Biocide Potential of *Jatropha curcas* L. Extracts

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Abstract

*Jatropha curcas* L., a multipurpose oilseed plant, is very important for biodiesel production; it also has a wide range of bioactive compounds with medicinal properties and biocidal activity for control of crop pests and diseases. This review presents the state-of-the-art of the biocidal activity of *J. curcas* extracts. Chemical constituents such as phorbol esters are responsible for high bioactivity of *J. curcas*, due to their toxicity to humans and animals and to their high fungicidal and insecticidal activity. The fungicidal activity of these constituents may be due to destroy endoplasmatic reticulum and hyphae cell walls. The activity of these compounds on insect pest metabolism is well known, leading to an antifeedant effect, repellency, mating inhibition, oviposition inhibition or suppression and/or induction of infertile egg production, and inhibition of larva, nymph, and pupa development. Several studies have shown that although all organs of *J. curcas* plant are toxic, the degree of toxicity varies in accordance with the extract formulation, the nature of the active substance, the administration rate and procedure, and the individual sensitivity of pests and diseases. Thus, *J. curcas* stands out as a promising species for bioenergy purposes, as well as for control of pests and diseases that affect agriculture production.

Keywords: plant pathogens, insect pests, secondary metabolites, physic nut
1. Introduction

The *Jatropha* genus (Euphorbiaceae - Platiobae subfamily) has more than 70 shrub-like species, such as *J. pohliana*, *J. gossypiifolia*, and *J. curcas* (Xu et al., 2012). Fast growth, easy propagation, and adaptation to many environments are some of the traits that favor wide distribution of the plants of this genus. *J. curcas*, commonly known as physic nut, is a diploid species of 22 small chromosomes (Dahmer et al., 2009). The inflorescences with male or female (and occasionally hermaphrodite) flowers give rise to fruit with three seeds (trilocular ovary). The stem with multiple branches holds inflorescences, which appear at the beginning of the rainy season. As a shrub species, it reaches 5 m height, while the root system reaches 5 m depth, with a primary root and four lateral roots (Brasileiro et al., 2012; Divakara et al., 2010). Studies have confirmed that the center of origin, diversity, and domestication is Mexico, as suggested by (Dias et al., 2012), although it can be grown throughout the world and in all regions of Brazil (Heller, 1996). *J. curcas* is widely distributed and is found at altitudes ranging from sea level to 3000 m, in regions with annual rainfall from 250 to 2500 mm. It requires a temperature between 18 and 28 °C (Dias et al., 2012). As a hardy oilseed plant that develops under adverse dry and rocky soil conditions, it may be useful for recovery of degraded areas.

An additional advantage of *J. curcas* is its perennial cycle and high yield as a crop; it may yield more than 1500 L ha⁻¹ of oil after the fourth year of cultivation (Oliveira, 2016; Laviola et al., 2014; Dias, 2007). *J. curcas* and palm species such as oil palm (with production of around 4000 L ha⁻¹ of oil) offer considerable promise for biodiesel production. Soybean, currently the crop of choice for most Brazilian biodiesel production (70%), yields 500 L ha⁻¹ of oil (ABIOVE, 2019; Oliveira, 2016).

The ominous consequences projected in a scenario of global climate changes and the gradual reduction in petroleum reserves drive the search for alternatives to supply world demand for transportation energy. Priority should be placed on available sources of energy that are economically feasible, socially just, and ecologically correct. Liquid biofuels, ethanol and biodiesel, can be considered in this context (Dias, 2011; Ribeiro et al., 2011). The biodiesel derived from transesterification of plant oils is an environmentally sound alternative since it is a renewable source of energy that may be used to complement petroleum diesel (Roque et al., 2017). The use of biodiesel reduces release of greenhouse gases from burning of fossil fuels and reduces petroleum dependency. *J. curcas* offers the most positive balance among the bioenergy crops that have considerable potential for fuel oil production, both in terms of high oil production per hectare (38% oil in its seeds, with a mean of 1500 L ha⁻¹) and of lack of competition with the food chain, as occurs for other oilseed crops (Dias et al., 2012; Dias, 2011; Ribeiro et al., 2011; Dias, 2007). These characteristics make this species a great green promise for biodiesel production, in spite of the scarcity of improved varieties and the present heterogeneity of the cultivated population (Oliveira, 2016; Dias, 2007).

*J. curcas* has been known from antiquity for its exceptional medicinal properties (Dias et al., 2012). This characteristic is even responsible for its name: the Greek word *jatrós* means doctor, and *trophé* means food (Kumar and Sharma, 2008). Studies report its healing
(Sachdeva et al., 2011), anticarcinogenic (Devappa et al., 2011), antidiabetic (Jayakumar et al., 2010), and anti-inflammatory (Nayak and Patel, 2010) activities. However, its seeds and oil must be used with caution since they have an array of compounds understood to be antinutritional; its oil and pressed residues are inappropriate for animal and human consumption. This toxicity arises from the presence of compounds such as protease inhibitors (curcine), phytates, lectins, saponins, and even more toxic compounds, such as co-carcinogens and phorbol esters (Devappa et al., 2012; He et al., 2011; Haas and Mittelbach, 2000).

The array of products obtained from J. curcas has increased, highlighting the multipurpose nature of the species. Extracts from oils of the seed, leaf, and stem have exhibited not only medicinal properties but also molluscicide, insecticide, and fungicide activities (Saetae and Suntornsuk, 2010), with possible future use as a biocide. In most cases, pests and diseases are currently controlled through intensive and indiscriminate use of synthetic insecticides and fungicides. This strategy leads to selection for pesticide-resistant populations, making control ever more difficult, less efficient, and, consequently, more costly. Organochlorides and organophosphates are the most common chemical groups of synthetic pesticides. Pesticides with low toxicity, persists in the human body and in the environment and may remain active for a considerable time. Whereas the biocides though quickly degraded in the environment (Moragas and Schneider, 2003). Plant-derived biocides clearly provide bioactive substances for integrated pest and disease management programs, and they may reduce undesirable effects from application of organo-synthetic products in the environment (Sharma, 2017; Ashraf et al., 2014). They have even greater specificity for target organisms (Sharma, 2017; Ashraf et al., 2014) and have lower production cost, making the final product economically feasible for small farmers.

The aim of this review is to offer a broad perspective on the state-of-the-art of the biocide activity of Jatropha curcas L extracts.

2. Main Metabolites of J. curcas for Pest and Disease Control

Compounds arising from chemical reactions within a cell are called metabolites (Simões et al., 2010). In accordance with their distribution in the plant kingdom and their participation in vital processes, they may be divided into primary and secondary metabolites. Primary metabolites are essential to life and common to all plants. They perform some functions in transformation of molecules, such as photosynthesis and amino acid and protein synthesis (Simões et al., 2010).

