# Chapter 11
# Phytosanitary Aspects of Jatropha Farming in Brazil

**José Carlos Fialho de Resende, Nívio Poubel Gonçalves, Mário Sérgio Carvalho Dias, Carlos Juliano Brant Albuquerque, and Danielle de Lourdes Batista Morais**

## Introduction

The species *Jatropha curcas* L., commonly known as physic nut, purging nut, *pinhão manso* (in Brazil) is referred to as Jatropha hereafter. It has been studied in many research fields by various international institutions. Jatropha is a promising species that is being now tested as a crop in several countries, justifying the loans and investments that numerous research centers and funding agencies have implemented. Several aspects of its culture have been addressed, notably the plant health since the species was earlier deemed resistant to pests and diseases (Carneiro et al. 2009; Laviola 2011). It is this fame of a rustic plant that has been responsible for the wide acceptance of Jatropha as a crop by farmers in Brazil. Indeed, the latex that oozes from the stem and leaves is caustic and is considered an anti-nutritional factor for various insects. However, under field conditions of high temperature and humidity, fungal diseases and arthropod attacks are common.

J.C.F. de Resende (✉)
Fazenda Experimental de Montes Claros, BR 251, Km 11, CEP 39404-128
Montes Claros, Minas Gerais, Brazil
e-mail: jresende@epamig.br

N.P. Gonçalves
Fazenda Experimental do Gorutuba, MGt 122, Km 150, CEP 39525-000
Nova Porteirinha, Minas Gerais, Brazil

M.S.C. Dias
Fazenda Experimental de Pouso Alegre, Av. Prefeito Tunay, 470 Campus Fátima – Univas, CEP 37550-000 Pouso Alegre, Minas Gerais, Brazil

C.J.B. Albuquerque
Fazenda Experimental de Uberlândia, Caixa Postal 2248, CEP 38402-019
Uberlândia, Minas Gerais, Brazil

D.de.L.B. Morais
Mestranda Unimontes, Bolsista Epamig, Fazenda Experimental do Gorutuba, MGt 122, Km 150, CEP 39525-000, Nova Porteirinha, Minas Gerais, Brazil

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Proper management of pests and diseases should focus on reducing production costs associated to plant protection as well as the environmental costs that are related to agricultural practices. Thus, the correct identification of causal agents is the main objective of pest and disease control programmes. The association of the biology of pest and disease, damage assessment and monitoring methodologies with cultivation practices of Jatropha enables the control of parasite populations in such a way as to cause the least possible impact on environment and human health, thus collaborating and strengthening the sustainability of Jatropha agriculture.

The presence of weeds that emerge in agricultural ecosystems may condition a number of biotic factors acting on a cultivated species, which will affect, not only the productivity, but also the operation of the crop system under production (Silva et al. 2007). In the case of perennial trees, the soil is not renewed every year and is not subject to fallow period when herbicide control should normally be done. In addition, weeds act as hosts for several species of pathogens and arthropods. Together, these factors are responsible for larger losses than when measured apart.

The number of publications in this area has increased in the last few years and, as pointed out by Laviola (2011), pest and disease control is of great importance since it represents around 50% of the productivity of a formalized crop system. Hereafter, we focus on weeds, pests and diseases found in plantations of Jatropha, which can be considered as key problems of this new crop in Brazil.

## Harmful Arthropods

Broad mite, two-spotted spider mite, European red mite, thrips, stink bugs, green leafhopper, mealy bugs and termites were recognized as the main organisms that use Jatropha as a food source in Brazil (Saturnino et al. 2005).

*Broad mite – Polyphagotarsonemus latus* (Banks 1904) (Acari: Prostigmata: Tarsonemidae), a polyphagous, cosmopolitan organism (Gallo et al. 2002) with great economic importance in papaya, beans, cotton, citrus, tomato, mango and grapes, among others, also causes serious damage to Jatropha. In the northern region of Minas Gerais (Brazil), the occurrence of this arachnid has been observed during every months of the year, when new shoots are being produced.

Broad mite occurs preferentially in the young parts of a plant; it is, initially, located in clusters within isolated regions of the field. The symptoms it causes are (1) leaves with a shiny appearance and coriaceous texture (Fig. 11.1), (2) new shoots with short internodes and (3) later, the death of the apical meristem, which causes the appearance of multiple shoots (Fig. 11.2).

When monitoring broad mite threat in a cultivated area, sampling should be made in various locations at random in order to identify broad mite clusters. Mite control must be managed immediately where clusters are found in order to avoid their spread, which would consequently cause an intervention at the level of the whole area. In cotton crop, occurrence of clusters of plants showing leaves with edges turned upwards before tearing is the indicator of mite. The infestation is considered widespread,

**Fig. 11.1** Jatropha leaves with symptoms of broad mite


**Fig. 11.2** Jatropha plants with multiple shoots resulting from the attack of broad mite (Photo courtesy: Marcos Drumond)

when plants with early symptoms reach 40% of a field, which is the proportion that determines the moment where a control action is needed. Commercial products including profenofos, triazophos and abamectin have acaricide activity however none of these compounds are registered in Brazil for use in Jatropha.

