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Major Diseases of the Biofuel Plant, Physic Nut (*Jatropha curcas*)

Alexandre Reis Machado and Olinto Liparini Pereira

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1. Introduction

Worldwide, concern over the consequences of global warming has resulted in intensified searches for potential plants that could supply raw materials for producing renewable fuels. Therein, physic nut (*Jatropha curcas* L.) has gained attention as a perennial culture that produces seeds with high oil content and excellent properties. In addition to these attributes, many studies have described physic nut as a culture resistant to pests and disease. However, in recent years, the expansion of areas under cultivation has been accompanied by the appearance of various diseases. Thus, this chapter aims to provide information about the main diseases that occur in physic nut and their diagnosis and to encourage further research on disease control.

The existing literature contains various descriptions of the pathogens occurring in culture, most of which are caused by fungi, and of which we address the following: *Glomerella cingulata* (Ston.) Spauld. et Schrenk.; *Psathyrella subcorticalis* Speg.; *Schizophyllum alneum* L.; *Aecidium cnidoscoli* P. Henn.; *Ramulariopsis cnidoscoli* Speg.; *Uromyces jatrophiicola* P. Henn. (Viégas 1961); *Pestalotiopsis versicolor* Speg. (Phillips 1975); *Colletotrichum gloeosporioides* (Penz.) Sacc.; *Colletotrichum capsici* (Syd.) Butl. & Bisby.; *Passalora ajrekari* (Syd.) U. Braun (Freire & Parente 2006); *Phakopsora arthuriana* Buriticá & J.F. Hennen (Hennen et al. 2005); *Cochliobolus spicifer* Nelson (Mendes et al. 1998); *Cercospora jatrophiicola* (Speg.) Chupp; *Cercospora jatrophiigena* U. Braun; *Pseudocercospora jatrophae-curcas* (J.M. Yen) Deighton; *Pseudocercospora jatrophae*; *Pseudocercospora jatrophae* (Speg.) U. Braun (Crous & Braun 2003); and *Elsinoë jatrophae* Bitanc. & Jenkins (Bitancourt & Jenkins 1951). Existing reports on pathogens include research on collar and root rot *Nectria haematococca* Berk. & Br. [*Haematonectria haematococca* (Berk. & Broome) Samuels & Nirenberg], and its anamorph *Fusarium solani* (Martius) Appel & Wollenweber (Yue-kai et al. 2011), as well as *Lasiodiplodia theobromae* (Pat.) Grif-

fon & Maubl (Latha et al. 2009; Pereira et al. 2009), *Phytophthora palmivora* var. *palmivora* (E.J. Butler) E.J. Butler (Erwin & Ribeiro 1996) and *Clitocybe tabescens* (Scop, ex Fr.) Bres (USDA 1960).

2. Diseases

Although several descriptions of fungi exist, this chapter will discuss the most common and damaging diseases that affect physic nut, and draws on the following descriptions:

2.1. Anthracnose (figure 1)

Colletotrichum gloeosporioides (Penz.) Sacc.

Colletotrichum capsici (Syd.) Butl. and Bisby

This disease was first described in physic nut by the USDA (1960) in the USA, in Brazil by Viégas (1961), and later by Freire & Parente (2006) and Sá et al. (2011). Currently, the disease is present in all areas where physic nut is cultivated.

The most commonly observed symptoms are brown to black necrotic lesions that are irregularly shaped and appear on the edges and center of the leaf and which may contain a yellow halo. The lesions appear in the form of small, isolated points that coalesce and subsequently cause the complete destruction of the leaves. The fruit can also become infected, which leads to the appearance of dark brown lesions.

In addition to these symptoms, research in Mexico has indicated that the fungus *Colletotrichum capsici* caused stem canker and apical death of seedlings (Torres-Calzada et al. 2011).

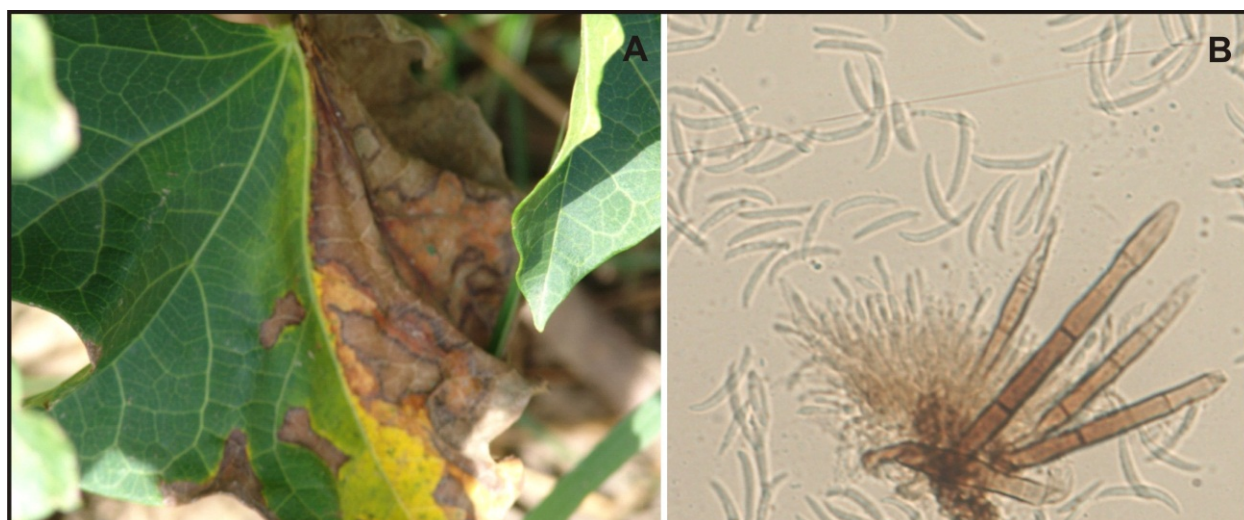


Figure 1. Anthracnose in *Jatropha curcas*. Symptoms on leaf (A). Curved conidia, dense conidiophores and septate setae of *Colletotrichum capsici* (B).

Colletotrichum is a fungus anamorph of the phylum Ascomycota and teleomorph genus *Glomerella*. The species of this genus have the following characteristics: conidiomata that are acervular, subcuticular or epidermal, and may contain setae; conidiophores that are hyaline to brown; conidiogenous cells that are enteroblastic, phialidic and hyaline; conidia that are hyaline, aseptate (except prior to germination), straight or falcate, smooth and thin-walled; and appressoria that are brown, entirely or with crenate to irregular margins produced with germination of conidia (Sutton 1980).

