Foliar damage by adults of spring weevils (Coleoptera: Curculionoidea) on *Quercus* species from Mediterranean oak forests in the Iberian Peninsula

Patricia Gallardo & Ana M. Cárdenas*

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This paper describes the feeding damage by adults of spring leaf-eating weevils (Coleoptera: Curculionoidea) colonizing the canopies in Mediterranean oak forests in southern Iberian Peninsula. The weevils, captured by the beating tree-top method, belonged to nine species of Curculionoidea. To describe their respective damage, feeding studies were performed by supplying leaves of *Quercus ilex* and *Q. suber* as food. To each beetle, one hardened leaf and one sprout of each oak-plant species were supplied for knowing differences in feeding damage related to age of leaves. The essay was performed with eight replicates for each weevil species. Three of the nine species caught did not feed and eventually died during the experiment. The observations indicate that the most of the species can consume indifferently leaves of *Q. ilex* and *Q. suber* and that hole-feeding and skeletonising were the most common damage.

P. Gallardo, Department of Zoology, Campus Rabanales, E-14071, University of Córdoba, Spain. Phone: +34 957 218604; E-mail: b42gatop@uco.es
*A. M. Cárdenas, Department of Zoology, Campus Rabanales, E-14071, University of Córdoba, Spain; *Corresponding author's e-mail: ba1cataa@uco.es*

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1. Introduction

Several *Quercus* species constitute the predominant vegetation in large areas of Andalusia (southern Iberian Peninsula), the holm oaks (*Q. ilex* subsp. *ballota* L.), the cork oaks (*Q. suber* L.) and the gall oaks (*Q. faginea* Lam.) being the most representative. As with any type of vegetation, a high number of insect herbivores are associated with *Quercus* species (Romanyk & Cadahia 1992) as carpophages, folivores or xylophages (Johnson & Lyon 1976, Foahom 2002). Leaf-eating insects preferentially attack the leaves of vigorous trees instead of individuals in a physiological state of impairment (Dajoz 2001) and food selection is made according to plant species, leaf age or its position on the tree, water content, type of nutrients, concentration of secondary compounds and degree of hardening (in sclerophyllous species) (Gullan & Crauston 2005). These insects play an important role in food chains (Dajoz 2001) and also act as regulators of primary production in forests, helping to stabilize ecosystems over time by lessening variations in primary productivity (Mattson & Addy 1975). Conversely, under certain conditions, several species can become important worldwide forest pests, some of which attack species of *Quercus* (Rexrode 1971).

As the most common insects feeding on

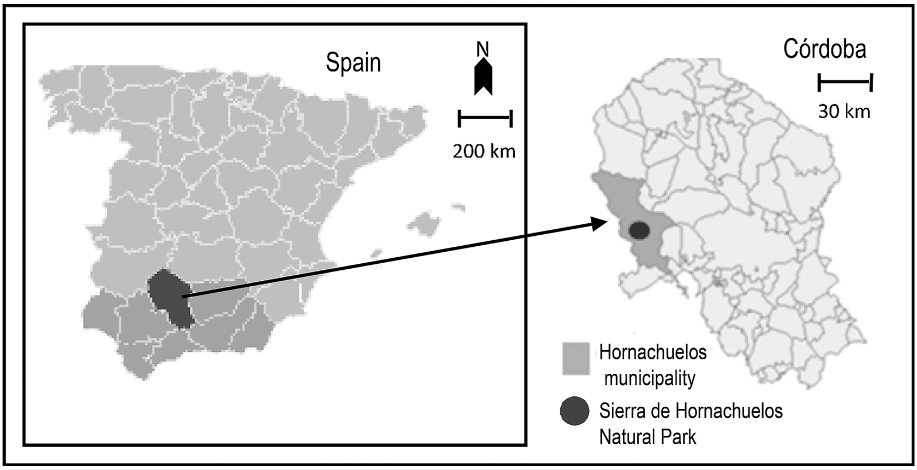

Fig. 1. Location of the research area.

