Bulletin of Insectology ***57*** *(2): 117-126, 2004*
ISSN 1721-8861

Ethology, field biology and host suitability of *Coniatus repandus*, a natural enemy of tamarisk in France

Luca FORNASARI
Clos de l'Ermitage, 636, Av. du Prof. E. Jeanbrau, 34090 Montpellier, France

Abstract

The life history of *Coniatus repandus* (F.) (Coleoptera Curculionidae) was studied in southern France, where it occurs naturally. This weevil is a natural enemy of tamarisk, *Tamarix gallica* L. (Violales Tamaricaceae) and the plant-insect interactions were studied to characterise the ecology of their association. *T. gallica* is a deciduous phreatophyte which can grow under halinous soil and water conditions. Studies were conducted on the ethology and biology of all developmental stages of *C. repandus*. The weevil has several generations per year and damages the host plant both in the larval and adult stages. Four larval instars were observed. It pupates inside a silk cocoon in the ground. The first generation of *C. repandus* completed its development from egg to adult in about 41 days. The adults reach sexual maturity about one week after emergence and mate during the day. The eggs are usually laid singly in niches made by females at leaf axils on one-year-old twigs. Observations conducted on the phenology and the entomofauna associated with the host plant indicate that the weevil seems to have a considerable impact on the growth of its host without negative interactions with other phytophagous insects. Tests conducted with closely related species of plants within the Sections *Tamarix* and *Oligadenia* and with *Myricaria germanica* (L.) Desvaux showed a high degree of host specificity. The weevil appears to be a promising candidate for the biological control of Tamarisk in parts of the world where this plant became a noxious weed.

Key words: *Coniatus repandus*, life history, *Tamarix gallica*, *Tamarix parviflora*, *Tamarix africana*, *Myricaria germanica*, tamarisk, biological weed control.

Introduction

The genus *Coniatus* Schönherr, 1826 (Coleoptera: Curculionidae, Hyperinae, Hiperini), includes some 12 species of small size, host specific, occurring from the Mediterranean region to the Caucasus and to Iraq (Hoffmann, 1954). The life history of this genus is poorly known. According to the literature, this genus is exclusively associated with *Tamarix* spp. (Violales Tamaricaceae) and with the closely related *Myricaria* Desvaux, 1825 (Violales Tamaricaceae) (Hoffmann, 1954), which was previously classified as *Tamarix* (L., 1753). *Coniatus repandus* (F., 1792) appears to have a very narrow host range. It is reported to live on *Tamarix gallica* L., *T. africana* Poiret, *Tamarix* spp. and *C. repandus* v. *wenckeri* Capiomont on *Myricaria germanica* (L.) Desvaux =*Tamarix germanica* L. (Bargagli, 1884 and 1886; Vitale, 1904; Kleine, 1910; Binaghi, 1951; Hoffmann, 1954; Zocchi, 1970).

C. repandus occurs in southern Europe and Morocco until 1800 m a.s.l. (Csiki, 1934; Kocher, 1961). It has a wider ecological valence in comparison with the partially sympatric *C. tamarisci* (F.), which prefers mild climates. It occurs along the Mediterranean, but also inland, along rivers and at higher elevations, in colder regions. In Italy Bertolini (1871) and Porta (1932) report the weevil in Lombardy, Piedmont, Sicily and Sardinia regions. According to Binaghi (1951) *C. repandus* replaces the Mediterranean *C. tamarisci* in the Po river valley and mountainous regions of Italy. It is also reported along rivers on the Alps in France (Hoffmann, 1954; Zocchi, 1970) and Italy (Zocchi, 1970). I found *C. repandus* in the Mediterranean part of southern France on *T. gallica*.

Tamarix species are hardy small trees or shrubs with scalelike leaves, mostly deciduous, widely distributed in southern France, where *T. gallica* (tamarisk) is particularly common. This genus comprises 54 species of halophytic or xerophytic phreatophytes native of Eurasia and Africa (Baum, 1978) and its native range extends from western Europe to the Himalaya Mountains (Robinson, 1965). Crins (1989) has proposed that there are two centers of diversity of this genus, the Indo-Turanian region and the Middle East. In the former, considered to be its center of origin, the species exibits primitive characters, such as a poorly developed nectariferous disk and large flowers, as in *T. ericoides* Rottler. Nevertheless, it has also been hypothesized (Kovalev, 1995) that the center of origin is Central Asia and that *Tamarix* migrated south in the Paleogene.