Colletotrichum spp. is known to infect a large range of hosts and to cause various symptoms, the most common of which is anthracnose. This fungus can survive in seeds, crop residues, infected plants, and in soil as saprophytes. Although the disease occurs in various regions of the world, it is more severe in regions with a hot and humid climate (Agrios 2005).

So far, there are no recommendations for controlling this disease. Because of the damage it can cause to physic nut, this disease should be studied further.

2.2. Passalora leaf spot

Passalora ajrekari (Syd.) U. Braun

Passalora jatrophi U. Braun & F.O. Freire

This disease was first described in Brazil by Braun & Freire (2004), and later by Freire & Parente (2006) in leaves of *Jatropha curcas* and *Jatropha podagrica*, and in others countries by Crous & Braun (2003).

The primary symptoms of this disease are rounded leaf lesions that are creamy to light brown in color, with a narrow dark brown halo, and later become limited by leaf veins and darken. Lesions measure 1-2 cm in diameter and rarely coalesce (Freire & Parente 2006).

The genus *Passalora* is a cercosporoid fungus, previously included in the genus *Cercospora* that has as its teleomorph the *Mycosphaerella*. Species share taxonomic characteristics such as branched, septate, smooth, hyaline to pigmented hyphae; absent to well-developed stromata; solitary or fasciculate to synnematus conidiomata conidiophores, arising from stromata or hyphae, internal or superficial, pluriseptate, subhyaline to pigmented; conspicuous conidiogenous loci, with scars that are somewhat thickened and darkened; conidia that are solitary to catenate in simple or branched chains, asexual to scolecosporeous, aseptate to pluriseptate, and pale to distinctly pigmented and hila that are somewhat thickened and darkened (Crous & Braun 2003).

Although it has been reported in several countries, to date this disease has not presented risk to physic nut cultivation.

2.3. Cercospora/Pseudocercospora leaf spot (figure 2-3)

Cercospora jatrophi (Speg.) Chupp,

Cercospora jatrophi U. Braun

Pseudocercospora jatrophae-curcas (J.M. Yen) Deighton

Pseudocercospora jatrophae (G.F. Atk.) A.K. Das & Chattopadh.

Pseudocercospora jatrophae (Speg.) U. Braun

This disease manifests in the form of leaf spots that consist of well-delimited brown irregular necrotic spots (Dianese et al. 2010).

The genera mentioned above have the following taxonomic characteristics:

The genus *Cercospora* groups anamorphs of *Mycosphaerella* with hyphae that are colorless or near-colorous to pigmented, branched, septate, and smooth to faintly rough-walls. Stromata are lacking to well-developed, subhyaline to usually pigmented. Conidiophores are solitary to fasciculate, arising from internal hyphae or stromata, erect, subhyaline to pigmented. Conidiogenous loci (scars) are conspicuous, thickened and darkened. Conidia are solitary, scolecosporous, cylindrical-filiform, hyaline or subhyaline, mostly pluriseptate, and smooth and hila are thickened and darkened (Crous & Brown 2003).

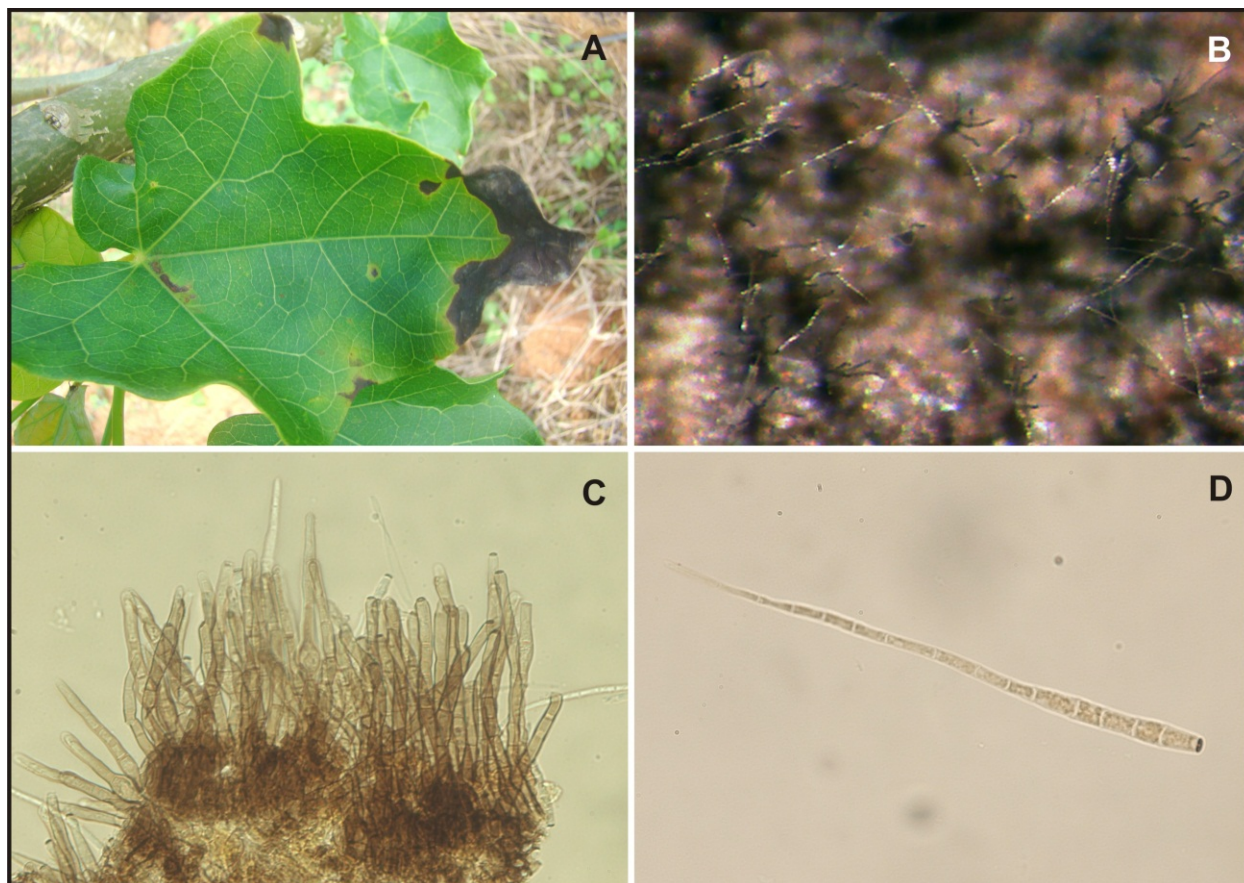


Figure 2. *Cercospora* leaf spot on *Jatropha curcas*. Necrotic symptoms on leaf (A); Fungal structures on leaf lesions (B); Pigmented conidiophores with conspicuous scars (C); Filiform conidia with conspicuous pigmented hilum (D).

