Fig tree xylophagous pest's effects in the Bejaia region (central-north Algeria)

Efectos de la plaga xilófaga de la higuera en la región de Bejaia (Argelia centro-norte)

Efeitos da praga xilófaga da figueira na região de Bejaia (centro-norte da Argélia)

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Abstract

In response to alerts from farmers in Bejaia region (central-north Algeria) about the decline of their fig trees, a survey was conducted between 2019 and 2021 in the main localities known for fig crops. *Hypocryphalus scabricollis* (Eichhoff) (Coleoptera, Curculionidae: Scolytinae) was identified as the causal agent of fig tree decline in the region. This species is reported for the first time in Algeria. Here, a morphological description and main biological traits of this species are given. Distribution of *H. scabricollis* in the Bejaia region is illustred, and an overview of its behaviour, symptoms and damage caused to the host plant, and their potential impact in commercial fig production is discussed. This work aims to provide a preliminary database to the scientific community about this xylophagous pest of fig trees and to alert regional and national policy makers to take it seriously and address emerging bark beetle problems before it is too late.

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Resumen

En respuesta a las alertas de los agricultores de la región de Bejaia (centro-norte de Argelia) sobre el declive de sus higueras, se realizó una encuesta entre 2019 y 2021 en las principales localidades conocidas por los cultivos de higuera. *Hypocryphalus scabricollis* (Eichhoff) (Coleoptera, Curculionidae: Scolytinae) fue identificado como el agente causal del declive de la higuera en la región. Esta especie se reporta por primera vez en Argelia. Aquí se describe la morfología y principales rasgos biológicos de esta especie. Se ilustra la distribución de *H. scabricollis* en la región de Bejaia y se analiza una descripción general de su comportamiento, síntomas y daños causados a la planta hospedera, y su impacto potencial en la producción comercial de higos. Este trabajo tiene como objetivo proporcionar una base de datos preliminar a la comunidad científica sobre esta plaga xilófaga de las higueras y alertar a los responsables políticos regionales y nacionales para que la tomen en serio y aborden los problemas emergentes del escarabajo de la corteza antes de que sea demasiado tarde.

Palabras clave: huertos, *Ficus carica*, escarabajos de corteza, *Hypocryphalus scabricollis*, Argelia.

Resumo

Em resposta aos alertas dos agricultores da região de Bejaia (centro-norte da Argélia) sobre o declínio das suas figueiras, foi realizado um levantamento entre 2019 e 2021 nas principais localidades conhecidas pela cultura do figo. *Hypocryphalus scabricollis* (Eichhoff) (Coleoptera, Curculionidae: Scolytinae) foi identificado como o agente causal do declínio da figueira na região. Esta espécie é relatada pela primeira vez na Argélia. Aqui, uma descrição morfológica e principais características biológicas desta espécie são dadas. A distribuição de *H. scabricollis* na região de Bejaia é ilustrada, e uma visão geral do seu comportamento, sintomas e danos causados à planta hospedeira, e seu potencial impacto na produção comercial de figos é discutida. Este trabalho visa fornecer um banco de dados preliminar para a comunidade científica sobre esta praga xilófaga das figueiras e alertar os formuladores de políticas regionais e nacionais para levá-la a sério e abordar os problemas emergentes do besouro da casca antes que seja tarde demais.

Palavras-chave: Pomares, *Ficus carica*, besouros de casca, *Hypocryphalus scabricollis*, Argélia.

Introduction

The fig tree (*Ficus carica* L.) is a globally important crop that has been cultivated for at least 11,000 years originated in the Middle East (Cutajar and Mifsud, 2017), and is well-adapted to the Mediterranean climate. In Algeria, the vast majority of plantations are located in the Kabylia region which represents 40 % of the national fig orchard (Chouaki *et al.*, 2006), including the provinces of Béjaia (13352 ha) and Tizi-Ouzou (6387 ha). The fig fruit was one of the staple foods and a source of income for the majority of farming families in the region.

