Chapter 10
Jatropha Pests and Diseases: An Overview

K. Anitha and K.S. Varaprasad

Introduction

Jatropha curcas L., a non-edible oilseed, drought tolerant, is gaining popularity commercially as a biodiesel plant in India and many other developing countries. It is mostly grown as a medicinal plant or hedge crop and is being advocated for the development of waste lands and dry lands throughout the world. The crop has been expected to be less prone to damage due to different categories of pests and diseases as wild varieties were used as live fence in dry lands. Another reason is that the seed oil is reported to have insecticidal, molluscicidal, nematicidal and fungicidal properties. However, reports of pest outbreaks on *J. curcas* have started appearing with planting *J. curcas* as a regular monocrop in both marginal and arable lands using high yielding and high fertilizer responsive cultivars. Serious problems of economic significance have been reported in *J. curcas* plantations due to attack of fungi, bacteria, viruses, insects and other pests. Cryoconservation did not reduce the incidence of fungi on *J. curcas* seeds though the physiological quality was preserved (Goldfarb et al. 2010). Adverse impact on the crop economics is expected from pest and disease attacks since it could seriously affect production costs.

In view of the considerations above, the global status of insect pests and diseases on *J.curcas* and some species of the *Jatropha* genus has been reviewed and compiled. Below, we report on common and scientific names of pests and diseases along with photos of their corresponding symptoms wherever available. We also report on the management options given in the literature for each of the important pests and diseases.

K. Anitha (✉)
National Bureau of Plant Genetic Resources Regional Station,
Rajendranagar, Hyderabad, 500 030, India
e-mail: aniyagnya@yahoo.com

K.S. Varaprasad
Directorate of Oilseeds Research,
Rajendranagar, Hyderabad, 500 030, India

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Fungal Diseases

Root Rot

Different fungal pathogens, *viz., Fusarium moniliforme, Lasiodiplodia theobromae, Phytophthora* sp., *Rhizoctonia bataticola* or *Macrophomina phaseolina, Sclerotium rolfsii, Clitocybe tabescens*, etc., are known to cause root rot or collar rot in *J. curcas*.

Fusarium moniliforme [*Gibberella fujikuroi*] causes root rot under waterlogging conditions as observed for the first time during routine surveys in Bawal, Haryana, India, causing 20–25% mortality of *J. curcas* (Sharma et al. 2001).

Symptoms: Yellowing of leaves at 45–50 days after planting, followed by defoliation, drying or wilting of the plant from the tip downwards, and finally death. The presence of sooty roots is also observed. The disease is more pronounced during winter months.

Lasiodiplodia theobromae root rot and collar rot was reported for the first time on *J. curcas* grown in the state of Tamil Nadu, India with heavy losses in 2007 (Latha et al. 2009). Pathogenicity was confirmed by artificial inoculations on 1-year-old plants. In China, the pathogen caused gummosis of *J. podagrica* (Fu et al. 2007). The most damaging root and collar rot disease caused by *L. theobromae* was observed on adult plants of *J. curcas* in the states of Minas Gerais, São Paulo (Pereira et al. 2009) and Ceara (Freire and Mosca 2009) in Brazil. Seed health tests undertaken on 213 germplasm accessions of *J. curcas* from Andhra Pradesh, Chattisgarh, Uttaranchal, Kerala and Tamil Nadu states in India revealed that *L. theobromae* was the most prevalent seed borne pathogen, occurring in 83 accessions from all sources (Anitha et al. 2005).

Symptoms: Yellowing, drooping and shedding of leaves, wilting, blackening and decaying of the collar region and rotted roots, followed by death of the plants, especially those undergoing drought stress. Black pycnidia are seen on the collar region and black necrotic patches are observed when the bark is removed from the collar region. A blackening of the vascular region is consistently observed on collar and root regions of ill plants. The disease can also lead to the death of adult plants.

***Phytophthora* sp.** was reported to cause root rot in Ghent, Kenya (http://betterglobe-forestry.com/research/pests-and-diseases.html). Large plantations of *J. curcas* in Chiapas, Mexico had been destroyed by *Phytophthora* sp. in 2009, causing collapse and death of young plants (CABI UK Centre Annual Report 2009). Interspecific hybridization between *J. curcas* and *J. integerrima* was undertaken with the objective of combining desirable traits such as resistance to root rot, tolerance to frost and high oil content (Dhillon et al. 2009a). The hybrids were successfully obtained only when *J. curcas* was used as seed (female) parent. Dhillon et al. (2009b) also found that the cleft grafting of *J. curcas* scions on *J. gossypiifolia* rootstock let to resistant individuals to root rot.

Rhizoctonia bataticola *or* Macrophomina phaseolina

The collar rot disease is more common in the drip irrigated fields, excessively irrigated fields or fields with high water table/poor drainage. The plant tries to recover by producing new roots in the rotted area. Secondary root growth is stimulated by covering the rotted area with soil (http://jatropha.pro). Twenty to thirthy-days-old *J. curcas* plants showing root rot symptoms (10–13% severity) were observed in Bawal, Haryana, India, from April to May 2005 (Sharma and Kumar 2009) and found that *R. bataticola* was responsible for the disease. *R. bataticola* caused basal stem rot of seedlings in nurseries raised in Mexico (CABI UK Centre Annual Report 2009). The epidemiological factors that affected the root rot development were studied (Kumar and Sharma 2010) and found that inoculum density of 20 $g\,kg^{-1}$ soil resulted in 42% *pre-emergence mortality* (PEM) and 23% *post-emergence mortality* (POEM). Inoculum at a depth of 5 cm induced 42% and 31% PEM and POEM, respectively. Irrigation at 20 days interval showed maximum PEM (42%) and POEM (35%). *R. bataticola* or *M. phaseolina* is known to cause collar rot of young seedlings (Heller 1996; Daey Ouwens et al. 2007; Sharma and Sarraf 2007).

Symptoms**:** Small light-brown lesions develop on hypocotyl/collar region, which later turn dark brown and girdle the entire collar region (Fig. 10.1). The infection moves downwards rapidly. The tissue inside the bark shows black coloration.

Seed and Seedling Rots (Sclerotium rolfsii)

Seed and seedling rot of *J. curcas* caused by *S. rolfsii* was observed in a nursery raised in Karnataka state, India (Hegde et al. 2009).

Fig. 10.1 Collar rot (*Macrophomina phaseolina*) affected *J. curcas* plant (Courtesy: http://jatropha.pro)

Symptoms: Seedlings show complete wilting. When such seedlings are uprooted, white mycelium is seen at the basal portion with sclerotial bodies on rotting seeds or seedlings. Hegde et al. (2009) isolated *S. rolfsii* from such wilted plants and could link fungal infection to pathogenicity since seed failed to germinate, seeds rotted or germinated only after 40 days leading discolored seedlings to completely wilt within 4 days.

Armillaria tabescens *Root Rot*

Armillaria tabescens (***Clitocybe tabescens***) was reported to be responsible for Armillaria root rot of *J. curcas* in USA (Agriculture Hand book 165, 1960) and Sudan (Dalia Amin 2001). *A. tabescens* is on the disease list that justifies quarantine in India (Plant Quarantine Order 2003).

Management: There are no cost-effective fungicidal sprays to control *Fusarium* root rot, according to Michigan State University. Therefore, prevention is the common method for controlling root rot. It is indicated to avoid overly moist soil conditions. *M. phaseolina* root rot can be effectively managed by soil drenching with fungicides like carbendazim at 0.1%, hexaconazole at 0.1%, mancozeb at 0.2% or carboxin + thiram at 0.1%. Carbendazim application increased the plant vigour significantly (Hegde and Chavhan 2009/2010). However, there is no registered chemical product for this pathogen on *J. curcas* in Brazil.

The collar rot disease of *J. curcas* can be controlled by using 1% Bordeaux solution (http://www.k4rd.org/jatropha.htm) (TERI 2007). The disease due to *R. bataticola* or *M. phaseolina* can be controlled with 0.2% copper oxychloride (COC) or 1% Bordeaux drenching (Sharma and Sarraf 2007).

Plant Wilt (Fusarium oxysporum)

The pathogen attacks the plant in the seed bed or in the field. The disease spreads from one plant to another, sometimes through flood and open channel irrigation (http://jatropha.pro/wilt.html).

Symptoms: Both young and fully grown plants collapse in a very short time (starting from the bottom) as they do not get water due to the blockage of vascular system by the fungus (Fig. 10.2). When the seedling is attacked, the leaves become pale green, wither, dried (Fig. 10.3) and fall down leaving only the younger leaves from upper plant floors (Fact Foundation 2010).

Management: Several cultural strategies can be followed to control infectious plant wilt. These include healthy seedling selection, use of resistant varieties, avoiding flooding around the plant, improving soil drainage conditions, avoid the creation of a hard crust when using a machine for planting, ridge planting, burn the trash or infected plant materials and avoid inter cropping with plants from the

Fig. 10.2 Wilt (*Fusarium sp.*) affected *J. curcas* seedling (Courtesy: http://jatropha.pro)

Fig. 10.3 Vascular discolouration due to *Fusarium oxysporum* (Courtesy: www.jatropha.pro)

Solanaceae family, which are alternate hosts of *Fusarium* spp. The seed treatment with carbendazim, soil fumigation or drenching with benlate (50 g/100 l) is effective in combating the problem although expensive. The application of *Trichoderma viride* as a biocontrol agent at 250 g ha^{-1} at planting has also given good results.

Leaf Spot (Cercospora jatrophae-curcas)

The incidence *of C. jatrophae-cur*cas responsible for leaf spot symptoms on *J. curcas* has been reported in India (Kar and Das 1988; Sharma and Sarraf 2007). *C. ricinella* was also found responsible for leaf spots on *J. curcas* in Indonesia (http://www.waterlandasiabio.com). *Cercospora* sp. has been isolated from leaf spots observed on *J. curcas* at the University of Florida (http://strawberry.ifas.ufl.edu/DiagnosticLab). The disease is severe during the rainy season and spreads primarily by conidial propagation through rain splash. Temperatures ranging between 24°C and 26°C and above 60% relative humidity (RH) are favorable for the disease development.