*Two-spotted spider mite – Tetranychus urticae* (Koch 1836) (Prostigmata: Tetranychidae) is considered of great importance worldwide because of its association with crops of economic importance such as, cotton, strawberry, rose, tomato, bean, soybean, peach tree, castor bean, grape and papaya. Attacks by this arachnid


**Fig. 11.3** Jatropha plant with symptoms of European red mite (Photo courtesy: Marcos Drumond)

initially occur in clusters as well, starting on the lower side of leaves. The first signs observed are pinpoint leaf lesions, which gradually fill the entire leaf surface and cause death. Under conditions of high population levels, webs may occur in the lesioned parts and cause great damage to plants.

*European red mite – Tetranychus bastosi* Tuttle et al. 1977 (Prostigmata: Tetranychidae) has been reported as a pest of *Jatropha* spp. and also of weed amaranth (*Amaranthus viridis* L.), weed black jack (*Bidens pilosa* L.), bam-burral (*Hyptis suaveolens* Poit.), sweet potato (*Ipomoea batatas* (L.) Lam), jiritana (*Ipomoea glabra* Choisy), Bellyache bush (*Jatropha gossypiifolia* L.), mallow (*Malva rotundifolia* L.), blackberry (*Morus nigra* L.) and seedlings of *Manihot pseudoglaziovii* Pax & Hoffmann (Santos et al. 2006). According to Saturnino et al. (2005), attacks of European red mite usually occur in older leaves (Fig. 11.3).

*Termites* (Isoptera: Termitidae) are insects genuinely Brazilian. They also received popular names, such as white ants, *siriris* or *hallelujahs*. The basic food of termites is live plant materials, recently dead or in various stages of decomposition and also humus. The natural habitat of termites is a forest, but, since termites are currently invading agro ecosystems and damaging crops of economic importance, they become a major problem for humanity. However, literature indicates that only a small proportion of termite species in rural and urban environments should be considered as pests. Many species of termites are important components of the soil fauna in tropical regions because of their role in organic matter fragmentation, playing a key role in the processes of decomposition and nutrient cycling (Menezes et al. 2007).

Termites begin their attacks on roots of both young and adult plants. The attacks initially appear in isolated regions within the area of cultivation (cluster), where plants are found dead or compromised concerning yield capacity and intensely


**Fig. 11.4** Final stage of an attack by termites on the root system of Jatropha

producing adventitious roots. Usually, the plant cannot be saved because the root system is already irreversibly damaged when symptoms are clear (Fig. 11.4).

To date there is no product registered in Brazil for pest control of *Jatropha*. A control measure that has been adopted experimentally is the application of termite insecticides used in forest plantations at the level of the plants within a cluster and those in their immediate neighbourhood.

*Thrips – Selenothrips rubrocinctus* (Giard 1901) (Thysanoptera: Thripidae) is a pest that can cause severe damages to crops, such as Jatropha, grapes, lychee, cashew, mango, avocado, guava, cocoa, rose, annatto, carambola, etc. Females introduce their eggs under the lower surface of leaves and cover them with a secretion that becomes dark when dry. Young thrips appear after 10–12 days. They are yellowish and their two first abdominal segments are red; they also carry a small drop of liquid excrement between the terminal bristles of the abdomen (Fig. 11.5). The duration of the life cycle of this species is about 30 days (Gallo et al. 2002).

The pest *stem borer* of Jatropha – *Sternocoelus* (= *Coelosternus) notaticeps* Marshall 1925 (Coleoptera: Curculionidae) must, in fact, be considered as *Coelosternus notaticeps*, according to the observations by Bondar (1913) in Bahia (Brazil) reported in Costa Lima (1956). It was found in Tatuí, state of São Paulo (Brazil), causing severe damage to *Jatropha* (Gabriel et al. 1988a).

Adult females lay their eggs in the parenchymal tissue from which larvae hatch; they feed on internal tissues of stems and branches, forming galleries within them. The pupal stage occurs within the tissues and the insect emerges to infect new plants (Ungaro and Regitano Neto 1996).

Damages can be considerable and lead to plant loss when the infestation rate is too high. Plants should be periodically inspected for perforations and residue at the base of stems that could testify attacks by this insect (Fig. 11.6).

**Fig. 11.5** Young thrips (*red*) on the abaxial face of a Jatropha leaf (Photo courtesy: Heloisa Mattana Saturnino)

**Fig. 11.6** Drilling at the base of the trunk of a Jatropha plant caused by *Sternocoelus notaticeps* Marshall 1925 (Photo courtesy: Dalva Gabriel)

The lack of boron in soil makes plants more susceptible to borers, therefore boron application is recommended for prevention of stem borer. The monitoring of plants, especially during the summer, is also recommended. Stems should be cut and burnt in order to prevent larval development. Chemical control is not advisable because larvae are difficult to reach inside stem tissues (Ungaro and Regitano Neto 1996). Moreover, there are no chemicals registered for Jatropha's stem borer in