Fig trees host more than thirty insect pests and diseases (Cutajar and Mifsud, 2017), and in the last few years, Mediterranean regions have been invaded by alien wood-boring bark beetles (Family Scolytinae) (Kirkendall and Faccoli, 2010; Rassati *et al.*, 2016). Bejaia, a region in north-central Algeria, is not safe from this scourge, and warning signals have been given by farmers and local associations due to the weakening of fig trees. The decline of fig tree plantations in Kabylie is due to a group of xylophagous beetles in the subfamily Scolytinae (Coleoptera, Curculionidae). The majority of species belonging to this group attack dead wood, while some of them can attack living and healthy trees (Kirkendall *et al.*, 2015). After analyzing samples from different orchards on infested trees, it has been found that the bark beetle, *Hypocryphalus scabricollis* was responsible for the dieback.

The bark beetle frequently attacks trees weakened by drought, disease, injuries, nutritional deficiencies, and sun scald (Cutajar and Mifsud, 2017). It was discovered over a century ago in Burma and Asia, where it is regarded a harmful organism, and it was just discovered in Malta in 1991 (Mifsud and Knížek, 2009), in Sicily in 2014 (Faccoli *et al.*, 2016), in the northeast of Tunisia in 2016 (Gaaliche *et al.*, 2018). It seems that this pest is continuously expanding its range in the Mediterranean region. Confronted with the rapid progression of fig tree dieback caused by this pest and its potential socioeconomic implications, we carried out surveys in the main localities renowned for fig production in Bejaia, Algeria. Given that xylophagous pests of fig trees have not been documented yet in this country, this study represents a timely baseline for future work on fig pests.

Materials and methods

Study area

This investigation was conducted in Bejaia province, situated in the central north of Algeria, in the Kabylia province (figure 1). It is located 181 km east of Algiers (36°45′00″N 5°04′00″E), and extends over an area of 3268 km^2. The area is dominated by mountainous massifs on 75 % of its surface, and the whole region is drained by the Soummam River (A. S. W. B., 1996). This area is characterized by a Mediterranean climate, with mild and humid winters alternating with hot and dry summers. There is a rainy season from October to May, and a dry season from June to September. It is subject to high water conditions due to heavy, often irregular rainfall varying annually between 600 mm and 800 mm (B. N. D. R., 1980).

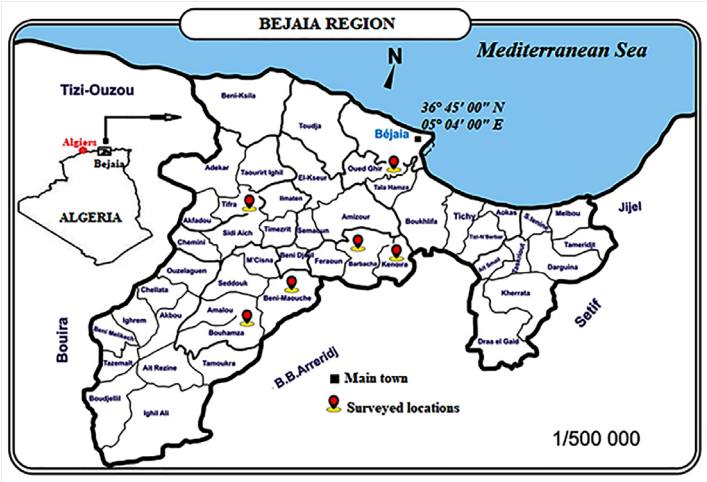

Figure 1. Study area and surveyed localities of the fig killer bark beetle. Source: own elaboration.

Sampling methodology

The bark beetle specimens found under the bark of fig trees and plant parts such as stems and branches were collected from six sites in the Bejaia region. The sites, which ranged in elevation from 35 to 945 meters, were visited over a two-year period, from March 2019 to April 2021 (table 1).