Symptoms: Initially, small brownish necrotic irregular spots with a yellowish halo appear on the leaf surface. As the disease advances, these spots enlarge, coalesce and leave characteristic shot hole on the middle. The damage caused by this pathogen on *J. curcas* can be very heavy. Sometimes, black or brown round spots surrounded by a pale green ring are found on both surfaces of leaves. When the spot enlarges, it becomes gray and is surrounded by a brown crown that finally becomes irregular (http://www.fact-foundation.com/). The conidia are hyaline, tapering at one end and 70×3 μm with 2–7 septa.

Management: This disease normally does not hamper fruit production by *J. curcas*. In case of severe incidence, application of 0.2% carbendazim (180–200 litre per acre), mancozeb or any fungicide is helpful. It is recommended to use varieties that are resistant to the pathogen. The systemic resistance of *J. curcas* to pathogens such as *Cercospora* sp. and viruses was increased by soaking seeds in leaf extracts of *Clerodendrum aculeatum* (Debnath and Verma 2008). A minimal care is to adopt the recommended cultural practices that is the removal and burning of infected leaves around plant bases as well as the avoidance of overhead irrigation.

Alternaria *spp*.

Leaf spot disease caused by *A. alternata* (Fr.) Keissler was observed in the *J. curcas* plantation at Marathwada Agricultural University, Parbhani, Maharashtra in 2006 (Hudge and Datar 2010) and in Jabalpur, Madhya Pradesh (Shukla and Jamaluddin 2010), India. Leaf spots caused by *Alternaria* spp. were recorded in India (http://www.rrljorhat.com/) and Kenya (http://betterglobeforestry.com/). The disease incidence was maximum in the month of August and subsequently decreased up to November. High humidity and temperatures in the range of 16–20°C favour the disease development and the attack may reach 70% affecting the fruit yield and oil content (http://www.waterlandasiabio.com/).

***Symptoms*:** Initially yellow spots appear on the leaves, later they turn to brown. If the infection is massive, the plant becomes stunted, and may also die. If the attack occurs at the onset of flower initiation, the buds may die; if it occurs at the end of flowering, the flowers may open, but capsules may not form. If the attack is light, the flowers may dry. The fungus develops very quickly on the capsules when humidity is high and fruits become black. Premature drop of the green blighted fruits also occurs in severe cases. The disease may appear throughout the year, but intensive attack occurs in the rainy season. The disease may spread through seeds, internally or externally. It may also tumble young seedling in the seed bed. Premature leaf fall

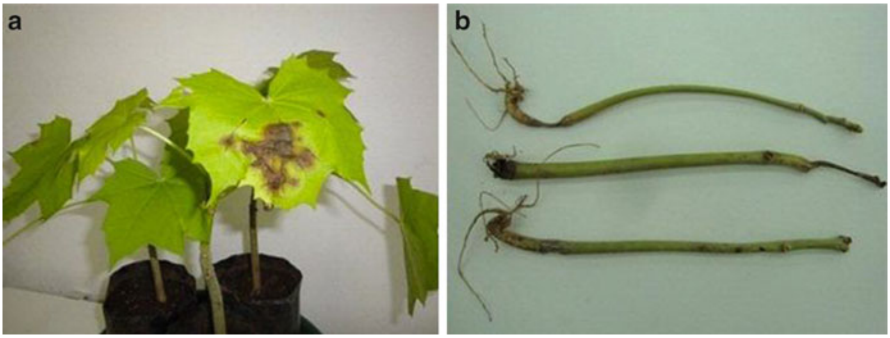

Fig. 10.4 Angular leaf spot stage of anthracnose (*Colletotrichum* spp.) symptoms on *J. curcas* leaf (Courtesy: Dra. Daisy de la C. Perez Brito, Yucatan, Mexico)

due to *Alternaria* sp. infection on *J. curcas* was reported in Zimbabwe (http://www.jatropha.de/sudan/jatropha-project).

In vitro effect of temperature and humidity against *A. alternata* leaf spot of *J. curcas* in India was studied by Hudge and Datar (2009). These authors found that the optimum temperature for its growth was 25°C, followed by 30°C and 35°C. Mycelial growth was found to be positively correlated with the incubation period. Maximum sporulation was observed at 25°C, followed by 30°C and 20°C, while sporulation was poor at low temperatures, i.e., 15°C and 10°C. The largest mycelial growth (90 mm) occurred at 100% relative humidity. The optimum relative humidity for growth and sporulation of the fungus lies between 84.5% and 100%.

Management: Seed treatment with contact fungicide is useful to prevent the first phase of its development.

Anthracnose (Colletotrichum *spp.*)

The leaf spot disease caused by *C. gloeosporioides* was recorded on *J. curcas* plants in Sudan (Dalia Amin 2001) and Brazil (Freire and Mosca 2009). Brown angular lesions with yellow halo (Fig.10.4) followed by enlarged necrotic lesions (Fig.10.5) on leaves are the most common symptoms. Crown canker, apical death of seedlings and foliar necrosis were observed on *J. curcas* in fields located in the Yucatan Peninsula in Mexico in 2008 affecting 25% of the production (Torres-Calzada et al. 2011).

C. jatrophae-curcas was found responsible for leaf necrosis in Mexico in 2009 (CABI UK Centre Annual Report 2009). Periodic surveys of different places (Chitrakoot, Seoni, Narsinghpur and Bilaspur) in Madhya Pradesh, India, and in the neighbourhood of *J. curcas* revealed that *J. curcas* plants were infected with *C. dematium* (Gupta et al. 2007; Shukla and Jamaluddin 2010). Naik (1993) reported the incidence and pathogenicity of *C. gloeosporioides* [*Glomerella cingulata*] on

Fig. 10.5 Advanced necrotic lesions (*Colletotrichum* spp.) on *J. curcas* leaf

J. glandulifera in India for the first time. Seed health tests undertaken on 213 germplasm accessions of *J. curcas* from different states in India revealed the presence of *C. acutatum* and *C. graminicola* (Anitha et al. 2005). Stephen and Mark (2010) reported the incidence of anthracnose and leaf spot due to *Colletotrichum* sp. on *J. integerrima* in Lee county, USA by the University of Florida.

Management: Infected leaves should be removed when the plant is dry. Leaves fallen around the base of the plant should be raked up and disposed of. Overhead irrigation should be avoided as far as possible and water should be directed at soil level. Watve et al. (2009) studied the management of *C. gloeosporioides* using biocontrol agents, plant extracts and fungicides and found that *Trichoderma harzianum* (in *in vivo* assay), neem leaf extract (in *in vitro* assay) and carbendazim followed by propiconazole were effective against the disease.

Powdery Mildew (Oidium *spp*.; Erysiphe euphorbiae; E. jatrophe)

Powdery mildew damages leaves and flowers of *J. curcas* in Zimbabwe (http://www.jatropha.de/sudan/jatropha-project) and Kenya (http://betterglobeforestry.com/). *Oidium* sp. was observed on *J. gossypiifolia* in Cuba (Bocourt et al. 2005). Reddy and Reddy (1980) reported *Erysiphe euphorbiae* on *J. gossypiifolia* L. from India. Later Braun (1987) reported *E. jatrophe* Doidge on *J. zeyheri* Sond from

Fig. 10.6 *J. curcas* seedling infected with powdery mildew (Courtesy: http://jatropha.pro)

South Africa. Occurrence of *E. jatrophe* on *J. curcas* plants was reporded in Manipur, India (Sharma et al. 2010).

Powdery mildew occurred in the nursery damaging leaves and stems in Zhenkang County, China in July of 2008 (Li et al. 2009). Infection characteristics of powdery mildew on *J. curcas* were studied in China and the results showed that plantations of *J. curcas* were easily infected by several waves of powdery mildew over the duration of the experiment. The period of August to October corresponded to the peak incidence of the disease given the favorable temperatures and humidity. After November, the disease development decreased, but never stopped (Li et al. 2010).

Symptoms**:** The white powdery mycelium of the fungus is seen mainly on younger leaves and terminal shoots (Fig. 10.6). Powdery mildew damages leaves and flowers of *J. curcas* more often in areas with low average temperatures and relatively high humidity.

Management: Products based on dithiocarbamate (Zineb, Dithane, Manzate, etc.) may be used to fight the disease (http://jatropha.pro/).

Pestalotiopsis Blight (Pestalotiopsis *spp*.)

J. curcas is reported to be a host of *Pestalotiopsis guepinii* (Mordue 1971). Leaf spot caused by *P. versicolor* (Phillips 1975) and *P. paraguarensis* (Singh 1983) on *J. curcas* was reported earlier. *P. mangiferae* was isolated from affected plants in Allahabad, Uttar Pradesh and it was confirmed that in the absence of bark injury, the pathogen failed to enter the plant system to cause the disease (Pandey et al. 2006).

The incidence and severity of *Pestalotiopsis* blight was recorded in 2006 in all plantations and hedges of *J. curcas* in two agro-climatic zones in Karnataka with very high levels of disease severity index (DSI) (Chavhan et al. 2010). *Pestalotiopsis* sp. is also known to cause leaf spot on *J. curcas* (Sharma and Sarraf 2007).

***Symptoms*:** Stems of affected plants exhibit multiple injuries at the collar region and above. The exposed inner tissue is dark brown to black. Small to extended cankers are formed at these wounds, giving the area a charcoal black appearance (Pandey et al. 2006).

Management: Two sprays of 0.1% mancozeb at 30-day intervals proved to be highly effective in decreasing the disease in the field at very low disease severity index (DSI of 1.17) compared to a DSI of 1.85 in the control (Chavhan et al. 2010).

