dothiorella* spp. responsible for stem end rot and *Phoma mangiferae* (Dodd et al., 1997; Kuos, 1999; Okigbo and Osuinde, 2003; Arauz, 2000). Termination of fungal quiescence on climacteric fruits like mangoes appears to be related to the reduction of antifungal compounds (Prusky, 1996) and/or the production of ethylene by the ripening fruit (Freeman et al., 1998). As the fruit ripens, a reduction in the concentration of phenolic compounds active against *C. gloeosporioides* and *A. alternata* is observed (Prusky and Keen, 1993). The change in nutritional status of the host upon ripening has also been suggested as a factor in quiescence termination, but experimental evidence is contradictory (Ploetz and Prakash, 1997).

The present work was conducted to understand better the interactions between fungi involved in post harvest rotting of mango and local production practices and the changing climatic conditions during the maturation period.

MATERIAL AND METHODS

Sampling sites

The study was carried out in seven orchards situated in the Niayes area. This covers an inshore strip of 185 km and 7 to 40 km width from Dakar to Saint-Louis. It is characterized by sand dunes and depressions with emerging groundwater. The temperatures are mild and vary between 20°C in January up to 29°C in September. This area benefits from the proximity of the Atlantic Ocean with a relatively high moisture level throughout the year (Cissé, 2000). These ecological characteristics made out of this area, situated in a semi arid climatic zone receiving a yearly rainfall of about 250 mm, the main supplier for agricultural goods for the capital city, Dakar. The Niayes area harbors a high concentration of mango orchards and vegetable production fields as well. Different mango varieties are planted, however, with a dominance of variety "Kent". Mango trees are generally planted in rows spaced with 8 m, while 6 m separated two neighboring trees in the row.

Fruit sampling

A total number of 500 mango fruits were sampled twice, on July 17th and August 14th. The two respective sampling periods not only coincided with the beginning and the end of the mango (Kent) business campaign but also with the end of the dry season (no rainfall) and the middle of the rainy season (150 mm rainfall over 4 weeks). Green mature mangoes were sampled. A stratified sampling procedure with two levels was adopted. In each orchard, twenty mangoes laying on the ground and twenty others situated at mid-height of the trees were randomly picked. The fruits were labeled and placed in clean bags and kept in cardboards for the transportation to the laboratory.

Evaluation of fruit rotting and identification of the causing agents

The fruits were washed one by one under the tap, and placed in expedition boxes in a way to prevent contact between them and avoid contaminations. They were let to ripen at room temperature (27 - 30°C) for 15 days. The boxes were examined every day for rotting mangoes. Fruits showing rotting symptoms were sorted out for the isolation of the causal agents. The symptoms observed were first described and classified. The isolation and identification of the causal agents were performed for every single rotting fruit. Fungal pathogens responsible for mango rotting were isolated from the flesh beneath the peal. Therefore the mangoes were first soaked in a 1% NaOCl solution for 15 min and two crossed incisions in the form of V were made at the front of progression of the rotting process with a sterile scalpel. A piece of flesh under the peal was taken and placed in a Petri dish containing Potato Dextrose Agar amended with 100 ppm of chloramphenicol and incubated at 30°C in the dark. One day later, the mycelium growing out of the mango flesh was transferred into new Petri dishes to obtain pure culture of the fungi.

The induction of fungal sporulation, when it did not occur on PDA, was achieved by culturing the fungi in Petri dishes containing water agar and leaf discs of *M. indica* sterilised by soaking in a 1% NaOCl solution containing 100 ppm chloramphenicol for 2 h. The Petri dishes were then incubated for four weeks in the dark. The pathogenicity of the isolated fungal species was confirmed by inoculating them to healthy mangoes to induce the rotting symptoms.

Data Analysis

Multivariate statistical analysis of data was performed with the ADE4 system (Thioulouse et al., 1991) using factor analysis (AFC).

