Arthropod pests and their management, natural enemies and flora visitors associated with castor (Ricinus communis), a biofuel plant: a review

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Abstract: Interest in bioenergetic crops, such as the castor oil plant Ricinus communis (Euphorbiaceae), for production of biodiesel has increased in recent years. In this paper, phytophagous arthropods, their natural enemies and floral visitors associated with this plant in the world are reviewed. Despite its insecticidal properties, arthropods have been reported feeding on Ricinus communis plants. The arthropod pests of Ricinus communis damage all parts of the plant, including the seeds, where some toxic compounds are even more concentrated. In the scientific databases, we found reports of 193 arthropods associated to Ricinus communis in different parts of the world. This information obtained in the scientific databases was concentrated in a database and analyzed according to the coevolutive hypothesis, which allows us to predict that the greatest wealth and abundance of phytophagous arthropods is found in the center of origin by Ricinus communis. According to this review, Achaea janata, Spodoptera littura, Edinisiana flavescens, Liriomyza trifolii, S. obliqua, Apis mellifera, T. australicum, T. dormini, T. preitosum, T. evanescens, Microplitis rufiventris, M. maculipennis, M. ophiussae, Telenomus remus, T. proditor, Stethorus siphonulus and S. histrio. Apis mellifera is recorded as the main insect pollinator of Ricinus communis. Pest management methods used against the arthropod pests of Ricinus communis include biological, ethological, mechanic, cultural, genetic, and chemical control.

Keywords: Castor-oil plant, biodiesel, pests, entomophagous organisms, pollinators.

Resumen: El interés por los cultivos bioenergéticos, tales como Ricinus communis (Euphorbiaceae) para producir biodiesel ha aumentado en años recientes. En este documento se hace una revisión sobre los artrópodos fitófagos, enemigos naturales y visitantes florales asociados a esta planta en el mundo. A pesar de las propiedades insecticidas de Ricinus communis, existen registros sobre artrópodos que se alimentan de él. Los artrópodos de Ricinus comunis dañan toda la planta, incluso las semillas, donde se localizan compuestos tóxicos más concentrados. En las bases de datos científicas, se encontró registro de 193 artrópodos asociados a Ricinus communis en diferentes partes del mundo. Esta información se concentró en una base de datos y se analizó de acuerdo con la hipótesis coevolutiva, la cual permite predecir que la mayor riqueza y abundancia de artrópodos fitófagos, se encuentra en el centro de origen de Ricinus communis. De esta revisión se desprende que entre las plagas más devastadoras en Asia se encuentran Achaea janata, Spodoptera littura, Edinisiana flavescens, Liriomyza trifolii, S. obliqua, Apis mellifera, T. australicum, T. dormini, T. preitosum, T. evanescens, Microplitis rufiventris, M. maculipennis, M. ophiussae, Telenomus remus, T. proditor, Stethorus siphonulus y S. histrio. Apis mellifera es registrado como el principal insecto polinizador de Ricinus communis. Métodos de manejo de plagas utilizados contra los artrópodos de Ricinus communis incluyen control biológico, etológico, mecánico, cultural, genético y químico.

Palabras clave: Higuerrilla, biodiesel, plagas, entomófagos, polinizadores.
Introduction

The castor-oil plant, *Ricinus communis* L., is an oleaginous plant belonging to the Euphorbiaceae family, which comprises 280 genera. This species has been cultivated for more than 6000 years on the Asian continent, and more recently on the African and American continents (Govaerts et al. 2000; Salihu et al. 2014). *R. communis* is a non-edible plant, mainly used in chemical, pharmaceutical, and automobile industries, where it has numerous applications (Savy 2005; Barnes et al. 2009; Severino et al. 2010). All parts of this plant contain lectin ricin – one of the most potent lethal natural poisons known – but is particularly concentrated in the seeds and pods (Audi et al. 2005).

In recent years, *R. communis* oil has acquired importance as a biofuel, due to the possibility of its use in producing biodiesel (Baldwin and Cossar 2009; César and Batalha 2010). *R. communis* is distributed in tropical and subtropical regions and is also adaptable to temperate zones (Lima et al. 2011). The principal producer countries of *R. communis* seeds are India, China, and Mozambique; whereas the countries with the highest consumption of the products of this plant are Holland, Japan, and Italy (Faostat 2015). India, China, and Brazil contribute approximately 95 % of the world production of seeds (Sailaja et al. 2008).

*Ricinus communis* seeds are outstanding for their high oil content, between 40 and 60 %, compared with sunflower (*Helianthus annuus* L.) seeds with 38 to 48 %, soybean (*Glycine max* (L.) Merr.) between 18 and 19 %, moringa (*Moringa oleifera* L.) with 14 to 24 %, neem (*Azadirachta indica* (Juss)) between 17 and 39 %, and cotton (*Gossypium hirsutum* L.) with 15 to 19 % (Kittock and Williams 1970; Severino 2006; Melo et al. 2007; Baldwin and Cossar 2009; Martin et al. 2010), a characteristic that makes this plant very attractive as a source of biofuel, particularly biodiesel.

The extensive cultivation of varieties and hybrids of *R. communis* under different management practices has made the plant vulnerable to biotic and abiotic factors. *R. communis* plants may lose leaves, seeds and pods for different reasons: damage by pests, diseases, wind, hail, traffic of machinery, and inappropriate use of herbicides and defoliation (Severino et al. 2010). Even though a castor-oil plant can recover from severe defoliation, the damage suffered by the leaves may reduce the production. It is estimated that for 1 m² of lost leaf area, seed production diminishes by 37.8 g and oil production by 24.4 g (Lakshmamma et al. 2009; Lakshmi 2010; Severino et al. 2010). Continuous sowing of *R. communis* in the same areas, as well as the lack of intercropping has increased the occurrence of pests and diseases. There are reports that more than 100 species of insects in different parts of the world feed on *R. communis* and can cause serious damage (Barteneva 1986; Kolte 1995). In India, for example, insect pests caused losses in seed production from 35 to 50 % (Kolte 1995). Integrated pest management programs are therefore important to prevent losses that can affect the economy of producer-countries.

The present literature reviewed focuses on the phytophagous arthropods associated with *R. communis* in different parts of the world, as well as, their natural enemies and natural visitors. The information was obtained through extensive search of scientific literature on these subjects published in the Web of Science database, Ebsco database and Google Scholar, using appropriate key words (e.g. ‘insects on *Ricinus communis*’ ‘arthropods on *Ricinus communis*’, ‘pests of *Ricinus communis* or castor-oil’); the search was conducted until January 2019. Afterwards, the information collected was analyzed from the perspective of the co-evolutionary hypothesis following the approach of literature review analysis of arthropod herbivory on physic nut (*Jatropha curcas* L.) conducted by Lama et al. (2015).