Fungicidal screening revealed that carbendazim completely inhibited the *P. mangiferae* colony growth even at the lowest concentration (0.1%). Dithane M-45 [mancozeb] was effective only at 0.3%, while captan proved to be ineffective even at 0.3% (Pandey et al. 2006).

Botrytis Decay (Botrytis ricini)

***Symptoms*:** The initial symptoms appear as black spots on the flowers. The disease is a very serious problem in the rainy season especially when it coincides with the capsule forming phase. The disease spreads with rains during the nights when the temperature is cool. The infected flowers start to rot and end up covered. Pathogen spreads from the flower to the fruit capsule easily (http://www.waterlandasiabio.com/rd/).

Rust (Phakopsora jatrophicola; P. arthuriana)

There are two rust species recorded on *J. curcas*—*Phakopsora jatrophicola* and *P. arthuriana*. Although *P. pachyrhizi* has quite a broad host range within the legumes, it has not been recorded on *J. curcas* (http://biofuelexperts.ning.com/).

Incidence of *P. jatrophicola* on *J. curcas* was noticed in Sudan (Dalia Amin 2001). Survey conducted in 2009 revealed that rust caused by *Phakospora* spp. was the most widely spread and damaging disease in Mexico (CABI UK Centre Annual Report 2009), infecting plants of all ages. *J. curcas* infected by rust (*P. jatrophicola*) with 25–30% disease severity was also recorded in Singapore (AVA 2010).

New isolates of *P. jatrophicola* from Central and South America have been tested on six different Australian varieties of *J. gossypiifolia*, which is a declared noxious weed in Australia (Seier et al. 2009). All varieties tested, including *J. curcas*, were susceptible to the rust species. Hence, it was decided to collect and evaluate additional strains of *P. jatrophicola* with an increased host specificity for *J. gossypiifolia*.

Symptoms**:** The disease looks like rust spots with symptoms as small, bright orange, yellow, or brown pustules on the lower surface of the leaf. When touching it with the finger, it leaves a colored spot of spores. Leaf necrosis and defoliation of seedlings are the major symptoms. The pathogen attacks many plants from *Euphorbiaceae*.

Management: Spraying or dusting using sulfur powder and mancozeb fungicide may reduce the intensity of the attack. In anticipation of new resistant varieties, some basic cares such as maximum air circulation, clean up of plant debris especially around plants that have been infected, avoidance of overhead irrigation and water irrigation only during the day to allow plant drying before night are efficient means of inoculum control.

Viral Diseases

Jatropha Mosaic Virus Disease

The *Jatropha mosaic virus* (JMV) was first reported on *J. gossypiifolia* from Puerto Rico and identified as begomovirus (Brown et al. 1999). There are reports on occurrence of JMV (JMV-PR) on *J. gossypiifolia* and *J. multifida* from Puerto Rico (USA) (Bird 1957; Brown et al. 1999). JMV was also reported from Cuba on *J. gossypiifolia* (Martinez 2008).

The Jatropha mosaic virus disease (JMVD) has emerged recently and is now widely spread in India. The incidence of JMVD ranged between 13% and 47% in Karnataka state, India, causing significant yield loss (Narayana et al. 2006). The putative *Jatropha mosaic Indian virus* (JMIV) is transmitted through grafting, the dodder *Cuscuta subinclusa* and the whitefly, *Bemisia tabaci.* Phylogenetic analysis of the core coat protein (CP) sequences of JMIV and begomoviruses shows that JMIV groups in a separate cluster close to *Indian* and *Sri Lankan cassava mosaic virus* isolates and shared highest nucleotide identities (90–95%) with them (Narayana et al. 2007). The association of a begomovirus with JMD has been found in north India where it possesses the highest identity level and the closest relationships with *Indian* and *Sri Lankan cassava mosaic virus* isolates (Raj et al. 2008). The begomoviruses causing JMD in the Americas grouped separately from JMIV and shared only 72.8–75.2% nucleotide identity with the core CP and are, thus, distinct.

JMD was identified in *J. curcas* plantations as well as in wild stands in semi arid regions of India (http://www.phytotron.com/jatropha1.htm). Serious disease symptoms were observed on a large number of *J. curcas* plants in various localities of Balrampur District, Uttar Pradesh during the rainy season of the year 2005 (Tewari et al. 2007). The disease was sap transmissible and cleft graft transmissible,

Fig. 10.7 *J. curcas* plant affected with *Jatropha mosaic virus* (Courtesy: Aswatha Narayana et al. 2006)

but not transmitted through seed, dodder and insects (aphids and whiteflies). The disease could not be transmitted to any other plant except *J. curcas*. Attempts made by sap inoculation and grafting to *Nicotiana glutinosa*, *Lycopersicon esculentum*, *Solanum melongena*, *Datura stramonium* and *Carica papaya* were not successful (Tewari et al. 2007).

The disease resembles to some extent with the *tobacco leaf curl virus* (TLCV) (Shanta and Menon 1959). Chlorosis is prominent in case of the disease in *J. curcas*, while not common on plants attacked by TLCV. The virus causing the mosaic disease in *J. curcas* is not transmitted by whiteflies, while TLCV is neither transmitted by whiteflies (Smith 1957) nor by sap (Garga 1960), hence it is considered as a distinct record of mosaic. Metabolic and histopathological alterations of *J. curcas* induced by the Jatropha mosaic begomovirus were studied by HR-MAS NMR spectroscopy and magnetic resonance imaging (Sidhu et al. 2010).

Symptoms**:** Naturally infected plants showed mosaic, reduced leaf size, leaf distortion, blistering and stunting (Fig. 10.7). Whitefly inoculated plants developed typical symptoms such as veinal netting, chlorotic specks, leaf distortion and stunting of seedlings within 30 days of inoculation (Narayana et al. 2006). The disease was successfully established in healthy plants through grafting using scions from infected cuttings. Graft-inoculated plants produced typical mosaic symptoms within 25 days after graft inoculation. The success rate of disease transmission of JMVD to healthy plants through silverleaf whitefly (*Bemisia tabaci* 'B biotype') was reported to be as high as 40% (Narayana et al. 2006). Although its vector was found in 1994, JMVD has not yet been found in Australia (Jones and Csurhes 2008).

Gao et al. (2010) reported the completion of the nucleotide sequence of the virus. Phylogenetic analysis of the virus genome suggests it is a new strain of *Indian cassava mosaic virus*. The authors suggest that with the genome sequence and the availability of the two infective clones, it may be possible to use double-stranded hairpin RNA or artificial miRNA-mediated RNA interference technology to generate transgenic *J. curcas* lines that would be resistant to this new disease.

Management: The application of ZILLON™ is quite effective against JMVD. Virus free planting material should be propagated to check the disease spread (http://www.phytotron.com/jatropha1.htm). The investigations on epidemiology and development of specific diagnostic techniques have helped to develop suitable management strategies to combat the disease, which is likely to become a serious threat for *J. curcas* cultivation in the country.

African cassava mosaic virus

J. multifida is known to be a host of *African cassava mosaic virus* (ACMV), as a related species of *J. curcas* and, thus, may serve as a reservoir for ACMV. *J. curcas* should not be grown in association with cassava (http://www.jatropha.de/photo-show/index.htm#use) as it is also believed to be capable of transmitting the cassava super-elongation disease (*Sphaceloma manihoticola*) (Achten et al. 2008).

Cucumber mosaic virus

Occurrence of *Cucumber mosaic virus* (CMV) on *J. curcas* in India was reported in Uttar Pradesh, India during 2006 (Raj et al. 2008) where the major symptoms were severe mosaic accompanied by yellow spots. Sap transmission, gel diffusion tests, RT-PCR assays, cloning, sequencing and BLAST analysis indicated a 98–99% identity of the virus responsible for the symptoms with CMV isolates. Sporadic incidence of several other pathogens infecting *J. curcas* plantations was recorded from places to places all over the world (Table 10.1).

Nematode Diseases

Root-Knot Nematode (Meloidogyne javanica; M. incognita)

J. podagrica is registered as a new host for root-knot nematode (*Meloidogyne javanica*) in Brazil (Freire and Mosca 2009; Erum et al. 2005). However, the reaction of *J. curcas* to *M. javanica* was studied in Brazil by Fernandes and Asmus (2007) and found that *J. curcas* was immune to *M. javanica*. Incidence of *M. incognita* has been recorded on *J. podagrica* from Pakistan (Zarina 1996) with maximum population observed during the months of January to April and a rapid decline during summer months.

Table 10.1 Other diseases recorded on *Jatropha* spp.