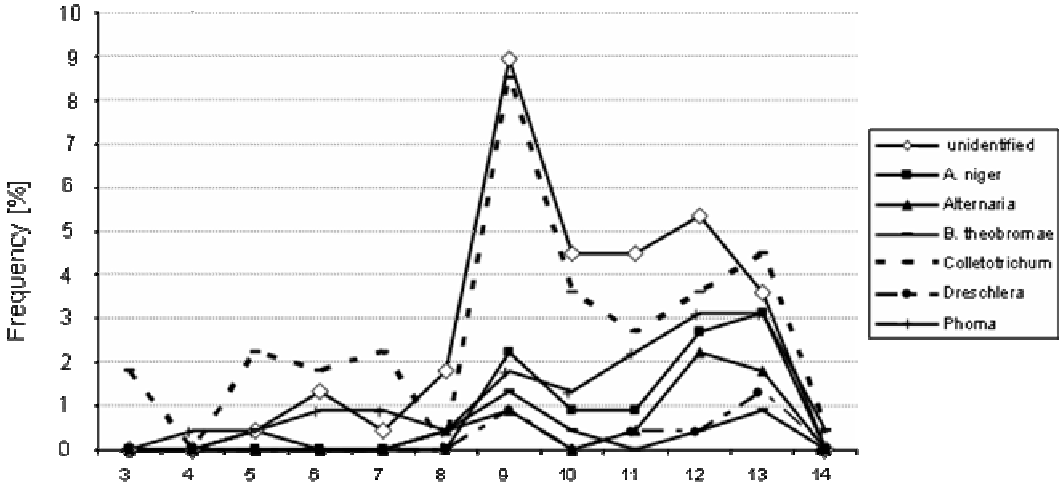

Figure 2. Frequency of mango rotting caused by different fungal pathogens during an incubation period of 14 days at room temperature (27 – 30 °C).

RESULTS

Rotting symptoms

The fungal rotting agents that infested the mangoes were composed mainly of *Aspergillus niger*, *Alternaria* sp, *C. gloeosporioides*, *B. theobromae*, *Dothiorella* sp., *P. mangiferae*, *Stemphylium* sp., *Dreschlera* sp., as well as fungi that did not sporulate and therefore were not identified.

C. gloeosporioides (Figure 1a) caused dark-brown to black decay spots. They coalesced sometimes and penetrated deep into fruit, resulting in extensive fruit rotting. Fruits infected by *Alternaria* sp. showed small black spots (Figure 1b). The flesh beneath showed no changes either in color or in consistency. Other fungi like *Drechslera* sp. and *Stemphylium* sp. were isolated from a few fruits with spots similar to those caused by *Alternaria* sp. These fungi infest fruits from injured parts. *A. niger* is essentially saprophytic. It penetrated the fruits through injuries or the peduncle (Figure 1c). It is responsible for brown round shaped spots, showing a depression. The fungus weakens the mango flesh below and at high moisture, sporulation occurred directly on the fruit. *P. mangiferae* caused irregular brown spots that affected deeply the flesh beneath (Figure 1d). *B. theobromae* is the causal agent of stem end rot of mango (Figure 1e). Once initiated, the rotting process is capable of affecting the entire fruit within 2 to 3 days. *Dothiorella* sp. was also isolated from mangoes showing similar symptoms.

Dynamics in symptom development by fungal species

Mango rotting began at the second day of incubation (Figure 2). Mango rotting was first due to maggot's feeding on the fruit flesh, resulting from oviposition by fruit flies. A combined infection by both juveniles of fruit flies and *C. gloeosporioides* was found as the rotting agents for 2 fruits on the second day. Mangoes rotten by fruit flies maggots were sorted out from the second day of incubation up to day 7.

A portion of rotten fruits at the second day of incubation were infested by *C. gloeosporioides*. This fungal species was isolated throughout the incubation period with high prevalence between day 8 and 14. It was one of the most important causal agents of post-harvest fruit rot, together with the non-identified fungi, found from day 4 until the end of the experimental period. They also reached their highest incidence after day 8.

Mango rotten by *A. niger* were first recovered at the 8th day of incubation. They were then regularly detected until the end of the experiment. Symptoms of *Alternaria* sp. infection were first observed at day 8 of incubation and regularly thereafter until day 14. *Curvularia* sp. and *Stemphylium* sp. were isolated from mangoes sorted out at day 13 and 12, respectively. *Drechslera* sp., one of the fungi isolated from the black spots similar to those caused by *Alternaria* sp., was isolated from day 9 to 14. *P. mangiferae* was also one of the most regularly isolated fungi, occurring between day 4 and 14 of incubation. Mangoes infected by *B. theobromae* were regularly isolated from day 5 until the end of the incubation period, whereas *Dothiorella* sp. was isolated twice at day 9 and 13 of incubation (= 0.77 % of fruits).