The genus *Pseudocercospora* groups anamorphs of *Mycosphaerella* with basically pigmented conidiophores and inconspicuous, unthickened, not darkened conidiogenous loci; solitary,

or catenulateconidia, aseptate to pluriseptate with conidial scars that are inconspicuous and not thickened (Crous & Braun 2003).

Crous & Braun (2003) cite the occurrence of five species of cercosporoid, indicated above, in the culture of physic nut. However, few studies have examined fungi cercosporoid in this crop. As a result, there is no information about favorable conditions, symptoms or disease control. To date, this disease has not presented risk to the cultivation of physic nut.

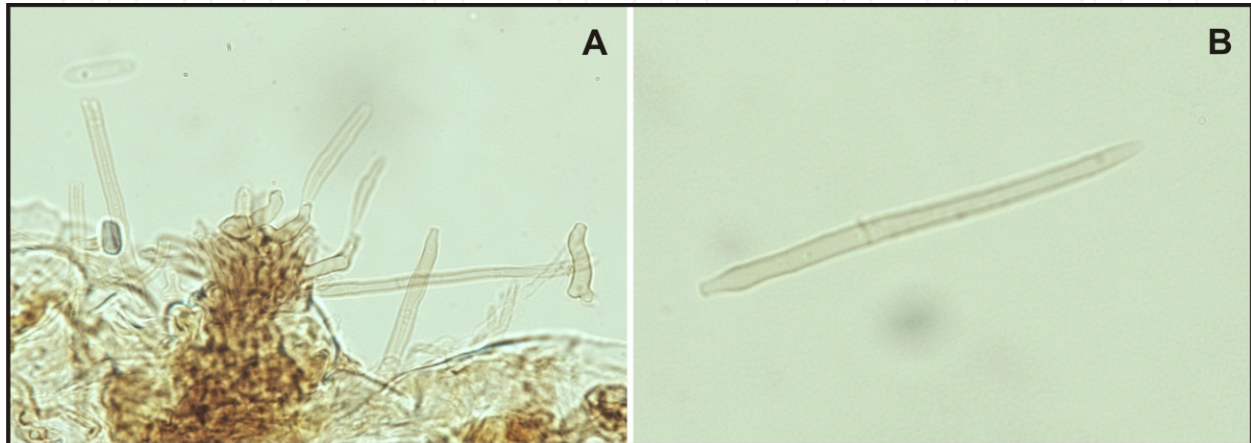


Figure 3. *Pseudocercospora* leaf spot on *Jatropha curcas*. Pigmented conidiophores with inconspicuous scars on conidiogenous cells (C) and filiform pigmented conidia with inconspicuous hilum (D).

2.4. Powdery mildew (figure 4)

Pseudoidium jatrophae (Hosag., Siddappa, Vijay. & Udaiyan) U. Braun & R.T.A. Cook

The powdery mildew caused by the fungus *Pseudoidium jatrophae* (Braun & Cook 2012) was previously described as *Oidium heveae* Steim by Viégas (1961) in Brazil and *Oidium jatrophae* Hosag., Siddappa, Vijay. & Udaiyan (Braun & Cook 2012) in India. This disease occurs commonly in physic nut plantations and it has been frequently observed in various regions of Brazil and the rest of world.

The most common symptoms of the disease are the production of abundant white or gray mycelia in leaves, petioles, stems, flowers and fruits (Dianese & Cargnin 2008). With the evolution of the disease, infected plants may show necrotic lesions, which cause leaf fall, underdevelopment, death of buds and young fruit deformation (Bedendo 2011).

The fungus that causes this disease is a typical biotrophic pathogen of the phylum Ascomycota, order Erysiphales. This pathogen may be characterized by white or grayish colonies, septate and branched mycelia; conidiophores that are erect or ascending, cylindrical, hyaline, septate and forming conidia singly; conidia that are usually large in proportion to the diameter of the conidiophores, simple, smooth, ellipsoid-ovoid doliiform, hyaline, single-celled (Braun & Cook 2012).

