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ECOLOGY

Lema quadrivittata (Coleoptera: Chrysomelidae): morphological description and its use as a biological control agent of *Commelina benghalensis* L.

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ABSTRACT. Weed infestation is one of the main challenges in crop management. The environmental, economic and social impacts attributed to pesticides lead to the search for new sustainable possibilities for the management of these plants, especially for *Commelina benghalensis,* which is considered one of the worst weeds in the world. This work consists of a description of the external morphology of the insect *Lema quadrivittata* and its potential use as a biological regulator of *C. benghalensis*, a weed plant, which suffers effective injuries by this natural enemy. Plots with high infestation of *C. benghalensis* were inspected to find plant damage and its possible causes. Upon identifying the occurrence of *L. quadrivittata*, it was decided to cultivate *C. benghalensis* in a greenhouse in order to observe the interaction of the insect with the plant. In this sense, during the study, we identified the insect *L. quadrivittata* by describing its morphological structures of adults and larvae and its interaction with *C. benghalensis* as a biological control agent. This work is an approach to the attack of *L. quadrivittata* on *C. benghalensis*. Future studies are needed to indicate the potential of this insect as a biological regulator of this weed from the knowledge of its behavior, morphology and evaluations of potential hosts.

Keywords: weed control; Integrated weed management; Environmentally-friendly pest control.

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Introduction

By competing mainly for water, light, nutrients and space, weed infestation is one of the main problems in agricultural crops, with negative impacts on the reduction of yield and quality of harvested products (Movaghatian & Khorsandib, 2014; Dass et al., 2017).

Found in several regions of Brazil and the world, *Commelina benghalensis* is considered a challenging weed in agriculture, because in addition to causing losses in crops of great economic importance such as citrus, coffee, soybeans and corn, its control is difficult and costly (Hassemer, 2019).

Commelina benghalensis belongs to the Commelinaceae family, a family of monocots very variable and ecologically diverse, ranging from miniature and robust herbs to climbing plants. Plants in this family are herbaceous plants, annual or perennial, succulent and sparsely hairy, with tri-flowers, petals and sepals, of different colors. Its reproduction is carried out sexually by seeds, and asexual through its fibrous, thin or thick roots that arise from the nodes that come in contact with the soil. In addition, it is the only species of the genus that presents cleistogamous flowers, which are self-pollinated underground (Faden, 1998; Xu & Chang, 2017). In Brazil, the Commelinaceae family has 116 species and 15 genera (Aona, Pellegrini, & Amaral, 2020).

The specie *C. benghalensis* occupies a prominent place among the species of weeds that cause greater damage to crops, due to its perennial habit, efficient reproduction, high ability to survive in adverse conditions and tolerance to a range of herbicides, reasons why it is considered one of the worst weed plants of the world (Cury et al., 2012; Hassemer, 2018).

Among the weed control measures, chemical control is widely used and widespread, however this management practice in addition to promoting selection pressure, which results in herbicide-resistant weed populations, causes environmental pollution, and many molecules of these products are carcinogenic to human health (Mudhoo, Bhatnagar, Rantalankila, Srivastava, & Sillanpää, 2019; Meena et al., 2020).

In this sense, weed management through biological control becomes an alternative to the use of chemicals in agriculture. The groups of most studied organisms and used as weed biocontrol agents are mainly phytophagous insects and phytopathogenic fungi and, to a lesser extent, phytopathogenic mites, bacteria and viruses (Machado, Mochi, & Monteiro, 2013; Moraes, Monteiro, Machado, Barbosa, & Mochi, 2014).

Phytophagous insects used as biological control agents for spontaneous plants can consume leaves, roots or prey on seeds, limiting and weakening them. Weakened plants have less competitive potential with other species present in their agroecosystem, since herbivory at high intensities can cause problems for the attacked species due to the reduction of leaf area and reduction of the photosynthesis process, leading to a decrease in development, tending to cause high loss of crop yield (Martin & Chari, 2020).

The study of phytophagous insects with potential use in the biological control of weed plant is of great importance in the sustainable alternatives of controlling and cost reduction with herbicides given that, globally 115 target weed species (65.7% of all weeds targeted) are under some degree of control through the action of biological control agents, including phytophagous insects (Schwarzländer, Hinz, Winston, & Day, 2018).