Pathogen	Host	Country of report	Reference
Amphobotrys ricini	*J. podagrica*	Brazil	Lima et al. (2008)
Botryodiplodia theobromae	*J. podagrica*	China	Fu et al. (2007)
Alternaria sp., *Colletotrichum* sp., *Dothiorella* sp., *Fusarium* sp., *Oidium* sp., and *Xanthomonas* sp.	*J. curcas*	Nicaragua	Padilla and Monterroso (1999)
Cordana musae (leaf spot) and *Chlaropsis thielavioides* (Marginal necrosis)	*J. curcas*	Philippines	Tuan et al. (2009)
Dothiorella gregaria (Stalk rot); *Diplodia* sp. (Root and stem rot)	*J. curcas*	China	Wang et al. (2009)
Elsinoë and *Sphaceloma* spp.	*J. aconitifolia* var. *papaya*	Central and South America	Zeigler and Lozano (1983)
Elsinoë brasiliensis (superelongation disease of cassava)	*J. curcas*	n.a	www.cabi.org
Fusarium solani	*J. glandulifera*	India	Das (1995)
Fusarium spp., *Phytophthora* spp., *Pythium* spp., (Root rot and Damping-off)	*J. curcas*	n.a.	Heller (1996)
Fusarium solani; *Macrophomina phaseolina*; *Pestalotia* sp; *Phoma* sp.	*J. curcas*	Andhra Pradesh, India	Sudhir et al. (2007)
Helminthosporium [*Drechslera*] *tetramera*	*J. curcas*	India	Singh (1983)
Meliola jatrophae (Black mildew)	*Jatropha* sp	n.a	Hosagoudar and Archana (2009)
Nigrospora sphaerica	*J. curcas*	n.a	Kirk (1991)
Passalora ajrekari	*J. curcas*	Ceara state of Brazil	Freire and Mosca (2009)
P. jatrophigena	*Jatropha* sp	Brazil	Braun et al. (2004)
Pseudocercospora jatrophae	*J. curcas*	India	Das and Chattopadhyay (1990)
Powdery mildew and damping-off	*J. curcas* nursery	Zhenkang County	Li et al. (2009)
Five species of fungi (seed quality deterioration)	*J. curcas*	India	Neelu et al. (1996)
Cassava superelongation disease (*Sphaceloma manihoticola*)	*Jatropha*	n.a.	http://www.gardenguides.com
Cassava latent virus-C strain	*J. multifida*	Kenya	Bock et al. (1981)
Bunchy top virus	*J. curcas*	India	http://www.phytotron.com/jatropha1.htm

(continued)

Table 10.1 (continued)

Pathogen	Host	Country of report	Reference
Bacterial diseases			
Angular spot (*Xanthomonas* sp.)	*J. curcas*	Nicaragua during 1993–94	Padilla and Monterroso (1999)
Xanthomonas malvacearum	*J. curcas*	n.a	Hayward and Waterston (1964)
Xanthomonas axonopodis pv. *manihotis*	*J. curcas*	Mexico	CABI UK Centre Annual Report (2009)
Erwinia amylovora (Fire blight)	*J. integerrima*	Lee county, USA	Stephen and Mark (2010) http://lee.ifas.ufl.edu/Hort/, browsed in Dec 2010

Lesion Nematode (Pratylenchus *spp.*)

Pratylenchus roseus was isolated from the soil around the roots of *J. podagrica* from Umerkot, Nawabshah and Karachi, Pakistan (Zarina and Maqbool 1998). *P. roseus* can be separated from all the other species of the genus by the presence of lateral vulval flaps.

Other Nematode Species

Fernandes and Asmus (2007) studied the reaction of *J. curcas* to *Rotylenchulus reniformis* in Brazil and found that *J. curcas* was tolerant to *R. reniformis*. Two nematode species from the family Hemicycliophoridae (Criconematoidea: Nematoda) *viz., Hemicycliophora demani* from *J. gossypiifolia* and *Caloosia exilis* from *J. glandulifera* were reported from Orissa (Ray and Das 1980). A field survey conducted in Northern Samar, Philippines revealed the presence of *Aphelenchoides besseyi* from the soil samples taken from the rhizosphere of *J. curcas* (Tuan et al. 2009).

Insect Pests

A global list of phytophagous insects consisting of 60 species in 21 families and four orders has been compiled in Australia, where *J. curcas* is considered as a weed. At least 15 species from the insect order Heteroptera were reported to affect *J. curcas* in Nicaragua (Manoharan et al. 2006).

Fig. 10.8 Nymph of shield backed bug (*Scutellera nobilis*) attacking *J. curcas* (Courtesy: www.Jatropha.pro)

Scutellarid Pests (Scutellera nobilis, Pachycoris klugii *and* Chrysocoris purpureus)

Scutellera nobilis, Pachycoris klugii and *Chrysocoris purpureus* are the scutellarid bug pests of *J. curcas*. *S. nobilis* is very common in Asia and Africa. Ambika et al. (2007b) conducted studies on the biology, potential damages and management of scutellarid bugs using microbials, plant products and insecticides.

Scutellera nobilis **(the shield-backed bug or scutellarid bug)** has been considered as a key pest of *J. curcas* plantations in India (Chitra and Dhyani 2006; Sharma 2006), Brazil (Carels 2009) and Nicaragua (*Pachycoris klugii*). Very high to medium incidence of *S. nobillis* on *J. curcas* was also reported in Rajanandgaon District of Chattisgarh (Pankaj 2007; Khande et al. 2008) and Andhra Pradesh (Prabhakar et al. 2008). Another scutellarid bug, *Agonosoma trilineatum*, is also a serious problem on *J. curcas* in India due to its seed-feeding habit (Sharma 2006).

Damage: Damage due to *S. nobilis* is mainly observed during the stage of pod development stage to pod maturity. The pest attacks the fruits by sucking the fluid from the young and premature pods (Fig. 10.8). The pest mainly causes flower fall, fruit abortion and seed malformation (www.Jatropha.de). It also reduces the seed weight. Seed yield losses upto 19% were recorded due to the damage caused by *P. klugii* at a density of 3,500 bugs per hectare (Grimm and Guharay 1998). Feeding by *P. klugii* and *L. zonatus* leads to fruit abortion, hollow and deformed seeds. In Jhansi, *S. nobilis* population was observed to occur at an average of five per bunch, with a maximum of 15 bugs per bunch. The incubation period, nymphal period and adult longevity of *S. nobilis* were reported to be 5.9, 26.9 and 38.8–43.5 days, respectively (Ambika et al. 2007b). The potential damages are positively correlated with the bug population. Two bugs per plant did not cause significant damage, while 20 bugs per plant resulted in significant damages (Sharma and Srivastava 2010).

Fig. 10.9 *C. purpureus* incidence on *J. curcas* (Courtesy: http://jatropha.pro)

Chrysocoris javanus *and* C. purpureus

C. javanus is easily recognized by its bright red colour with black lines across its body. Its length can reach 2 cm. This pest is found in *Ricinus communis* and *J. curcas*. *C. purpureus* (Fig. 10.9) was recorded in North Western provinces, Sikkim, Calcutta, Assam and several parts of South India (Prabhakar et al. 2008), including Pondicherry (Kershaw and Kirkaldy 1908).

Damage: *C. purpureus*, another scutellarid bug pest of *J. curcas* with egg, nymphal and adult longevity of 5.75, 33.49 and 45–51 days, respectively with a fecundity of 25 eggs/female (Ambika et al. 2007b).

Management: *S. nobilis* can be controlled by spraying carbosulfan 25 EC at 1 ml l^{-1} (NOVOD Board 2009). Mechanical removal of *C. javanus* adults during pruning and plant maintenance is recommended.

An egg parasitoid, *Trissolcus* sp. was found to parasitise both the pests, *viz., S. nobilis* and *C. purpureus*. *Beauveria bassiana* was found effective, but neem products were ineffective in controlling the pest. Among the insecticides, carbosulfan (0.025%) was found effective followed by monocrotophos (0.045%) and dichlorvos (0.076%) (Ambika et al. 2007b).

A treatment of two foliar sprays of lambda-cyhalothrin (5 EC at 25 g a.i. ha^{-1}) and imidacloprid (17.8 SL 100 mL ha^{-1}) given at monthly interval followed by carbosulfan (25 EC at 250 g a.i. ha^{-1}) and monocrotophos (36 SL at 500 g a.i. ha^{-1}) was found effective. Spinosad, endosulfan, and entomopathogenous fungi, *viz.,* *Beauveria bassiana* and *Metarhizium anisopliae* resulted in moderate reduction in pest population. A maximum reduction of bug population was noticed after the third and seventh day of insecticides and bioagents spray, respectively. Chlorpyriphos (50 EC at 250 g a.i. ha^{-1}) and neem oil (2%) were found less effective and exhibited minimum reduction in bug population as compared to other components of the integrated pest management (Sharma and Srivastava 2010). Control of bugs with *B. bassiana* and *M. anisopliae* resulted in 65% mortality of *P. klugii* and 94% of *L. zonatus*, increasing the yield by 28% (Grimm and Guharay 1998).

Rainbow Shield Bug (Calidea dregii)

This pest is known to pose a threat to *J. curcas* plantations in Guinea-Bissau and has potential to cause much more damage to yield and quality of oil (Nielsen 2010). It has been reported as a minor pest on *J. curcas* in India. It also infests sorghum, maize, rice, okra, sunflower, Noog Abyssinia (*Guizotia abyssinica*), Star Burr (*Acanthospermum hispidum*), *J. podagrica*, and cotton. In Ghana, *C. dregii* Germar infestation on *J. podagrica* as well as oviposition on the flower parts and stems was reported throughout the year (Kaufmann 1966). Although there are number of diferent *Calidea* spp. in Africa, South of Sahara and Arabia, *C. dregii* was only reported on *J. curcas* in Guinea-Bissau and Mozambique (Nielsen 2010). In Mozambique, it occurs in insignificant numbers whereas in Guinea-Bissau, it is a major pest.

Damage: The bug sucks the sap from developing seeds leading to premature seed dropping or incomplete seed development and low mature seed yield. Seed weight from pest affected plants was reduced upto 20% as compared to those from dry areas of Mozambique. In cotton, it leads to fiber staining, which affects the quality although premature boll dropping does not occur (Nielsen 2010). In Tanzania, the development of fewer and smaller seeds due to the pest infestation was also reported on sunflower (Freeman 1939), which demonstrated a large potential of alternative host and increased the threat. It was also found that the infestation increased the *free fatty acid* (FFA) content of the sunflower oil, which results in a drop of transesterification efficiency and biodiesel quality.