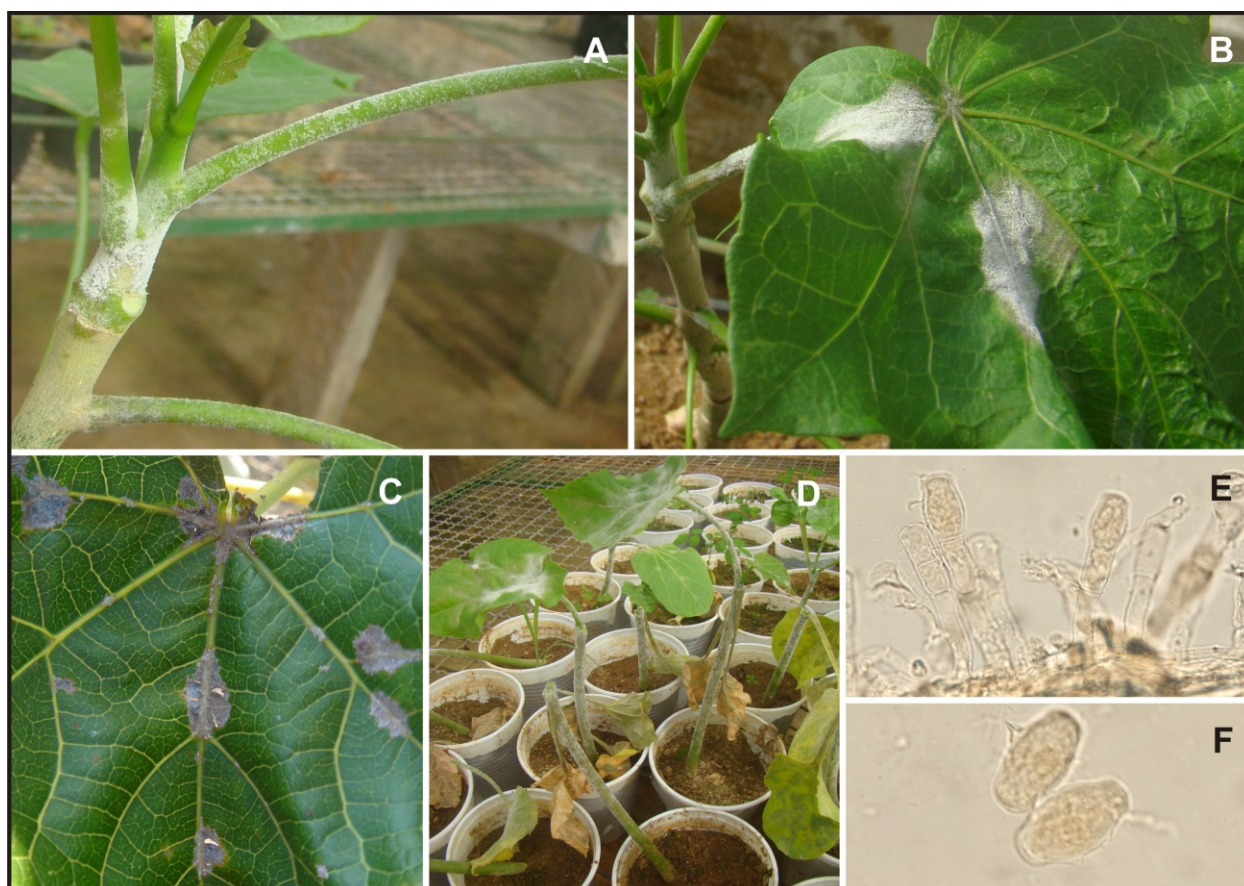


Figure 4. Powdery mildew on *Jatropha curcas*. Symptoms on petiole and stem (A); Symptoms on leaf (B) Leaf lesions on old infections (C); Symptoms on seedlings (D); Conidiophores (E); Conidia (F).

The disease generally favors warm temperatures, humidity of 75-80% and reduced light. Heavy rains are generally unfavorable to the pathogen (Furtado & Trindade 2005). In Brazil, the disease usually occurs in the dry season, apparently without causing extensive losses, because its occurrence coincides with the plants' period of natural defoliation (Saturnino et al. 2005).

Currently, there are no fungicides recommended for culture, but some studies cite that spraying sulfur fungicides works to control this fungus. Another measure is to control alternative hosts, especially plants of the family Euphorbiaceae (Furtado & Trindade 2005; Saturnino et al. 2005; Dias et al. 2007).

2.5. Rust (figure 5)

Phakopsora arthuriana Buriticá & Hennen

The first report of this disease in *Jatropha curcas*, described its cause as *Uredo jatrophicola* Arthur (Arthur 1915). In Brazil, this disease was first found in 1936 in São Paulo (Viégas 1945). Currently, it is widely distributed throughout Brazil (Dias et al. 2007) and several other countries.

The fungus that causes this disease was previously classified as *Phakopsora jatrophiicola* (Arthur) Cummins; however, it was reclassified as *Phakopsora arthuriana* Buriticá & Hennen (Hennen et al. 2005).

The symptoms manifest in the leaves, initially in the form of small chlorotic points on the upper surface, which correspond to the underside of the leaf, and then small protruding pustules, which after breaking, release a powdery mass of uredospores of orange color, giving a ferruginous aspect. In severe infections, pustules coalesce to form necrotic spots, which are reddish brown and irregularly shaped and can destroy the leaf (Dias et al. 2007; Carneiro et al. 2009).

The *Phakopsora arthuriana* belongs to the phylum Basidiomycota, class Pucciniomycetes. It is characterized by uredinia hypophyllous, occasionally epiphyllous, in small groups opening by a pore, surrounded by numerous not septate paraphyses that project outside the host; urediniospores, ellipsoid, to obovoid, sessile, closely and finely echinulate, germ pores obscure; telia hypophyllous, subepidermal in origin, closely around the uredinia; teliospores irregularly arranged, cuboid, ellipsoid to polygonal (Hennen et al. 2005).

Currently there are no fungicides recommended for this culture. However, according to Dias et al. (2007), protective copper fungicides can control this disease.

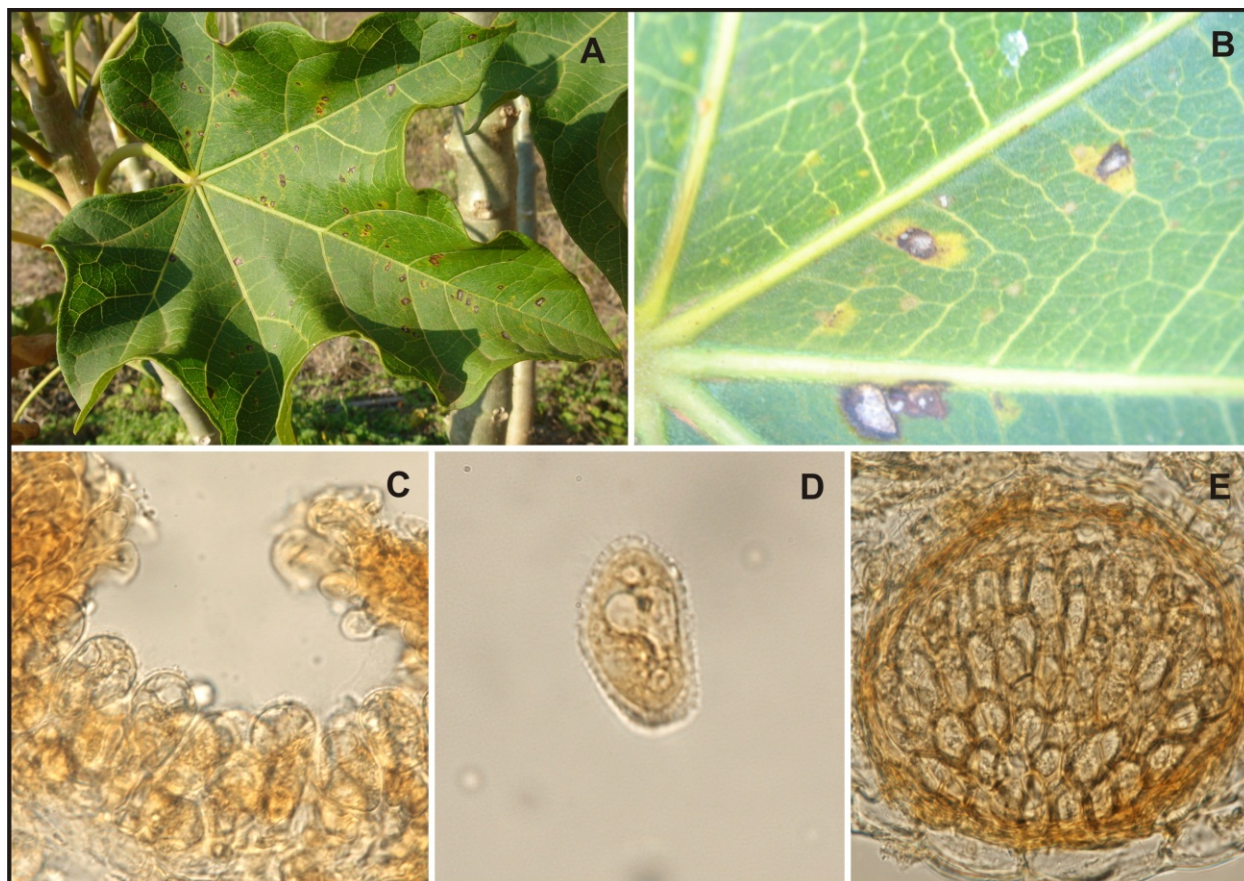


Figure 5. Rust disease on *Jatropha curcas*. Symptoms on adaxial leaf surfaces (A-B); Uredinia (C); Urediniospores (D); Telia with teliospores (E).