Secondary metabolites are organic compounds produced by plants which are not directly involved in the normal growth, development, or reproduction of plants and they contribute to plant adaptation and survival (Simões et al., 2010). They play an important role in plant-environment interactions, including the plant-pathogen interaction. Since they are not ubiquitous, they are often used as defining traits in taxonomy. Most secondary metabolites are biosynthesized from intermediates provided by primary metabolism. These intermediates are used as precursors in the biosynthetic routes of aliphatic amino acids, malonate, acetate, mevalonate, deoxyxylulose phosphate, shikimate, and aromatic amino acids, culminating in
the formation of secondary metabolic compounds (Leite, 2009). Secondary metabolites are of
great interest, not only because of the biological activities of plants in response to
environment but also because of it immense pharmacological activity. Many metabolites have
significant agronomic value (Simões et al., 2010). All plant extract activities originate from
their evolutionary history. Plants have developed their chemical defenses and enhanced their
defense mechanisms through pathways that synthesize these compounds (Wiesbrook, 2004).
These substances exhibit biological activity, including activity on microorganisms through
diverse mechanisms.

*J. curcas* is an important species for analysis of secondary metabolite production and these
compounds are distributed in all its organs. Like other plants of the Euphorbiaceae family, it
produces a great deal of latex, and its metabolome (Van den Berg et al., 1995) and proteome
(Yang et al., 2017) exhibit a great variety of primary and secondary metabolites. However,
phorbol esters are the most prominent toxic compound. It can cause acute toxicity, provoking
an intense inflammatory response, and/or chronic toxicity. It prompts the appearance of
tumors by the kinase C enzyme bonding and activation mechanism, responsible for cell
differentiation and for promoting growth regulation (Abdelgadir and Van Staden, 2013; Goel
et al., 2007). Six different derivations of phorbol esters have been identified in this species
(Haas et al., 2002). These metabolites are sources of bioactive substances compatible with
integrated pest and disease management programs. For that reason, it may be possible to
combine them with other methods for control of insects, bacteria, and fungi, allowing
maintenance of ecological balance without leaving harmful residues (Trivedi et al., 2018;
Patil et al., 2016). Biocides constitute an excellent alternative because they are natural
products derived from plants and produced by plants or derived from plants through aqueous
extractions or extractions with organic solvents (Wiesbrook, 2004).

*J. curcas* plant is highly toxic as a whole, not only to microorganisms but also to animals and
humans. All parts of the plant are toxic, and the degree of toxicity varies according to the
extract, the chemical composition of the extracted substance, the environment, and the rate
and mode of application. Toxicity can be also influenced by the individual sensitivity of an
organism (Devappa et al., 2010). Curcine, the protein present in *J. curcas* seeds, for example,
has expressive antifungal activity, and may completely inhibit the formation of spores of
*Pyrucularia oryzae*, a fungus that damages the rice crop. However, this substance may inhibit
protein synthesis processes in animals (Jaramillo-Quintero et al., 2015; Wei et al., 2004). 2S
albumin is another example of a molecule present in *J. curcas* with diverse effects. It may
cause adverse effects due to allergenic activity and may bring about skin and eye irritation
(Machado and Silva, 1992). Other compounds, such as phytates and saponins, also require
precautions (Wei et al., 2004). These metabolites must be used with care. In integrated pest
and disease management, phorbol esters are key molecules, due to their antifungal activity
(Saetae and Suntornsuk, 2010) and toxicity to some insect pests (Ratnadass et al., 2009).

As seen above, *J. curcas* is a potential producer of bioactive secondary metabolites of the
most diverse types (Abdelgadir and Van Staden, 2013; Sabandar et al., 2013). This
considerable potential should be studied and used to advantage in all areas, particularly in
agriculture.
3. Pests and Diseases Controlled by Extracts of *J. curcas*

Extracts derived from the leaves, stems, roots, and seeds of *J. curcas* exhibit diverse properties for pest (Table 1) and disease (Table 2) control in plants. The efficacy of *J. curcas* extracts as a biocide has been confirmed in various studies (Sharma, 2017; Ogbebor et al., 2007; Adebowake and Adedire, 2006) and their application is a useful alternative from an agronomic perspective, considering resistance of some pests and pathogens to synthetic insecticides and fungicides. Integrated management programs have encouraged this alternative control measure to minimize ecological damage found in ecosystems since natural products are innocuous to the environment (Trivedi et al., 2018; Patil et al., 2016).

Table 1. Different parts and extracts of *Jatropha curcas* L. used in pest control

| Insect                  | Pest of               | Solvent                  | Plant organ          | References                                                                 |
|-------------------------|-----------------------|--------------------------|----------------------|-----------------------------------------------------------------------------|
| *Aphis fabae* Scop.     | Cowpea                | Ethanol                  | Oil from the seed    | Botti et al. (2015); Habou et al. (2011)                                    |
| *Aphidos crassivora*    | Cowpea                | Acetone                  | Oil from the seed    | Ahuchaogu et al. (2014)                                                    |
| *Bactrocera zonata*     | Peach                 | Ethyl acetate; methanol  | Oil from the seed;   | Rampadarath et al. (2016)                                                   |
| *Bactrocera cucurbitae* | Melon                 | Ethyl acetate; methanol  | Oil from the seed;   | Rampadarath et al. (2016)                                                   |
| *Brevicoryne brassicae* | Cabbage               | Water                    | Oil from the seed    | Botti et al. (2015)                                                        |
| *Callosobruchus maculatus* | Cowpea              | Water; ethanol; acetone  | Oil from the seed    | Bouteng and Kusi (2008); Abdoul Habou et al. (2014); Ahuchaogu & Ojiako (2015); Opuba et al. (2018) |
| *Ceratitis capitata* (Wied) | Different kinds of fruits | Water                  | Leaf                | Silva et al. (2015)                                                        |
| *Clavigralla tomentosicollis* | Cowpea              | Ethanol                  | Oil from the seed    | Katoune et al. (2011)                                                      |
| *Cnaphalocrocis medinalis* | Rice                 | Methanol; ethanol; petroleum ether | Oil from the seed | Dowlathabad et al. (2010)                                                   |
| *Coptotermes vastator* | Different kinds of timber | Crude oil              | Oil from the seed    | Acda (2009)                                                                |
| *Helicoverpa armigera*  | Cotton                | Water; methanol; ethanol; petroleum ether | Oil from the seed | Ratnadass et al. (2009); Dowlathabad et al. (2010); Ingle et al. (2017a) |
| *Maruca testulalis*     | Cowpea                | Acetone                  | Oil from the seed    | Ahuchaogu & Ojiako (2015)                                                   |
| *Megalectrothrips sjoestedi* | Cowpea              | Ethanol; acetone         | Oil from the seed    | Katoune et al. (2011); Ahuchaogu & Ojiako (2015)                          |
| *Microtermes obesi*     | Different agricultural Plants | Butanol; ether; hexane; methanol | Leaf; root; stem bark | Verma et al. (2013)                                                        |
| *Mussidia nigrivenella* | Maize                 | Water                    | Oil from the seed    | Agboka et al. (2009)                                                       |
| *Odontotermes obesus*   | Different perennial crops | Methanol                | Oil from the seed    | Verma et al. (2011)                                                        |
| *Odontotermes sp*       | Different stored crops and grains | Crude oil              | Oil from the seed    | Lateef et al. (2014)                                                       |
| *Oecophylla longinoda*  | Different forest trees | Ethanol; acetone; water  | Root; seed          | Ojiako et al (2015)                                                        |
| *Oligonychus coffeae*   | Different tea-growing  | Crude oil                | Oil from the seed    | Roy et al. (2016)                                                          |
| *Planococcus citri*     | Coffee                | Water                    | Oil from the seed;   | Holtz et al. (2016)                                                        |
| Species                        | Source of Extract                  | Solvent(s)          | Mortality Rate | Reference(s)                                                                 |
|-------------------------------|-----------------------------------|---------------------|---------------|-------------------------------------------------------------------------------|
| *Schistocerca gregaria*       | Different kinds of crops          | Hexane              | Oil from the seed | Bashir & El-Shafie (2013)                                                      |
| *Sitophilus granaries*        | Stored grains                     | Petroleum ether     | Oil from the seed | Nabil & Yasser (2012)                                                          |
| *Sitophilus oryzae* L.        | Rice                              | Chlороform; petroleum ether | Oil from the seed | Khani et al. (2011)                                                           |
| *Sitophilus zeamais*          | Cereal seeds (rice, maize, etc)    | Acetone; petroleum ether | Oil from the seed; seed | Asmanizar & Idris (2011); Musa et al. (2011);                                 |
| *Spilarctia obliqua* Walk     | Oilseed crops, vegetables, and medicinal plants | Benzene | Leaf | Katiyar (2016)                                                               |
| *Spodoptera frugiperda*       | maize, rice, sugarcane, cotton    | Methanol            | Oil from the seed | Devappa et al. (2012)                                                         |
| *Spodoptera litura*           | Cotton, rice, tobacco, etc.       | Methanol            | Leaf; stem; seed; seed hull; root | Ingle et al. (2017b)                                                          |
| *Tetranychus urticae*         | Okra                              | Water               | Leaf          | Premalatha et al. (2018)                                                      |