Relative importance of the fungal pathogens in mango rotting

Fruit incubation at room temperature allowed the expression of post harvest mango pathogens in terms of rotting. The percentage of fruit colonization as well as the prevalence of individual fungal species was determined. The

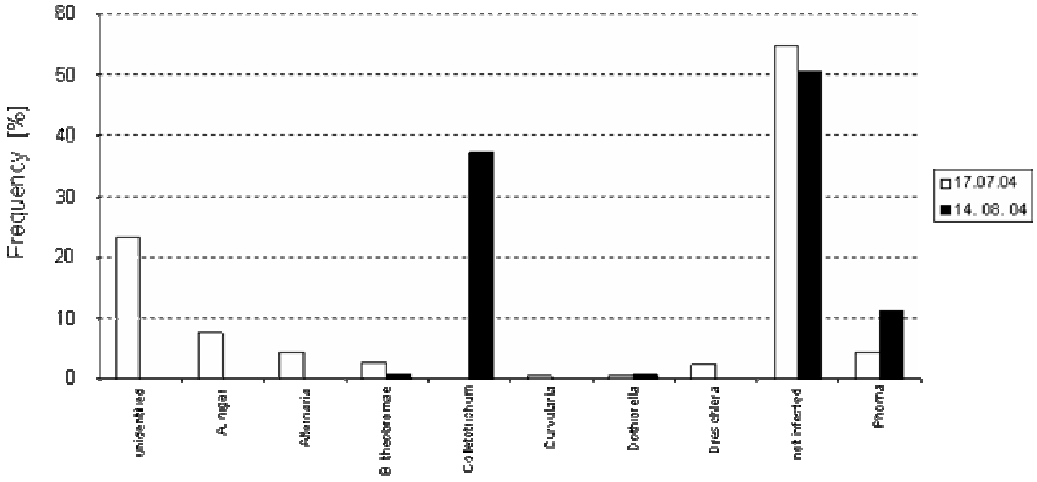

Figure 3. Frequency of fungi causing rotting of mangoes from the Niayes area after 14 days incubation at room temperature (27 – 30°C; n = 500 fruits).

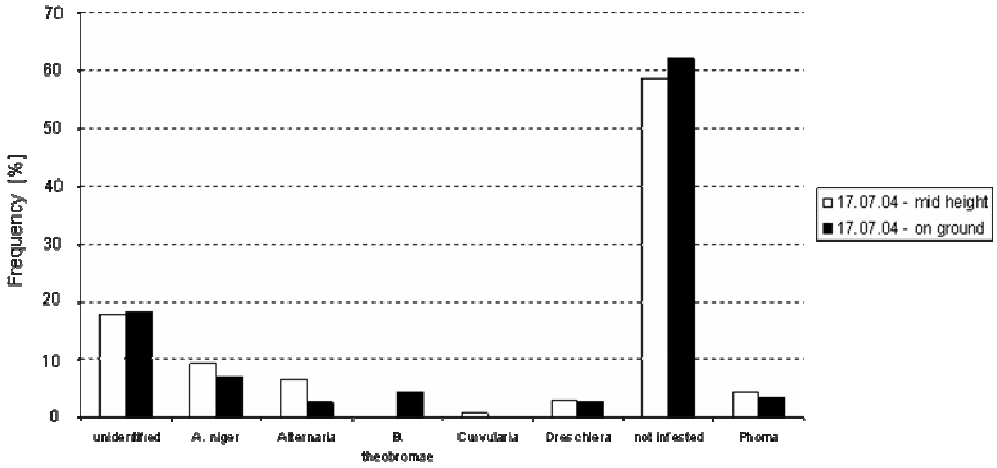

Figure 4. Influence of fruit position on the tree on the prevalence (%) of mango rotting agents at first harvest (n = 260).

results are presented in Figure 3. Infection rate reached almost 50% at first harvest as well as at the second sampling. However, the fungal flora responsible for fruit rotting varied between the first and the second harvest. The portion of rotten mangoes from the first harvest (dry season) was infected by a large number of fungi, in particular *A. niger*, *Alternaria* sp., *Stemphylium* sp., *Drechslera* sp., *B. theobromae*, *Curvularia* sp., *P. mangiferae* as well as non-identified fungi. This last group of fungi was responsible for rotting of 24% of the fruits while the other fungi infested less than 8% each.

The second harvest (rainy season) showed a completely different situation with the predominance of *C. gloeosporioides* that infected 37% of mango fruits. *P. mangiferae*, responsible for the rot of less than 5% of fruits at the first harvest, infested 12% of mangoes at the second harvest. The fungal flora present at the second harvest was completed by *Dothiorella* sp. and *B. theobromae*. Species like *Alternaria* sp. and *A. niger* were not detected.