2.6. Stem canker and dieback (figure 6)

Lasiodiplodia theobromae(Pat.) Griffon & Maubl

The first report of this disease in Brazil was made by Freire & Parente (2006) and in Malaysia by Sulaiman & Thanarajoo (2012).

The disease manifests in the form of dieback that can progress until it takes over the trunk of the plant. Stem cankers have also been observed, causing necrotic lesions on branches and vascular discoloration. In Malaysia, disease incidence can be as high as 80% of a plantation (Freire & Parente 2006; Sulaiman & Thanarajoo 2012).

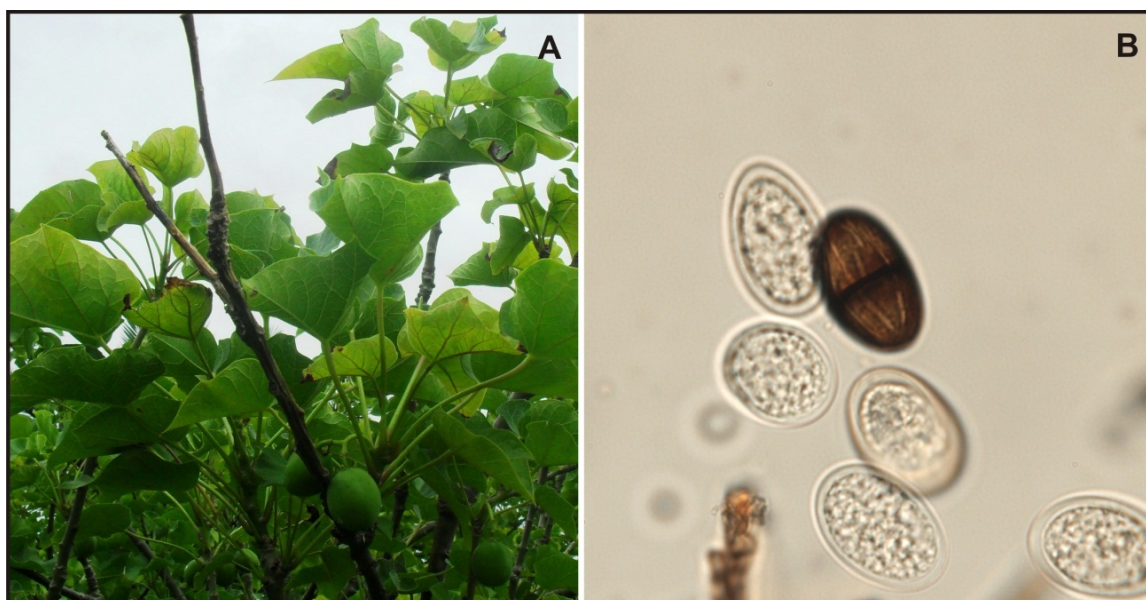


Figure 6. Dieback on *Jatropha curcas*. Symptoms observed in the field (A); Hyaline and pigmented conidia of *Lasiodiplodia theobromae* (B).

Characteristics of the *Lasiodiplodia* species commonly include the presence of paraphyses within the conidiomata pycnidial and conidia that are initially hyaline and aseptate. But in maturity, one median septum is formed, and the walls become dark brown with the formation of longitudinal striations due the deposition of melanin granules on the inner surface of the wall.

The identification of the *Lasiodiplodia* species based solely on morphological characteristics is not easy. Currently, it is known that what was initially identified as *Lasiodiplodia theobromae* is in fact a species complex (Alves et al. 2008). Thus, molecular studies are needed to correctly identify the pathogen, as was done by Thanarajoo & Sulaiman (2012).

Lasiodiplodia spp. is a fungus of the phylum Ascomycota, family Botryosphaeriaceae. Fungi in this family are known to survive as endophytes and demonstrate symptoms when plants are under some stress (Slippers & Wingfield 2007). Thus, many researchers see them as opportunistic pathogens.

Control of this disease can be achieved by pruning and destroying affected branches. Later plants should be brushed with copper fungicides or thiophanate methyl for injuries (Furtado & Trindade 2005). Additionally, balanced fertilization, soil analysis and sufficient levels of irrigation in regions with long periods of drought can aid in disease control.

2.7. Collar and root rot (figure 7)

Fusarium solani(Martius) Appel & Wollenweber

Lasiodiplodia theobromae(Pat.) Griffon & Maubl

Neoscytalidium dimidiatum(Penz.) Crous & Slippers

Macrophomina phaseolina(Tassi) Goid.

The first report of this disease in Brazil was made by Pereira et al. (2009), who identified it as being caused by *Lasiodiplodia theobromae*. In India, this same pathogen was reported by Latha et al. (2009), and *Macrophomina phaseolina* was reported by Patel et al. (2008). In China, Yue-Kai et al. (2011) identified the fungus *Fusarium solani*, and Machado et al. (in press) made the first description of *Neoscytalidium dimidiatum*(Penz.). Crous & Slippers associated this pathogen with collar and root rot in physic nut in Brazil.

All the pathogens mentioned above are typical soil fungi. They occur in a wide range of hosts, can be spread by seeds, and survive as parasites, saprophytes, endophytes or resistant structures, such as chlamydospores in *Fusarium* and *Neoscytalidium* or sclerotia in *Macrophomina*.

This disease has acquired great importance, because it can reduce productivity by causing the sudden death of plants and making cultivation areas unviable. The symptoms most commonly observed are wilting, leaf yellowing with subsequent fall, and cracks in the collar region. In the collar region, the appearance of black fungal structures in the bark of the plant has been consistently observed. Upon being removed from the soil, plant roots rot and the vascular system is affected by necrotic symptoms, ranging from light brown to black. Due to loss of support, the plants have often already fallen due to the wind.

The genus *Fusarium* has the following general characteristics: bright aerial mycelium, hyphae septate, conidiophores variable, single or grouped in sporodochia; conidia hyaline variable, principally of two kinds -multicellular macroconidia, slightly curved or bent at the pointed ends and typically canoe-shaped; unicellular, ovoid or oblong microconidia, borne singly or in chains and also grouped in false heads, formed in mono or polyphialides; thick-walled chlamydospores are common in some species (Barnett & Hunter 1998).