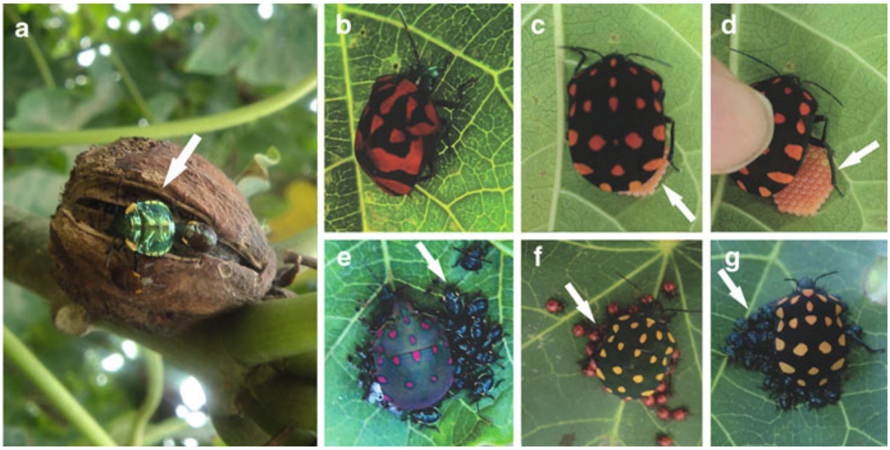


**Fig. 11.7** Stink bug on Jatropha. A nymph (*white arrow*) sucking a dry fruit (**a**). Variations in drawing and color pattern on bodies of *P. torridus* (**b–g**). An adult female covering its eggs (*white arrows*) (**c** and **d**). Nymphs (*white arrows*) protected by females (**e**, **f** and **g**)

Brazil. However, the use of aldicarb in experimental treatments for the control of this pest in the state of São Paulo showed promising results (Gabriel et al. 1988a).

*Green leafhopper – Empoasca* spp. (Hemiptera: Cicadellidae) is one of the most severe pests of Jatropha in northern Minas Gerais. Adults are green, measure about 3 mm and live up to 60 days, on average. Females lay 30–168 eggs (average of 107 eggs per female), each being individually inserted in leaf tissues (Gallo et al. 1988; Quintela 2002). Nymphs and adults are normally located on the lower leaf side, have the same color and move laterally (Quintela 2002). The green leafhoppers complete their life cycle on beans in about 3 weeks (Gallo et al. 1988).

Damages caused by nymphs and adults are physical as a result of the stylus penetration in phloem tissue, which leads to cell disruption, sap granulation and vessel blockage (Ospina 1980). According to Saturnino et al. (2005), the main symptom of attacks by *Empoasca* spp. in Jatropha is the yellowing of leaves, followed by leaf hardening and slight bending down of the leaf blade; occasionally it may also promote flower abortion. After performing leafhopper control, new leaves develop with normal color.

In April 2005 (autumn), population levels of *Empoasca* spp. were high in all areas planted with Jatropha in the North of Minas Gerais and systemic insecticides had to be applied for its control (Saturnino et al. 2005). To date, there is no pesticide registered in Brazil for Jatropha. Since Jatropha is a natural host for leafhoppers, it is important to set up its culture area far enough from its other natural hosts. Insect migration from one crop to the other is to be expected and may cause damages not only because of their own direct action, but also because of their potential for dispersal of the pathogenic agents that these insects may carry.

Another important insect pest is the *stink bug – Pachycoris torridus* Scopoli, 1772 (Hemiptera: Scutelleridae) (Fig. 11.7). Peredo (2002) reported that the species of *Pachycoris* are very similar to each other and there is little difference between the characteristics used for their identification. The similarities between them have promoted confusion concerning their identification. *P. torridus,* commonly known in Brazil as the "bug of *pinhão-bravo*" (Silva et al. 1968), is the best known species of Scutelleridae (Gallo et al. 1988). They are widely distributed in America, being found from the United States (California) to Argentina (Froeschner 1988), occurring more frequently in South America and rarely in Mexico (Peredo 2002).

According to Bondar (1913), this insect appears in Brazil during the summer sucking the sap from leaves and fruits of guava (*Psidium guajava*) and *P. araça*. Saturnino et al. (2005), reported that during the period between June 2004 and the first half of May 2005, this stink bug was found in wild condition on an endemic *Jatropha* sp. from the North and northeast of Minas Gerais. In addition, *P. torridus* was also found on *Oryza sativa* (rice), *Anacardium occidentale* (cashew), *Eucalyptus* spp. (Eucalyptus), *Citrus sinensis* (orange), *Manihot esculenta* (cassava), *Mangifera indica* (mango), *Aleurites fordii* (tung) (Silva et al. 1968), *Malpighia glabra* (acerola) (Sánchez-Soto and Nakano 2002), *Schinus terebinthifolius* (an ornamental species) (Sánchez-Soto et al. 2004) and *Sapium haematospermum*, this last occurrence found in Paraguay (Hussey 1934).

The occurrence of these insects can be verified by examining leaves and fruits by looking for the presence of eggs, nymphs and adults. When found, the insect must be immediately destroyed because they quickly produce large numbers of nymphs and both insect stages may promote fruit alterations because of their sucking activity. Actually, they may cause premature abortion of young fruits and affect endosperm development (Tominaga et al. 2007), cause seed shriveling (Saturnino et al. 2005), affect the oil content and germination potential in mature fruits.