Table 1. Geographic data of the surveyed sites in Bejaia region.

Sites	Localities	Elevation (m)	Latitude	Longitude
Inra	Oued Ghir	35	36°42′25″N	4°57′23″E
Igher n'Deni	Benimaouche	620	36°29′56″N	4°46′47″E
Ait Ouamer		945	36°29′12″N	4°44′43″E
Guenana	Kendira	813	36°32′22″N	5°00′46″E
Tibkert		848	36°33′15″N	4°58′23″E
Ait Sidi Ali	Berbacha	480	36°60′74″N	4°99′48″E

Source: own elaboration.

Once a month, adults and larval stages collected from infested trees were stored in 70 % alcohol for further identification. Plant parts potentially containing eggs were also picked once a month and placed in plastic bags, then transferred to large plastic boxes (50 x 30 x 40 cm) covered by fine mesh. These samples were deposited in the laboratory of the National Institute of Agronomic Research (NIAR) and maintained at an average temperature of 20 °C and relative humidity of ~70 %, which will allow the larvae, nymphs, and immatures present in the wood to reach the adult stage and emerge.

Morphological examination of adult bark beetle specimens observed was carried out using a binocular magnifying glass and relevant identification work was related to bark beetles (Faccoli *et al.*, 2016; Mifsud and Knížek, 2009). Macro-photography used in this report was done using a Panasonic Lumix DMC-FZ50 camera. For the *Hypocryphalus scabricollis* specimens, a digital camera mounted on a microscope was used. A total of 30 individuals were deposited at National Institute of Agronomic Research (NIAR).

External morphological characters were taken from the accurate descriptions reported by Mifsud and Knížek (2009), Faccoli *et al.* (2016) and Cutajar and Mifsud (2017).

Results and discussion

Identification and morphological description

Morphological examination of adult specimens that emerged and were observed under the bark of trunks and branches of dead and wilted trees revealed the presence of two different bark beetle species belonging to two tribes and two families of Scolytinae: *Hypoborus ficus* (Erichson) and *Hypocryphalus scabricollis* (Eichhoff). The former species was already reported on the fig tree by Mifsud and Knížek (2009) along with other species of Scolytinae such as *Liparthrum mori* (Aubé) and *Hypothenemus leprieuri* (Perris). The latter species, *H. scabricollis*, is a new record as a fig pest in Algeria (table 2). Both species were found in association with *Hypocryphalus scabricollis* under the bark of dead wood in the Beni Maouche locality (table 2), and also in close association with another species of Cerambycidae, *Trichoferus fasciculatus* (Faldermann, 1837) in most of the surveyed orchards.

Description and identification of the beetle

Proper identification of the main pest causing the damage, the bark beetle, *H. scabricollis*, is essential, especially since other similarly looking bark beetles might be present in the same tree at the same time (Cutajar and Mifsud, 2017). Females lay small, oval, and whitish eggs just beneath the outer bark (figure 2A). *Hypocryphalus scabricollis* adults are small, hard-bodied, rather squat shape insects (figure 2D).