Specifically, we set out to answer the following questions regarding the arthropods associated with *R. communis*: (1) What is the diversity of arthropod taxa associated with this plant? (2) In what geographic area does the greatest richness of associated arthropod species occur? (3) What are the parts of the plant most preferred by the herbivorous arthropods? and (4) What mouthpart classes of the arthropods associated with *R. communis* can be identified? According to the co-evolutionary hypothesis, it would be expected to find greater richness of native arthropod species in Asia and Africa, the origin area of *R. communis*, in comparison with those areas where this plant has been introduced or cultivated more recently.

Phytophagous arthropods associated with *R. communis*

*Ricinus communis* has been considered tolerant and/or resistant to pest attack due to the toxic compounds present in different parts of the plant. Some of the most common compounds found in this plant species are ricin, ricinine, N-demethylricinicine, flavonoids, gallic acid, gentisic acid, coumaric acid, syringic acid, cinnamic acid, vanillic acid and rutin, and allergen proteins such as Ric c1 and Ric c3 (Usha Rani et al. 2006; Gahukar 2010; Vandenborre et al. 2011; Usha Rani and Pratyusha 2014). Some of these are toxic compounds that may even have insecticidal or antifeedant properties against insect pests of other crops (Rossi et al. 2012; Amoabeng et al. 2014; Dinesh et al. 2014). Despite the insecticidal properties of *R. communis*, there are reports of arthropods that feed on several parts of this plant. Ricinine, for example, one of its main alkaloids that has shown insecticidal effect on some insect pests of other plants (Bigi et al. 2004; Liu and Li 2006; Rossi et al. 2012) does not have any detrimental effect on certain specialist phytophagous insects that are common pests of *R. communis*, such as *Achaea janata* (L., 1758) (Lepidoptera: Noctuidae), *Spodoptera littura* (F., 1775) (Lepidoptera: Noctuidae) and others (Prabhakar et al. 2003; Usha Rani and Pratyusha 2014). This is due to the presence of enzymes in the midgut of these insects that are able to degrade toxins and thus breakdown the plants' natural defenses (Yasur et al. 2009; Usha Rani and Pratyusha 2014).

The arthropod pests of *R. communis* damage all parts of the plant, including the seeds, where some toxic compounds such as lipases, the alkaloid ricinine (including the protein ricin) and glycosides of ricinoleic, isoricinoleic, stearic and dihydroxystearic acids are even more concentrated (Jena and Gupta 2012). The type of pest and damage varies from place to place; some pests of *R. communis* can be present in different regions. Table 1 presents information published in the literature on arthropods that attack *R. communis*.

According to Table 1, 59 % of the arthropod species feed on foliage, 20 % on roots and seedlings, 17 % on flowers, fruits and seeds, and 5 % on stems and branches. The low percentage of arthropods feeding on seeds and roots can be explained in part by the high concentration of ricinine in these parts of the plant (Salihu et al. 2014). To feed on seeds and roots, these arthropods have had to develop highly efficient mechanisms of detoxification (Yasur et al. 2009).
Table 1. Order, family and geographical distribution of the phytophagous arthropod species that attack cultivated *Ricinus communis*.

| Order          | Family          | Species                          | Geographical distribution                                      | References                                      |
|----------------|-----------------|----------------------------------|----------------------------------------------------------------|------------------------------------------------|
| Coleoptera     | Curculionidae   | *Protostrophus* spp.              | Africa                                                         | Salihu et al. (2014)                           |
|                | Elateridae      | *Agriotes* sp.                   | Costa Rica                                                     | Anónimo (1991)                                 |
| Scarabeidae    |                 | *Amphimallon solstitialis* (Linnaeus, 1758) | Russia                                                      | Arkangel’Skii and Romanova (1930)           |
|                |                 | *Holotrichia consanguinea* Blanchard, 1850 | India                                                        | Gahukar (2018)                               |
|                |                 | *Phyllophaga* sp.                | Colombia and Costa Rica                                         | Anónimo (1991); Londoño-Zuluaga (2008)       |
|                |                 | *Holochelus aequinoctialis* (Herbst, 1790) | Russia                                                      | Arkangel’Skii and Romanova (1930)           |
|                |                 |                                   |                                                               |                                                |
| Diptera        | Agromyzidae     | *Liriomyza trifoli* (Burgess, 1880) | India                                                         | Anjani et al. (2007)                          |
| Lepidoptera    | Noctuidae       | *Agrotis ipsilon* (Hüfnagel, 1766) | Colombia and Egypt                                             | Saldarriaga Cardona et al. (2011)           |
|                |                 | *Helicoverpa zea* (Boddie, 1850)  | USA                                                           | Wene (1933)                                   |
|                |                 | *Spodoptera frugiperda* (J. E. Smith, 1797) | Colombia                                     | Saldarriaga et al. (2011)                    |
|                |                 | *Spodoptera marima* (Schaus, 1904) | Brazil                                                        | Ribeiro and Costa (2008)                     |
|                |                 | *Spodoptera spp.*                | Brazil                                                        | Ribeiro and Costa (2008)                     |
|                | Sphingidae      | *Erinnis ello* (Linnaeus, 1758)   | Brazil                                                        |                                                |
| Orthoptera     | Gryllidae       | *Brachypterus* spp.              | Africa                                                        | Salihu et al. (2014)                          |
|                | Pyrgomorphidae  | *Chrotogonus* spp.               | Africa                                                        | Salihu et al. (2014)                          |
|                |                 | *Zonocerus variegatus* (Linnaeus, 1758) | Africa                                      | Salihu et al. (2014)                          |
| Isoptera       | Termitidae      | *Odontotermes obesus* (Rambur, 1842) | India                                                        | Gahukar (2018)                               |