The use of aqueous leaf extract killed *Ceratitis capitata* (fruit fly) larvae (Silva et al., 2015) and the insect pests *Sitophilus zeamais* and *Rhyzopertha dominica* in stored grain (Silva et al., 2012a). Promising results were also obtained from stem and leaf hydroalcoholic acidic extracts in control of *Aedes aegypti* larvae (Beserra et al., 2014). In the five extracts evaluated, the presence of proteins, amino acids, and polysaccharides were detected, as well as secondary metabolites such as tannins, phenols, alkaloids, steroids, and saponins (Silva et al., 2015; Beserra et al., 2014). The extract may sometimes prolong the larval phase of the pest insect, together with its mortality. This activity is very important in the field because it will increase exposure time of the pest to natural enemies and the mean time of each generation, with consequent reduction in population growth of the pest (Torres et al., 2001). Toxicity evaluation of methanol extracts from plant parts (leaf, stem, seed, and root) of *J. curcas* on the larval stages of *Spodoptera litura* showed that the leaf extract was most effective, with mortality rates of 60% (Ingle et al., 2017b). Similar results were observed from use of stem and seed (oil) extracts on larvae of *Bactrocera zonata* and *Bactrocera cucurbitae* (Rampadarath et al., 2016). The difference in effectiveness of the extracts was due to the differences in metabolite contents of various plant organs (Rampadarath et al., 2016). Methanol extract seed oil was able to control 100% of the population of adult individuals of the *Odontotermes obesus* termite (Verma et al., 2011). This result is might be due to the presence of high concentration of phorbol ester in this extract.

In addition to the solvent and organ used in preparation of the extract, the method of application also is important so that control occurs in an efficient manner. For control of *Planococcus citri*, known as citrus mealybug, aqueous extracts of the stem and leaf were applied in two ways: 1) spraying the extract directly on the mealybugs with the Potter spray tower (direct application) and 2) application of the extracts on coffee leaf disks, with subsequent placement of the insects on it (indirect application). These forms of application represent post-infection and preventive control, respectively (Holtz et al., 2016). Direct application of stems and leaves exhibited the best results.
Table 2. Different parts and extracts of *Jatropha curcas* L. used in control of fungal diseases

| Fungi                     | Pest of                          | Solvent          | Plant organ                        | References                                                                 |
|---------------------------|----------------------------------|------------------|------------------------------------|---------------------------------------------------------------------------|
| *Alternaria alternata*    | Cotton, rice, bean, etc.         | Petroleum ether; water; methanol | Oil from the seed; leaf; stem (without bark); stem bark; root | Srivastava et al. (2012); Gaikwad et al. (2012); Sachdeva et al. (2011) |
| *Aspergillus flavus*      | Garlic, rice, cacao, oats         | Water; petroleum ether; ethanol; methanol; hexane | Oil from the seed; leaf; stem (without bark); latex; stem bark; root | Makun et al. (2011); Srivastava et al. (2012); Gaikwad et al. (2012); Bassey et al. (2013); El-Nour et al. (2015); Aremekose et al. (2011); Igbinoso et al. (2009) |
| *Aspergillus niger*       | Lettuce, garlic, beet, soybean   | Water; acetone; alcohol; methanol; petroleum ether; ethanol | Oil from the seed; leaf; stem (without bark); stem bark; root; root skin; root; calli | Ahirwar et al. (2015); El-Nour et al. (2015); Srivastava et al. (2012); Gaikwad et al. (2012); Bassey et al. (2013); Danish & Robab (2015); Igbinoso et al. (2009); Sahidin et al. (2011) |
| *Cercospora coffeicola*   | Coffee                           | Ethanol          | Leaf                               | Muniz (2019); Zaidan (2018)                                               |
| *Colletotrichum capsici*  | Pepper                           | Ethanol          | Oil from the seed                   | Saetae & Suntornsuk (2010)                                                |
| *Colletotrichum gloeosporioides* | Garlic, cacao, pea, etc.              | Ethanol; water | Oil from the seed; leaf             | Saetae & Suntornsuk (2010); Ogbebor et al. (2007); Li et al. (2006)  |
| *Colletotrichum musae*    | Banana                           | Water            | Leaf                               | Thangavelu et al. (2004)                                                  |
| *Curvularia lunata*       | Garlic, rice, potato              | Ethanol          | Oil from the seed                   | Saetae & Suntornsuk (2010)                                                |
| *Drechlera heveae*        | Rubber tree                      | Water            | Leaf                               | Ogbebor & Adekunle (2008)                                                 |
| *Fusarium oxysporium*     | Tomato, pepper, sugarcane, etc.   | Water; alcohol; ethanol; petroleum ether; *Lectin protein* | Oil from the seed; leaf; stem (without bark); stem bark; root; root skin; calli | Córdova-Albores et al. (2014); Córdova-Albores et al. (2016); Saetae & Suntornsuk (2010); Al-Saman et al. (2015); Siva et al. (2008); Gaikwad et al. (2012); Bassey et al. (2013) |
| *Fusarium semitectum*     | Soybean                          | Ethanol          | Oil from the seed                   | Saetae & Suntornsuk (2010)                                                |
| *Fusarium solani*         | Potato, pea, bean, etc.           | Water; ethanol; methanol; acetone; water | Oil from the seed; stem bark        | Córdova-Albores et al. (2014); Igbinoso et al. (2009); Sachdeva et al. (2011) |
| *Fusarium sp*             | A wide range of crops and vegetables | Water; acetone; alcohol | Oil from the seed; leaf; stem bark; root skin | Ahirwar et al. (2015)                                                     |
| *Fusarium verticillioides*| Rice, bean, maize                | Water            | Oil from the seed                   | Makun et al. (2011)                                                       |
| *Lasiodiplodia theobromae*| Avocado, pineapple, garlic        | Ethanol          | Oil from the seed                   | Saetae & Suntornsuk (2010)                                                |
| *Macrophomina phaseolina* | Garlic, rice, potato              | Water            | Leaf                               | Savaliya et al. (2015)                                                    |
| *Rhizoctonia solani*      | Lettuce, rice, oat                | Water            | Leaf                               | Gaikwad et al. (2012)                                                     |
| *Rhizopus sp*             | A wide range of fruits and vegetables | Water; acetone; alcohol; petroleum ether; methanol | Oil from the seed; leaf; stem bark; root skin | Ahirwar et al. (2015); Sahidin et al. (2011) |