Biological control is one of the best alternatives to reduce the population of the stink bugs. Adults can be parasitized by *Hexacladia smithii* Ashm. (Hymenoptera: Encyrtidae) and by *Trichopoda pilipes* Fabr. (Diptera: Tachinidae) (Costa Lima 1940) and their eggs can be parasitized by *Telenomus (Pseudotelenomus) pachycoris* Costa Lima (1928) (Hymenoptera: Scelionidae) (Costa Lima 1940; Peredo 2002). However, in an experiment carried out in the São Paulo state (Brazil) when *T. pachycoris* (parasitoid) was tentatively used as a control agent, only 27% of the total egg number was parasitized. The low efficiency of the parasitoid is due to the protective activity by stink bug females that leave the nymphs to their own destiny only when they are in their first instar stage, which upset the female parasitoid in its hunting. Thus, the eggs at the periphery of stink bug female spawn are the only one to end up infected (Gabriel et al. 1988a).

In India, Sahai et al. (2011) reported a fruit symptomatology similar to that induced by *P. torridus*, but caused by *Scutellera perplexa* (Hemiptera: Scutelleridae). The nymphal stages of this insect also caused damage on fruits and seeds, such as premature abortion, reduction of fruit weight, seed number and germination potential. Shanker and Dhyani (2006) suggested biological control with *Stegodyphus* sp., *Pseudotelenomus pachycoris* [*Telenomus pachycoris*], *Beauveria bassiana* and *Metarhizium anisopliae*.

## Diseases

Saturnino et al. (2005) quoting Viégas (1961) and USDA (1960) report that many pathogens have been found infecting *J. curcas* such as *Cercospora jatrophae-curcas, Helminthosporium tetrâmera, Pestalotiopsis paraguarensis, Pestalotiopsis versicolor, Clitocybe tabescens, Colletotrichum gloesporioides, Elsinoe jatrophae* Bitanc. *Et Jenkins, Fusarium* spp., *Glomerella cingulata, Oidium hevea* Steinm., *Phakopsora jatrophicola* Cumm., *Phytophthora* spp. *Psathyrella subcorticalis* Speg, *Pythium* spp*., Schizophyllum alneum* (L.) Schoroet. and *Uredo jatrophicola* Arth.

Powdery mildew is an important disease of Jatropha reported in all regions of its cultivation. The causal agent of this disease is a highly evolved obligate fungus that occurs in various parts of the world, in many cultivated species. The characteristic symptom is the formation of whitish, powdery colonies on the surfaces of the aerial parts of living plants (Fig. 11.8), like young branches, flowers, fruits and especially the leaves.

This pathogen usually appears during the dry season, coinciding with the time of natural defoliation of Jatropha. Powdery mildew belongs to family Erysiphaceae. Its imperfect stage corresponds to the genus *Oidium,* a fungus responsible for the disease occurrence in Brazilian conditions. According to Franco and Gabriel (2008), the species that is pathogenic to Jatropha is *Oidium hevea.*

The chief measures used to control powdery mildew are restricted to recommend the use of resistant varieties and chemicals. The application of fungicides is still one of the key control methods of powdery mildew.

The diseases caused by *Colletotrichum* are known as anthracnosis whereas the most commonly associated species is *Colletotrichum gloesporioides*. *Colletotrichum* spp. are facultative fungal parasites whose control is performed by recommending the use of resistant varieties, fungicide application and disposal of residues. The symptoms are easily noticeable. In the case of Jatropha in the North of Minas Gerais, this fungus has been isolated from necrotic lesions that begin on the leaf edges and move towards the centre of the leaf (Fig. 11.9), which then dries quickly and fall off.

In the state of Ceará (Brazil), anthracnosis of Jatropha occurs almost exclusively during the rainy season and is caused by two *Colletotrichum* species: *C. gloeosporioides* and *C. capsici* (Freire and Parente 2006). Symptoms are similar for both pathogens and the infection starts as small round leaf lesions (0.2–0.5 cm) with light brown color. Spots become dark brown as the disease progresses and in some cases, total leaf necrosis could be observed. Dark-brown color injuries also occur on fruits.

In Nicaragua, Padilla and Monterroso (1999) reported that anthracnosis lesions on Jatropha leaves are necrotic, large and irregularly shaped. Usually, the lesions start on leaf edges, but can eventually start at the center. Anthracnosis due to *C. gloeosporioides* has also been reported in South Korea and confirmed by molecular markers (Jin-Hyeuk et al. 2012).

*Alternaria* spp. stand out among those causing leaf spots as the one with the largest widespread occurrence in Jatropha. In Nicaragua, the pathogen was found only sporadically, however it has been identified on mature fruits producing pedicel wilting