| Order          | Family          | Species                          | Geographical distribution                                      | References                                      |
|----------------|-----------------|----------------------------------|----------------------------------------------------------------|------------------------------------------------|
| Coleoptera     | Curculionidae   | *Naupactus glaucus* Perty, 1832   | Brazil                                                        | Cavalcante et al. (1974)                        |
|                |                 | [= *Pantomorus glaucus* Perty, 1830] |                                                              |                                                |
| Diptera        | Agromyzidae     | *Liriomyza sativae* Blanchard, 1938 | China                                                         | Zhang et al. (2006)                            |
|                |                 | *Liriomyza subpusilla* Frost, 1943 | USA                                                           | Wene (1933); Parkman et al. (1989)             |
|                |                 | *Liriomyza trifoli* Burgess, 1880 | India                                                         | Galande et al. (2005)                          |
| Hemiptera      | Aleyrodidae     | *Bemisia tabaci* (Gennadius, 1889) | Costa Rica and Africa                                         | Anónimo (1991); Salihu et al. (2014)          |
|                |                 | *Trialeurodes ricini* (Misra, 1924) | India                                                         | Idriss et al. (1997); Sarma et al. (2005); Raghavaiah (2011) |
|                | Aphrophoridae   | *Pseudaphis glycines* (Fabricius, 1842) | Uganda                                                     | Darling (1946)                                |
| Cicadellidae   | *Amrasca (Amrasca) biguttula* (Ishida, 1913) | [= *Amrasca biguttula biguttula* (Ishida, 1912)] | India                                                        | Sharma and Singh (2002); Raghavaiah (2011)     |
|                | *Agallia* sp.   |                                   | India                                                        | Durán et al. (2010)                           |
|                | *Edwardiana flavescens* (Fabricius, 1794) | [= *Empousa flavescens* (Fabricius, 1794)] | India                                                        | Jayaraj (1964); Sarma et al. (2005); Lakshmi et al. (2005); Jyothsna et al. (2009) |
|                | *Empousa* (Empousa) solana Delong, 1931 | (= *Empousa solana Delong, 1931*) | USA                                                          | Wene (1933)                                   |
|                | *Empousa sp.*   |                                   | Costa Rica and Egypt                                          | Anónimo (1991)                                |
|                | *Empousa sp.*   |                                   | Africa                                                        | Salihu et al. (2014)                          |
|                | *Jacobiasca farcystylus* (Ramakrishnan y Menon, 1972) |                               | India                                                        | Parmar et al. (2006)                          |
| Miridae        | Falcidae        | *Falcinae antioquiensis* Carvalho, 1987 | Colombia                                                     | Saldarriaga Cardona et al. (2011)             |
|                | Polymeridae     | *Polymerus cognatus* Fieber, 1858 | Russia                                                        | Arkangel’Skii and Romanova (1930)             |
| Pentatomidae   | Acrosternum pallidoconspersum (Stål, 1858) |                                    | Egypt                                                        | Jannone (1952)                                |
| Pseudococcidae | Paracoccus marginatus Williams and Granara de Willink, 1992 |                               | Costa Rica and Egypt                                          | Jannone (1952); Anónimo (1991)                |
| Tingidae       | Corythucha gossypi* (Fabricius, 1794) |                               | USA, Colombia, Mexico, and Cuba                              | Miller and Nagamine (2005); Londoño-Zuluaga (2008); Saldarriaga Cardona et al. (2011), López-Guillén et al. (2012) |

Lepidoptera

| Order          | Family          | Species                          | Geographical distribution                                      | References                                      |
|----------------|-----------------|----------------------------------|----------------------------------------------------------------|------------------------------------------------|
| Arctidae       | *Amsacta moorei* Butler, 1876 |                               | India                                                        | Sarma et al. (2005)                            |
|                | *Amsacta albistrixa* Walker, 1864 |                               | India                                                        | Sarma et al. (2005)                            |
|                | *Pericallia ricini* (Fabricius, 1775) |                               | India                                                        | Mathur et al. (1994); Neelanarayanan and Indira (2010) |
|                | *Spilosoma obliqua* Walker, 1855 |                               | India and Pakistan                                            | Singh and Grewal (1982); Khattak et al. (1991); Sarma et al. (2005) |

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Dalceridae  
*Anacraga citrinopsis* Dyar, 1927  
Brazil  
Lourenço *et al.* (1989)

Limaecodidae  
*Parasa lepida* Cramer, 1799  
India  
Raghavaiah (2011)

Lymantridae  
*Dasychira* sp.  
Africa  
Salihu *et al.* (2014)

*Exproctis fraterna* Moore, 1883  
India  
Paul *et al.* (2000); Suganthy (2010)

Noctuidae  
*Achaea janata* (Linnaeus, 1758)  
India, USA, and China  
Hua (1984); Delaya *et al.* (1985); Basappa and Lingappa (2001); Mau and Kessing (2007)

*Helicoverpa armigera* (Hübner, 1803-1808)  
Brazil and USA  
Wene (1933); Ribeiro and Costa (2008)

*Spodoptera cosmioides* (Walker, 1858)  
Brazil  
Bavaresco *et al.* (2003)

*Spodoptera exigua* (Hübner, 1808)  
Egypt  
Ribeiro and Costa (2008)

*Spodoptera ornithogalli* (Guenée, 1852)  
Brazil  
Ribeiro and Costa (2008)

*Spodoptera* sp.  
Costa Rica  
Anónimo (1991)

Nymphalidae  
*Ariadne merione* Cramer, 1779  
($= Ergolis merione$ Cramer, 1779)  
India  
Ghosh (1914); Sarma *et al.* (2005)

Saturniidae  
*Samia ricini* (Drury, 1773)  
Egypt, India, and Brazil  
El-Shaarawy *et al.* (1975); Negreiros *et al.* (1998)

Orthoptera  
Acrididae  
*Chrotogonus* (Chrotogonus) *robertsi* Kirby & W. F., 1914  
India  
Sarma *et al.* (2005)

Thysanoptera  
*Retithrips syriacus* (Mayet, 1890)  
India  
Sarma *et al.* (2005)

*Arianea merione* Cramer, 1779  
($= Ergolis merione$ Cramer, 1779)  
India  
Ghosh (1914); Sarma *et al.* (2005)

Acarina  
Tetranychidae  
*Eutetranychus orientalis* (Klein, 1936)  
India  
Ahuja (1994)

*Eutetranychus* sp.  
India  
Raghavaiah (2011)

*Tetranychus piercei* McGregor, 1950  
China  
Lui and Lui (1986)

*Heliothis* sp.  
Costa Rica  
Anónimo (1991); Golden and Follett (2006)

Stems and branches

| Coleoptera | Buprestidae | Sphenoptera sp. | Africa | Salihu *et al.* (2014) |
| --- | --- | --- | --- | --- |
| Tenebrionidae | Blaptinus sp. | USA | De Ong (1918) |