Management: It is difficult to kill this pest with insecticide as it feeds and breeds on a wide variety of plants including poisonous ones like *J. curcas* and castor. In addition, their population size increases rapidly with the spreading and devastation rates that one may expect. In Tanzania, early planting of cotton reduced the bug infestations, probably because the boll formation stage coincided with a time when there were other food sources available for the bug. This method cannot be used for perennial plants like *J. curcas*. Pruning can delay or break dormancy and thus influence the flowering time of *J. curcas*. Field trials should be established to assess its feasibility and effectivity. In Ghana (Kaufmann 1966), the bug population was found to be more or less constant. Nymphs eat eggs, thus a higher density of nymphs reduces the number of eggs for the next generation. These bugs are highly mobile and fly around in the area to whatever food source is available. The high number of bugs observed in Guinea-Bissau is probably due to a lack of alternative feed sources in the middle of the dry season.

True Bugs Leptoglossus zonatus (*Dallas*) (*Het.: Coreidae*), Pachycoris klugii *Burmeister* (*Het.: Scutelleridae*), Hypselonotus intermedius *Distant* (*Het.: Coreidae*)

Two species of fruit feeding true bugs, *Leptoglossus zonatus* (Leaf-footed bug) and *Pachycoris klugii* and one flower feeding true bug, *Hypselonotus intermedius*, are known to cause damages to *J. curcas* plantations. In Nicaragua, fruit borers (*L. zonatus, Hyalymenus tarsatus*) and flower borer (*H. intermedius*) has been reported (Grimm and Maes 1997b). The most frequent true bug found in Central America is *P. klugii,* which has been observed throughout the year at densities upto 127 insects per tree or 140,000 per ha of plantation (Wink et al. 2000). *J. curcas*, with its regular fruiting of homogeneous nutritional quality, is as a highly suitable food plant for *L. zonatus* allowing it to maintain its populations throughout the year (Grimm and Somarriba 1999). Among the populations of phytophagous bugs (Heteroptera) monitored by Grimm and Fuhrer (1998) during three growing periods in *J. curcas* plantations of Nicaragua and Cape Verde, *P. klugii* and *L. zonatus* were the two most frequently occurring species.

Damage: The qualitative and quantitative damages caused to the fruits and seeds of *J. curcas* by these true bugs were assessed using field cages (Grimm 1999). All three species caused overall yield reduction of *J. curcas* production. The fruit feeding bugs caused premature fruit abortion and seed malformation. Parameters such as fruit number, seed and seed kernel weight as well as seed length were positively correlated with population density of adult individuals. The oil content of seeds was slightly reduced by the bugs, but protein content remained unchanged. Damage increased with the developmental stage of the larvae. Female *P. klugii* caused less damage than nymphs, while male *P. klugii* caused no significant damage at all. Adult *L. zonatus* of both sexes produced more damages than nymphs. The flower feeding bug *H. intermedius* is a pollinator of *J. curcas* and at high densities, it reduced the number of maturing fruits (Grimm 1999). Grimm and Somarriba (1998) studied the biology and life cycle of the scutellarid bug *P. klugii* in the field and the laboratory in Nicaragua. They found that the species is multivoltine and each female oviposits repeatedly during the rainy season. The adults go hiding during the dry season.

***Management*:** The entomopathogenic fungi, *viz., B. bassiana* and *M. anisopliae* were effective to control populations of scutellarid bugs. Applications of *M. anisopliae* through ultra-low volume droplet of mineral oil at a rate of 1×10^{10} conidia tree^{-1} caused bug mortalities ranging from 65% in *P. klugii* to 94% in *L. zonatus. B. bassiana* increased fruit yield by 28%, and was more effective than malathion or an aqueous extract of ground neem seeds (Grimm and Guharay 1998). The egg parasitoid, *Pseudotelenomus pachycoris* [*Telenomus pachycoris*] was found effective against *P. klugii* in Nicaragua and *Pachycoris torridus* in Sao Paulo, Brazil (Gabriel et al. 1988).

Leaf and Flower Webber Cum Fruit Borer, Salebria (Pempelia) morosalis (*Saalm Uller*)

Salebria (Pempelia) morosalis is reported to only affect few forest species like *Desmodium gangeticum*, *Flemingia* sp., *Uraria lagopides* (Beeson 1941) as well as *J. curcas*, but it does not occur on field crops grown in India. It is a major pest in Jhansi, Uttar Pradesh (Chitra and Dhyani 2006) and an emerging pest in Tamil Nadu (Regupathy and Ayyasamy 2006), Andhra Pradesh (Prabhakar et al. 2008) and Gujarat (Nayak et al. 2008) states of India. *P. morosalis* may likely become a regular pest of *J. curcas* with growing importance due to the extending monoculture of this crop. The occurrence of this pest on *J. cur*cas has also been reported in Kenya (http://betterglobeforestry.com/).

The adult moth is gray with snout like labial palpi in the head and hyaline hind wings. The male is slightly smaller than the female with pointed abdominal tip. The biology of this pest was studied extensively by different workers (Regupathy and Ayyasamy 2006). Ambika et al. (2007a) also studied the biology of leaf webber and the results revealed that egg, larval, pupal, and adult longevity of males and females was 5.83, 28.50, 7.50, 5.67 and 7.25 days, respectively.

Damage: The webber affects the leaves, bark, inflorescence, and fruits during the growth of new flush immediately after rain and flowering stage. It reduces the crop growth and flower formation. The greenish brown/brownish green caterpillars (Fig. 10.10) were observed to feed by digging leaves and remaining in the leaf web (Fig. 10.11). At flowering they bore into peduncle and fruits, which show galleries made of silk and frass. The caterpillar bores into the fruits throwing out faecal matter. The greenish larvae turn pinkish at the time of pupation. It pupates on the fruits. The larvae are seen under a cover of silk, frass or excreta, which extend between flowers or fruits (Regupathy and Ayyasamy 2006).

Management: Tamil Nadu Agricultural University (TNAU) (Paramathma et al. 2004) recommends to spray endosulfan, neem oil (2%), monocrotophos 36 WSC (1.25 ml l^{-1}), profenophos 50 EC (1 ml l^{-1}) or endosulfan (2 ml l^{-1}) (NOVOD Board 2009). Topical application method to assess the toxicity of insecticides to *P. morosalis* was described by Regupathy and Ayyasamy (2006). A dipteran parasite and spider, *Stegodyphus* sp. was reported as a natural controlling agent in Jhansi, India (Chitra and Dhyani 2006). However, the mass culture and release technology is yet to be improved. Among the microbes tested, *Bacillus thuringiensis* was found to be

Fig. 10.10 Leaf webber larvae (*Salebria morosalis*) attacking *J. curcas* leaf (Courtesy: http://jatropha.pro)

Fig. 10.11 Leaf webber damage on *J. curcas* (Courtesy: http://jatropha.pro)

the most effective against leaf webber. The NLC fly ash (125 mg leaf^{-1}) was more effective against leaf webber than paper board fly ash. All the insecticides tested under field conditions, i.e., monocrotophos, profenofos, dichlorvos, chlorpyrifos, quinalphos, endosulfan and methyl parathion [parathion-methyl] were effective in reducing the larval population of leaf webber (Ambika et al. 2007a).

Thrips (Rhipiphorothrips cruentatus, Retithrips syriacus, Selenothrips rubrocinctus)

J. curcas fields in Madurai, Tamil Nadu, India, were severely infested by grapevine thrips (*Rhipiphorothrips cruentatus*) during November 2006 (Shanthi et al. 2007). The incidence was widespread throughout the field, with populations ranging from 200 to 250 nymphs and adults per young leaf. The nymphs were white when they hatched from the eggs, but they soon developed pale red markings. The female thrips were 1.2–1.5 mm long, blackish-brown, with the legs and antennal segments yellow and the fore wings pale with yellowish veins. Male thrips were similar to females, but their pronotum and abdomen were yellow (Shanthi et al. 2007). Damage due to *R. cruentatus* on *J. curcas* was observed in Karnataka, India (Rani and Sridhar 2002). Saturnino et al. (2005) recorded thrips damage on *J. curcas* in Brazil. Thrips were dominant among the insect pests present at the *J. curcas* plantation located in Northern Samar, Philippines (Tuan et al. 2009).

Retithrips syriacus was reported for the first time in Puerto Rico on *J. curcas* leaf during quarantine inspection on 30 April 1993 in San Juan (Medina-Gaud and Franqui 2001). *R. syriacus* incidence was recorded on *J. curcas* in parts of Andhra Pradesh (Prabhakar et al. 2008). In addition to the above two species, *Heliothrips haemorrhoidalis* and *Scirtothrips kenyensis* were reported on *J. curcas* in Kenya (http://betterglobeforestry.com). *Thrips hawaiiensis* and *Scirtothrips dorsalis* were reported to cause damage to *J. curcas* in Andhra Pradesh, India (Raju and Rao 2003).

Damage: Both nymphs and adults of *R. cruentatus* colonize the lower surface of leaves and suck the sap. Younger leaves are preferred by thrips for feeding. Young infested leaves become silvery white initially, later on pale brown and crinkled with roughening of upper surface. Thrips are observed in older leaves with yellow spots on the leaves. In severe cases, shedding of leaves is observed (Shanthi et al. 2007). *R. syriacus* causes leaf mottling, yellowing and browning of leaves and infestation is severe during hot weather condition. This promotes flower dropping and premature shedding of pods.

Management: Research at TNAU, India, revealed that the pest can be controlled by spraying methyl parathion 25 EC (2 ml l^{-1}) or dimethoate 30 EC (2 ml l^{-1}) (NOVOD Board 2009).

Yellow or Golden Flea Beetle (Aphtona *sp.,* Podagrica *spp.*)

The yellow or golden flea beetle (*Aphtona* sp., Halticinae, family Chrysomelidae, Coleoptera) is the main insect pest of *J. curcas* in Africa (Mozambique, Zimbabwe, Tanzania and Kenya). Incidence of *Aphtona* sp., on *J. curcas* plants (few weeks to 1.5 years old) in 6 different planting sites in the East slope of Simba hills, Kenya was noticed in 2006. The beetles were 5 mm long and 2 mm wide, and mostly reddish. These beetles are known to feed on *Euphorbia* species and were introduced in USA for biological control of leafy spurge. Golden flea beetle (*Podagrica* spp.) damage on leaves and shoots of young plants of *J. curcas* was noticed in some areas of Zimbabwe (http://www.jatropha.de/zimbabwe/).