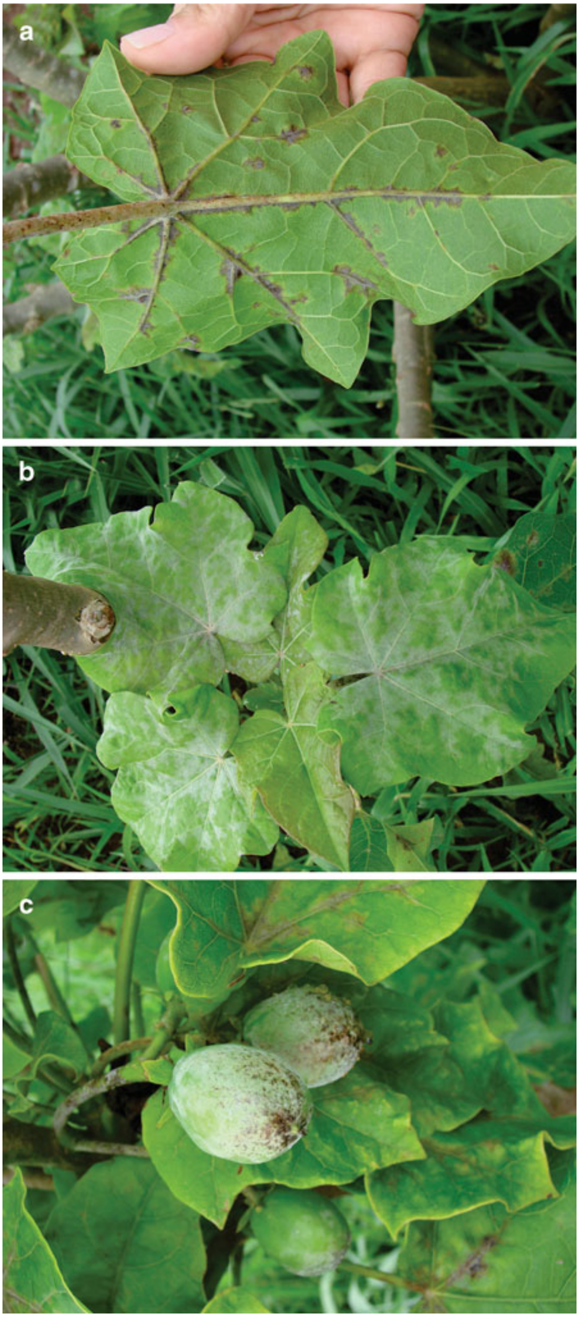


**Fig. 11.8** Symptoms of powdery mildew (*white*) on lower (**a**) upper (**b**) sides of leaves and on fruits (**c**)

and fruit fall (Padilla and Monterroso 1999). The general practice for crop control contaminated by *Alternaria* spp. is recommending the use of resistant varieties, fungicide application and removal of residues.

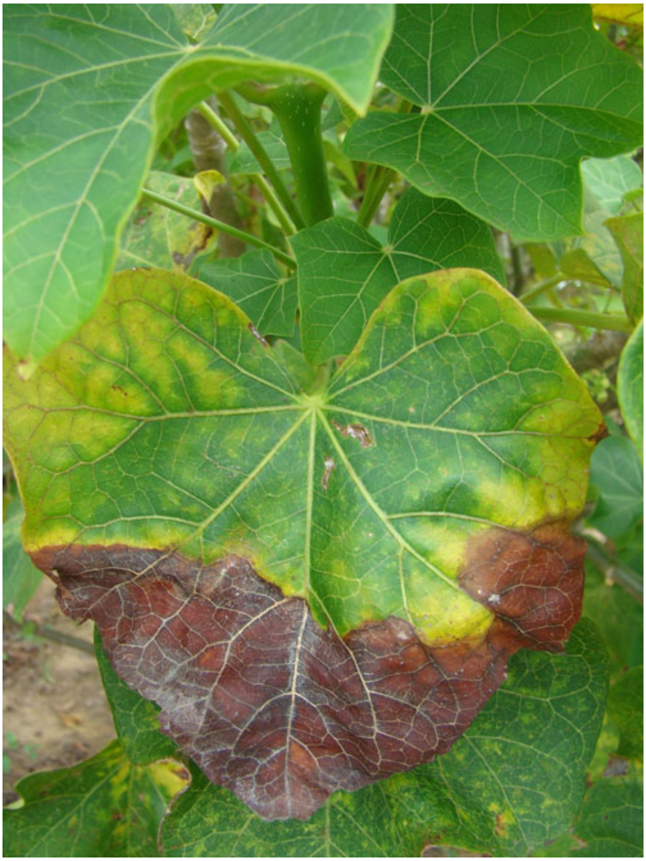

**Fig. 11.9** Anthracnosis necroses on Jatropha leaves

The fungus *Cercospora jatrophae-curcas* is also reported to cause leaf spots on Jatropha. In India, the control of this disease is carried out by spraying Bordeaux mixture at 1% (Swamy and Singh 2006). In the experimental areas of North Minas Technological Center (*Empresa de Pesquisa Agropecuaria de Minas Gerais* – EPAMIG) in Nova Porteirinha the fungi *Cercospora* and *Alternaria* have been isolated from small necrotic lesions of Jatropha leaves (Fig. 11.10). These lesions occur throughout the leaf and may cause total leaf necrosis by convergence in the case of high disease incidence or adverse climatic conditions.

The rust disease was first reported on Jatropha by Viegas (1945) in the state of São Paulo. The causal agent was the fungus *Phakopsora jatrophicola.* According to Franco and Gabriel (2008), this pathogen causes rust disease on leaves (Figs. 11.11a, b) and may lead to plant defoliation. Correia de Sá et al. (2008) claim that rust is one of the main diseases of Jatropha because of the high degree of defoliation it can cause to the plants. These authors observed 100% incidence of rust in 18 month old plants among 50 accessions in the state of Tocantins. However, when severity was