Hemiptera  
Membracidae  
*Oxyrhachis taranda* (Fabricius, 1798)  
India  
Ali *et al.* (2006)

Lepidoptera  
Cossidae  
*Strigocossus capensis* (Walker, 1856)  
($= Xyleutes capensis$ (Walker, 1856))  
Africa  
Salihu *et al.* (2014)

Flowers, fruits and seeds

| Coleoptera | Anobiidae | Lastiodermara serricorne* (Fabricius, 1792) | India and Africa | Hussain and Khan (1966); Salihu *et al.* (2014) |
| --- | --- | --- | --- | --- |
| Tribolium castanenum (Herbst, 1797) | Africa | Salihu *et al.* (2014) |

Hemiptera  
Cicadellidae  
*Empoasca sp.*  
Costa Rica  
Anónimo (1991)

*Miridae*  
*Euryystylus* sp.  
Africa  
Salihu *et al.* (2014)

*Helopeltis* sp.  
Africa  
Salihu *et al.* (2014)

Pentatomidae  
*Nezara viridula* (Linnaeus, 1758)  
Costa Rica, and USA  
Anonymous (1991); Golden and Follett (2006)

Scutelleridae  
*Calidea* sp.  
Africa  
Salihu *et al.* (2014)

Lepidoptera  
Crambidae  
*Conogethes punctiferalis* (Guénée, 1854)  
($= Dichocrocis punctiferalis$ (Guénée, 1854))  
India and Australia  
Anonymous (1913); Sharma *et al.* (1995); Jyothisa *et al.* (2009); Patel and Patel (2009); Hedge *et al.* (2009)

*Noctuidae*  
*Achaea janata* (Linnaeus, 1758)  
India, USA, and China  
Hua (1984); Delaya *et al.* (1985); Basappa and Lingappa (2001); Mau and Kessing (2007)

*Heliothis* sp.  
Costa Rica  
Anónimo (1991)

*Helicoverpa armigera* (Hübner, 1803-1808)  
India, and USA  
Wene (1933); Geetha *et al.* (2003); Satyanarayana and Sing (2003)

*Spodoptera* sp.  
Costa Rica  
Anónimo (1991)

Pyralidae  
*Cadra cautella* (Walker, 1863)  
($= Ephesia cautella$ (Walker, 1863))  
Africa  
Salihu *et al.* (2014)

Tortricidae  
*Thaumatomita leucotreta* (Meyrick, 1913)  
($= Cryptophlebia leucotreta$ Meyrick, 1913)  
Africa  
Salihu *et al.* (2014)
A total of 76 species of phytophagous arthropods associated to cultivated plants of *R. communis* is found worldwide (Table 1). Before the present literature review, the report was of 60 species (Raoof et al. 2003). The arthropods reported in Table 1 belong to eight orders and 38 families; 40% of these species belong to Lepidoptera, 27% to Hemiptera, 14% to Coleoptera and 19% to other orders. The species that belong to Lepidoptera, Hemiptera and Coleoptera represent 81% of the total. These phytophagous arthropods are distributed geographically in Asia (39%), America (34%), Africa (25%) and Europe (2%). As it was supposed, it was not uncommon to find that the greatest richness of arthropods associated to *R. communis* occurred in Asia and Africa, continents considered as the center of origin of this plant (Govaerts et al. 2000). 63% of the species had mandibulate mouthparts (Lepidoptera, Coleoptera, Orthoptera, Isotreta and Diptera) and 37% were piercing-and-sucking mouthpart classes (Hemiptera, Thysanoptera and Acarina).

Of the pests listed in Table 1, the castor semilooper *A. janata*, the tobacco caterpillar *S. litura*, the green leafhopper *Edwardsiana flavescens* (F., 1794) [= *Empeosca flavescens* (F., 1794)] (Hemiptera: Cicadellidae), the serpentine leafminer *Liriomyza trifolii* Burgess, 1880, the vegetable leafminer *L. sativae* Blanchard, 1938 (Diptera: Agromyzidae), the Bihai hairy caterpillar *Spilosoma obliqua* Walker, 1855 (Lepidoptera: Arctiidae), the shoot and capsule borer *Conogethes punctiferalis* (Gueneé, 1854) [= *Dichocrocis punctiferalis* (Gueneé, 1854)] (Lepidoptera: Crambidae), the cowbug *Oxyrhachis taranda* (F., 1798) (Hemiptera: Membracidae), and the cotton bullworm *Helicoverpa armigera* (Hübner, 1803-1808) (Lepidoptera: Noctuidae), among others, are the most devastating pests in Asia. In Africa, the black cutworm *Acrietes spp.*, some defoliator larvae including *S. litura**cotton bullworm* *R.* *communis* *Phyllonorycter rosaceana* (F., 1798) (Olethreutidae), among others, are mentioned as the most important. In Asia and Africa, continents considered as the center of origin of this plant (Govaerts et al. 2000). 63% of the species had mandibulate mouthparts (Lepidoptera, Coleoptera, Orthoptera, Isotreta and Diptera) and 37% were piercing-and-sucking mouthpart classes (Hemiptera, Thysanoptera and Acarina).

Such insects were observed feeding on leaves of *R. communis* plants, and even though some species have been reported as pests of *R. communis* in other countries, most of them cause no considerable damage. However, they have the potential of becoming pests of *R. communis* if it is cultivated as a monoculture or, *R. communis* could be a host plant for important pests as the invasive ambrosia beetle *Euwallacea* sp. (Coleoptera: Curculionidae) (Boland 2016; Egonyu et al. 2017). Among these potential pests are insect and mite species of various families of Lepidoptera, Hemiptera, Orthoptera, and others (Table 2).

### Pollinator insects and floral visitors in *R. communis*

*Ricinus communis* is a monoecious cross-pollinating plant, cultivated as a hybrid in India, Brazil, China, and other countries because they produce better yields than pure lines or varieties (Moll et al. 1962; Birchler et al. 2003; Reif et al. 2007). Several studies demonstrate that certain species of pollinator insects may improve seed production of *R. communis*. For example, it is mentioned that *Apis mellifera* (L., 1758) (Hymenoptera: Apidae) contributes to increasing *R. communis* crop productivity by incrementing fruit numbers as well as oil content in seeds (Freitas and Cruz 2010).