Influence of fruit position in the tree on fruit rot prevalence

Another factor tested for its influence on infection of mango fruits was their position on the tree. Fruits harvested at the lower parts of the tree and particularly with contact to the soil was compared to fruits harvested at mid height of the trees. This test was carried out for both harvest times (Figure 4). After the first harvest, fruit infection for both levels was caused by the same species, in

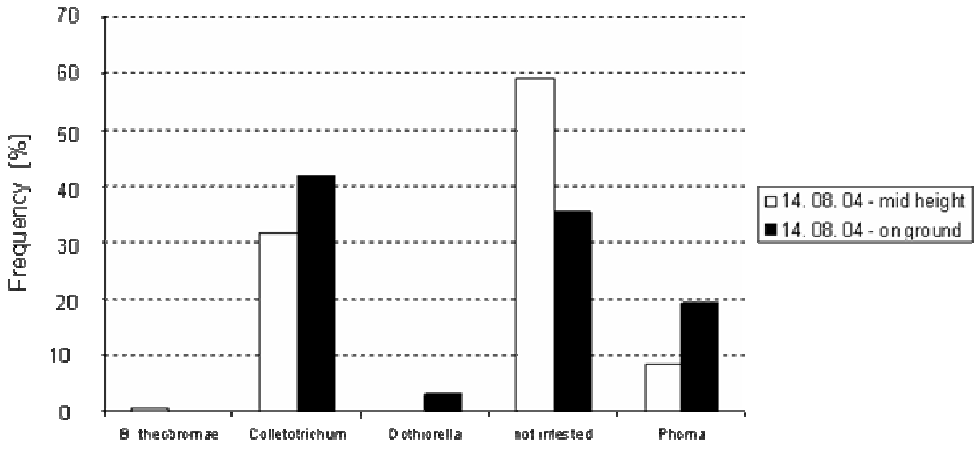

Figure 5. Influence of fruit position on the tree on the prevalence of mango rotting agents at second harvest (n = 240).

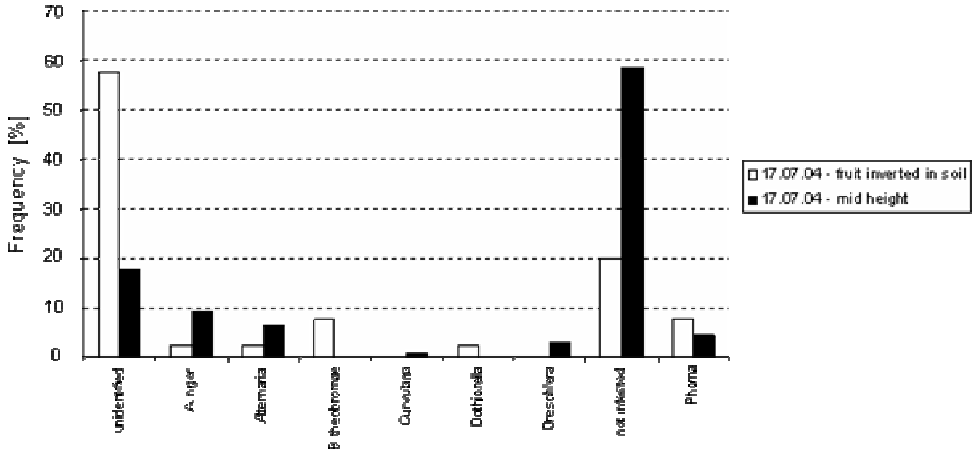

Figure 6. Influence of inversion of fruits from first harvest in the soil on the prevalence of rotting agents of mangoes (n = 140 fruits).

similar proportions, regardless of their situation in the tree. However, infestation by *Stemphylium* sp. was recorded only on fruits that had contact with the soil. This situation was subjected to a change in dept after the second harvest (Figure 5).

Beyond the change in fungal species causing fruit rot, the mangoes laying on the soil were more heavily infected (> 65%) than fruits harvested from the mid height of trees (42%). A marginal proportion of fruits with contact to the soil were subjected to stem end rot.