Damage**:** The larvae and adults feed on young reddish leaves and sometimes on the large green leaves and shoots as well; their larvae also penetrate the roots (Nielsen 2007; Gagnaux 2008). The beetle damages can become severe in young seedlings (not more than 1.5-year-old) and affect the yield in mature plants. Beetle damage was more severe in areas where the vegetation suggested low soil fertility. There are reports that the pest has almost destroyed plantations in Uganda, Mozambique, Mali and Zambia. During 2006, in Mozambique, a mortality rate of 95–100% was experienced in nurseries and in fields with plants upto 3-year-old (Nielsen 2007). The yellow flea beetle (*Aphtona dilutipes*) is reported to cause more severe damage than the golden flea beetle, resulting in upto 100% mortality (Timothy Mahoney, Pers. comm.).

Management**:** The planting of a trap crop around the *J. curcas* field can'intercept' beetles wherever they try to enter the field. In order to avoid the beetles from leaving the trap crop and moving to the adjacent *J. curcas* field, they should be controlled with an insecticide soon after their arrival. Lambda cyhalothrin has proved to be effective against the beetle. Pesticides containing Chlorpyrifos or Cyphenothrin were also found effective against *Aphtona* spp. Pyrethroids or carbamates (Sevin) are generally effective. For organic farms, neem or insecticidal soap may be applied, but these are less effective. Other insecticides containing pyrethrins (Pyganic) or kaolin clay (Surround) have also sometimes proved to be effective. Insect repellents containing hot pepper or garlic may also provide some control. Commercial formulations of entomopathogenic nematodes may be helpful in reducing flea beetle damage. On soil application, the nematodes attack beetle larvae, reduce root feeding and help to prevent the next cycle of adults. For effectiveness, they should be applied when larvae are present and the soil is wet.

Cutworm (Agrotis ipsilon)

Cutworm is considered as a major pest of *J. curcas* in Philippines (The Philippine Star 2010). Occurrence in Indonesia (http://www.used-cars.co.jp/biotec/jatoropha.pdf) and China (Li et al. 2009) has also been reported.

Damage: *A. ipsilon* attacks seedlings and young plants from the soil surface. The damage is indicated by the cutting of the stem near the soil surface and the plant withering. The assessment of critical pest damages showed that of the five identified insect pests attacking *J. curcas*, cutworms were confirmed as one of the major pests with a threshold of economic loss on yield due to cutworms of ~19%. This level signifies the need for appropriate measures to control this pest. Using the leaf damage index and the critical damage index, researchers established the economic threshold level equivalent to 5–6 larvae/50 plants for cutworms (PCARRD 2009). The researchers also determined that temperature affected the growth and development of cutworms. For instance, a warm temperature of 28.5°C enhanced the reproductive rate of cutworms from egg to larval stage. Likewise, warmer temperatures speed up the hatching of the cutworm eggmass. Under the maximum daily temperature of 28.5°C, it took only a day and a half for the eggs to hatch. Conversely, it took more than a week for the eggs to hatch under the lowest registered temperature of 25°C (PCARRD 2009).

Management**:** The mechanical control is performed by collecting the larvae around the plant and killing them. Prevention by keeping the field free of weed several weeks before planting will help to reduce the cut worm incidence. Toxic baits such as bran, sawdust, or cassava mixed with insecticides are effective in killing the larvae. The mixture is poured out around the plant, after the attack is noticed. Insecticide can be in liquid form sprayed on the lower part of the stem and the surrounding soil. Granular insecticides can be mixed with soil at the time of ploughing and harrowing. Insecticides, which contain active ingredients such as deltamethrin, thiodicarb, carbofuran, or beta cyfluthrin are effective.

Grasshoppers

Some kinds of grasshoppers (*Valanga nigricornis* and *Locusta migratoria*) may attack *J. curcas* plants anytime (Fig. 10.12). However, in Indonesia, the attack of *L. migratoria* is seldom observed. Generally heavy attack would occur on young plants. Occurrence of grasshopper (*Attractomorpha ranacea*) on *J. curcas* plantations has been reported in South India (Manoharan et al. 2006) and Nicaragua (Grimm and Maes 1997a) with seed yield losses upto 1% (Grimm and Guharay 1998). Giant grasshoppers are known to attack *J. curcas* in Zambia (BAZ 2007). A survey conducted in Philippines revealed that the incidence of leaf chewing grasshoppers is not abundant (Tuan et al. 2009). A grasshopper-like insect, which feeds on *J. curcas* plant was responsible for withering and death of the plant in Swaziland (Friends of the Earth 2009). Surveys conducted in parts of Mexico revealed that grasshoppers and ants are the major insect pests, which are responsible for severe defoliation and death of young plants, hampering the successful establishment of seedlings (Marc 2010). In feeding preference tests in Madras with the grasshopper, *Eyprepocnemis alacris alacris* (Serv.), of the 38 plant species tested, only eight were consumed without reluctance and *J. glandulifera* is one among them (Mralirangan 1978).

Management: Spraying with insecticide is not always successful as the grasshopper attack is periodic and spontaneous. The recommended insecticides are betacyfluthrin, cypermethrin, thiodicarb, MIPC and fipronil, but the application should be careful and wise.

Fig. 10.12 Grasshopper attack on *J. curcas* plant (Courtesy: Jose Ines Bazan-Mota)

Army Worm (Spodoptera litura)

Spodoptera litura was identified as a pest of *J. curcas* during periodical surveys at Barha, near Jabalpur, Madhya Pradesh, in 1992–93 and the incidence reached an extent of 60–70% (Meshram and Joshi 1994). The pest is widely distributed especially in Asia, Pacific and Australia. It has a wide host range covering more than 120 plant kinds, *viz.,* tobacco, corn, paddy, tomato, chilli and legumes including soybean, *J. curcas* and taro. It is identified as a pest of *J. curcas* in India (Dalia Amin 2001).

***Damage*:** Larvae eat the leaves of the young and mature plants and often left the leaves bitted. If the attack is heavy, only veins of the leaves are left, and plant becomes bald (Fig. 10.13).

Management: Natural enemies such as egg parasitoid, *Telenomus spodoptera* (Hymenoptera: Scelionidae), larval parasitoid, *Microplitis manilae* (Hymenoptera: Braconidae), predator from Carabidae, Pathogens, *Nuclear polyhedrosis virus* and *Borrelinavirus litura* were identified against the pest. Mechanical control is done by collecting and killing the egg masses and young larvae. When the larval population is high, insecticide with *Bacillus thuringiensis* or *S. litura*-NPV (S1-NPV) at a concentration of 6×1.0^{11} polyhedral inclusion bodies (PIB ha^{-1}) can be applied. Natural insecticide from neem (*Azadirachta indica*) seeds at a concentration of 4 $g\,l^{-1}$ of water was also found effective. Proper application of synthetic insecticides such as betacyfluthrin and prothiofos is advised.

Mites

Species of *Jatropha* have been observed to be attacked by mites of different species. Major phytosanitary problems of *J. curcas* in Brazil include attacks by two mite

Fig. 10.13 *Spodoptera litura* larva attacking *J. curcas* leaf (Courtesy: www.fact-foundation.com)

species, the broad mite *Polyphagotarsonemus latus* and the spider mite *Tetranychus bastosi* (Sarmento et al. 2011). Mite damages on *J. curcas* was also reported in Kenya (http://betterglobeforestry.com/).

Broad Mite [*Polyphagotarsonemus latus* (Tarsonemidae)]

The broad mite, *P. latus*, is a polyphagous mite that has been quoted as one of the most important pests of *J. curcas* in Brazil (Carels 2009). *P. latus* was able to complete its life cycle and reproduce on all tested genotypes (Filomena, Bento, Oracília, Gonçalo and Paraguaçú) indicating its damaging potential (Lopes et al. 2010) for *J. curcas*. A strong and permanent attack of the broad mite mostly during the rainy season was also reported on *J. curcas* in Costa Rica (Aguilar et al. 2010). The pest was observed regular on *J. curcas* in Chattisgarh, but sporadic in Tamil Nadu (Regupathy and Ayyasamy 2007) and has been found to be emerging as a major problem in Tamil Nadu, India. The populations of broad mite were the largest during November and the total life cycle of broad mites lasted 6 days; females and males lived for 9 and 7 days, respectively (Kavitha et al. 2007).

A great diversity of mites was found on *J. curcas*, especially predaceous phytoseiids (a species of *Amblyseius* and two species of *Neoseiulus*); *Iphiseiodes zuluagai* Denmark & Muma and *Phytoseiulus macropilis* (Banks), 2 morpho-species of Oribatida, *Tydeus* (Tydeidae) and *P. latus* found. The presence of predatory mites indicated their role in the control of the phytophagous species (Almeida et al. 2010).

***Tetranychus* sp.**

Mites damage the leaf and make the plant weak. Mite is a polyphagous organism that can attack various plants such as cotton, tomato, legumes, citrus, papaya, cassava, peanut and weeds. *J. curcas* with no wax on the flower is more resistant to this pest. In Brazil, *J. gossypiifolia* plant proved to be an important mite reservoir. In all tested samples, two *Tetranychus* species (Acari: Tetranychidae) and one *Neoseiulus* species (Acari: Phytoseiidae) were consistently found, especially on the basal leaves. Leaves of this species are glabrous, differently from leaves of *Jatropha* sp., onto which low levels of a single species of phytophagous mite, *Tetranychus* sp., and a phytoseiid species were found (Almeida et al. 2010). The red spider mite, *T. utricae* is severe in Tamil Nadu, India on plants raised as hedges during warmer months, which may be due to water stress and high temperature (Regupathy and Ayyasamy 2007). The populations of red spider mite were the largest during October and the total life cycle of the spider mite was 6 days (Kavitha et al. 2007).