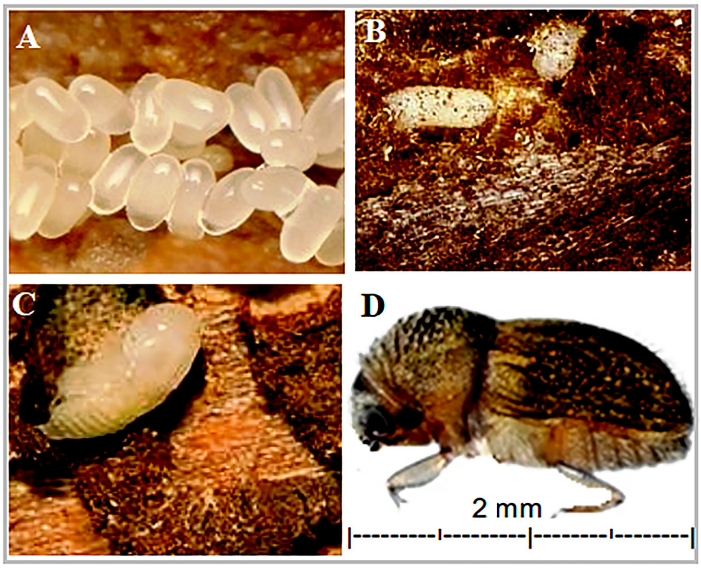

Figure 2. Life stages of *Hypocryphalus scabricollis* on fig trees: (A) Eggs; (B) Larvae; (C) Pupae; (D) Adults. Source: own elaboration.

Body length is about 2 mm. The colour changes from yellowish brown (young bark beetle) to dark brown (adult bark beetle). When viewed from above, the head is partly or completely hidden by the pronotum. Frons convex, flattened above epistoma, strongly shagreened, finely sparsely punctuate; its eyes are emarginated; antenna characterised by a 4-segmented funicle and a rounded antennal club. The pronotum is bicoloured, lighter posteriorly, and nearly as wide as it is long. The anterior margin of the *pronotum* is armed by 5-6 conspicuous and protruding teeth of which the two central ones are bigger than the others. The elytral surface of *H. scabricollis*, instead, is covered with dense but microscopic scalelike setae and erect sparse hairs. Larvae are whitish (figure 2B), apodous, robust, arcuate in shape, and may have a dark brown head. Pupae are off-white and plump (figure 2C). *H. scabricollis* could be confused with other bark beetle species such as, *Hypoborus ficus* (Erichson), where an association with this species is observed in one of the surveyed localities of the Bejaia region (table 2).

According to Faccoli *et al.* (2016), *H. scabricollis* can be distinguished from other species by the body length, antennae and pronotum shape. Indeed, *H. ficus* is usually smaller (1-1.3 mm in length) than *H. scabricollis*, with a pronotum covered by long, recumbent, white scale-like setae. Moreover, *H. ficus* has entire eyes, which are instead emarginated in *H. scabricollis*. Lastly, in *H. ficus*, no teeth occur along the anterior margin of the pronotum.

Table 2. Identification of bark beetle species and the infested section of fig trees in Bejaia region.

Family	Sub-family	Tribe	Species	Location	Infested plant part
CURCULIONIDAE Latreille, 1802	Scolytinae Latreille, 1804	Hypoborini Nüsslin, 1911	*Hypoborus ficus* Erichson, 1836	Benimaouche (Igher N'Deni)	Dead branches and twigs of *Ficus carica*
	Scolytinae Latreille, 1804	Cryphalini Lindemann, 1876	*Hypocryphalus scabricollis* (Eichhoff, 1878)	In all surveyed localities of the Bejaia region	Usually under the bark of dead wood of *F. carica*, and often on the main trunk and branches of suffering trees.

Source: own elaboration.

Biology and behaviour

Globally, the life cycle of a bark beetle is organized, in each generation, around a basic life cycle in 4 phases: reproduction, development, maturation, and dispersion. Like all other bark beetles, *H. scabricollis* spends most of its life under the bark of dead or dying fig trees where it passes through four successive stages: egg, larva, pupa, and adult (figure 3A).