Plant-derived secondary metabolites might induce effects on insect metabolism and leads to an antifeedant effect, repellency, oviposition inhibition or suppression and/or induction of infertile egg production, inhibition of larva, nymph, and pupa development, and inhibition of
mating (Hartmann, 2004). The superiority biocidal activity of J. curcas oil extracts might be related with the presence of pherbol ester at high concentration in the seeds (Gonçalves et al., 2009). Application the extracts directly was more efficient than their application indirectly, since extract molecules are absorbed by integuments of insects, affecting their central nervous system and leading to their death. In indirect application, these molecules first pass through the digestive system of the insect before reaching vital systems (Holtz et al., 2016).

Extracts from different parts of J. curcas plant also proved to have a fungicidal effect (Table 2). In the banana crop, aqueous leaf extract was effective in control of the fungus Colletotrichum musae, the agent of anthracnose, through inhibition of mycelial growth (Thangavelu et al., 2004). In recent studies, ethanolic extract from J. curcas leaf reduced the mycelial growth of Cercospora coffeicola, by up to 20%, and completely inhibited germination of Hemileia vastatrix (Muniz, 2019; Zaidan, 2018).

In ornamental Gladiolus plants, Fusarium oxysporum f. sp. gladioli is a main pathogen that affects its production. Systemic fungicide applications are the common method of control. J. curcas oil, extracted by petroleum ether, was tested for control and caused changes – in the morphology of the inner lining of the mycelia and of the conidia, in the presence of vacuoles, and in inhibition of the metabolic activity of the membrane in the Fusarium oxysporum (Córdova-Albores et al., 2016). Although these results did not bring about effective control of the fungus, they are important, due to their effect on the fungal reproductive structures and on the life cycle of the fungus.

Possible mechanisms of antifungal activity are destruction of the cell walls of the hyphae (Wei et al., 2005) and of the endoplasmatic reticulum (Jing et al., 2005). Most of the cell organelles had been destroyed up to 72 h after the treatment with Jatroopherol-I, a phorbol-type diterpene from J. curcas (Jing et al. 2005), and β-1,3-glucanase, a protein isolated from J. curcas (Wei et al., 2005). Unlike what was observed for insect pests, antifungal activity comes from extracts derived from each J. curcas plant organ, showing the importance of substances other than phorbol esters. Furthermore, it shows the greater sensitivity of these organisms because it is possible to obtain good results even from use of plant organs that have a lower concentration of the compound.

Ahirwar et al. (2015) found that extract of J. curcas using solvents with different polarities (i.e. petroleum ether, acetone, alcohol, water, ethanol, and methanol) resulted in different antifungal activities. The methanol extract generally has the best biocide activity, followed by ethanol and water. The varied effectiveness of the extracts can be explained by the uneven distribution of metabolites in plant organs and by metabolites themselves extracted as a result of solvent polarity. The highest concentrations were responsible for the best results.

In addition to the biocide activity reported above, studies indicated the allelopathic properties of different J. curcas organs against various plant species such as Brassica napus (Silva et al., 2012b; Antonelli et al., 2016), Hibiscus esculentus (Abugre and Sam, 2010; Abugre et al., 2011), Helianthus annuus L. (Silva et al., 2012b), Phaseolus vulgaris (Abugre and Sam, 2010), Cichorium intybus (Cremonez et al., 2013), Capsicum annum L. (Rejila and Vijayakumar, 2011), Lycopersicon lycopersicum (Abugre and Sam, 2010) and Zea mays L.
(Abugre and Sam, 2010; Silva et al., 2012b). The main allelopathic signals generated by *J. curcas* are reduction in root growth and changes in the fresh or dry matter weight of other species. In contrast, a positive allelopathic effect was observed when soybean (*Glycine max*) seeds were placed to germinate in the presence of the root exudate of *J. curcas* (Silva et al., 2012b).

4. Conclusion

Studies on extracts of *Jatropha curcas* have shown that this plant exhibits considerable promise for formulation of new biocides. The range of metabolites from *J. curcas* requires the use of solvents with different polarities so that all compounds are extracted in an efficient manner and then tested. Among the compounds with biocide effect, phorbol esters are most prominent because of their high toxicity to most pests and fungi. However, studies should be carried out particularly to test the activity of these compounds on plant pathogenic bacteria.

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References

Abdelgadir, H. A., & Van Staden, J. (2013). Ethnobotany, ethnopharmacology and toxicity of *Jatropha curcas* L. (Euphorbiaceae): A review. *South Afr J Bot.* 88, 204-218. https://doi.org/10.1016/j.sajb.2013.07.021

Abdoul, H. Z., Haougli, A., Basso, A., Adam, T., Haubrege, E., & Verheggen, F. J. (2014). Insecticidal effect of *Jatropha curcas* L. seed oil on *Callosobruchus maculatus* Fab and *Bruchidius atrolineatus* Pic (Coleoptera: Bruchidae) on stored cowpea seeds (*Vigna unguiculata* L. Walp) in Niger. *Afr J Agric Res.* 9, 2506-2510. https://doi.org/10.5897/AJAR2013.7578

ABIOVE - Associação Brasileira das Indústrias de Óleos Vegetais (2019). [homepage on the internet]. Produção de biodiesel por matéria prima. [cited 2019 Feb 16]. Available at, <http://www.abiove.org.br/site/index.php?page=estatistica&area=NC0yLTE=>.

Abugre, S., & Sam, S. J. Q. (2010). Evaluating the allelopathic effect of *Jatropha curcas* aqueous extract on germination, radicle and plumule length of crops. *Int J Agric Biol.* 12, 769-772.

Abugre, S., Apetorgbor, A. K., Antwiwaa, A., & Apetorgbor, M. M. (2011). Allelopathic effects of ten tree species on germination and growth of four traditional food crops in Ghana. *J Agric Technol.* 7, 825-834.

Acda, M. N. (2009). Toxicity, tunneling and feeding behavior of the termite, *Coptotermes vastator*, in sand treated with oil of the physic nut, *Jatropha curcas*. *J Insect Sci.* 9, 1-8. https://doi.org/10.1673/031.009.6401

Adebowale, K. O., & Adedire, C. O. (2006). Chemical composition and insecticidal
properties of the underutilized *Jatropha curcas* seed oil. *Afr J Biotechnol.* 5, 901-906.