Damage: Leaves become yellowish and then gets rusted. The shrinking leaf is reddish and then falls on the ground. Mites are commonly found at the lower surface of the leaves and its bites appear as yellow or red spots. Mites can only induce leaf malformation and, ultimately, their fall. These mites spread through the falling leaves blown by the wind or through contact with workers in the garden or estate. In case of broad mite damages (Fig. 10.14), young plants get very thick and sturdy with leathery leaves and salient top veins. Shoots will dry and plants stop growing until a new flush starts with the onset of rain or irrigation. Mite is a typical problem of nursery plants and young plantations. Infected plants sometimes recover, but produce a bunch of flowers in the top.

Management: The basic care of cleaning the plant area by collecting and burning all thrash and infested leaves is important. If the attack is minimal, it is recommended to wait untill pruning time and to cut all the attacked plant parts. Larger areas can be treated with avermectin (1.9 EC at 0.5 ml l−1), dicofol (18.5 EC at 3 ml l−1), or vertimec (1.9 EC at 0.5 ml l−1), or any common miticides. Acaricide or miticide with propargit, dicofol, tetradifon, amitraz and dinobuton as active ingredients can also be used as chemical control agents by spraying upward from below and directly pointed to the mites. Frequency of spraying can be as many times as required. Studies conducted at Maharana Pratap University of Agriculture & Technology, Udaipur revealed that the red mites affect the leaves during the rainy

Fig. 10.14 Damage on *J. curcas* leaf due to broad mite (Courtesy: http://jatropha.pro)

season and are controlled by proparzyte (58% SL, Simba, at 1 ml l^{-1}) (NOVOD Board 2009). Among several chemical assays, abamectin (0.0009%) provided the best control for both broad mites and spider mites (Kavitha et al. 2007).

The natural enemies of mites such as predator from *Phytoseiidae* family, and beetles of *Coccinellidae, Stethorus* sp. attack their eggs and larvae. The suitability of predatory mite species, *viz., Iphiseiodes zuluagai* and *Euseius concordis* in controlling *P. latus* and *T. bastosi* on *J. curcas* was evaluated for the first time by Sarmento et al. (2011) and these authors found that *I. zuluagai* was more efficient than *E. concordis* in reducing populations of *P. latus* and *T. bastosi* under field conditions.

Nettle Caterpillar (Parasa lepida)

Nettle caterpillars (Lepidoptera; family: Limacodidae) attack *J. curcas* periodically. Initially they live in group on a leaf and spread to all parts of the plant as the larvae grow older. The adult female lays its eggs as a mass on the soft part of the plant. The caterpillar is of 1.5–2.5 cm long, green with blue dots lengthwise. The pest moves like snail and produces certain chemical compound, which stings the skin.

Management: Mechanical control is performed by killing young larvae and cocoons by soaking in water or kerosene. In addition to spraying organophosphate insecticides, biocontrol agents such as fungal pathogen (*Cordyceps cocconae*), virus, parasitoid (*Apanteles parasae*) and *Bacillus thuringiensis* are also used to control mites.

Leaf Caterpillar or Castor Semilooper (Achaea janata)

Sporadic occurrence of *A. janata* was recorded on *J. curcas* in selected locations of Tamil Nadu (Regupathy and Ayyasamy 2007). The larvae can eat all the leaves in a short time. Heavy attack will influence the quantity and quality of seeds.

Management: The mechanical collection and burning of old larvae is the most effective mean of combating the pest. Suitable planting distance prevents larvae to migrate from one plant to another. Another way is to throw away the attacked leaves where many young larvae are attached at the lower surface. Until now, there is no variety of *J. curcas* available, which can stand *A. janata*, but there are natural enemies such as *Trichogramma evanescens* (egg parasitoid) and *Microplitis maculipennis* (larval parasitoid). Plant insecticides containing a neem extract can be used as well as a synthetic insecticide such as alfamethrin.

Stem Borer (Ostrinia furnacalis *and* Xyleborus *spp*.)

Damages (Fig. 10.15) by stem borers were mainly noticed on *J. curcas* grown in heavy soils in Tanzania (http://jatropha.pro/). In Indonesia, there are two stem borers, *viz., O. furnacalis* and *Xyleborus* spp. *O. furnacalis* is commonly called as Asian corn borer. Old larvae usually drill stems and cause plant break by the wind. Sometimes there is a hole at the stem basis that indicates the point of entry by a larva.

Management: A good practice is to incinerate all trashes from pruning since the proper maintenance of plants will help to control the population size of this pest. Carbofuran can be used to control the pest.

Termite (Odontotermis *sp*.)

Termite damages occur mainly on laterite red soils, and sandy soils with a very low organic matter content (http://jatropha.pro/). Termites attack plants at their base (Fig. 10.16), causing plant destruction and total loss. Occurrence of natural termite (*Odontotermis* sp.) colonies in West Bengal, India was reported (Chattopadhyay 2009) in an area that causes no harm to plants though in some cases mounds are formed around plant bases, which causes uprooting due to floods of pre-monsoon storm during May-June. The estimated loss is less than 1% so far. Termite incidence on *J. curcas* was also reported in Tanzania (http://www.jatropha.de/photo-show/index.htm#use). However, the termicidal activity of *J. curcas* oil was reported against the Philippine milk termite *Coptotermes vastator* Light (Isoptera: Rhinotermitidae, Acda 2009).

The application of neem infusions prepared by soaking neem leaves in water for 4 days on infested areas is useful against termites as it stops their feeding and finally causes their death by starving. (http://jatropha.pro/).

Fig. 10.15 Stem borer (Courtesy: www.fact-foundation.com) damage on *J. curcas* plant (Courtesy: www.Jatropha.pro)

Fig. 10.16 *J. curcas* plant affected by termites (Source: Jatropha: A Smallholder Bioenergy Crop. The Potential for pro-poor development, Food and Agricultural Organization)

Fig. 10.17 *Nezara viridula* adult sucking on *J. curcas* leaf (Courtesy: www.fact-foundation.com)

Tip Borer Caterpillar (Dichocrosis punctiferalis)

The pest incidence on *J. curcas* was reported in Southeast Asia, Australia and Pacific Islands. In Java, its incidence was found in low land areas upto 1,750 m above the sea level. It attacks usually at the time of flowering initiation. The pest bores the tips of plants and fruits. Females lay their eggs on the soft part of plants. After the eggs hatch into larvae, the attack begins at the tip of young plants, or on seeds of old plants.

Management: The pest incidence can be minimized mechanically by collecting and burning infested shoot tips and seeds. The spraying with monocrotophos and bensultap during flowering or the application of carbofuran prior to flowering and 15–20 days after flowering was found to be useful in minimizing plant infestations.

Stink Bug (Nezara viridula) (*Pentatomidae*)

Stink bug (Fig. 10.17) plays an important role in the tropical region. This pest sometimes attacks *J. curcas* during flowering time, which causes heavy damage to the fruit capsule. This pest is spreading all over the world and is easy to recognize because of its green color. The other host plants are paddy, tomato, legumes, chilli, cotton, potato, soybean and corn. The main damage is not due to the direct suction of plant sap, but by the toxin in its saliva. This toxin may wither the plant and cause the death of its tip and leaves.

Fig. 10.18 *Helicoverpa armigera* larva on *J. curcas* leaf (Courtesy: www.fact-foundation.com)

Management: Eggs and adult insects should be collected and burnt. The pest incidence can be minimized by avoiding alternate host plants in the vicinity. If the pest population is too high, one recommends the application of insecticides such as chlorfluazuron, diflubenzuron, alfamethrin, and lamda cyhalothrin.

Ear Corn Caterpillar (Helicoverpa armigera)

H. armigera is a polyphagous insect that attacks soybean, tomato, chilli, cotton and many other hosts including *J. curcas* (Fig. 10.18).

Management: Applications of chlorphyriphos, lamda sihalothrin, fenvalerate, permethrin or sipermethrin may reduce the population of the pest in the field. Other alternatives are applications of *H. armigera*–NPV virus, eggs of *Trichogramma armigera* parasitoid, and a bioinsecticide powder prepared from *Azadirachta indica* at the concentration of 4 $g\,l^{-1}$ of water.

Leaf Hopper (Empoasca *sp*.) (*Homoptera*)

Leaf hopper is an important pest of *J. curcas* in tropic and sub-tropic regions. It also attacks tea and other crops. On the field, these hoppers could be found throughout the year, but are very dangerous to the plant on the seed bed. These species were affecting *J. curcas* in industrial cultures in Brazil (Carels 2009).

Damage: Females lay their eggs on the leaf net, close to the leaf ribs at the lower surface. Nymphs and adults suck the plant sap from the lower surface of the leaf and induce it to dry and die. Sometimes, the curly leaf occurred at the tip. The pest attack is influenced by the color of leaf and texture of flowers. *The J. curcas plants with their low* content of leaf carotene and thick flower wax are more tolerant to this pest.

Management: Use of systemic insecticides such as imidacloprid, beta cyfluthrin or carbosulfan on seed bed can minimize the incidence.

Jatropha Leaf Miner (Stomphosistis thraustica) (*Gracillaridae; Lepidoptera*)

The infestation of this insect has been observed by the researchers during 1997–1998 for the first time in Chhattisgarh plains in India (http://www.botanical.com/site/column_poudhia) and later in Karnataka (Rani and Sridhar 2002) and Andhra Pradesh (Arif et al. 2007). The *J. curcas* leaf miner is known as a medicinal insect by the traditional healers of Chhattisgarh plains. The larvae collected just before pupation are considered the best stage for medicine preparation. The newly born larvae are not used. After the collection of larvae, they are dried in the shade, powdered and kept for future use as Galactagogue. The powder is given orally with lukewarm water in order to increase the flow of milk in lactating women (http://www.botanical.com/site/column_poudhia). Leaf mining moth (*Epicephala* sp.: Gracillaridae) is known to attack *J. gossypiifolia* in Australia (Wilson 1997).