Among the pollinator insects of *R. communis*, *A. mellifera* is recorded as the main pollinating insect. It is also mentioned that this insect feeds on the nectar produced by the plant’s extrafloral nectar glands (Rizzardo et al. 2012; Waters et al. 2014). *A. mellifera* is the principal pollinating insect of *R. communis*, and laboratory work has demonstrated that the pollen of this plant reduces bee survival (Junior et al. 2011). According to these studies, expansion of *R. communis* as a crop in the semi-arid region of Brazil for biodiesel production represents a risk for the native and domestic bees used for honey production.

As shown in Table 3, a total of 36 species of pollinator insects and floral visitors of non-cultivated plants of *R. communis* is found in the world. These species belong to four orders and 16 families. 25% of the species belong
to Lepidoptera (19 %) and Hemiptera (6 %), while 75 % belong to Hymenoptera (67 %) and Diptera (8 %). 55 % of the arthropod species registered in Table 3 are distributed geographically in Asia (33 %) and Africa (22 %), while 45 % are registered in America; no records were found for Europe.

In Mexico, Cameroon, USA, India, and Brazil, entomopathogenic Hymenoptera, as well as several species of Lepidoptera, Diptera, and Hemiptera have been reported to feed on nectaries and flowers of *R. communis*; however, only *A. mellifera* has been reported as a pollinator. Therefore, it is necessary to carry out studies on pollination and floral ecology in order to determine if there are other insect pollinators of *R. communis* that should be protected or may be used to increase crop yield (Table 3).

Some pests can affect pollinators through herbivory. In the case of *R. communis*, Wäckers et al. (2001) showed that plants damaged by larvae of *Spodoptera littoralis* (Boisd., 1833) (Lepidoptera: Noctuidae) increased the total amount of nectar produced by extrafloral nectaries compared to undamaged plants. De Sibio and Rossi (2016) found a similar result for the herbivory of *S. frugiperda* on *R. communis*. The secretion of carbohydrates through extrafloral nectaries is considered an indirect strategy of plant defense because it serves to attract parasitoids and predators (Heil 2008). Unlike floral nectar, extrafloral nectaries do not participate in pollination, however, in plants pollinated by insects, extrafloral nectaries can negatively affect the effectiveness of pollination by distracting pollinators away from floral nectaries or when the ants that are attracted by the nectar attack the floral visitors (Wäckers et al. 2001; Turlings and Wäckers 2004).

### Natural enemies of the pests of *R. communis*

Among the natural enemies of the key pests of cultivated *R. communis*, there are parasitoids, predators, and entomopathogens such as fungi, bacteria, nematodes, and viruses, which are used as biological control agents or have been found parasitizing, depredating, or naturally infecting some pests of the crop. An extensive list of natural enemies of phytophagous arthropods of *R. communis* grouped by taxa with information of their host or prey and geographical distribution is shown in Table 4; as it can appreciate in this table, the most commonly reported natural enemies in countries like India, Brazil, China, and USA, are *Bacillus* spp., *Trichogramma* spp., *Microplitis* spp., *Telenomus* spp., *Sethorus* spp., and other species attacking pests such as *A. janata*, *S. litura*, *Anacranga citrinopsis* Dyar, 1927, *S. obliqua*, *Phyllophaga* sp., *Eutetranychus banksi* (McGregor, 1914), *Tetranychus picei* McGregor, 1950, *Zaniathrips ricini* Bhatti, 1967, and other species. Table 4 shows a total of 61

| Order  | Family               | Species                                      | Geographical distribution | References |
|--------|----------------------|----------------------------------------------|----------------------------|------------|
| Coleoptera | Bostrichidae          | *Prostephanus truncatus* (Horn, 1878)         | Mexico                     | Bourne-Murrieta et al. (2014) |
|         | Chrysomelidae         | *Diabrotica grammee Baly, 1886*              | Puerto Rico                | Woloott (1917) |
|         | Scarabaeidae          | *Leptodores sinicus* Burmeister, 1855 (= *Adoretas sinicus* Burmeister, 1855) | USA                        | McQuate y Jameson (2011) |
|         | Scolytidae            | *Euraclia sp.*                               | Uganda and USA             | Boland (2016), Egonyu et al. (2017) |
| Hemiptera | Aleyrodidae           | *Aleuridicus dispersus* Russell, 1965         | Cape Verde                 | Monteiro et al. (2005) |
| Cicadellidae | *Amrasca (Amrasca) giganta* (Ishida, 1913)  |                                             | India                      | Jacob et al. (2000) |
| Cicadellidae | *Emoasca (Emoasca) kerri* Singh-Pruthi, 1940 (= *Emoasca kerri Pruthi*, 1940) |                                             | India, Singh et al. (1991), Jacob et al. (2000) |
|         | *Emoasca (Emoasca) motii* Singh-Pruthi, 1940 (= *Emoasca motii Singh-Pruthi*, 1940) |                                             | India                      | Jacob et al. (2000) |
| Flatidae | *Metacra pruinosa* (Say, 1830) |                                             | Spain                      | Pons et al. (2002) |
| Miridae  | *Apolygus lucorum* (Meyer-Dür, 1843) |                                             | China                      | Lu et al. (2010) |
| Lepidoptera | Arctiidae             | *Amstacella moorei* Butler, 1876             | India                      | Singh et al. (1989) |
| Cosmopterigidae | *Pyrodexes rileyi* (Walsingham, 1882) (= *Sathrobota rileyi* Walsingham, 1882) |                                             | Egypt                      | Oshaibah et al. (1986) |
| Lymantriidae | *Euproctis lunata* Walker, 1855 |                                             | Bangladesh                 | Islam et al. (1988) |
| Noctuidae | *Agrotis ipsilon* (Hüfnagel, 1766) |                                             | Egypt                      | Younis (1992) |
| Pyralidae | *Phycita diaphana* (Staudinger, 1870) |                                             | Spain                      | Huertas Dionisio (2002), Ylla et al. (2008) |
| Tortricidae | *Thaumatomitabia lecotreata* (Meyrick, 1913) (= *Cryptophlebia lecotreata* Meyrick, 1913) |                                             | South Africa               | Kirkman and Moore (2007) |
| Orthoptera | Acrididae             | *Melanoplus differentialis* (Thomas, 1865) | USA                        | Spain (1940) |
| Acarina  | Tetranychidae         | *Eutetranychus banksi* (McGregor, 1914) | USA                        | McGregor (1914) |
| Acarina  | Tetranychidae         | *Eutetranychus orientalis* (Klein, 1936) | Palestine and Egypt        | Klein (1936) |
| Acarina  | Tetranychidae         | *Tetranychus grovesi* Banks, 1900 (= *Tetranychus quinquenychus* McGregor, 1914) | USA                        | McGregor (1914) |
natural enemies of phytophagous insects of *R. communis*. Three species are bacteria belonging to the same genus; four species are nematodes of different genera; two species are fungi of different genera; two reports are viruses; 36 species are parasitoids of eight families of Hymenoptera and one family of Diptera; and 14 species are predators of six different families and order 74 % of the species is distributed geographically in Asia, 24 % in America, 2 % in Africa and 0 % in Europe.