The common characteristics of *Lasiodiplodia* species include the presence of paraphyses within the conidiomata pycnidial and initially hyaline and aseptate conidia. However, in maturity, one median septum is formed, and the walls become dark brown with the formation of longitudinal striations, due the deposition of melanin granules on the inner surface of the wall.

The genus *Neoscytalidium* is a group of fungi that produces synanamorph *Scytaalidium*-like with septate and oblong to globose arthroconidia formed from aerial mycelia. Initially hyaline, with age, the arthroconidia become brown and with a thick wall. Commonly observed

are pycnidia that are dark and globose immersed or superficially in a stroma that produces *Fusicoccum*-like conidia that are hyaline and ellipsoid to nearly fusiform. Dark septate conidia can also be observed.

Characteristics of the *Macrophomina* spp. generally include the formation of dark mycelia and abundant production of sclerotia in PDA. Eventually, the formation of conidiomata pycnidial can be observed, with the release of hyaline conidia with apical mucoid appendages.

In areas prone to prolonged dry seasons, a higher incidence of collar and root rot has been observed. Therefore, it is believed that the water stress is the main factor that predisposes plants to this disease.

The above-mentioned pathogens are difficult to control, due to the fact that they survive in soil. Therefore, to reduce disease incidence, it is first necessary to provide water and fertilizer balanced for proper plant development. When transplanting seedlings to the field, all forms of injury should be avoided. Another control measure would be to use healthy propagative material as well as seed treatments.

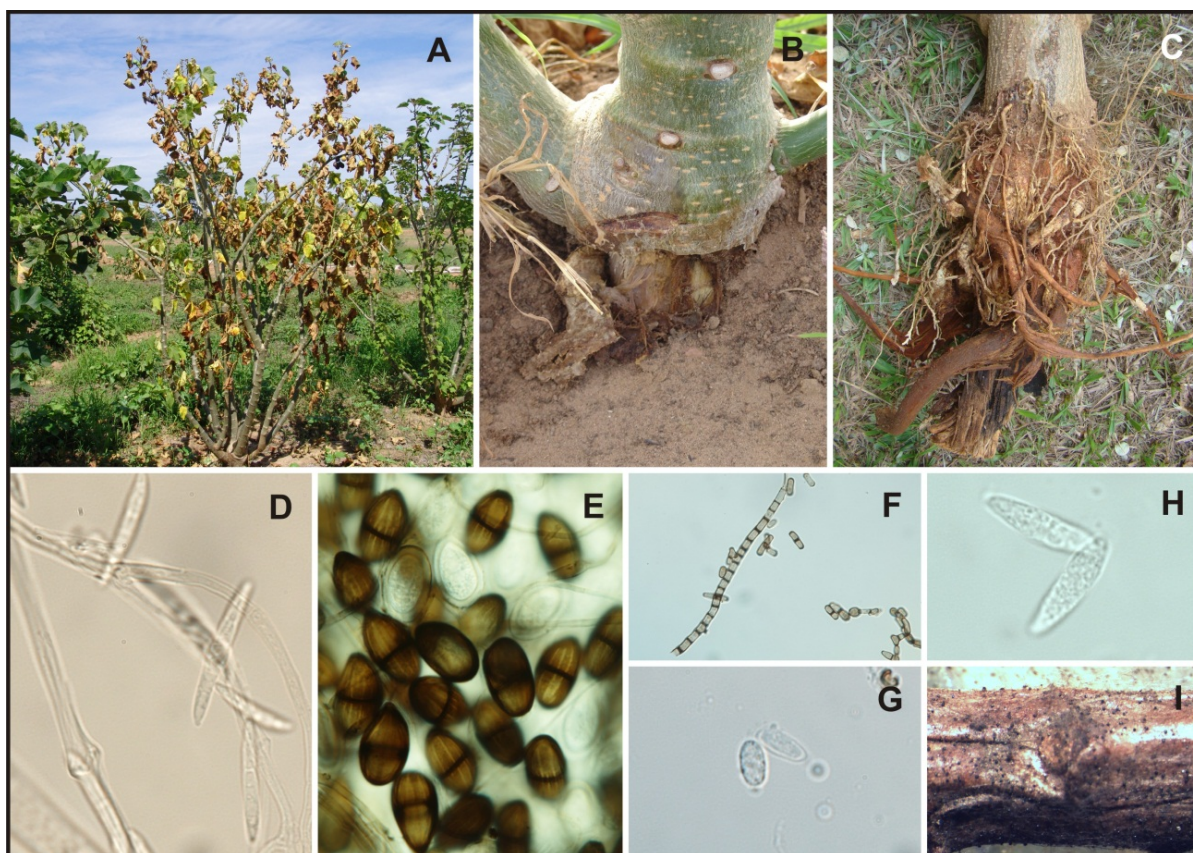


Figure 7. Collar and root rot on *Jatropha curcas*. Wilting symptoms observed in the field (A); Detail of the collar rot (B); Detail of root rot (C); Macroconidia of *Fusarium solani* (D); Pigmented and hyaline conidia of *Lasiodiplodia theobromae* (E); Arthroconidia of *Neoscytalidium dimidiatum* (F); *Fusicoccum*-like conidia of *Neoscytalidium dimidiatum* (G); Conidia of *Macrophomina phaseolina* (H). Sclerotia of *Macrophomina phaseolina* produced on sterilized Pine twigs in culture (I).

2.8. Yellow mosaic

In addition to the several fungal diseases mentioned, there is also yellow mosaic, a disease caused by a strain of the virus *Indian Cassava Mosaic Virus* (Gao et al. 2010). This disease, detected in physic nut plantations in India, causes mosaic, reduced leaf size, leaf distortion, blistering and stunting of diseased plants. The disease is transmitted by the vector *Bemisia tabaci* in a non-persistent manner, but not through mechanical inoculation or seeds (Narayana et al. 2006).

3. Seed associated fungi

Seeds propagate the majority of cultures worldwide. These cultures are vulnerable to infection by several pathogens that can survive in seeds. These pathogens may cause reduction of seed germination, as well as deformation, discoloration, reductions in size and weight, and deterioration during storage. They can further contribute to rotting roots, damping-off, necrosis in leaves, and the spread of diseases across long distances. Consequently, these diseases cause losses valued at billions of dollars (Neergaard 1977; Agarwal & Sinclair 1997). To date, few studies have addressed the seed pathology of physic nut, and there is no information available about the losses that seed pathogens cause in this culture. But, follows below the major pathogens and saprophytic fungi associated with seeds.