Only three species of herbivorous insects are known to biologically control species of the Commelinaceae Family, among them: *Lema* (*Neolema*) *dorsalis* (= *L. orbignyi*) and *Lema* (*Neolema*) *quadrivittata* (both Chrysomelidae: Criocerinae) and *Liriomyza commelinae* (Diptera: Agromyzidae) (Defagó, Fenoglio, & Salvo, 2010). Therefore, the study and knowledge of these phytophagous insects in this family weed of difficult control is essential.

This work consists of a morphological description of structures of *Lema quadrivittata* adults and larvae and its interaction with *C. benghalensis* as a biological control agent. It's about an approach to the attack of *L. quadrivittata* on *C. benghalensis*.

Material and methods

The work was carried out in the experimental area (20°46'2.8" south latitude and 41°27'39.2" west longitude) of the *Universidade Federal do Espírito Santo* (UFES), Alegre, Brazil.

Plots with high infestation of *C. benghalensis* were inspected to find plant damage and its possible causes. Upon identifying the occurrence of *L. quadrivittata*, it was decided to cultivate *C. benghalensis* in a greenhouse in order to observe the interaction of the insect with the plant.

Branches of adult plants whose leaves contained mines and larvae were collected. These branches were divided into stem sections with an average size of 15 cm and three buds, which were previously washed with water and disinfected with a 0.0038 mL L-1 sodium hypochlorite solution for 5 minutes. These plants were kept in a container with water until planting.

During planting, one hundred cuttings were placed individually in plastic pots with a capacity of 1L spaced 0.2 m x 0.2 m and kept on benches located 70 cm from the ground in the greenhouse with a cover made of translucent polypropylene material.

The pots were filled with soil from the area and presented the following values in the chemical and physical analysis: pH in the water 6.43; 5.22 mg dm-3 of P (Mehlich-1); 92 mg dm-3 K; 2.99 cmol dm-3 Ca; 0.90 cmolc dm-3 Mg; 0.00 cmol dm-3 of Al; 4.13 cmolc dm-3 sum of bases; 4.13 cmolc dm-3 effective CTC; 8.33 cmol dm-3 CTC at pH 7.0; 49.51% base saturation; 0.00% Aluminum Saturation; 42% coarse sand, 16% fine sand, 7% silt and 35% clay. The textural classification of the soil was considered clayey. There was no need for soil correction for the planting of *C. benghalensis*. As the plants grew and developed, beetles began to appear and consume the leaves. Thus, inspections of the aerial part of the plants were carried out weekly.

The beetles were observed feeding on the leaf blade (adults), while in the mesophyll many larvae developed. Adult insects and leaves containing larvae leafminers were collected, cataloged and placed in gerbox containers (10x10x5cm) for identification and characterization of the insect and its lesions.

Leaf mining larvae were kept in the laboratory until they completed their cycle in a 40 x 40 x 40 entomological cage (wood and mesh screen) with leaves of *C. benghalensis* without highlighting the branches as a source of natural food. The temperature and light conditions were controlled, being 25°C and 12-hour photoperiod.

Results

The insect was identified as *L. quadrivittata* (Coleoptera: Chrysomelidae: Criocerinae). These chysomelids show a hypognathic head that fits partially or almost entirely in the prothorax and relatively short antennas, filiform and gradually thickened from the base to the apex (Figure 1). The legs have anterior globular thighs. The jaws are strong, dark brown, with sharp teeth and jaws with palps made up of three segments. They are relatively small, with length ranging from (0.64 to 1.0 mm).