Quercus leaves are Lepidoptera, there are many studies focusing on the characterization and assessment of the damage due to carterpillars (Moore *et al.* 1991, Extremera *et al.* 2004, Southwood *et al.* 2004, Glavendekić & Medarević 2010). However, approximately 2/3 of the individuals of the insect fauna collected on oak forests are Coleoptera (Arahou 2008) and many of them can also significantly damage oaks (Chakali *et al.* 2002, Martínez-Gonzalvo *et al.* 2006). In spite of this, most of the research related to these beetle herbivores are restricted to the study of their spatial-temporal patterns (Arahou *et al.* 1992, Southwood *et al.* 2004, Stejskal 2004) without identifying the type of damage or associating them to the respective plant species. Recognition of the nature of feeding damage is important information for the identification of causal agents (Maclauchlan *et al.* 2009) and in making accurate diagnoses of the impact of the herbivore damage.

This study is a part of a research project devoted to assess the incidence of harmful insects in *Quercus* forests surrounding the Sierra de Hornachuelos Natural Park, in southern Iberian Peninsula. It aims to describe the damage by feeding of adults of spring weevils linked to the oaks in the area.

2. Materials and methods

Sampling was performed in Hornachuelos Natural Park (southern Iberian Peninsula) (Fig. 1), where the landscape is dominated by Mediterranean mixed-sclerophyllous forests. The most representative plant species are *Q. ilex* subsp. *ballota*, *Q. suber*, *Q. faginea*, *Pistacia lentiscus* L., *Asparagus albus* L., *Erica australis* L. and different species of *Cistus* (*C. ladanifer* L., *C. crispus* L., *C. monspeliensis* L., *C. salviifolius* L. and *C. albidus* L.) in the shrub (Pinilla 2006). Detailed information about climate, soil and lithology of the area is available in Gallardo *et al.* (2010).

To collect spring leaf-chewing insects, a weekly sampling was done in 2008, since mid-March to late June (Table 1), just after the *Quercus* species sprout in the southern Iberian Peninsula. The beating tree-top method was used (Basset *et al.* 1997, Extremera *et al.* 2004, Torres-Vila *et al.* 2008). Beating was performed two times, on three positions equidistant around the entire top of each tree in each sampling day. The same haphazardly selected 59 trees (35 holm oaks, 19 cork oaks and 5 gall oaks) were sampled throughout the entire sampling period (Table 1). Overall, the sample is homogeneous in size and constituted by middle-aged trees, ranging between 65 and 100 years, and with a density of ~45 trees/ha (Cárdenas & Gallardo 2012). The difference in the number of sampled trees of the tree species is because of their different respective abundances in the field. Once collected in the field, the insects were placed into plastic containers (diameter 20 cm, height 15 cm), perforated for aeration and provided with some vegetal debris for best accommodation of the beetles. In the laboratory, the weevils were referenced, taxonomi-

Table 1. Sampling date (year 2008) and numbers of sampled trees (*Q. ilex*, *Q. suber* and *Q. faginea*).

Sampling date	*Q. ilex*	*Q. suber*	*Q. faginea*
20/03	4	4	1
07/04	5	0	0
16/04	4	1	0
24/04	3	2	0
30/04	3	1	0
05/05	3	1	0
16/05	2	2	1
20/05	3	1	0
29/05	1	1	2
04/06	2	2	0
12/06	2	2	0
28/06	3	2	1
Total	35	19	5

cally identified, and individually placed into perforated plastic cylinders (diameter 4 cm, height 2.5 cm) at outdoor conditions.

For each collected beetle, one old (hardened) leaf and one sprout of *Q. ilex* subsp. *ballota* or *Q. suber* were supplied as food. Forty-eight hours later, the leaves were removed and replaced. In order to describe the damage, we performed 8 replicates for each weevil species, changing each 48 hour the food source by supplying: first, well-developed leaves of *Q. ilex* subsp. *ballota*; second, young and soft, developing leaves (sprouts) of *Q. ilex* subsp. *ballota*; third, well-developed leaves of *Q. suber*; and, fourth, young and soft, developing leaves (sprouts) of *Q. suber*. Later, a complete repetition of these four steps was made to obtain the 8 replicates. In order to make a detailed description of the damages, photographic monitoring was performed throughout the entire observation time, and the leaf remains were examined with a LEICA GZ 6 microscope (15 × 15.6 magnifications).