Tamarix spp. are very effective competitors with other vegetation because of their biology and because they can grow in a variety of soils, under different and extreme environmental conditions. The main biological features that give them a competitive advantage include their perennial form; high longevity even under harsh environmental conditions - trees as old as 150 years were found on sand dunes in the central Negev, Israel (Friedman and Waisel, 1964); resistance to drought; resistance to flooding; resistance to severe air pollution (Chiusoli *et al.*, 1994); production of seeds throughout the growing season; cross-pollination by wind; self-compatibility when cross-pollination does not occur; abundant production of seeds; long- and short-range dispersal capabilities; vigorous vegetative reproduction; allelopathy; deep root system - up to a depth of 30 m was observed in the Suez Canal zone (Robinson, 1958); vigorous regrowth from roots following destruction of the epigeous part by fire; vigorous growth of new branches following grazing or pruning (Friedman and

Waisel, 1964); and difficulty to control with foliar chemicals (Merkel and Hopkins, 1957; Brotherson and Field, 1987). Tamarisks are able to live under halinous soil and water conditions, eliminating the salt by special glands on their leaves (Wilkinson, 1966). They prefer humid habitats, being extraordinarily tolerant to flooding, and as poikilohydric they utilize soil moisture in proportion to the amount available (Waisel, 1960). However, although *Tamarix* spp. have an extremely high evapotranspiration rate, they are xeric plants and very resistant to drought and high temperatures, being able to survive in deserts. This is allowed also by their capability to reduce evapotranspiration during the day under high temperature regimes, closing their stomata (van Hylckama, 1969). This survival technique results from an endogenous circadian rhythm of transpiration in *T. aphylla* (L.) Karsten (Hagemeyer and Waisel, 1987), and other species are likely to have the same phenology. *Tamarix gallica* occurs in areas with cold winters as well, without prejudice to its growth (Traverso, 1926).

In their native range of distribution these pioneer perennials are beneficial for ecosystem functions and for individual species of specific biomes. They are also used as ornamentals, as windbreaks, to fix sand dunes, to control soil erosion and for many other uses (Heywood, 1978; Fornasari, 1995). However, some species of *Tamarix* became noxious weeds after introduction (Baum, 1967; Crins, 1989) in other parts of the world, such as North America (Robinson, 1965; Crins, 1989; DeLoach, 1991; DeLoach *et al.*, 1996), where they developed dense stands and invaded thousand of hectares displacing native vegetation. In those regions *Tamarix* spp. represent an ecological and agricultural problem, mainly because of the (a) invasion of riparian habitats, reducing water flow in rivers and canals and often causing flooding; (b) water consumption due to the huge evapotranspiration of this phreatophyte, that lowers the water table; (c) reduction of agricultural land; and (d) displacement of native vegetation (Fornasari, 1995), such as *Populus fremontii* Watson (Salicaceae, cottonwood) and *Salix gooddingii* Ball (Salicaceae, willow). The control of tamarisk in the areas where it became a weed is very difficult, since it is resistant to fire and many chemical herbicides, sprouting and regrowing readily and vigorously from underground buds (Turner, 1974; Everitt, 1980; Crins, 1989; Busch and Smith, 1993; Frasier and Johnsen, 1991). Also, effective chemical herbicides currently available are not selective for tamarisk and may have a negative impact on the environment and on ground water, contaminating the water table and water streams (Kerpez and Smith, 1987; Frasier and Johnsen, 1991). Mechanical control methods have been unsuccessful as well (Gary, 1960; Kerpez and Smith, 1987). The weed problem is mainly due to the lack of the complex of natural enemies present in their native area of distribution as a result of coevolution. Therefore biological control organisms are very promising and also desirable, since they are ecologically sound, can afford permanent control and are likely to be successful against this alien plant (Watts *et al.*, 1977; Johnson, 1986; DeLoach, 1991; Fornasari, 1995; DeLoach *et al.*, 1996).

Numerous insects, mites and pathogens attack different parts of the plant and *C. repandus*, as *C. tamarisci* (Fornasari, 1996; Fornasari, 1997; Fornasari, 1998), is one of these natural enemies contributing to the balance existing in nature among animal and plant populations in various types of biomes and biotopes.

Materials and methods

Insects

C. repandus was studied in southern France, where it occurs naturally on *T. gallica*. Populations of *C. repandus* were studied in particular in the Camargue, a flat and humid region with lagoons, marshes, ponds and rangelands which extends for about 800 km^2 between the two main terminal arms of Rhône river. Part of the land is cultivated, mainly with vineyards and cereals. These studies were conducted throughout the year over a three-year period, during 2000 - 2002, and with daily observations during the months of activity of the weevil. The biology and ethology of all developmental stages of the weevil were studied in nature and in outdoor cages, with natural temperature, humidity and photoperiod. The insects used in the experiments were collected on *T. gallica* in the field in the Camargue in Grau du Roi (Gard), 1 km from the coast and 18 km SE of Montpellier (43°36'N, 3°53'E), France, or were their progeny, newly emerged outdoors (in Plan des Quatre Seigneurs, Montpellier).