Agboka, K., Mawufe, A. K., Tamò, M., & Vidal, S. (2009). Effects of plant extracts and oil emulsions on the maize cob borer *Mussidia nigrenella* (Lepidoptera: Pyralidae) in laboratory and field experiments. *Int J Trop Insect Sci.* 29, 185-194. https://doi.org/10.1017/S1742758409990348

Ahirwar, R. K., Ahirwar, S., Pandeya, J. P. N., Mishra, A. S., & Kumar, K. S. (2015). Antimicrobial activities of different plant extracts of *Jatropha curcas* Linn. *Bull Environ Sci Res.*, 4, 21-28.

Ahuchaogu, C. E., & Ojiako, F. O. (2015). Comparative study of the toxic effects of *Jatropha curcas* L. extracts and Actellic 25 E.C® on *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae) in stored cowpea. *FUTA J Res Sci.*, 11, 231-242.

Ahuchaogu, C. E., Ojiako, F. O., & Kabeh, J. D. (2014). Evaluation of *Jatropha curcas* Lam. extracts in the control of some field insect pests of cowpea (*Vigna unguiculata* L. Walp). *Int J Sci Technol Res.*, 3, 136-141.

Al-Saman, M. A., Farfour, S. A., Tayel, A., & Rizk, N. M. (2015). Bioactivity of lectin from Egyptian *Jatropha curcas* seeds and its potentiality as antifungal agent. *Global Adv Res J Microbiol.*, 4, 87-97.

Antonelli, J., Lindino, C. A., Bariccatti, R. A., Souza, S. N. M., Nadaletti, W. C., & Cremonez, P. A., et al. (2016). Allelopathic effect of irrigation with different concentrations of leaf extracts of *Jatropha curcas* L. on growth *Brassica oleracea*. *Afr J Agric Res.*, 11, 779-782. https://doi.org/10.5897/AJAR2013.7692

Arekemase, M. O., Kayode, R. M. O., & Ajiboye, A. E. (2011). Antimicrobial activity and phytochemical analysis of *Jatropha curcas* plant against some selected microorganisms. *Int J Biol.*, 3, 52-59. https://doi.org/10.5539/ijb.v3n3p52

Ashraf, M. A., Ullah, S., Ahmad, I., Qureshi, A. K., Balkhari, K. S., & Abdur Rehman, M. (2014). Green biocides, a promising technology, current and future applications to industry and industrial processes. *J Sci Food Agric.*, 94, 388-403. https://doi.org/10.1002/jsfa.6371

Asmanizar, D. A. & Idris, A. B. (2011). Evaluation of *Jatropha curcas* and *Annona muricata* seed crude extracts against *Sitophilus zeamais* infesting stored rice. *J Entomol.*, 9, 13-22. https://doi.org/10.3923/je.2012.13.22

Bashir, E. M., & El-Shafie, H. E. F. (2013). Insecticidal and antifeedant efficacy of *Jatropha* oil extract against the Desert Locust, *Schistocerca gregaria* (Forskål) (Orthoptera: Acrididae). *Agric Biol J North America.*, 4, 260-267. https://doi.org/10.5251/abjna.2013.4.3.260.267

Bassey, I. N., Ogbemudia, F. O., Harold, K. O., & Idung, K. E. (2013). Combined antifungal effects of extracts of *Jatropha curcas* and *Chromolaena odorata* on seed borne fungi of *Solanum gilo* Raddi. *Bull Environ, Pharmacol Life Sci.*, 2, 13-17.

Beserra, F. P., Aguiar, R. W. S., Carvalho, E. E. N., Borges, J. C. M., & Vale, B. N. (2014). *Jatropha curcas* L. (Euphorbiaceae) como novo bioinseticida: análise fitoquímica preliminar e atividade larvicida contra *Aedes aegypti* (Diptera: Culicidae). *Rev Amazônia.*, 2, 17-25.
Boateng, B. A., & Kusi, F. (2008). Toxicity of *Jatropha* seed oil to *Callosobruchus maculatus* (Coleoptera: Bruchidae) and its parasitoid, *Dinarmus basalis* (Hymenoptera: Pteromalidae). *J App Sci Res.*, 4, 945-951.

Botti, J. M. C., Holtz, A. M., Paulo, H. H., Franzin, M. L., Pratissoli, D., & Pires, A. A. (2015). Controle alternativo do *Brevicoryne brassicae* (Hemiptera: Aphididae) com extratos de diferentes espécies de plantas. *Agrária.*, 10, 178-183. https://doi.org/10.5039/agraria.v10i2a3520

Brasileiro, B. G., Dias, D. C. F. S., Bhering, M. C., & Dias, L. A. S. (2012). Floral biology and characterization of seed germination in physic nut (*Jatropha curcas* L.). *Rev Bras Sementes.*, 34, 556-562. https://doi.org/10.1590/S0101-31222012000400005

Córdova-Albores, L. C., Sandoval Zapotitla, E., Ríos, M. Y., Barrera-Necha, L. L., Hernández-López, M., & Bautista-Baños, S. (2016). Microscopic study of the morphology and metabolic activity of *Fusarium oxysporum* f. sp. *gladioli* treated with *Jatropha curcas* oil and derivatives. *J Microsc Ultrastruct.*, 4, 28-35. https://doi.org/10.1016/j.jmau.2015.10.004

Córdova-Albores, L., Bautista-Baños, S., Martínez-Herrera, J., Barrera-Necha, L. L. B., Hernández-López, M., & Cruz Hernández, A. (2014). Morphological and molecular characterization of pathogenic isolates of *Fusarium* spp. obtained from gladiolus corms and their sensitivity to *Jatropha curcas* L. oil. *Afr J Microbiol Res.*, 8, 724-733. https://doi.org/10.5897/AJMR2013.6413

Cremonez, P. A., Feiden, A., Santos, R. F., Bassegio, D., Rossi, E., Nadaleti, W. C., et al. (2013). Allelopathic influence of the aqueous extract of *Jatropha curcas* L. leaves on wild *Cichorium intybus*. *Afr J Agric.*, 8, 6575-6578.