Damage: The larvae feed on *Jatropha* species (including *J. curcas* and *J. gossypiifolia*). They mine the leaves of their host plant. Galleries often form several irregular blotch nets per leaf. The moth's larva produces a silvery mine on the upper leaf surface (Fig. 10.19). This moth was first collected in north Queensland in 1989 and has since been observed annually on bellyache bush in late summer. Damage caused by the moth is not sufficient to motivate its control.

Management: The application of *Bacillus thuringiensis* sub sp. *kurstaki* is recommended.

Mealy Bug (Ferrisia virgata)

Mealy bugs are soft body insects belonging to the family Pseudococcidae in the Order Hemiptera. Damages due to the white tailed mealy bug, *Ferrisia virgata*, was recorded from Tamil Nadu, India (Regupathy and Ayyasamy 2007). Cotton mealy bug (*Phenacoccus solenopsis*) incidence was recorded on *J. integerrima* in Multan district of Pakistan (Arif et al. 2009). Mealy bug species, *viz., F. virgata* and *Planococcus* spp. were reported to cause damage to *J. curcas* in Kenya (http://betterglobeforestry.com/).

Damage: Mealy bugs suck the sap from leaves and stems (Fig. 10.20), sometimes from fruits if heavily infested and causes crinkling leaves, dry stems and reduced reproductive parts.

Fig. 10.19 Leaf miner damage of *J. curcas* leaves

Fig. 10.20 Mealybug infestation on a *J. curcas* plant (Courtesy: plantoils.in)

Management: Application of chlorpyrifos or mercaptothion, dimethoate, malathion (50%) is recommended for controlling the infestation (http://jatropha.pro/).

White Grub (Holotrichia consanguinea *and* H. serrata)

White grub is a polyphagous pest whose damages are more severe in sandy and sandy loam soil. Adults are 18–24 mm long and 8–9 mm wide with three segmented thoracic legs and strong mouth parts. The young grubs are translucent, white and 5–6 mm long and beetles emerge out of the soil within 3–4 days after the onset of monsoon. Report of white grub (*H. consanguinea*) occurrence on *J. integerrima* was reported in Punjab, India during 1978 and 1979 (Brar and Sandhu 1982). Both adults and larvae can cause damage to plants. The larvae feed on roots and damage the stems, while grubs feed on fine rootlets, resulting in pale, wilted plants, dying in patches. The caterpillar can cause 20–30% damage to the young plants (http://www.sunplantgroup.com/jat_curcas9.htm).

Management: Repeated ploughing in summer, use of well decomposed organic manure and deep irrigation to restrict the respiration of grubs are some of the good cultural methods of control. The grubs and adults can also be collected and destroyed from host trees around the field. Braconids, dragon flies, *Nuclear polyhedrosis virus* and green muscardine fungus are some of the bioagents against the pest. Cypermethrine (25%) or chloropyriphos (50%) mixed with wood dust are effective against the pest under field conditions.

Giant African Land Snail

The giant land snails are important pests in Africa especially in *J. curcas* seedling nurseries (http://jatropha.pro/). These snails do not like coarse sand around the seedling beds; hence application of coarse sand around the seedling beds keeps them out of the nurseries. The smaller slugs attack the adult plants. They also can be kept away from plants by applying coarse sand around them, however, this method is not very practical on huge plantations. Application of carbamate insecticides can minimize the incidence.

Indian Quarantine Regulations

Reports of incidence of certain other insect pests, *viz.,* white flies, carpenter bee, bugs, weevils, stem and twig girdlers, cushion scale, soft scale etc. on *J. curcas* species through out the world are depicted in Table 10.2.

Table 10.2 Other insect pests recorded on *Jatropha* spp.

Pest	Host	Country of report	Reference
White flies (*Bemisia tabaci*)	*J. gossypiifolia*	Uganda, Kenya	Sseruwagi et al. (2006)
	J. curcas		http://betterglobeforestry.com/
Spiralling whitefly (*Aleurodicus dispersus*)	*J. multifida*	Tirunelveli, Tamil Nadu, India	Babu and David (1999)
Carpenter bee (*Xylocopa fenestra*)	*J. gossypiifolia*	Jodhpur, India	Sharma (1981)
Red pumpkin beetle (*Aulacophora foveicollis*)	*J. curcas*	India	Sharma (2006)
Cotton stainer bug (*Dysdercus suturelius*); moths (*Stomphastis* spp.)	*J. curcas*	Kenya	http://betterglobeforestry.com/
Oxyrachis tarandus Fabricus (Homoptera: Membracidae) Jan-Dec	*J. curcas*	Bihar, India	Ali et al. (2006)
Millepede (*Julus* sp.)	*J. curcas* (loss of seedlings)	—	Heller (1996)
Locust (*Oedaleus senegalensis*)	*J. curcas* (leaves, seedlings)	—	Heller (1996)
Cushion scale (*Pinnaspis strachani);* Wooly aphid (*Ferrisia virgata*)	*J. curcas* (Die back of branches)	—	Van Harten, pers comm (Heller 1996)
Blue bug (*Calidea dregei*)	*J. curcas* (Sucking on fruits)	—	Van Harten, pers comm (Heller 1996)
Flies (*Chrysomya megacephala*), bees (*Apis florea, A. indica* [*Apis cerana indica*] and *Trigona iridipennis*)	*J. curcas*	Andhra Pradesh, India	Raju and Rao (2003)
Phycita sp. (May-June)	*J. curcas*	Bangalore, Karnataka, India	Rani and Sridhar (2002)
Pachycoris torridus	*J. curcas*	Brazil	Soto and Nakano (2002)
Weevil (*Lepropus lateralis*); leaf miners	*J. curcas* nursery	Shuangjiang County	Li et al. (2009)
Nephopteryx larvae	*J. curcas*	Pusa and Mandalay, India	Hampson (1912)
Mylabris pustulata (Thnb.) adults	*J. panduraefolia* flowers	Aligarh, Uttar Pradesh, India	Siddiqui (1983)
White grub, *Holotrichia consanguinea* in 1978 and 1979	*J. integerrima*	Punjab, India	Brar and Sandhu (1982)

(continued)

Table 10.2 (continued)

Pest	Host	Country of report	Reference
Twig girdler (*Oncideres limpida)*	*J. curcas*	India	Prabhakar et al. (2008)
Soft scale (*Megapulvinaria maxima* (Green)	*J. curcas*	Andhra Pradesh	Prabhakar et al. (2008)
Anasa scorbutica (Coreidae)	*J. curcas*	Nicaragua	Grimm (1996)
Hemiptera: *Chelysomidea variabilis*, *Pachycoris torridus* and *Sphyrocoris punctellus*	*J. curcas*	Nicaragua	Grimm and Maes (1997a)
19 species of Coreidae (Heteroptera), 3 species of Rhopalidae and 3 species of Alydidae	*J. curcas*	Nicaragua	Grimm and Maes (1997a)
15 species of Pentatomidae and 1 species of Tessaratomidae	*J. curcas*	Nicaragua	Grimm and Maes (1997c)
Tussock caterpillar *(Orygia postica);* Black hairy caterpillar *(Estigmene lactinea);* Ash weevil *(Myllocerus maculosus);* Grasshopper *(Atractomorpha ranacea);* Neem scale *(Pulvinaria maxima)*; Calotropis leaf hopper bug (*Eurybrachis tomentosa*)	*J. curcas*	India	Manoharan et al. (2006), Regupathy and Ayyasamy (2007)

Three pests have been categorized as quarantine pests of *J. curcas* in India (Plant Quarantine Order 2003). When *J. curcas* plants meant for propagation are imported from USA, care has to be taken that the plants should be free from *Diaprepes abbreviatus* (citrus weevil), *Pseudococcus jackbeardsleyi* (Jack Beardsley mealy bug), and *Armillaria tabescens* (Armillaria root rot): Syn: *Clitocybe tabescens.* Post-entry quarantine growing for a period of 45 days is mandatory. Plants/cuttings meant for propagation from Singapore also should be free from Jack Beardsley mealy bug. All tissue cultured plants from any country should be certified that the tissue cultured plants are obtained from mother stock tested and maintained free from viruses.

Conclusions

J. curcas is susceptible to several pests and diseases. Certain pests with diverse hosts, such as mealy bugs may attack many more plants with the passage of time. Therefore, effective manipulation of weeds and ornamental plants, adopting crop rotation and quarantine measures, etc., will be of high significance, while devising integrated management strategy for such pests.

In the literature, insecticides belonging to different groups have been recommended against some pests; however, main reliance on insecticides may result in resistance, resurgence, environmental hazards and thus leading to discontinuation of their use. In view of the above, focus on alternative control measures is needed. Information on biological parameters of insects and their host preference for feeding and oviposition are very important to develop alternative strategies effective for their control like other important insects.

Systematic research on biotic stress resistance has not been carried out till date in *J. curcas*. Attention to increasing resistance to pests and diseases is needed in the selective breeding of *J. curcas*. A novel interspecific *Jatropha* hybrid “Nandan-4” was developed by the hybridization of *J. gossypiifolia* with *J. curcas* (protected by a patent) and this hybrid is claimed resistant to several pests and diseases (Karanam and Jayakumar 2010) *viz.,* inflorescence & capsule borer (*Pempelia morosalis*), leaf miner (*Neurobathracu rcassi* Busck.), bugs (*Scutellera nobilis* Fabr.) and powdery mildew (*Erysiphe euphorbiae*). There is a definite need for the search of resistant sources in *J. curcas* against other pests also. If neglected, the pests, which are of minor significance, may attain the status of major pests on *J. curcas*.

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