Macrophomina phaseolina (Figure 8)

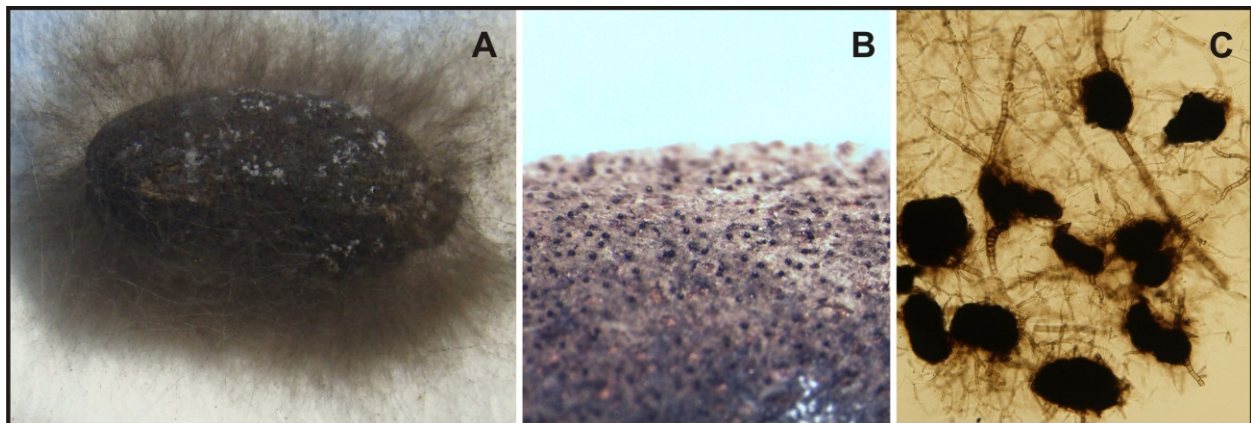


Figure 8. *Macrophomina phaseolina* on *Jatropha curcas* seed. Seed covered by mycelium (A); Detail of sclerotia on seed (B); Black sclerotia (C).

Colletotrichum capsici (Figure 9)

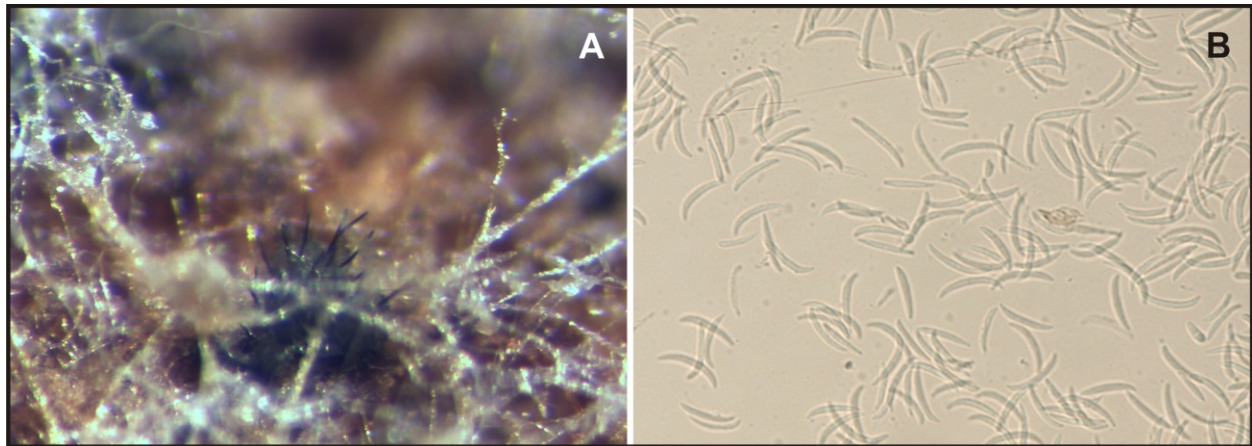


Figure 9. *Colletotrichum capsici* on *Jatropha curcas* seed. Conidiomata with black setae on seed surface (A). Curved asseptate conidia (B).

Fusarium sp. (Figure 10)



Figure 10. *Fusarium* sp. on *Jatropha curcas* seed. Seed covered by hyaline mycelium (A); Radicle with necrotic lesion (B); Macroconidia (C).

Lasiodiplodia theobromae (Figure 11)

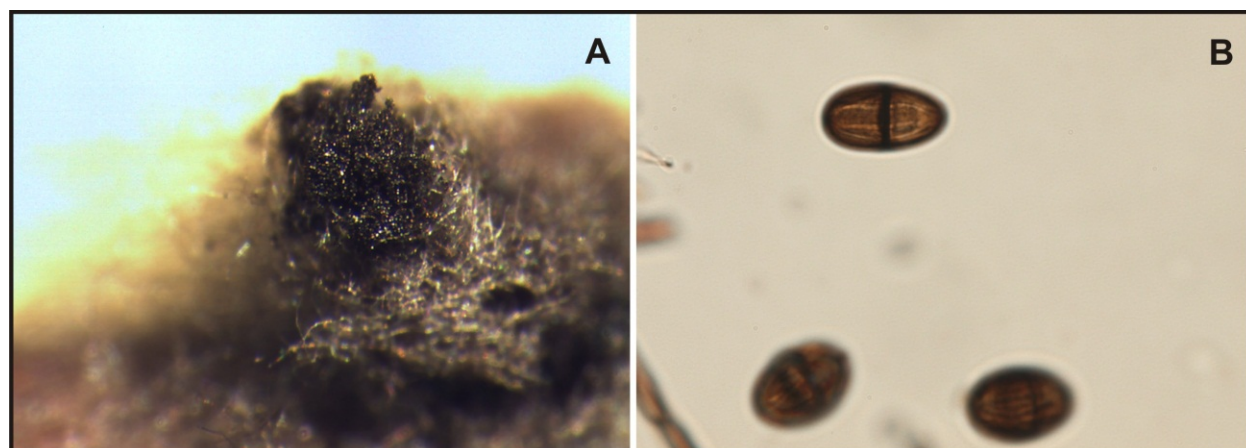


Figure 11. *Lasiodiplodia theobromae* on *Jatropha curcas* seed. Conidiomata producing a black cirrus of conidia on seed surface (A); Detail of mature conidia (B).