Dahmer, N., Wittmann, M. T. S., & Dias, L. A. S. (2009). Chromosome numbers of *Jatropha curcas* L: an important agrofuel plant. *Crop Breed Appl Biotechnol.*, 9, 386-389. https://doi.org/10.12702/1984-7033.v09n04a14

Danish, M., & Robab, M. I. (2015). *In vitro* studies on phytochemical screening of different leaf extracts and their antifungal activity against seed borne pathogen *Aspergillus niger*. *J Plant Pathol Microbiol.*, 6, 1-5. https://doi.org/10.4172/2157-7471.1000320

Devappa, R. K., Makkar, H. P., & Becker, K. (2010). *Jatropha* toxicity - a review. *J Toxicol Environ Health A.*, 13, 476-507. https://doi.org/10.1080/10937404.2010.499736

Devappa, R. K., Makkar, H., & Becker, K. (2011). *Jatropha* diterpenes - a review. *J Am Oil Chem Soc.* 88, 301-322. https://doi.org/10.1007/s11746-010-1720-9

Devappa, R. K., Makkar, H., & Becker, K. (2012). Localization of anti-nutrients and qualitative identification of toxic components in *Jatropha curcas* seed. *J Sci Food Agric.*, 92, 1519-1525. https://doi.org/10.1002/jsfa.4736

Dias L. A. S (2011). Biofuel plant species and the contribution of genetic improvement. *Crop Breed Appl Biotechnol.*, *S11*, 16-26. https://doi.org/10.1590/S1984-70332011000500004

Dias, L. A. S (ed.) (2007). Cultivo de pinhão manso (*Jatropha curcas*). Viçosa: UFV.
Dias, L. A. S., Missio, R. F., & Dias, D. C. (2012). Antiquity, botany, origin and domestication of *Jatropha curcas* (Euphorbiaceae), a plant species with potential for biodiesel production. *Genet Mol Res., 11*, 2719-2728. https://doi.org/10.4238/2012.June.25.6

Divakara, B. N., Upadhyaya, H. D., Wani, S. P., & Laxmipati Gowda, C. L. (2010). Biology and genetic improvement of *Jatropha curcas* L.: A review. *Applied Energy, 87*, 732-742. https://doi.org/10.1016/j.apenergy.2009.07.013

Dowlathabad, M. R., Anitha, S., Aravinda, A., Karunakar, B., & Devanna, N. (2010). Pharmaceutical investigation and biopesticidical activity of *Jatropha curcas* L. seed oil on digestive enzymic profiles of *Cnaphalocrocis medinalis* (rice leaf folder) and *Helicoverpa armigera* (cotton boll worm). *Int Res J Pharmacy., 1*, 194-200.

El-Nour, M. E. M., Ezzdeen, L., & Elhassan, A. A. (2015). Antifungal activities and phytochemical screening of seeds, leaves and callus (hypocotyls and cotyledons) extracts of *Jatropha curcas* L. *J Advan Biol., 8*, 1623-1628.

Gaikwad, R. S., Kakde, R. B., Kulkarni, A. U., Gaikwad, D. R., & Panchal, V. H. (2012). *In vitro* antimicrobial activity of crude extracts of *Jatropha* species. *Curr Bot., 3*, 9-15.

Goel, G., Makkar, H. P., Francis, G., & Becker, K. (2007). Phorbol esters: structure, biological activity, and toxicity in animals. *Int J Toxicol., 26*, 279-288. https://doi.org/10.1080/10915810701646461

Gonçalves, S. B., Mendonça, S., & Laviola, B. G. (2009). Substâncias tóxicas, alergênicas e antinutricionais presentes no pinhão-manso e seus derivados e procedimentos adequados ao manuseio. Brasília: Embrapa. (Circular Técnica).

Haas, W., & Mittelbach, M. (2000). Detoxification experiments with the seed oil from *Jatropha curcas* L. *Ind Crops Prod., 12*, 111-118. https://doi.org/10.1016/S0926-6690(00)00043-1

Haas, W., Sterk, H., & Mittelbach, M. (2002). Novel 12-deoxy-16- hydroxyphorbol diesters isolated from the seed of *Jatropha curcas*. *J Nat Prod., 65*, 1434-1440. https://doi.org/10.1021/np020060d

Habou, Z. A., Haougui, A., Mergeai, G., Habruge, E., Toudou, A., & Verheggen, F. J. (2011). Insecticidal effect of *Jatropha curcas* oil on the aphid *Aphis fabae* (Hemiptera: Aphididae) and on the main insect pests associated with cowpeas in Niger. *Tropicultura., 29*, 225-229.

Hartmann, T. (2004). Plant-derived secondary metabolites as defensive chemicals in herbivorous insects: a case study in chemical ecology. *Planta., 219*, 1-4. https://doi.org/10.1007/s00425-004-1249-y

He, W., King, A. J., Awais Khan, M., Cuevas, J. A., Ramiaramanana, D., & Graham, I. A. (2011). Analysis of seed phorbol-ester and curcin content together with genetic diversity in multiple provenances of *Jatropha curcas* L. from Madagascar and Mexico. *Plant Physiol Biochem., 49*, 1183-1190. https://doi.org/10.1016/j.plaphy.2011.07.006

Heller, J. (1996). Physic nut. *Jatropha curcas* L.: promoting the conservation and use of underutilized and neglected crops. Rome: Int Plant Genetic Res Inst.
Holtz, A. M., Franzin, M. L., Paulo, H. H., Botti, J. M. C., Marchiori, J. J. P., & Pacheco, E. G. (2016). Controle alternativo de Planococcus citri (Risso, 1813) com extratos aquosos de pinhão-manso. Agric Entomol., 83, 1-6. https://doi.org/10.1590/1808-1657001002014

Igbinosa, O. O., Igbinosa, E. O., & Aiyegoro, O. A. (2009). Antimicrobial activity and phytochemical screening of stem bark extracts from Jatropha curcas (Linn). Afr J Pharmacy Pharmacol., 3, 58-62.

Ingle, K. P., Deshmukh, A. G., Padole, D. A., Dudhare, M. S., Moharil, M. P., & Khelurkar, V. C. (2017a). Screening of insecticidal activity of Jatropha curcas (L.) against diamond back moth and Helicoverpa armigera. J Ent Zool Stud., 5, 44-50.

Ingle, K. P., Deshmukh, A. G., Padole, D. A., Dudhare, M. S., Moharil, M. P., & Khelurkar, V. C. (2017b). Bioefficacy of crude extracts from Jatropha curcas against Spodoptera litura. J Ent Zool Stud., 5, 36-38.

Jaramillo-Quintero, L. P., Montes de Oca, A. C., Romero Rojas, A., Rojas-Hernández, S., Campos-Rodríguez, R., & Martínez-Ayala, A. L. (2015). Cytotoxic effect of the immunotoxin constructed of the ribosome-inactivating protein curcin and the monoclonal antibody against Her2 receptor on tumor cells. Biosci Biotechnol Biochem., 79, 1-11. https://doi.org/10.1080/09168451.2015.1006572

Jayakumar, G., Ajithabai, M. D., Sreedevi, S., Viswanathan, P. K., & Remeshkumar, B. (2010). Ethnobotanical survey of the plants used in treatment of diabetes. Indian J Tradit Knowl., 9, 100-104.

Jing, L., Fang, Y., Ying, X., Wenxing, H., Meng, X., Syed, M. N., et al. (2005). Toxic impact of ingested Jatrophorol-I on selected enzymatic activities and the ultrastructure of midgut cells in silkworm, Bombyx mori L. J Appl Entomol., 129, 98-104. https://doi.org/10.1111/j.1439-0418.2005.00939.x

Katiyar, A. (2016). Exploration of certain indigenous phyto-chemicals against bihar hairy caterpillar, Spilarctia obliqua Walk. J Experimen Zoo., 19, 421-423.