Influence of desapping method on fruit rot

Harvesting means cutting fruit from the stem or the peduncle. The stem of picked mangoes spurt out large quantities of latex, the sap with low pH and high oil con-tent. This sap burns the fruits when it comes in contact with the peal leading to quality loss. Desapping or bleed-ing is therefore an important step in post harvest process-sing of mango. In Senegal, the application of the ped-uncle to the soil has been suggested as a safe method for fruit desapping. The influence of the practice of inverting fruits in the soil after having cut the peduncle to eliminate the sap was tested in comparison to mangoes sampled from mid height of trees (Figure 6). The results showed an important increase in the infection rate of mangoes. Compared to control mangoes with an infec-tion rate of about 40%, 80% of fruits inverted in the soil had fruit rot. Symptoms were associated with a very high prevalence of non-sporulating fungi, which prevalence went from 18% for the control to 58% and in a lower extent

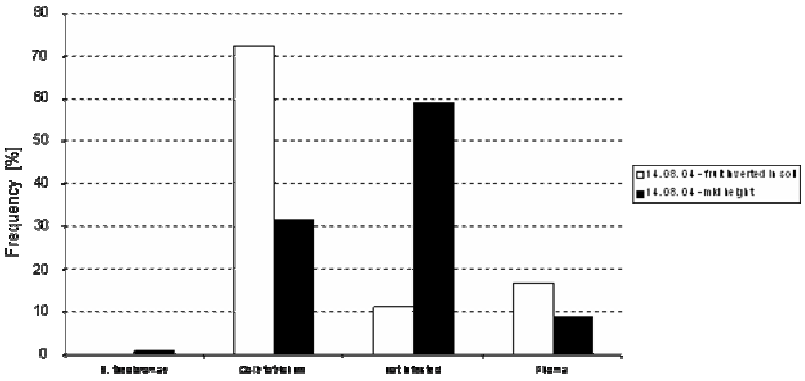

Figure 7. Influence of inversion of fruits from second harvest in the soil on the prevalence of rotting agents of mangoes (n = 140 fruits).

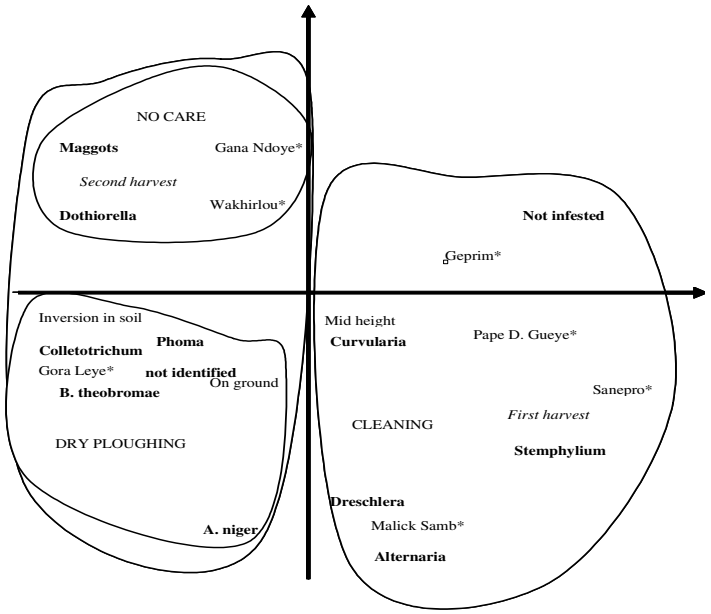

Figure 8. Distribution of the different variables affecting rotting after harvest of mangoes from the Niayes area (* specifies the orchards).

Table 1. Weights of the distribution axis generated by data analysis.

Axis	F1	F2	F3	F4
Eigen value	0.33	0.27	0.16	0.081
Inertia (%)	34.13	27.89	17.05	8.42

to infestation by *B. theobromae* and *P. mangi-ferae*.

At the second harvest, the comparison of fruits from the two treatments also showed an increased prevalence of fruit rotting after inversion in soil (Figure 7). The percenttage of fruit rot reached almost 90% as compared to about 40% for the control. Anthracnose of mangoes incr-eased from 30% to more than 70% prevalence. *P. mangiferae* was two times higher for mangoes inverted in soil.

Effect of production practice on incidence of fungal pathogens

The multivariate data analysis performed to find out the impact of the different production practices encountered on the phytosanitary situation of the fruits from the diffe-rent orchards showed that most of the information for the different variables was carried by the factorial axis F1 and F2 with 34.13 and 27.89%, respectively (Table 1). The factorial plan F1 x F2 was then chosen to represent the distribution of the different variables since it contains 62.03% of the information (Figure 8). Figure 8 showed that the F1 axis is determined by the variable harvest time with two modalities, first harvest and second harvest