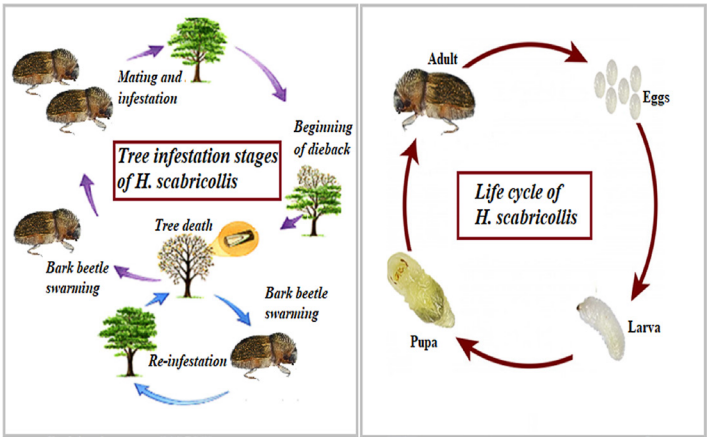

Figure 3. Illustration of the life cycle of *Hypocryphalus scabricollis* (B) and its interaction with the fig trees (A) in Bejaia region, Algeria. Source: own elaboration.

Based on our monthly *in-situ* observations in the orchard of the National Institute for Agronomic Research (NIAR) and of the different emergences of adults from the branches placed in the boxes under laboratory conditions, we can say that *H. scabricollis* develops at least two annual generations in the Bejaia region. Indeed, our various field surveys have given us an idea of its life cycle. In the field, the presence of the species as larvae and adults on dead wood and dying tree branches is almost always noted throughout the year. However, we noted the presence of eggs over two distinct periods. The females seem to lay eggs in May and September. Our monthly field observations have also allowed us to note a remarkable presence of adult individuals on dead branches surveyed in March and April as well as in August and September. The large number of individuals found in the branches of trees prospected in spring and summer explains perfectly what was observed in the laboratory. In fact, under laboratory conditions, we have assisted two major emergences of adults. The first emergence of young adults in the plastic boxes began on the 25th of March and extended to the first fortnight of April, and the second one starts around the 20th of August and continues until the first week of September. These records indicate that this bark beetle has more than one generation per year in the Bejaia region.

The spring generation probably occurs in early spring when the temperatures start warming, allowing mature adults to emerge from the tree. After emergence, adults may re-infest the same tree or, in most cases, disperse to attack other new susceptible trees (figure 3B). After mating, this bark beetle drills a small entrance hole in a branch. Females dig a gallery and lay eggs just beneath the outer bark. After hatching eggs, the larvae mine galleries that branch out from the egg-laying gallery. The last larval stage will end in pupation giving rise to immature adults, which, after a maturation phase of a few days, emerge at the end of the summer, forming the autumn generation (figure 4).

The females of this generation will in turn lay eggs in early autumn. Thus, the eggs laid will give rise to young larvae that will develop during this season and probably hibernate in the last larval stage or as pupae. Nevertheless, some older adults are noted inside the branches analysed in December, January and February; they seem to be able to survive the winter and participate in the production of the spring generation (figure 4).

Host plants and damage importance

In its native area the Asian thermophilous regions, *H. scabricollis* appears to be quite polyphagous and has been found in association with many tropical trees, including *Intsia bijuga* (Colebr.) Kuntze, 1891(Fabaceae), *Madhuca longifolia* (L.) J. F. Macbr. (1918) (Sapotaceae), *Bombax malabaricum* DC. (1824) (Malvaceae), *Canarium euphyllum* Kurz (1872) (Burseraceae), *Excoecaria agallocha* L. (1759) (Euphorbiaceae), *Ficus elastica* Roxb. ex Hornem., 1819 (Moraceae) (Wood and Bright, 1992). In the Mediterranean region, it has only been found on plants of the genus *Ficus*. In Malta, it was initially recorded from *Ficus retusa* (Mifsud and Knížek, 2009); subsequently, it has been mainly found on wild and cultivated fig trees (Mifsud and Knížek, 2009). In Sicily (southern Italy), this bark beetle has been found on both wild and cultivated varieties of the common fig (Faccoli *et al.*, 2016). However, in the Maghreb region, in the Mornag area (north-east of Tunisia) (Gaaliche *et al.*, 2018), and recently in the Bejaia region (north-central Algeria), it was only found on *F. carica*. Whether in Malta, Italy, Tunisia or Algeria, *H. scabricollis* has only been found on plants of the genus *Ficus*. The majority of the orchards studied, *H. scabricollis* attacks dead or dying trees, but in other localities, it attacks healthy trees, causing dieback or mortality. This was observed at the Ait Ouamar site, one of the orchards in the Beni Maouche locality. When looking at the fig tree from afar, the first apparent symptom of attack by this bark beetle is the partial desiccation of some branches, which will eventually lead to the death of the whole tree (figure 5A).