Katoune, H. I., Lafia, D. M., Salha, H., Doumma, A., Drame, A. Y., Pasternak, D., et al. (2011). Physic nut (Jatropha curcas) oil as a protectant against field insect pests of cowpea in Sudano-Sahelian cropping systems. SAT e-Journal, 9, 1-6.

Khani, M., Awang, R. M., Omar, D., Rahmani, M., & Rezazadeh, S. (2011). Tropical medicinal plant extracts against rice weevil, Sitophilus oryzae L. J Med Plants Res., 5, 259-265.

Kumar, A., Sharma, S. (2008). An evaluation of multipurpose oil seed crop for industrial uses (Jatropha curcas L.): a review. Ind Crops Prod., 28, 1-10. https://doi.org/10.1016/j.indcrop.2008.01.001

Lateef, F. A., Daudu, S. O., Jere, P., & Yusuf, D. (2014). Insecticidal effect of Jatropha curcas oil phorbol esters on the nymph, adult cockroaches and termites. Int J App Sci Eng Res., 3, 495-503.

Laviola, B. G., Anjos e Silva, S. D., Juhász, A. C. P., Rocha, R. B., Oliveira, R. J. P., Albrecht,
J. C., et al. (2014). Desempenho agronômico e ganho genético pela seleção de pinhão-manso em três regiões do Brasil. *Pesq Agropec Bras.*, 49, 356-363. https://doi.org/10.1590/S0100-204X2014000500005

Leite, J. P. V. (2009). Química dos produtos naturais: uma abordagem biossintética. In: Leite JPV. Fitoterapia: bases científicas e tecnológicas. São Paulo: Atheneu; p. 47-97.

Li, H. Y., Wang, L., & Zhao, Z. W. (2006). Endophytic fungi of *Jatropha curcas* Linn. and their antifungal activity. *Nat Prod Res Dev.*, 18, 78-80.

Machado, O. L. T., & Silva, Jr. J. G. (1992). An allergenic 2S storage protein from *Ricinus communis* seeds which is part of the 2S albumin precursor predicted by c-DNA data. *Braz J Med Biol Res.*, 25, 567-582.

Makun, H. A., Anjorin, S. T., Adeniran, L. A., Onakpa, M. M., Muhammad, H. L., Obu, O. R., et al. (2011). Antifungal activities of *Jatropha curcas* and *Ricinus communis* seeds on *Fusarium verticillioides* and *Aspergillus flavus* in yam. *J Agric Biol Sci.*, 6, 22-27.

Moragas, W. M., & Schneider, M. O. (2003). Biocidas: suas propriedades e seu histórico no Brasil. *Caminhos de Geografia.*, 3, 26-40.

Muniz, D. R. (2019). Potencial biocida de *Jatropha curcas* L. 63p. PhD Thesis in Plant Science-Departamento de Agronomia, Universidade Federal de Viçosa, Viçosa, Brazil.

Musa, A. K., Belewu, M. A., Muhammed-Lawal, A., Adekola, F. O., Olarewaju, B. O., & Ibraheem, S. O. (2011). Costs analysis and toxicity of *Jatropha curcas* L. on maize weevil, *Sitophilus zeamais* Motsch. *Afr J Plant Sci.*, 5, 233-236.

Nabil, A. E. A., & Yasser, A. M. K. (2012). *Jatropha curcas* oil as insecticide and germination promoter. *J App Sci Res.*, 8, 668-675.

Nayak, B. S., & Patel, K. N. (2010). Anti-inflammatory screening of *Jatropha curcas* root, stem and leaf in albino rats. *Romanian J Biol Plant-Biol.*, 55, 9-13.

Ogbebor, O. N., & Adekunle, A. T. (2008). Inhibition of *Drechslera heveae* (Petch) M. B. Ellis, causal organism of Bird’s eye spot disease of rubber (*Hevea brasiliensis* Muell Arg.) using plant extracts. *Afr J General Agric.*, 4, 19-26.

Ogbebor, O. N., Adekunle, A. T., & Enobakhare, D. A. (2007). Inhibition of *Colletotrichum gloeosporioides* (Penz) Sac.causal organism of rubber (*Hevea brasiliensis* Muell. Arg.) leaf spot using plant extracts. *African J Biotechnol.*, 6, 213-218.

Ojiako, F. O., Gabriel, I., & Aguwa, U. O. (2015). Comparative bioactivity of different solvent extracts of the root and seeds of *Jatropha curcas* L. and Chlorpyrifos against tailor ants (*Oecophylla longinoda* Latreille) (Hymenoptera: Formicidae). *FUTO J Series.*, 1, 118-211.

Oliveira, M. (2016). Óleo para o biodiesel. *Pesquisa FAPESP*, 245, 68-71.

Opuba, S. K., Adetimehin, A., Iloba, B., & Uyi, O. (2018). Insecticidal and antiovipositional activities of the leaf powder of *Jatropha curcas* (L.) (Euphorbiaceae) against *Callosobruchus maculatus* (F.) (Coleoptera: Chrysomelidae). *Anim Res Int.*, 15, 2971-2978.
Patil, C. D., Borase, H. P., Suryawanshi, R. K., & Patil, S. V. (2016). Trypsin inactivation by latex fabricated gold nanoparticles: A new strategy towards insect control. *Enzyme Microb Technol.*, 92, 18-25. https://doi.org/10.1016/j.enzmictec.2016.06.005

Premalatha, K., Nelson, S. J., Vishnupriya, R., Balakrishnan, S., & Santhana Krishnan, V. P. (2018). Acaricidal activity of plant extracts on two spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae). *J Entomol Zoo Stud.*, 6, 1622-1625.

Rampadarath, S., Puchooa, D., & Jeewon, R. (2016). *Jatropha curcas* L: Phytochemical, antimicrobial and larvicidal properties. *Asian Pac J Trop Biomed.*, 6, 858-865. https://doi.org/10.1016/j.apjtb.2016.01.019

Ratnadass, A., Togola, M., Cisse, B., & Vassal, J. M. (2009). Potential of sorghum and physic nut (*Jatropha curcas*) for management of plant bugs (Hemiptera: Miridae) and cotton bollworm (*Helicoverpa armigera*) on cotton in an assisted trap-cropping strategy. *J SAT Agric Res.*, 7, 1-7.

Rejila, S., & Vijayakumar, N. (2011). Allelopathic effect of *Jatropha curcas* on selected intercropping plants (Green Chilli and Sesame). *J Phytology.*, 3, 1-3.

Ribeiro, R. M., Dias, L. A. S., Berger, P. G., & Dias, D. C. F. S. (2011). Agroenergia na mitigação das mudanças climáticas globais, na segurança energética e na promoção social. Viçosa: Suprema.