contributing 37.4 and 27.89%, respectively. It enab-led the distinguishing of two groups; group I on the nega-tive abscise demonstrated a conglomeration of the orch-ards Gana Ndoye, Wakhirlou and Gora Leye and high prevalence of mango fruit rot. The rotting of mango from these orchards was mainly linked to infection by *C. gloeosporioides*, *Phoma* sp., *B. theobromae*, and fruit flies at the second sampling. In this group, the orchards Gana Ndoye and Wakhirlou built a subgroup charac-terized by the absence of sanitation (no care) and a high occurrence of fruit flies (maggots). The second subgroup, opposed to the first on the F1-axis, included only orchard Gora Leye, which benefited from sanitation but was ploughed while the soil was dry, causing deposit of a dust layer and therefore fungal spores on the mango leaves and fruits, a situation that probably increased fruit infect-ion as for orchards without care. The fungal populations involved in fruit rot as well as the infection rate were similar to that causing fruit rot of mangoes picked from the ground or that when fruits had been inverted in the soil.

The third group, on the positive abscise, included the orchards Geprim, Malick Samb, Sanepro and Pape Demba Gueye. These orchards are characterized by some sanitation in terms of cleaning and pruning. The prevalence of rotting of mango from these orchards was the lowest, mainly at second harvest, during the rainy season.

DISCUSSION

Post-harvest rot affects an important portion of mangoes from the Niayes region. The fungal flora responsible for this infestation is diverse and seems to be strongly influenced by the climatic conditions. The first harvest coincided with the end of the dry season that prevailed during nine months. The fungal species that infected mangoes in this period involved a broader species range including *Alternaria* sp., *B. theobromae*, *Dothiorella* sp., *A. niger* and non-identified fungi. The fruits harvested during the humid season were more heavily infested but a smaller number of fungal agents were involved; *C. gloeosporiodes* and secondarily *P. mangiferae* played the main role. In the dry season, *C. gloeosporiodes* was missing and *P. mangiferae* was only of marginal importance.

The influence of climatic conditions on the occurrence of fungal pathogens could be explained by their ecological requirements and the competitiveness of the species. The predominance of *C. gloeosporioides* in the rainy season could result from optimal conditions for infection and temperatures around 28°C (Dodd et al., 1997). These conditions were prevailing in the Niayes area over the four last weeks before the second sampling.

Similar results were reported by Johnson (1994) and Estrada (Estrada, 1994) suggesting that anthracnose becomes more competitive than stem end rot fungi under humid conditions. Furthermore, the fact that *C. gloeosporioides* is dispersed by rain drops, whereas spores of *Alternaria* sp. are spread by wind (Dodd et al., 1997) may explain the occurrence of these two fungal pathogens at the second and first sampling times, respectively. Fruit infections by *C. gloeosporioides* are reported to be associated with rainfall and occur from fruit set until harvesting, with dead leaves entangled in the tree canopy, defoliated branch terminals, mummified inflorescences and flower bracts constituting the main source of inocu-lum (Dodd et al., 1997). Conidia spread throughout the orchard by means of heavy dew, irrigation and light rain, with rainy weather being conducive to conidium produc-tion, dispersal and infection (Prusky, 1996). Interactions between *C. gloeosporioides* and the climate may lead to a variation of disease incidence and severity throughout the growing season with some export consignments being virtually disease-free and others, completely unmarketable (Kotzé, 1978; Cappellini et al., 1988). Incidence of anthracnose can reach 100% in fruits produced under wet or very humid conditions (Arauz, 2000).

The association between the dry season and the occurrence of *Alternaria* sp. confirmed earlier results according to which mango black spot caused by *A. alternata* is prevalent in dry countries (Dodd et al., 1997). Non-identified fungi preferentially infested fruits that were laying on the soil or mangoes inverted on sand to eliminate the sap, suggesting a telluric origin. The results concerning this last practice after harvest, demonstrated that it is an important source for heavy mango infestation by various fungal agents, as already reported by Dodd et al. (1997). The inversion of fruits in soil for sap elimination should be abandoned and replaced by another method that avoids contamination with pathogenic agents.

Orchard sanitation and particularly cleaning and pruning are very useful to decrease the infection rate of fungi-causing post-harvest rotting of mango as shown by the multivariate analysis. The most heavily infested mango samples were those from orchards with no care. They showed not only a higher proportion of mango rotting but also a wider range of fungal pathogens, in addition to a high infection rate by fruit flies. Control measures specific to the pathogens and taking into account their epidemiology should be used to keep the mango business running. Therefore, complementary studies on the efficacy of fungicides as well as on a treatment schedule considering the interactions between climate and epidemiology of the fungal flora should be carried out.

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