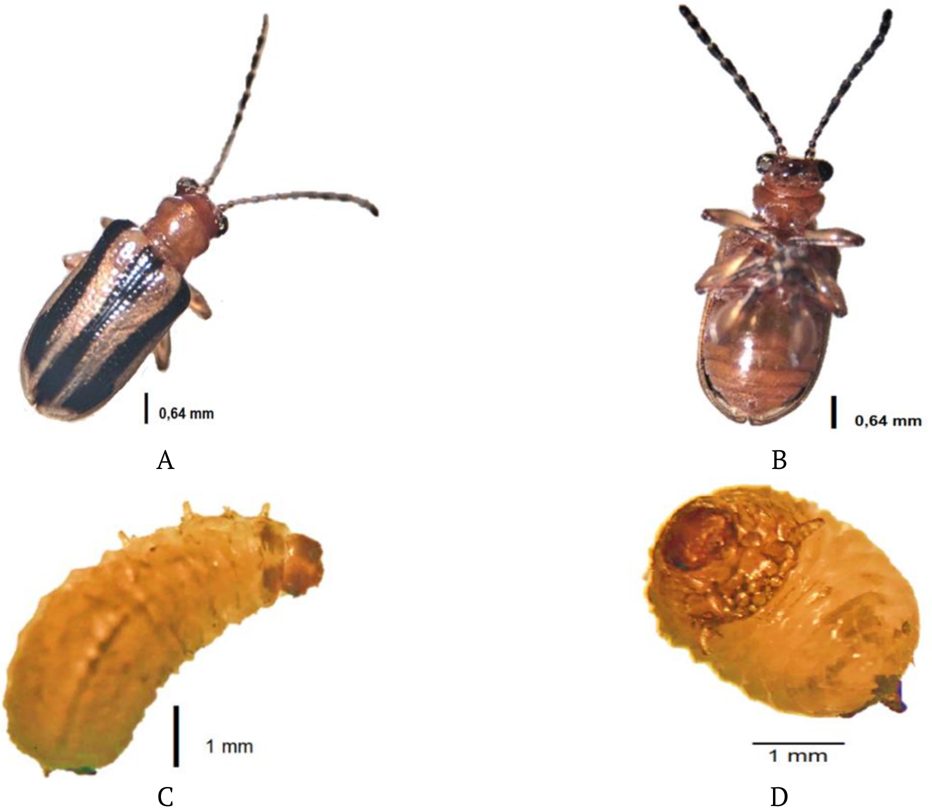

Figure 1. External morphology of *Lema quadrivittata* (Coleoptera: Chrysomelidae) adults (A- dorsal view; B - ventral view) and larvae (C- dorsal view; D - ventral view).

The larva is curved and elongated, whitish in color, with the exception of the cephalic capsule and dorsal region of the pronotum, both yellow-brown in color, with a higher degree of sclerotization than the rest of the body. It has well-developed thoracic legs, suitable for locomotion, with 3 segments (Figure 1).

Commelina benghalensis miner was observed from the thirtieth day of the cycle, in the initial phase of expansion of the first four leaves and throughout the development of the plant until its death. As a result of their feeding, the active photosynthetic area of the plant was reduced, as adults consume the leaf blade in a well-distributed way in the leaves in order to present a lacy aspect (Figure 2). The larvae are housed inside the leaf by making an incision in the leaf epidermis to feed on the mesophile.

Figure 2. Injuries caused by *Lema quadrivittata* on *Commelina benghalensis* (A) Injury of insect adult (B) Injury of larvae.

As a result of their diet, the larvae produce thick linear zigzag mines which, by coalescence, give rise to a pseudo-chamber, visible both at the top and at the bottom, giving the leaf a translucent appearance. Larval droppings were also visualized by small dark spots in the mines opened by the larvae. Two or more larvae shared the same leaf on some occasions, although in most of the leaves analyzed the mines carried a single developing larva within them, and the leaves were abandoned when fully consumed.

Discussion

Insects belonging to the genus Lema portray a wide range of colors such as *Lema bilineata* Germar (Chrysomelidae) (Monti, Ruocco, Grobbelaar, & Pedata, 2020), which damage Cape gooseberry (Physalis peruviana L.) in Brazil (Bischoff et al., 2021). In the dorsal region, the epicranial suture can be differentiated from the cephalic capsule in a 'Y' shape, with short antennae composed of three clubs. On each side of the head, there are six eye spots, four grouped behind the antennae and two below them. The spiracles are circular and open in the pleural region, one in the mesothorax and the remaining eight in each segment of the abdomen. The legs are short, have little hair and are armed with a brown preapical nail in the shape of a hook (Costa Lima, 1955; Riley, Clark, Flowers, & Gilbert, 2002).

The larvae are characterized by having adaptations to live on internal leaves: flattened body and short legs, often separated from each other, pulvil often present in the claw, spirals generally annular (Costa, Vanin, & Casari-Chen, 1988). The pupa and eggs phase were not evidenced in this work, but according to Schmitt (1988) the pupa phase occurs in all cases outside the mine, on a white surface generated by secretions from the larva that would be produced by the mesentery or mouth.

The eggs, on the other hand, have a sub-cylindrical shape with an ocher color that contrasts strongly with the green of the leaf, making them easily recognizable. Despite this detection, the 'mining' feeding habit in the larval forms of the species of the *Lema* genus is unusual, almost all of them being ectophages (Monrós, 1959; Vencl & Aiello 1997).

The knowledge of insects with bioecological potential is extremely important in the ways in which the *C. benghalensis* will be managed, as it is necessary to know the morphology and habit of these insects in nature and their interaction with other plants, especially those of economic interest. Thus, these results are emphatic, as they help to identify promising insects in the development of sustainable agriculture.