3. Results

The sampling provided 263 adult specimens of Coleoptera in two families, Curculionoidea Latreille, 1802 and Chrysomelidae Latreille, 1802. Most of them (94.68%, 249 specimens) were weevils and the rest (5.32%, 14 specimens) were leaf beetles. The weevils belonged to the nine species, which are displayed in Table 2. Most specimens were collected on holm oaks (*Q. ilex* subsp. *ballota*) and cork oaks (*Q. suber*) and, exceptionally, on *Q. faginea* (*Brachyderes* sp. and *Curculio nucum*).

The most common species in the area were *Polydrusus setifrons*, *Coeliodes ruber* and *P. pilosulus* and, to a lesser extent, *Curculio nucum*. A fact worth mentioning is that approximately 80%

Table 2. Number of weevil specimens (Curculionoidea) collected from each *Quercus* species (*Q. ilex* subsp. *ballota*, *Q. suber* and *Q. faginea*), total number (N) and time period (year 2008) during which each species was observed in field.

	Q. i.	*Q. s.*	*Q. f.*	N	Time period
Family Attelabidae					
Subfamily Attelabinae					
Attelabus (*Attelabus*) *nitens* (Scopoli)	8	3	0	11	30/04–16/05
Family Curculionidae					
Subfamily Ceutorhynchinae					
Coeliodes ruber (Marsham)	60	6	0	66	16/04–29/05
Subfamily Entiminae					
Polydrusus (*Chaerodrys*) *setifrons* Jacquelin du Val	64	24	0	88	07/04–29/05
Polydrusus (*Neoeustolus*) *pilosulus* Chevrolat	18	6	0	24	07/04–29/05
Brachyderes (*Brachyderes*) *incanus* (Linnaeus)	8	0	0	8	30/04
Brachyderes sp. Schoenherr	11	0	3	14	16–29/05
Subfamily Curculioninae					
Curculio (*Curculio*) *nucum* Linnaeus	0	17	4	21	16–29/05
Orchestes (*Orchestes*) *pilosus* (Fabricius)	0	9	0	9	29/05
Family Apionidae					
Subfamily Apioninae					
Apion sp. Herbst	0	8	0	8	20/05

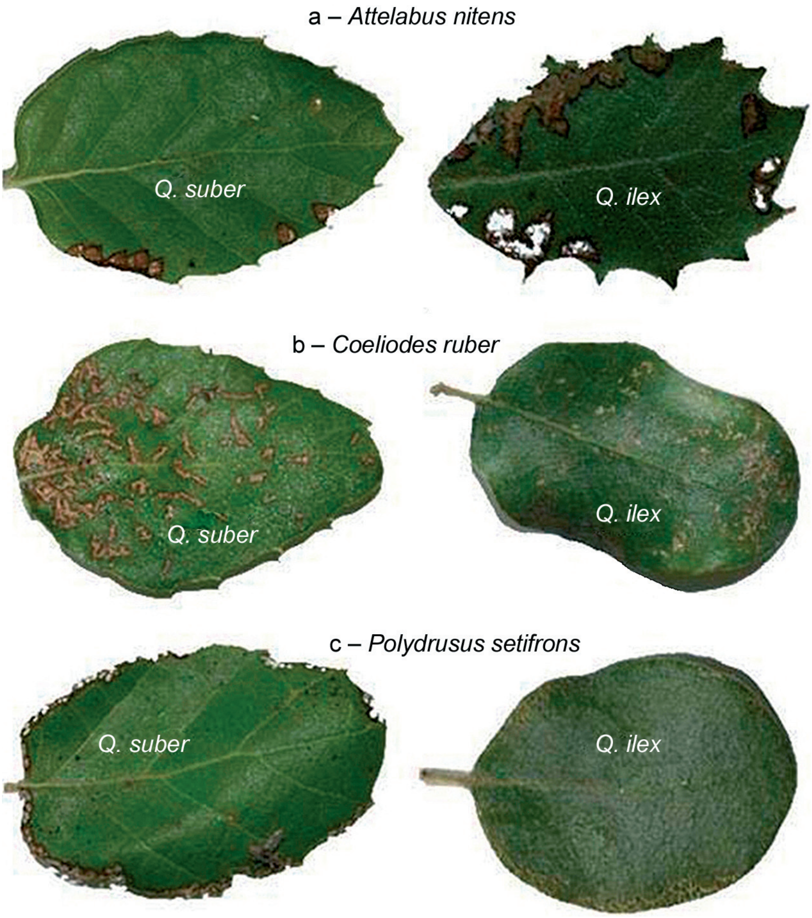

Fig. 2. Damage caused by three curculionoid species on leaves of *Q. suber* and *Q. ilex*. – a. *Attelabus nitens*. – b. *Coeliodes ruber*. – c. *Polydrusus setifrons*.

of the specimens of *C. nucum* were obtained from *Q. suber*, the rest from *Q. faginea*, and none of them were found on *Q. ilex* subsp. *ballota*. Likewise, *Orchestes pilosus* and *Apion* sp. were exclusively captured from *Q. suber* even though *Q. ilex* is the most abundant *Quercus* species in the area.