Curvularia sp. (Figure 12)

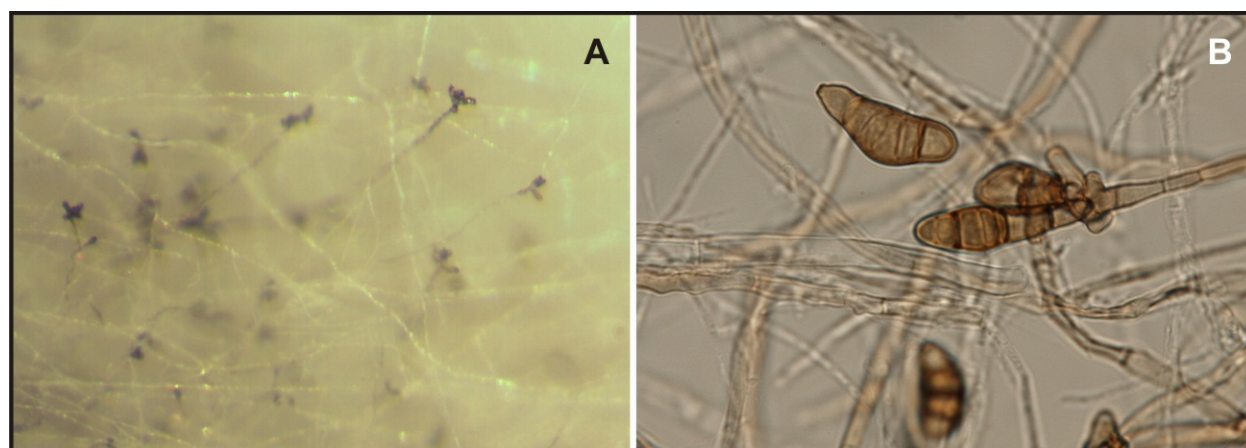


Figure 12. *Curvularia* sp. on *Jatropha curcas* seed. Mycelium and conidiophores producing conidia on seed surface (A); Dark septate conidia (B).

Other fungi commonly associated with *Jatropha curcas* seeds (Figure 13)

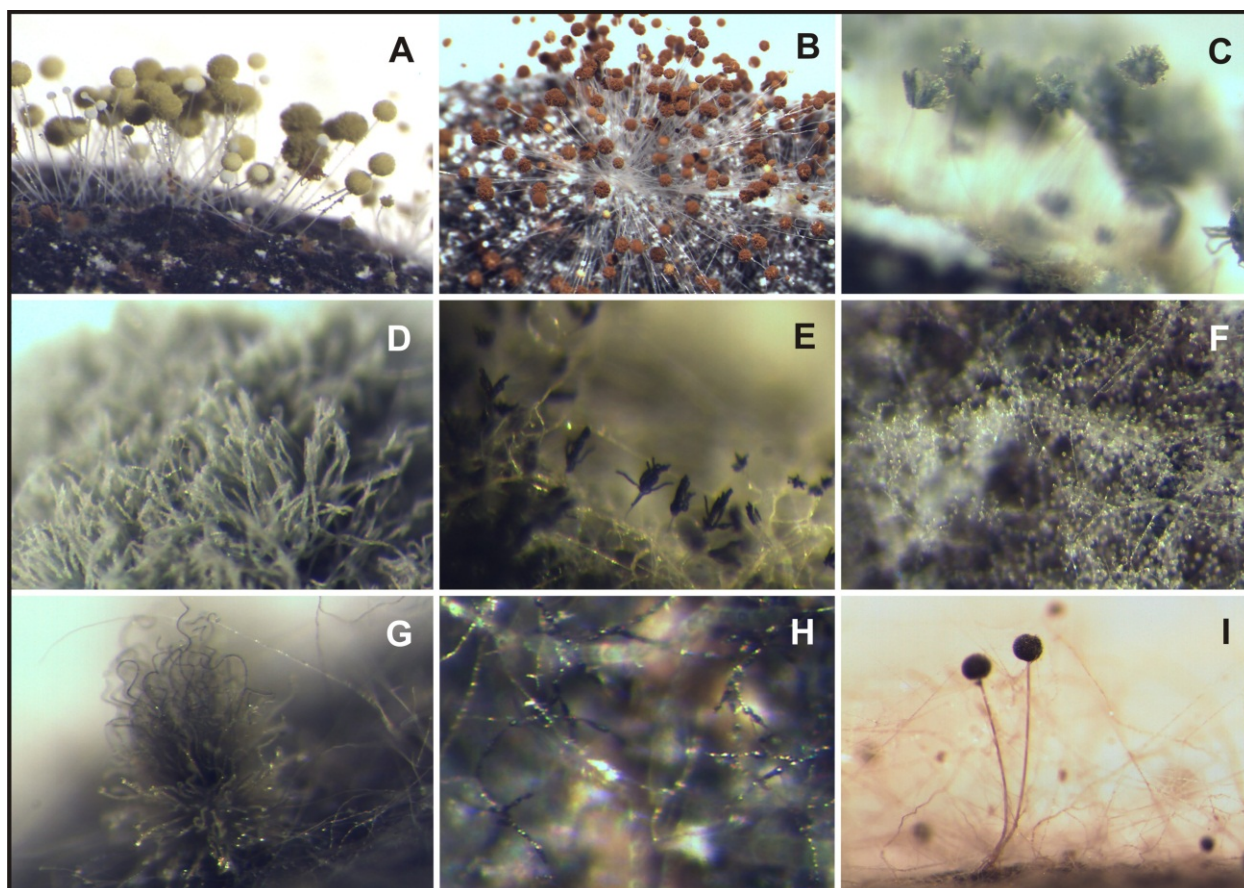


Figure 13. Genera of fungi often observed on *Jatropha curcas* seeds: *Aspergillus* (A-C); *Penicillium* (D); *Stachybotrys* (E); *Acremonium* (F); *Chaetomium* (G); *Alternaria* (H); *Rhizopus* (I).

Although there are no recommendations for fungicide use on physic nut, treatments can be administered by soaking seeds for 20 minutes in a solution of 1 liter of formaldehyde 40% diluted in 240 liters of water (Massola and Bedendo, 2005). This treatment is indicated for the seeds of *Ricinus communis* L., but it also works well for physic nut.

4. Conclusion

Despite the fact that most literature considered physic nut as resistant to pests and diseases, this review emphasizes the diversity of pathogens associated with this plant and the damage that they may cause. Most of these diseases may become a serious problem for Brazilian farmers, due to its severity and the lack of registered chemical products for these pathogens. Studies should be carried out in order to know the environmental conditions that favor to these diseases on *J. curcas*, as well as the development of control strategies and resistant varieties.

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Author details

Alexandre Reis Machado and Olinto Liparini Pereira

*Address all correspondence to: alexandrerm.agro@yahoo.com.br

*Address all correspondence to: oliparini@ufv.br

Departamento de Fitopatologia, Universidade Federal de Viçosa, Viçosa, MG, Brazil

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