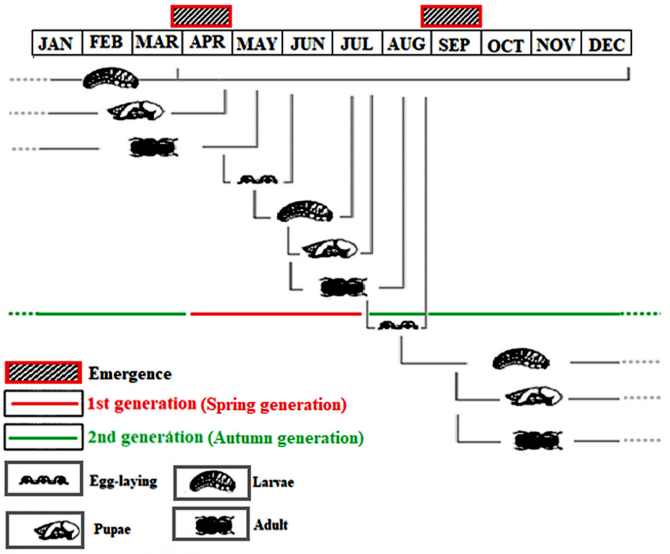

Figure 4. Diagram illustrating the succession of generations of *Hypocryphalus scabricollis* on fig trees. Source: own elaboration.

Figure 5. Signs of *Hypocryphalus scabricollis* attacks on fig trees in the different localities of the Bejaia area. Source: own elaboration.

A closer examination of the branches and trunks of affected trees reveals numerous small round holes of about 2 mm in diameter (figure 5B). On the branches and at the base of the trunk, the bark cracks and may peel off in some places (figure 5C). Scraping of the bark at the entry point shows damage to the tissue just below the bark (figure 5D). By lifting the bark, we can observe adults associated in some cases with larvae and characteristic gallery patterns if the infestation is not too recent (figure 5E-H). The proliferation of these galleries weakens attacked branches or trees, eventually leading to death in high-pressure situations (figure 5I). Damage initially limited to one or more branches can spread more or less rapidly to the whole tree and kill it if there is no rapid intervention. Such harm is caused by both adults and larvae killing the tissue just under the bark, and the tree quickly succumbs if the attack is very severe. This confirms the information reported by Mifsud and Knížek (2009) in Malta, as well as by Gaaliche *et al.* (2018) in Tunisia.

No statistics are currently available to calculate the number of trees affected by this pest. However, in the Béjaia region, during our field surveys, we noted the presence of this insect in all the localities known for fig production, and the degree of infestation varies considerably from place to place, especially depending on the degree of orchard maintenance and the trees' physiological condition. Nevertheless, the orchards of Beni Maouche and those of Kindera are the most affected by this pest, and mortality rates averaged around 10 %. In contrast, Faccoli *et al.* (2016) stated that over an eight-year period, more than 50 % of Maltese island fig trees were destroyed by this bark beetle. According to the testimonies of some farmers in the Beni Maouche community (Bejaia), this plague has been intensifying for about three years, and these attacks are undoubtedly linked to global warming because, in recent years, the North African region has had a succession of heat waves and hot, dry summers following abnormally mild winters (Khelifa *et al.,* 2021), which seem to have favorably influenced outbreaks of this beetle. Several authors studying bark beetles associated with certain forest trees observed and confirmed this pattern, indeed, these current climate changes are highly susceptible to influencing plant-insect interactions (Raffa *et al.*, 2008; Rassati *et al.*, 2016), and chronic water stress over long periods of time due to climate warming is generally the main cause of observed forest diebacks (Allen *et al.*, 2010; McDowell *et al.*, 2013). In any case, there seems to be a correlation between drought phases and attack intensity.