Regarding the period of activity observed in the field during the sampling phase, the records of the species were concentrated on the interval of April–May (Table 2). Concerning the features of damage caused by the feeding activity of adults of the weevils collected in the current study, no data are available for *C. nucum* or *Apion* sp., which died in the course of the feeding essay. The descriptions of the feeding damage of the rest of the species are given in the next paragraphs.

Attelabus (*Attelabus*) *nitens*
Adults devour a considerable part of the leaves, boring small holes of approximately 5.5 mm in diameter. This damage corresponds to the “window feeding” type because the holes are just located on the upper leaf surface. The insect eats part of this surface, without completely perforating the leaf, leaving intact the lower epidermis and a large part of the trichomas lining it. The injuries of *A. nitens* are usually located on the edge of the leaf. During the feeding essay, this beetle consumed leaves of both species of *Quercus* supplied (Fig. 2a).

Coeliodes ruber
This species feeds over the entire surface of the leaf, leaving small injuries such as pecks, avoiding the upper epidermis and the venation. This damage is something similar to the “window feeding” type. Although the single injuries are small, they are widely spread on the leaf surface. These beetles eat both *Q. ilex* ssp. *ballota* and *Q.*

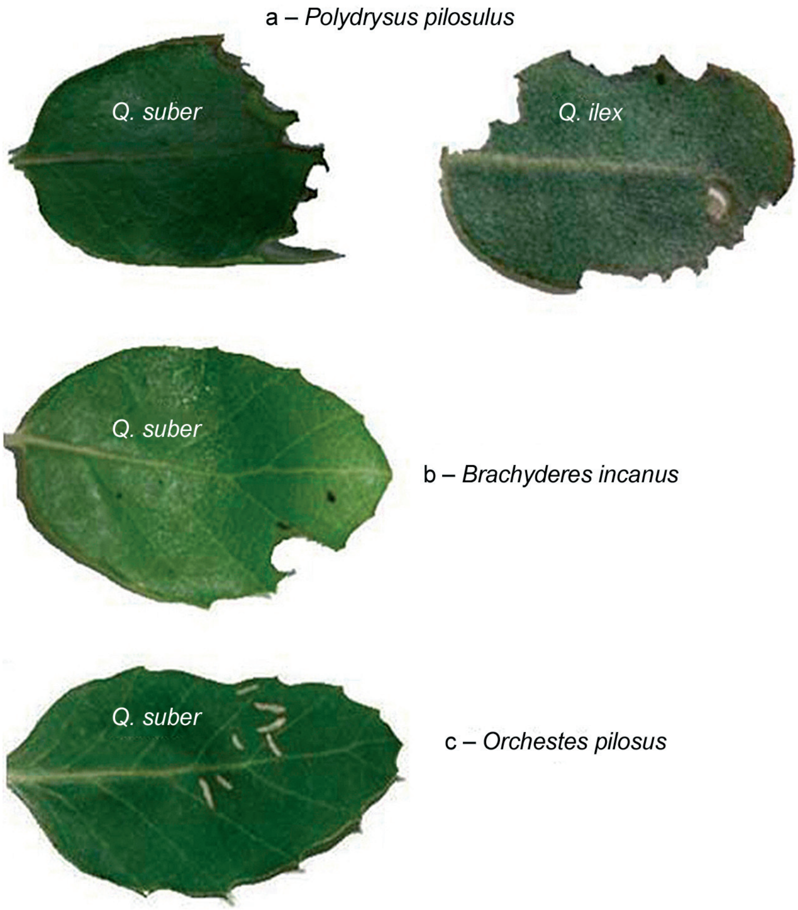

Fig. 3. Damage caused by three curculionoid species on leaves of two *Quercus* species. – a. *Polydrusus pilosulus* on *Q. suber* and *Q. ilex*. – b. *Brachyderes incanus* on *Q. suber*. – c. *Orchestes pilosus* on *Q. suber*.

suber; nevertheless, damage to *Q. suber* is more obvious, because the bites seem to be more elongated, as shown in Fig. 2b.