An example of natural enemies of pest of *R. communis* is presented by Basappa (2009). According to this author, parasitoids, insect predators, spiders, insectivorous birds and some microbial organisms are important natural enemies of the pest complex of *R. communis* ecosystem in India. In the case of *A. janata*, *Trichogramma chilonis* Ishii, 1941, *Trichogramma achaeae* Nagaraja and Nagarkatti, 1970, *Telenomus* sp. and *Trissolcus* sp. were recorded from eggs; *Microplitis maculipennis* (Szépligeti, 1900), *Euplectrus*...
Table 4. Natural enemies of phytophagous arthropods of *Ricinus communis*.

| Species | Host and/or prey | Geographical distribution | References |
|---------|----------------|---------------------------|------------|
| **Entomopathogens** | | | |
| Bacillus thuringiensis var. kurstaki (Berliner, 1915) | Larvae of *Achaea janata* | India | Vimala Devi and Sudhakar (2006) |
| Bacillus cereus (Manson, Pollock & Tridgell, 1954) | Larvae of *Achaea janata* | India | Kattegoudar et al. (1994) |
| Bacillus popilliae Dutky, 1940 | Larvae of Phyllophaga sp. | Colombia | Saldarriaga Cardona et al. (2011) |
| **Nematodes** | | | |
| Hexamermis dactylocercus Poinar and Linares, 1985 | Larvae of *Amsacta albistriga* | India | Prabhakar et al. (2010) |
| Steinernema carpocapsae (Weiser, 1955) | Larvae of *Spodoptera litura* | India | Raveendranath et al. (2008) |
| Heterorhabditis indica Poinar, Karunaka y David, 1992 | Larvae of *Spodoptera litura* | India | Raveendranath et al. (2008) |
| Mermis sp. | Larvae of *Achaea janata* | India | Sujatha et al. (2011) |
| **Fungi** | | | |
| Metarhizium rileyi (Farl.) Kepler, S.A.Rehner & Humber, 2014 [= Nomuraea rileyi (Farlow) Samson, 1974] | Larvae of *Spodoptera litura* | India and USA | Mau and Kessing (2007) |
| Beauveria bassiana (Balsamo) Vuillemin, 1912 | Larvae of *Achaea janata* and *Cogenethes punctiferalis* | India | Duraimurugan et al. (2015) |
| Nucleopolyhedrovirus | Larvae of *Spodoptera litura* | India | Basappa (2009) |
| Granulovirus | Larvae of *Achaea janata* and *Spodoptera litura* | India | Naveen Kumar et al. (2013) |
| **Parasitoids** | | | |
| INSECTA | | | |
| **Hymenoptera** | | | |
| Aphelinidae | | | |
| Encarsia formosa Gahan, 1924 | Nymphs of *Trialeurodes ricini* | China | Wang et al. (2016) |
| Braconidae | | | |
| Habrobracon hebetor (Say, 1836) | Larvae of *Cogenethes punctiferalis* | India | Basappa (2003) |
| Apanteles hyposidrae Wilkinson, 1928 | Larvae of *Achaea janata* | India | Basappa (2009) |
| Apanteles ricini Bhatnagar, 1948 | Larvae of *Cogenethes punctiferalis* | India | Basappa (2003) |
| Cotesia flavipes (Cameron, 1891) [Apanteles flavipes (Cameron, 1891)] | Larvae of *Spilosoma obliqua* and *Spodoptera litura* | India | Yadav et al. (2010); Basappa (2009) |
| Glyptapanteles dalosoma de Santis, 1987 | Larvae of *Anacraga citrinopsis* | Brazil | Lourenço et al. (1989) |
| Microplitis (= Microgaster) rufiventris Kokujev, 1914 | Larvae of *Spodoptera litoralis* | Egypt | Shalaby et al. (1988) |
| Microplitis maculipennis (Szepillegti, 1900) (= Microplitis ophiusae Aiyar, 1921) | Larvae of *Achaea janata* | India | Suganthy (2010); Naik et al. (2010) |
| Chalcididae | | | |
| Brachymeria euploeae (Westwood, 1837) | Pupae of *Cogenethes punctiferalis* | India | Sujatha et al. (2011) |
| Eulophidae | | | |
| Cerausimus menes (Walker, 1839) | 2º instar nymph of *Zaniothrips ricini* | India | Daniel et al. (1983) |
| Euplectrus maternus Bhatnagar, 1952 | Larva of *Achaea janata* | India | Basappa (2009) |
| Tetrastrichus howardi (Olliff, 1893) (= *Tetrastrichus ayyari* Rohwer, 1921) | Pupae of *Spodoptera litura* and *Achaea janata* | India | Basappa (2009) |
| Trichosphus pseudoviviporus Ferrière, 1930 | Pupae of *Spodoptera litura* and *Achaea janata* | India | Basappa (2009) |
| Trichogrammatidae | | | |
| Trichogramma achaeae Nagaraja and Nagarkatti, 1970 | Eggs of *Achaea janata* | India | Basappa (2009) |
| Trichogramma chilonis Ishii, 1941 | Eggs of *Achaea janata* and *Spodoptera litura* | India | Singh et al. (2008); Suganthy (2010); Naik et al. (2010) |
| Trichogramma minutum Riley, 1879 | Eggs of *Achaea janata* | USA | Mau and Kessing (2007) |
| Trichogramma australicum Girault, 1912 | Eggs of *Achaea janata* | China | Hua (1984) |
| Trichogramma dendrolimi Matsumura, 1926 | Eggs of *Achaea janata* | China | Hua (1984) |
| Trichogramma pretiosum Riley, 1879 | Eggs of *S. cosmioides* | Brazil | Cabezas et al. (2013) |
| Trichogramma evanescens Westwood, 1833 | Eggs of *Achaea janata* | India | Basappa (2009) |
**Scelionidae**