Regional and national decision-makers must take this alarming situation caused by the emergence of this bark beetle seriously to avoid scenarios such as the one recorded in Algeria in the 1980s on Aleppo pine (*Pinus halepensis* Mill., 1768) (Pinaceae) by the pine procession caterpillar *Traumatocampa pityocampa* (Denis & Schiffermüller, 1775) (Notodontidae) (Kadik, 1987). The failure to manage this problem in due time has favored the pest's geographic expansion, leading to large areas of infestation in the early 2000s.

Control means

In general, there are no effective methods or treatments available to control bark beetles. Control is difficult because the insect spends most of its life cycle under the bark, sheltered from potential insecticide treatments. No chemical treatment is currently registered to control this bark beetle on living trees. Since infested trees cannot usually be saved, preventive rather than curative control is preferable. Measures such as avoiding water stress in summer (watering), fertilizing and amending the soil, or installing pheromone traps to prevent adult beetles from colonizing healthy trees are promising. Currently, farmers are advised to quickly fell, remove, and burn the infested trees from the orchard. In the biological control of *Hypocryphalus scabricollis*, research should be focused on the natural enemies, predators, and parasites associated with this bark beetle, and promising solutions may emerge from the work of Belokobylskij and Maeto (2009) and Mifsud *et al.* (2012). These researchers have identified parasitoid species from the genus *Ecphylus* Foerster, 1863 (Braconidae) on bark beetles. According to Belokobylskij and Maeto (2009), all species of the genus *Ecphylus* are larval ectoparasitoids of *Scolytinae* and rarely of Bostrichidae and Cerambycidae. However, Mifsud *et al.* (2012), identified thirty-five specimens of *Ecphylus caudatus* Ruschka, 1916

(Hymenoptera: Braconidae: Doryctinae) from dead branches of *F. carica* infested with the bark beetle, *Hypoborus ficus*. According to these authors, it is important to recall that this parasitoid, *E. caudatus,* was recorded by Belokobylskij in the Mediterranean basin and in the Maghreb region, Algeria, Morocco, and Tunisia. This ectoparasite deserves to be tested on the larvae of *H. scabricollis*. This approach may prove successful in the coming years. Finally, various chemical studies should also be initiated to identify and synthesize the pheromonal molecules of this species. An attempt will then be made to use them as a means of detecting and capturing this pest.

Conclusions

The investigation report on the phenomenon of fig tree decline in some localities of the Bejaia region has allowed us to provide some answers to the distress and expectations of local farmers. The field survey revealed that the wilting and dieback of trees are due to a new xylophagous pest recently introduced in Algeria. This is *Hypocryphalus scabricollis*, a bark beetle known in the countries where it occurs as the "fig tree killer". The field survey showed that this new bark beetle prefers to attack old and weakened trees, but in some cases, young trees are not spared. The damage committed by this pest in the various fig tree plantations is probably the result of two essential complementary factors: on the one hand, inadequate management of the orchards; and on the other hand, the existence of receptive trees, i.e., decreased tree vitality due to water stress caused by successive droughts, which favours infestation and increases the degree of tree decline. This new alien bark beetle seems to develop at least two generations per year in the Bejaia region's climate: a spring generation and an autumn generation. In Algeria, if the fig tree is well known botanically, much remains to be done on the phytosanitary aspect. The problem associated with the emergence of this bark beetle should be addressed seriously with the intention of integrated management by the relevant services. Following this account dedicated to this bark beetle found in Bejaia area. Further research should be carried out in the coming years to obtain even more information on its biology and behaviour, and focus on parasitoids and predators potentially associated with this bark beetle in order to use them as biological agents for its control.

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