Polydrusus (*Chaerodrys*) *setifrons*
The insect consumes *Q. ilex* subsp. *ballota* and *Q. suber*, feeding on the edge of the leaf, and causing characteristic injuries that affect most of the margin. It devours the parenchyma, leaving the lower epidermis intact. However, the damage manifests as "holes" when young leaves of *Q. suber* were supplied as food (Fig. 2c). Occasionally, the damage affects the interior of the leaf.

Polydrusus (*Neoeustolus*) *pilosulus*
P. pilosulus feeds on the leaves of both species of *Quercus* by sawing the edges. As the leaves of *Q. suber* are softer than that *Q.ilex* subsp. *ballota*, the injuries on the former are more noticeable and affect a larger part of the foliar surface (Fig. 3a).

Brachyderes incanus
Individuals of this species create large notches along the edge of the leaf and chew from the outside towards the midvein of the leaf (Fig. 3b). These insects can be found on both *Q. ilex* subsp. *ballota* and *Q. suber*, although in this study, they exclusively ate the leaves of *Q. suber*.

Other specimens belonging to the *Brachyderes* genus that could not be identified to species level were also studied to observe the damage that they produce. Similar damage to those that have been described for *B. incanus* were observed. These insects consumed only the leaves of *Q. suber*.

Orchestes (*Orchestes*) *pilosus*
This weevil species performs elongated and scattered injuries throughout the entire leaf surface (Fig. 3c). The damage corresponds to the window feeding type because the injuries were observed

only in the upper epidermis. *Orchestes pilosus* was captured on *Q. suber* as well as on *Q. ilex* subsp. *ballota*, but in our feeding study, it only fed on the leaves of the former.

Regarding the typification of damage, Lanfranco *et al.* (2001) established two types of damage agents: leaf chewers (type I: consumes the entire leaf and type II: feeds just on the leaf margin) and leaf skeletonizers. According to these criteria, three weevil species of the present study are leaf chewers, which may consume the leaf almost completely (type I: *B. incanus* and *Brachyderes* sp.) or may attack only the leaf edges (type II: *P. pilosulus*). The species *A. nitens*, *C. ruber*, *O. pilosus* and *P. setifrons* are skeletonizers, more specifically, they cause damage attributed to "window feeding". This type of damage, or "screening", is generally located at the leaf edge. However, *O. pilosus* and *C. ruber* injure the entire leaf surface. The most extensive injuries were observed in newly sprouted leaves of *Q. suber*.

4. Discussion

Our study area belongs to a peculiar agrosilvopastoral environment, named "dehesa" which is known for its entomological diversity (Ramírez-Hernández *et al.* 2014). It is a transformation of the original Mediterranean habitat. However, spring weevils seem to be scarce there. Accordingly, our samples remained modest in terms of abundance and diversity, but nevertheless our data are in accordance with the data provided by Ugarte (2005) and Martínez-Gonzalvo *et al.* (2006) for other areas in the Iberian Peninsula and Europe (Southwood *et al.* 2004, Stejskal 2004). These results are further evidence of the specificity of these beetles to certain plant species (Southwood *et al.* 2004). This is most probably related to the complexity of their life cycles and that could explain the few number of weevil species feeding on oaks. However, at the lowest latitudes the communities of folivorous insects are more diverse, with more than 50 weevil species recorded in oak forests from the Middle Atlas (Marocco; Arahou 2008).

The adults of the species of this study are phenologically restricted to the period of April to May, coinciding with the data of Martínez Gonzalvo *et al.* (2006) in cork oaks of Valencia (southeastern Spain). This marked seasonality was mentioned by Southwood *et al.* (2004), who indicated, based on the hardness of the leaves, that there is a sequential succession of leaf-eating insects. The chewing insects peaked in May, followed by sucking species, leaf miners and gall formers. In fact, the latest species recorded in our field observations was *O. pilosus*, a leaf-miner, as will be commented below. The climatic conditions in the south of the Iberian Peninsula probably explain the drastic disappearance of the weevils at the end of May. The activity of the adults of these folivorous insects coincides with the period of increased leaf production. Thus, the maximum consumption of adult weevils occurs on the young leaves. From a temporal perspective, Glavendekić and Medarević (2010) include weevils in the group called early-season defoliators, which are species that overwinter in the egg or pupa stages and whose activity is related to early spring.