- *Telenomus remus* Nixon, 1937
  - Eggs of *Spodoptera litura*, *Spodoptera cosmioides* and *Spodoptera frugiperda*
  - India: *Satyanarayana et al.* (2005); *Pomari et al.* (2013)
  - USA: *Mau and Kessing* (2007)

- *Telenomus proditor* Nixon, 1937
  - Eggs of *Lepidoptera*
  - India: *Basappa* (2009)

- *Telenomus sp.*
  - Eggs of *Achaea janata*
  - India: *Basappa* (2009)

- *Trissolcus sp.*
  - Eggs of *Achaea janata*

**Vespidae**

- *Polistes sp.*
  - Larvae of *Phyllophaga sp.*, *Agrotis sp.* and *Spodoptera spp.*
  - Costa Rica: *Anónimo* (1991)

**Ichneumonidae**

- *Campoletis chlorideae* Uchida, 1957
  - Larvae of *Spodoptera litura*
  - India: *Satyanarayana et al.* (2005)

- *Charops obtusus* Morley, 1913
  - Larvae of *Spilosoma obliqua* and *Achaea janata*
  - India: *Basappa* (2009)

- *Hyposoter exiguae* (Viereck, 1912)
  - Larvae of *Achaea janata*
  - USA: *Mau and Kessing* (2007)

- *Diadegma ricini* Row & Kurian, 1950
  - Larvae of *Cogenethes punctiferalis*
  - India: *Basappa* (2003)

- *Theronia sp.*
  - Larvae of *Cogenethes punctiferalis*
  - India: *Basappa* (2003)

- *Iadromas monterai* (Costa Lima, 1948)
  - Larvae of *Anacraga citrinopsis*
  - Brazil: *Lourenção et al.* (1989)

**Tachinidae**

- *Palexorista parachrysops* Bezzi, 1925
  - Larvae of *Cogenethes punctiferalis*
  - India: *Kalra* (1984)

- *Eucelatoria armigera* (Coquillett, 1889)
  - Larvae and pupae of *Achaea janata*
  - USA: *Mau and Kessing* (2007)

- *Chaetogaedia monticola* (Bigot, 1887)
  - Larvae and pupae of *Achaea janata*
  - USA: *Mau and Kessing* (2007)

**Predators**

**Coleoptera**

**Carabidae**

- *Calosoma sp.*
  - Larvae of *Phyllophaga sp.*, *Agrotis sp.* and *Spodoptera spp.*
  - Costa Rica: *Anónimo* (1991)

**Coccinellidae**

- *Cheilomenes sexmaculata* (Fabricius, 1781)
  - Eggs larvae of *Achaea janata* and *Spodoptera litura*
  - India: *Basappa* (2009)

- *Micraspis cardoni* (Weise, 1892)
  - Zaniothrips ricini
  - Palestine and Egypt: *Klein* (1936)

- *Scymnus sp.*
  - *Eutetranychus orientalis*
  - USA: *McGregor* (1914)

- *Stethorus sp.*
  - *Eutetranychus banksi*
  - USA: *Lui and Lui* (1986)

- *Stethorus histrio* Chazeau, 1974
  - *Tetranychus urticae*
  - Chile: *Aguilera* (1987)

**Hemiptera**

**Pentatomidae**

- *Eoanticleona furcellata* (Wolff, 1811)
  - *Achaea janata*
  - India: *Rao* (1977); *Usha Rani* (2009)

**Reduviidae**

- *Rhynocoris kumarii* Ambrose and Livingstone, 1986
  - Eggs larvae of *Achaea janata* and *Spodoptera litura*
  - India: *Basappa* (2009)

**Thysanoptera**

**Aeolothripidae**

- *Frankliniorthris megalops* (Trybom, 1912)
  - Zaniothrips ricini
  - India: *Daniel et al.* (1983)

- *Mymarothrisc garuda* Ramakrishna and Margabandhu, 1931
  - Zaniothrips ricini
  - India: *Daniel et al.* (1983)

**Neuroptera**

**Chrysopidae**

- *Chrysoperla carnea* (Stephens, 1836)
  - *Tetranychus urticae*
  - India: *Rajasekhar et al.* (1999)

- *Chrysoperla sp.*
  - Eggs and larvae of *Achaea janata* and *Spodoptera litura*
  - India: *Basappa* (2009)

**Mantodea**

**Mantidae**

- *Haldwania lilliputana* Beier, 1930
  - Zaniothrips ricini
  - India: *Daniel et al.* (1983)

**ARACHNIDA / Acari**

**Phytoseiidae**

- *Sciulus sp.*
  - Eutetranychus banksi
  - USA: *McGregor* (1914)
Pest management methods used to control the principal arthropod pests of *R. communis* include cultural, genetic, ethological, biological, and chemical control.

Cultural control is the use of agronomical practices designed to reduce the presence of pests in crops of *R. communis*. Intercropping is a type of cultural control recommended to diminish the damage caused by insect pests in *R. communis*. Srinivasa Rao et al. (2012) found that plants of *Cynamopsis tetragonoloba* (L.) Taub., 1891, *Vigna unguiculata* (L.) Walp., 1845, *Vigna mungo* (L.) Hepper, 1956, and *Arachis hypogaea* L., 1753, intercropped with *R. communis* in a 1:2 proportion, decreased the incidence of insect pests such as *A. janata*, *E. flavescens*, and *C. punctiferalis*. Moreover, a more considerable presence of natural enemies of these pests was observed in these intercropping systems. Patel and Patel (2009) recommended intercropping *R. communis* with *Vigna radiata* (L.) Wilczek, 1952, *Sesamum indicum* L., 1753, *Vigna aconitifolia* (Jacq.) Marechal, 1969, and *V. unguiculata*, to reduce damage by *C. punctiferalis*. When *R. communis* was monocropped, *C. punctiferalis* caused 53 % damage, but when intercropped with the above-mentioned species, the damage was between 35 and 53 %. Sowing date is another cultural method for reducing damage and the presence of pests. Salihu et al. (2014) suggest that the correct time for planting *R. communis* crop must be related to the rainy season, which is more important than any other pest control measure in Africa, since the rains decrease the presence of certain pests.