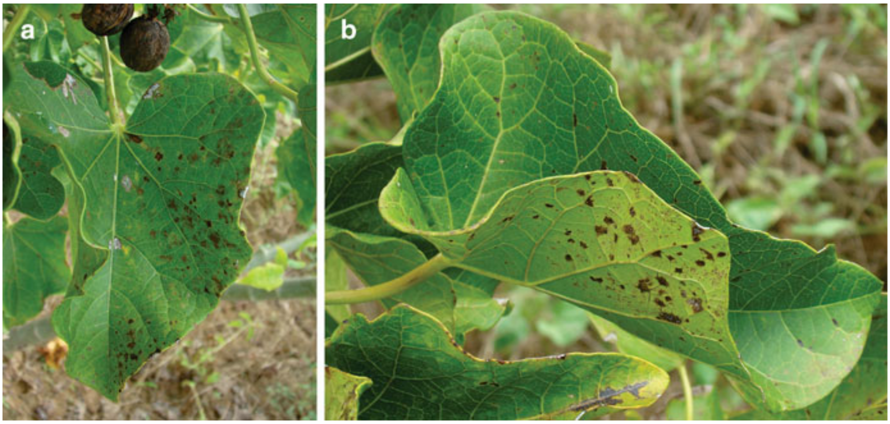


**Fig. 11.10** Lesions on Jatropha leaves induced by *Alternaria* spp. and *Cercospora* sp. on upper (**a**) and lower sides of a leaf (**b**)

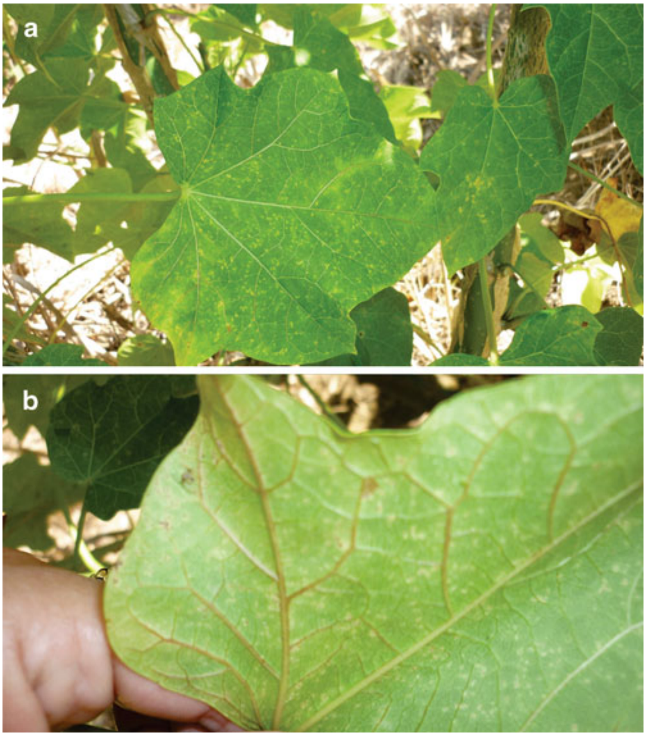


**Fig. 11.11** Rust on the upper side (**a**) and on the lower side (**b**) of Jatropha leaves (Photo courtesy: Jaime Menezes)

assessed in detail, variation in symptom intensity was observed suggesting that the genetic basis for tolerance could be improved by selective breeding.

Roese et al. (2008) reported a rust epidemic in Jatropha plantations in the State of Mato Grosso do Sul between 2006 and 2008. These authors reported that the occurrence of this disease has increased over the years as the total acreage increased. They also quoted a survey conducted by Embrapa in a field of approximately 100 ha, in Dourados (MS), which showed total defoliation caused by the rust in the lower part and partial defoliation in the upper part of Jatropha infected plants. Defoliation occurred right after the reproductive period and affected the fruit and seed production process. Regarding disease control, combinations of flutriafol + thiophanate methyl, pyraclostrobin + epoxiconazole, azoxystrobin + cyproconazole and myclobutanil + azoxystrobin were found effective in controlling the disease in the middle part of plant canopy. Despite the effectiveness of these fungicides, they have not yet been recommended for use in Brazilian commercial plantations because they are not registered at the Ministry of Agriculture, Livestock and Supply for use in Jatropha.

Root diseases caused by soil fungi have promoted the death of Jatropha plants in both experimental areas and commercial plantations in Brazil and worldwide. Fungi of genera *Phytophthora* spp. and *Fusarium* spp. have been isolated from Jatropha with symptoms of collar rot and root rot in northern Minas Gerais.

*Fusarium* spp. is a cosmopolitan fungus, which has a large number of species known to cause diseases in important agronomic crops. Bedendo (1995) describes that, generally, the symptoms of root rot caused by soil fungi begin with the browning of young roots and progress to the older ones. This gradual darkening starts with a slight brownish color or, in some cases, reddish brown color and then becomes darker as the disease progresses. At the end of the process, necrotic roots become dark-brown or completely black. The browning symptom is accompanied by decomposition process of roots and the fully darkened roots disintegrate when subjected to light finger pressure. The collar rot is characterized by the appearance of stem lesions that can be located just below or above the soil surface. The lesions are usually depressed and also fungal structures may appear on them. In tender stems, the development of lesions can lead to weakening of the lesioned area, which may cause plant overturning. In woody stems, onset of cracking and flaking is observed, which, in addition to local damage, can serve as a gateway to other pathogens. In the field, symptoms occur in clusters, but when there are irrigation furrows, diseased plants appear in the same line due to spread of pathogen structures through water. The first evidence of a disease occurrence caused by a soil fungus appear in plant canopy through symptoms, such as leaf and branch shriveling, leaf yellowing, nutritional deficiency, premature leaf and fruit dropping; this syndrome normally leads to plant death. Young branches of Jatropha dry and break easily upon infection by *Fusarium* spp. and fungal structures can be found over the lesions on branches in the aerial part of plants (Padilla and Monterroso 1999). Although *Fusarium* spp. are being consistently isolated from Jatropha plants with symptoms of stem rot in plantations of North of Minas Gerais, experiments identifying this pathogen and pathogenicity tests on healthy host have not yet been conclusive.