The most common species in our study area are *P. setifrons*, *C. ruber* and *P. pilosulus* and, to a lesser extent, *C. nucum*. A fact worth mentioning is that approximately 80% of the specimens of *C. nucum* were obtained from *Q. suber*, the rest from *Q. faginea*, and none of them were on *Q. ilex* subsp. *ballota*. Likewise, *Apion* sp. and *O. pilosus* were captured exclusively on *Q. suber*. For the latter weevil species, our field observations and results of the feeding essays are consistent in that *O. pilosus* exclusively fed on leaves of *Q. suber*. Nevertheless, some literature (Ellis 2015) indicates that this species is a more generalist leaf miner, whose larvae feed on *Q. ilex*, *Q. petraea*, Q. *pubescens* or *Q. robur*, the egg-laying taking place in the underside of a vein where a scar is the origin of the mine where the larva feeds and also the pupation occurs (Scherf 1964).

Regarding the type of damage, the detailed observation of the leaf surface after eating of the different weevil species studied showed that approximately half of the weevil species cause injuries corresponding to "free and hole feeding" (according to Lanfranco *et al.* 2001). Depending on the characteristics of the leaf, it may be consumed almost completely (Type 1: *B. incanus* and *Brachyderes* sp.) or may be attacked only close next to the leaf edge (Type 2: *P. pilosulus*). The severity of the attack, as the proportion of leaf area affected, seems to be related to the hardness of the leaf. This is because when the species consume mature leaves of *Q. suber* and *Q. ilex*, the damage is more severe in *Q. suber* (more tender leaves) or in sprouts as in the case of *A. nitens*, *C. ruber* or *P. setifrons*. In addition, the species that behaved as monophagous (i.e. *B. incanus* and *Brachyderes* sp.) only consumed *Q. suber*. The weevil species *A. nitens*, *C. ruber*, *O. pilosus* and *P. setifrons* cause damage of the "skeletonising" type, more specifically, damage attributed to "window feeding". This type of damage is generally located close of the leaf edge; however, when injuries are caused by *O. pilosus*, the entire leaf surface is affected. *A. nitens* belongs to the group of weevils commonly called "leaf-rolling weevil" because the females deposit each egg in leaf tissue, which roll into a sturdy tube, and usually chew through the principal vein of the leaf, after which it withers (Legalov 2007). This behaviour was not observed in our essay. Both the appearance and the extent of damage varied according to the consistency of the leaf. The sprouts and the leaves of *Q. suber* again showed more extensive injuries which is in agreement with Sánchez Ramos *et al.* (2010) who state that the hardness of the leaves is the main factor that determines the degree of defoliation.

We could not obtain information about damage by feeding activity of adults of *C. nucum*. Nonetheless, according to Akça and Tuncer (2005) its adults were observed feeding on leaves, but females also fed on flowers and developing fruits. These authors also specify that damage to leaves made by adults was not serious, but it is noticeable in flowers and immature nuts, being as important as that made during the larval stage.

In this study, caterpillars of moths were not considered. Nevertheless, we explored literature about the features of damage performed by the most recurrent moth species in our studied area for comparison with the damage observed in our feeding trials with adult weevils. For this, we considered the inventory of Lepidoptera from Sierra Morena (Extremera *et al.* 2004) and descriptions of damage caused by the most representative moths species recorded in it (Romanyk & Cadahia 1992), comparing their typology and trying to discern among the injuries caused by each one of these group of insects (weevils and moths). The most abundant Lepidoptera species of our study area (*Dryobotodes eremita* Fabricius, *D. monochroma* Esper, *Catocala nymphagoga* Esper and *Tortrix viridana* Linnaeus; Extremera *et al.* 2004) are considered true defoliators, i.e., they attack the leaves just on the edge. This type of damage agrees with the mandibular morphology of the larvae of these insects (biting-chewing mouthparts; Krenn 2010), while weevils have mouthparts at the end of a distinct snout which is used for boring holes on leaf tissues ("skeletonising" damage; Tara *et al.* 2010, Moon *et al.* 2011).

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