Roque, J. V., Dias, L. A. S., & Teofilo, R. F. (2017). Multivariate calibration to determine phorbol esters in seeds of *Jatropha curcas* L. using near infrared and ultraviolet spectroscopies. *J Braz Chem Soc.*, 28, 1-11. https://doi.org/10.21577/0103-5053.20160332

Roy, S., Handique, G., Barua, A., Bora, F. R., Rahman, A., & Muraleedharan, N. (2016). Comparative performances of jatropha oil and garlic oil with synthetic acaricides against red spider mite infesting tea. *Proc Natl Acad Sci.*, 88, 85-91. https://doi.org/10.1007/s40011-016-0734-y

Sabandar, C. W., Ahmat, N, Jaafar, F. M., & Sahidin, I. (2013). Medicinal property, phytochemistry and pharmacology of several *Jatropha* species (Euphorbiaceae): A review. *Phytochem.*, 85, 7-29. https://doi.org/10.1016/j.phytochem.2012.10.009

Sachdeva, K., Garg, P., Singhal, M., & Srivastava, B. (2011). Pharmacological evaluation of *Jatropha curcas* Linn (stem bark) for wound healing potential in rats. *Pharmacology online*, 3, 251-264. https://doi.org/10.5530/pj.2011.25.12

Sachdeva, K., Saini, N. K., Singhal, M., Srivastava, B., & Singh, C. (2011). Evaluation of analgesic and antimicrobial activity of stem bark extract of *Jatropha curcas*. *Int J Res Ayurveda Pharm.*, 2, 572-576.

Saetae, D., & Suntornsuk, W. (2010). Antifungal activitivies of ethanolic extract from *Jatropha curcas* seed cake. *J Microbiol Biotechnol.*, 20, 319-324. https://doi.org/10.4014/jmb.0905.05035

Sahidin, S., Ardiansyah, Taher M., & Manggau, M. (2011). Terpenoids from the stem bark of *Jatropha* plants and their biological activities. *Makara Sains*, 15, 106-110.
Savaliya, V. A., Bhalia, C., Marviya, P. B., & Akbari, L. F. (2015). Evaluation of phytoextracts against *Macrohymena phaseolina* (Tassi) Goid causing root rot of sesame. *J Biopest*, 8, 116-119.

Sharma, N. (2017). Evaluation of *Jatropha curcas* as potential biocide and biopesticide. *Int J Curr Research Biosci Plant Biol.*, 4, 92-97. https://doi.org/10.20546/ijcrgb.2017.406.011

Silva, G. N., Faroni, L. R. A., Sousa, A. H., & Freitas, R. S. (2012a). Bioactivity of *Jatropha curcas* L. to insect pests stored products. *J Stored Prod Res.*, 48, 111-113. https://doi.org/10.1016/j.jspr.2011.10.009

Silva, H. D., Souza, M. D. C., Giustolin, T. A., Alvarenga, C. D., Fonseca, E. D., & Damasceno, A. S. (2015). Bioatividade dos extratos aquosos de plantas às larvas da mosca-das-frutas, *Ceratitis capitata* (Wied.). *Plant Parasitol.*, 82, 1-4. https://doi.org/10.1590/1808-1657000132013

Silva, P. S. S., Fortes, A. M. T., Pilatti, D. M., & Boiago, N. P. (2012b). Atividade alelopática do exsudado radicular de *Jatropha curcas* L. sobre plântulas de *Brassica napus* L., *Glycine max* L., *Zea mays* L. e *Helianthus annuus* L. *Insula Rev Bot.*, 41, 32-41.

Simões, C. M. O., Schenkel, E. P., Melo, J. C. P., Mentz, L. A., & Petrovick, P. R. (2010). Farmacognosia: da planta ao medicamento. 6th edn. Porto Alegre: Editora da UFRGS: Florianópolis; Editora da UFSC.

Siva, N., Ganesan, S., Banumathy, N., & Muthuchelian (2008). Antifungal effect of leaf extract of some medicinal plants against *Fusarium oxysporum* causing wilt disease of *Solanum melogena* L. *Ethnobot Leaflets*, 12, 156-163.

Srivastava, S., Kumar, R., & Sinha, A. (2012). Antifungal activity of *Jatropha curcas* oil against some seed-borne fungi. *Plant Pathol J.*, 11, 120-123. https://doi.org/10.3923/ppj.2012.120.123

Thangavelu, R., Sundararaju P. & Sathiamoorthy, S. (2004). Management of anthracnose disease of banana caused by *Colletotrichum musae* using plant extracts. *J Hortic Sci Biotechnol.*, 79, 664-668. https://doi.org/10.1080/14620316.2004.11511823

Torres, A. L., Barros, R., & Oliveira, J. V. (2001). Efeito de extratos aquosos de plantas no desenvolvimento de *Plutella xylostella* (L.) (Lepidoptera: Plutellidae). *Neotrop Entomol.*, 30, 151-156. https://doi.org/10.1590/S1519-566X2001000100022

Trivedi, A., Nayak, N., & Kumar, J. (2018). Recent advances and review on use of botanicals from medicinal and aromatic plants in stored grain pest management. *J Entomol Zoo Stud.*, 6, 295-300.

Van den Berg, A. J. J., Horsten, S. F. A. J., Kettenes-van den Bosch, J. J., Kroes, B. H., Beukelman, C. J., Leeflang, B. R., et al. (1995). Curcacycline A - A novel cyclic octapeptide isolated from the latex of *Jatropha curcas* L. *FEBS Lett.*, 358, 215-218. https://doi.org/10.1016/0014-5793(94)01405-P

Verma, M., Pradhan, S., Sharma, S., Naik, S. N., & Prasad, R. (2011). Efficacy of karanjin and phorbol ester fraction against termites (*Odontotermes obsus*). *Int Biodeterior
Biodegradation, 65, 877-882. https://doi.org/10.1016/j.ibiod.2011.05.007

Verma, S., Verma, M., Sharma, S., & Malik, A. (2013). Determination of phytocomponents of Jatropha curcas root by GC-MS analysis and their termiticidal activity. Int J Ecol Environ Sci., 39, 159-169.

Wei, Q., Liao, Y., Chen, Y., Wang, S. H., Xu, Y., Tang, L., et al. (2005). Isolation, characterization and antifungal activity of β-1,3-glucanase from seeds of Jatropha curcas. South Afr J Bot., 71, 95-99. https://doi.org/10.1016/S0254-6299(15)30155-1

Wei, Q., Liao, Z., Zhou, L. J., Wang, S. H., & Chen, F. (2004). Antifungal activity of curcin from Jatropha curcas seeds. Chinese J Oil Crop Sci., 26, 71-75.

Wiesbrook, M. L. (2004). Natural indeed: Are natural insecticides safer and better than conventional insecticides? Illinois Pest Rev., 17, 1-3.

Xu, W., Sujatha, M., & Aizhong, L. (2012). Genetic diversity in the Jatropha genus and its potential application. CAB Reviews, 7, 7-15. https://doi.org/10.1079/PAVSNNR20127059

Yang, S., Ding, M. M., Chen, F., & Xu, Y. (2017). Proteomic analysis of latex from Jatropha curcas L. stems and comparison of two classic proteomic sample isolation methods: The phenol extraction and the TCA/acetone extraction. Electron J Biotechn., 27, 14-24. https://doi.org/10.1016/j.ejbt.2017.01.006

Zaidan, I. R. (2018). Potencial biocida de extratos de Jatropha curcas L. sobre Hemileia vastatrix e Cercospora coffeicola. 53p. Msc Thesis in Plant Science – Departamento de Agronomia, Universidade Federal de Viçosa, Viçosa.

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