*Phytophthora* spp. is a fungus that causes root and collar rots in plants in the early stages of development to maturity. Root symptoms induced by these fungi are browning followed by rotting. Franco and Gabriel (2008) described the symptoms of this disease in Jatropha as a manifestation of soft rot where necrotic tissues are darker than normal and exude a liquid with characteristic smell. Symptoms in the canopy are leaf yellowing and wilting that look as a nutritional deficiency. The disease can eventually progress until the branch death. As in the case of *Fusarium* spp., *Phytophthora* spp. are regularly being isolated from Jatropha plants with symptoms of collar rot and root rot in the North of Minas Gerais, but experiments for its identification on healthy host have not been conclusive.

Other soil fungi were also reported in the literature to be pathogenic for *Jatropha*; they are: *Macrophomina phaseolina* and *Rhizoctonia bataticola,* which cause the "collar rot". The characteristic injury symptom of these fungi is a lesion at the base of the main stem that occurs when the soil is waterlogged for long periods or in irrigated monocultures (Swamy and Singh 2006).

## Weed Management

The presence of weeds in agricultural ecosystems may condition a number of biotic factors acting on the cultivated species and affecting, not only its productivity, but also its operation (Silva et al. 2007).

The most pernicious weeds for Jatropha are the scandent or climbing ones, such as jitiranas (*Merremia* spp.), morning glory (*Ipomoea* spp.) and bitter melon (*Momordica charantia*), among others. These weeds climb on the trunk and branches causing them to choke, tangling the canopy, providing shade and reducing production or even leading to host death (Saturnino et al. 2005).

An experiment was conducted at EPAMIG in Nova Porteirinha in order to assess the damage caused by weeds in early growth of Jatropha. The predominant weeds of this experimental site were *Merremia* spp., *Ipomoea* spp., *Cenchrus echinatus* and *Brachiaria decumbens.* Reduction of Jatropha green matter became evident 45 days after the coexistence with weeds. After this period, some of the Jatropha plants died due to strangulation and shading caused by weeds (Albuquerque 2012). Shaded plants suffered a drastic reduction in photosynthesis, resulting in a lower growth rate and a less developed root system with lower ability to absorb water and nutrients from soil.

Many weed vine species such as flame vine (*Pyrostegia venusta*), can cause serious injury to perennial species, reducing crop stand due to elevated seedling mortality and also causing trunk deformities. Plants affected by these weeds are almost always the dominant species with the consequence that they do not fully express their genetic potential for biomass production (Pitelli and Marchi 1991). The control of these weeds in early growth of Jatropha is critical for the development of normal plants and to avoid unnecessary costs in replanting.

In a screening of 11 commercial herbicides applied in post-emergence, for selectivity towards weeds and inocuity for Jatropha, haloxyfop-r-metyl, bentazon and

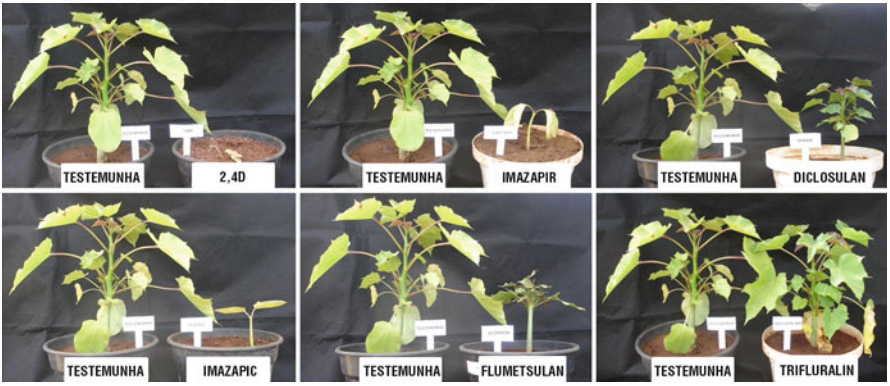


**Fig. 11.12** Effect of several herbicides applied in pre-emergence of Jatropha plantlets. *Upper panel*, from left to right: 2.4 D, Imazapyr and Diclosulam (the control is on the *left* of each panel and the treatment on the *right*). *Bottom panel*, from left to right: Imazapyc, Flumetsulam and Trifluralin (the control is on the *left* of each panel and the treatment on the *right*). The word "testemunha" is from Portuguese and means *control* in English

trifluralin were reported affecting the height of Jatropha's shoots (Albuquerque et al. 2008a). All the other products assessed in this experiment (cloransulam-metílico, diclosulam, flumetsulam, 2, 4-D, imazapyr, imazapic, imazethapyr, quinclorac) caused morphological alterations and/or variations in leaf color of seedlings.