Genetic control includes the use of cultivars resistant to insect pests, however, according to Singh et al. (2015), breeding *R. communis* is complicated by limited sources of pest resistance. In India, there are *R. communis* varieties that are tolerant or resistant to attack by pests of greater economic importance, such as *E. flavescens*, *T. ricini*, *S. litura*, *A. janata*, *C. punctiferalis*, and *L. trifolioli* (Anjani et al. 2010; Anjani 2012). Resistant or tolerant plants have high oil content (between 40 and 49 %) and yields that oscillate between 540 and 1,580 kg/ha (Lavanya et al. 2012). It is mentioned that the cultivars having purple leaves are resistant to the attack of *L. trifolioli*, while those with green leaves are

Pest management of phytophagous arthropods in *R. communis*

Research is being carried out on the use of transgenic plants of *R. communis*. In India, two transgenic varieties of *R. communis*, Jyothi and VP1, developed by genetic engineering induce *A. janata* mortality above 88 % due to the *Bacillus thuringiensis* gene CryAb (Malathi et al. 2006).

A little explored method for monitoring and massive trapping of *R. communis* pests has been the use of pheromones, kairomonal attractants and light traps. In India, the pheromone compounds of some pests of economic importance have been identified and used for monitoring and massive trapping of *C. punctiferalis*, *S. litura*, *A. janata*, and *S. obliqua* (Cork and Hall 1998). In this country, an important prerequisite for successful management of *S. litura*, the most destructive insect pest of *R. communis* damaging the crop from July-October during the south-west monsoon (kharif season), has been the implementation of an intensive monitoring program of *S. litura* population using sex pheromone traps (Satyagopal et al. 2014). Setting twelve traps baited with pheromone compounds per hectare for massive trapping of *S. litura* is recommended (Nandagopal and Rathod 2007; Raghavaiah 2011). In Brazil, researchers are now taking the first steps toward identifying the pheromone compounds of *C. gossypiella* (Fregadelli et al. 2012) with the aim of developing a commercial pheromone. In India, the kairomonal compounds of the most destructive lepidopteran insect pest of *R. communis*, *S. litura*, *A. janata*, and *C. punctiferalis* have been identified for trapping. In field experiment, water trap baited with phenyl acetaldehyde + 2-phenyl ethanol recorded significantly higher moth catches of *S. litura* (6.8 moths/trap/wk) and *C. punctiferalis* (5.8 moths/trap/wk) (Duraimurugan et al. 2017). Recently, Duraimurugan and Alivelu (2018), determined the relationship of pheromone trap catches corresponding to the economic threshold level of 25 % defoliation of *S. litura* on *R. communis*, which was estimated to be 81.4 moths/trap/week. Light traps using ultraviolet black-blue spectrum have also been suggested to capture *Phyllophaga* sp. adults as a measure of ethological control (Cardona et al. 2011).

Biological control (spraying entomopathogenic microorganisms and releasing entomophagous insects) has been implemented in the control of key *R. communis* pests in countries such as India and Colombia. In India, for example, parasitism rates between 10.4 and 28.7 % of *M. maculipennis* and *Cotesia* sp. were recorded on larvae of *A. janata* and *S.
In Colombia, Saldarriaga Cardona et al. (2011) recommended application of baits poisoned with carbaryl at a dose of 2 to 3 g/L for the control of *A. ipsilon* and *S. frugiperda*; the same authors recommended application of liquid chlorpyrifos at the base of the plants at a dose of 1.5 - 2.0 cc/L.

The most recommendable strategy of *R. communis* pest control is Integrated Pest Management (IPM). Most of the IPM programs have been directed against key pests of *R. communis*, such as *S. litura*, *C. punctiferalis*, and *A. janata* (Prabhakar et al. 2003; Singh et al. 2006; Basappa 2009). In India, the growers increased seed production of *R. communis* up to 28 %, by implementing IPM programs with insecticides, crop rotation, insect traps, application of neem extract, and intercropping (Basappa 2007). The results of research in India demonstrate that IPM is an efficient strategy for the control of *A. janata* and *S. litura*, two of the key pests of *R. communis*. It is possible to decrease populations of these pests by using the recommended IPM program, which includes the use of bird perches for predatory birds to rest and to look for preys, foliar applications of 5 % neem seed extracts, biological insecticide consisting of nuclear polyhedrosis virus (*S. litura* NPV 100 LE/ha), monocrotophos at 0.5 %, and manual removal of larvae (Suganth 2010). The pest control effectiveness of carbaryl 50W 0.2 %, endosulfan 35 EC 0.05 %, triazophos 40 EC 0.05 %, spinosad 45 SC 0.018 %, fipronil SSC 0.01 %, extract of neem seeds 5 % (weight/volume), *B. thuringiensis* 0.1 %, and a control without applying the dose of 500 L/ha, was evaluated under field conditions 30 and 45 days after establishing a plantation of a *R. communis* variety susceptible to leafminer *L. trilofi*. The results showed that the least damage (lowest number of insect mines) was found when spinosad and triazophos were applied and, at the same time, the best yield was obtained with both treatments (883 and 835 kg seed/ha, respectively) (Akashe et al. 2009). On the other hand, natural enemy impact has been proven to be greatest at sites adopting biointensive IPM (BIPM); par example, studies conducted by Basappa (2009) shown that BIPM modules were safer to *A. janata* eggs (*T. chilonis*) and larvae (*M. maculipennis*) parasitoids with 16.1 and 66.1 % average field parasitism, compared to chemical pesticide intensive integrated pest management modules with 6.9 and 21.2 % parasitism, respectively.

**Conclusions**

There is a wide range of arthropods that damage *R. communis* in different parts of the world where this plant is cultivated; many of these are considered pests of economic importance. Likewise, they are reports of a great variety of natural enemies, which have been used in biological control programs. According to the coevolutive hypothesis, it was found that the greatest richness and abundance of arthropods associated with *R. communis* is in Asia and Africa, considered as the center of origin of this plant. Most phytophagous arthropods feed on leaves. The natural enemies with more abundance and richness are the parasitoids that mostly attack the larvae of phytophagous arthropods. With respect to pollinators, *A. mellifera* is the principal pollinating insect, however, more research on pollination and floral ecology in *R. communis* is needed, in order to determine what other floral visitors may act as pollinators, and how they can be protected or manipulated to increase crop yield. The pest management...
programs of phytophagous arthropods of *R. communis* must be directed toward promoting and preserving natural enemies and pollinating insects by means of environment-friendly pest management techniques, for which use of wide-spectrum insecticides must be avoided.

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**Author contribution**

Guillermo López-Guillén, Jaime Gómez Ruiz and Juan F. Barrera defined the content of the study, conducted the literature review and wrote the manuscript. All authors read and approved the final manuscript.