Research with biological control of weed plants has advanced in the search for defoliating and phytophages agents (Table 1).

Table 1. Insects with potential to control weeds in agricultural management practices.

Weed plant	Biological control agents	Reference
Senecio jacobaea (Asteraceae)	*Tyria jacobaeae* L. (Lepidoptera: Arctiidae) *Longitarsus jacobeae* (Coleoptera: Chrysomelidae)	Markin and Littlefield (2008)
Eichhornia crassipes (Pontederiaceae)	*Neochentina eichorniae* (Coleoptera: Curculionidae) *Neochentina bruchi* (Coleoptera: Curculionidae) *Eccritotarsus catarinensis* (Heteroptera: Miridae) *Niphograpta albiguttalis* (Lepidoptera: Pyralidae)	Gopalakrishnan, Rajkumar, Sun, Parida, and Venmathi Maran (2011) Coetzee, Byrne, & Hill (2007) Ajuonu, Byrne, and Hill (2009)
Pistia stratiotes (Araceae)	*Neohydronomus affinis* (Coleoptera: Curculionidae) *Spodoptera pectinicornis* (Lepidoptera: Noctuidae)	Diop, Coetzee, and Hill (2010) Rosa, Samharinto, and Lyswiana (2017)
Eleusine indica (Poaceae)	*Geoica lucijiuga* (Homoptera: Aphididae) *Prosapia bicincta* (Homoptera: Cecopdae) *Blissus leucopterus* (Hemiptera: Lygaeidae)	Waterhouse (1994)
Parthenium hysterophorus (Asteraceae)	*Zygogramma bicolorata* (Coleoptera: Chrysomelidae)	Dhileepan (2003)
Alternanthera philoxeroides (Amaranthaceae)	*Agasicles hygrophila* (Coleoptera: Chrysomelidae)	Lu et al. (2010)
Echinochloa crus-galli (Poaceae)	*Dicladispa armigera* (Coleoptera: Chrysomelidae)	Waterhouse (1994)
Cirsium vulgare (Asteraceae)	*Rhinocyllus conicus* (Coleoptera: Curculionidae)	Buntin and Murphy (2018)
Echium plantagineum (Boraginaceae)	*Mogulones larvatus* (Coleoptera: Curculionidae) *Mogulones geographicus* (Coleoptera: Curculionidae)	Sheppard, Smyth, and Swirepik (2001)
Carduus nutans (Asteraceae)	*Rhinocyllus conicus* (Coleoptera: Curculionidae) *Trichosirocalus horridus* (Coleoptera: Curculionidae)	Sezen, Bjornstad, and Shea (2021) Milbrath and Nechols (2004)

Weed plant	Biological control agents	Reference
Hydrilla verticillata (Hydrocharitaceae)	*Hydrellia balciunasi* (Diptera: Ephydridae) *Hydrellia pakistanae* (Diptera: Ephydridae)	Doyle, Grodowitz, Smart, and Owens (2002)
Opuntia stricta (Cactaceae)	*Cactoblastis cactorum* (Lepdoptera: Pyralidae)	Paterson, Manheimmer, and Zimmermann (2019)
Salvinia molesta (Salviniaceae)	*Cyrtobagus salviniae* (Coleoptera: Curculionidae) *Paulinia acuminata* (Orthoptera: Pauliniidae) *Samea multiplicalis* (Lepidoptera, Pyralidae)	Coetzee and Hill (2020)
Persicaria perfoliata (Polygonaceae)	*Rhinoncomimus latipes* (Coleoptera: Curculionidae)	Guo, Li, Guo, and Ding (2011)

Although the practice of biological control in weeds is still considered of secondary importance, it is necessary to emphasize that this method can be integrated with others, such as cultural, mechanical and physical methods in order to replace or even reduce the use of chemical control in agriculture, since the misuse of herbicides has been causing many socio-environmental problems (Galon et al., 2016).

Considering the potential of this insect as a natural weed regulator, it is necessary ecological studies that allow the survival of the insects, through conservation practices as a natural control agent. In addition, it is necessary to increase the knowledge of host plants of this species, in order to predict possible effects of its presence on the agroecosystem.

Conclusion

This work is an approach to the attack of *L. quadrivittata* on *C. benghalensis*. Future studies are needed to indicate the potential of this insect as a biological regulator of this weed from the knowledge of its behavior, morphology and evaluations of potential hosts.

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