In pre-emergence (Fig. 11.12) and post-emergence (Fig. 11.13), trifluralin did not promote any visible toxicity to plants. It did not induce any changes in shoot diameter, shoot dry weight, plant height or stem diameter. Thus, this treatment was concluded to be the closest to an effective control of weeds in real conditions of Jatropha plantations in northern Minas Gerais (Albuquerque et al. 2008b).

In large culture areas, systemic chemicals can be applied between the rows of Jatropha. Among products for weed control, the widely used herbicide known as glyphosate stands out as the most efficient. Glyphosate inhibits the enzyme 5-enolpyruvyl-shikimate 3-phosphate synthase (EPSP) and retards the production of amino acids phenylalanine, tyrosine and tryptophan used for protein synthesis and also for the synthesis of some secondary metabolites, such as vitamins, lignin and hormones. If spray shields are located at the end of spray bars and sprays directed between the rows, the absence of selectivity of this potent systemic herbicide is not important as long as it does not come in contact with Jatropha leaves. The effectiveness of glyphosate depends on the efficiency of a series of processes, such as retention of the herbicide by leaves, adequate penetration, translocation and inhibition of the EPSP active site (Monquero 2003).

Weeds may cause losses in Jatropha cultivation and the lack of herbicides registered for the culture complicates the management of this crop. Environment friendly weed control should be considered for a more sustainable agriculture. A strategy that would be possible in soils without compaction problem, would be the use of desiccants with little residual effect that could be applied before Jatropha planting to give a comparative advantage to Jatropha seedlings. Another interesting strategy

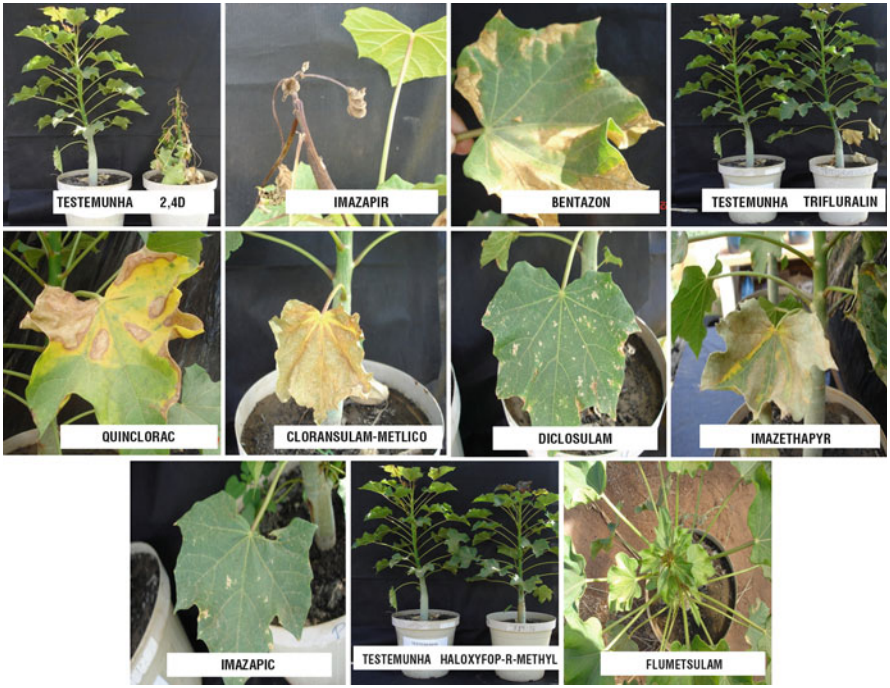


**Fig. 11.13** Effect of several herbicides applied in post-emergence of Jatropha plantlets. *Upper panel*, from left to right: 2,4 D (*left*: control, *right*: treatment), Imazapyr (symptoms of leaf and shoot mortality), Bentazon (symptoms of cell mortality on a leaf) and Trifluralin (*left*: control, *right*: treatment). *Medium panel*, from left to right: Quinclorac (symptoms of extended cell mortality on a leaf), Cloransulam-methyl (symptoms of leaf mortality), Diclosulam (symptoms of limited cell mortality on a leaf) and Imazethapyr (symptoms of leaf mortality). *Bottom panel*, from left to right: Imazapyc (symptoms of limited cell mortality on a leaf), Haloxyfop-R-methyl (*left*: control, *right*: treatment), Flumetsulam (induces a reduction of internodes and leaf area giving a rosy shape to the main shoot)

would be the intercropping of legumes between the lines of Jatropha in order to manage weeds and to provide a green manure able to fix nitrogen from air.

To ensure sustainability and competitiveness, Jatropha depends, among other factors, on a technology that meets the standards of quality and productivity reducing environmental impact. This reality brings forth the need for an effective investment in research for the adoption of proper cultural practices.

## Conclusions

The management of pests, diseases and weeds is an important part of the technological package to increase productivity levels of Jatropha worldwide. What was once considered a minor problem is now of primer importance in the cultivation of

Jatropha. The diagnosis of major pests and diseases as well as the establishment of appropriate management techniques aiming to optimize cost-benefits will also serve as a guide to other large areas of knowledge, such as genetic improvement and fossil fuel dependency in a feedback process toward Jatropha domestication and industrialization.

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