Various techniques were adopted to study the life history of *C. repandus* in the field. The ethology of the weevil was studied in the field and on 2-m-high potted plants of *T. gallica* in tulle-sleeve cages. The feeding, oviposition and mating behaviours were investigated in detail using newly emerged adults caged on plants kept outdoors, using tulle-sleeve cages of a size adequate to cage the entire plant (on average 120 cm high and 60 cm diameter). Field collected adults were reared outdoors for several generations and years on *T. gallica*, in order to describe the life cycle of the weevil and identify the overwintering stage. Groups of newly emerged adults were caged in tulle-sleeve cages (30 cm long and 8 cm diameter) on branch parts (about 18 cm long) of potted plants. The branch parts on which the adults were caged were cut daily and examined under a stereomicroscope for the presence of eggs, and the adults were transferred to a new branch. The eggs laid by these adults were collected and the larvae reared to adults. Observations were conducted on the activity and overwintering of a group of 120 adults (sex ratio 1:1) of *C. repandus* caged on a 2 m tall plant of *T. gallica*. Stones and bark pieces were placed on the soil to provide shelters and simulate natural conditions. Observations were also conducted on the phenological stages of the plant in connection with the phenology of *C. repandus* and on climatic conditions.

Plants

Observations were conducted at regular 10 day intervals throughout the year, and also several times per day during spring and summer, on the phenology of *T. gal-*

lica in nature in Grau du Roi, since the life history and behaviour of the weevil are strictly dependent on the phenological stages of the plant. The plants in the area studied were in a 11-ha open stand of medium and large-sized trees; density was 3.7 trees per 100 m^2 and the trees averaged 4.3 m high and 4.1 m canopy diameter.

In most experiments with the weevils, potted plants (23 cm diameter and 24 cm high pots) in a sandy loam soil (placed in plastic cups from where they were watered), or plant parts were used. In some cases plant parts with eggs, larvae, or pupae caged in transparent plastic vials were used. The vials were protected from direct sunlight by shading. Vigorous cuttings, 60 to 130 cm tall, were used. The plants used in the tests were previously determined to be healthy and were carefully inspected to remove from their branches adults, immatures, or eggs of other phytophagous insects, parasitoids, and predators, that might be present. Tulle-sleeve cages made of black nylon were used to confine adults on potted plants. Twist-ems® and rubber bands were used to close the top and the bottom of the cages, respectively.

Host plant species and tests

Although *C. repandus* in southern France occurs commonly on *T. gallica*, also *T. africana*, *T. parviflora* De Candolle and *M. germanica* were used to study the biology of the weevil, since also these species occur in nature in southern France and in the literature *C. repandus* has also been reported on *T. africana*, *Tamarix* spp. and *M. germanica* (Bargagli, 1884 and 1886; Vitale, 1904; Kleine, 1910; Binaghi, 1951; Hoffmann, 1954; Zocchi, 1970).

Statistical analyses

Data were subjected to analysis of variance (ANOVA) to test differences among treatment means. Pair-wise multiple comparisons were conducted to test for significant differences between means based on a protected least significant difference (LSD) test to separate means at a probability of $\alpha = 0.05$. Means ± SD are presented throughout.

Results and discussion

In the Camargue area, where *C. repandus* has been studied in nature on *T. gallica*, the population density of this weevil is much lower than that of *C. tamarisci*. In population samples of adults of *C. repandus* and *C. tamarisci* periodically collected in the field throughout the year, *C. repandus* were about 10 % and *C. tamarisci* 90 % (n = 400 per sample). Both weevils live in the same area and on the same plants, with similar ethology and without limiting their respective populations. In the Camargue *C. repandus* was found to coexist on the same plants, without negative interactions, also with other natural enemies of *Tamarix*, such as *Psectrosema tamaricis* (De Stefani) (Diptera Cecidomyiidae), *Stylosomus tamaricis* (Herrich-Schäffer) (Coleoptera: Chrysomelidae, Cryptocephalinae), *Corimalia* spp. (Coleoptera Curculionidae), *Nanophyes* spp. (Coleoptera Curculionidae), *Parapodia sinaica* (Frauenfeld) (Lepidoptera Gelechiidae), *Agdistis tamarisci* Zeller (Lepidoptera Pterophoridae), *Semiothisa aestimaria* (Hübner) (Lepidoptera Geometridae), *Clytie illunaris* (Hübner) (Lepidoptera Noctuidae), *Megalodactilus macularubra* (Mulsant et Rey) (Rhynchota: Heteroptera, Miridae), *Tuponia tamaricis* (Perris) (Rhynchota: Heteroptera, Miridae), *Opsius stactogalus* Fieber (Rhynchota: Homoptera, Cicadellidae), and *Aceria tamarisci* (Trotter) (Acari Eriophyidae).

In this Region *T. gallica* vegetates normally from February - March to December, depending on climatic conditions. Usually during February the plants start resuming their activity and swelling buds.

Size and appearance

Adults are oval, winged, with a squamous exoskeleton (figure 1). Their dorsum is metallic dark brown - with reddish brown areas - to copper or pinkish. They have bright reflections, especially on the external edge and inflexed side of elytra, inflexed pronotum and head, which are lighter. Lighter areas of the dorsal surface are separated by three wavy, V-shaped, dark brown stripes. Elitra are extended, oblong, slightly longer than the prothorax. The prothorax is transverse, very enlarged laterally. It has the same color as the elytra, but with a light median, longitudinal stripe. The abdomen is metallic light green - bright yellowish with pink hues. The rostrum has the same color, dorsally and ventrally, as the rest of the body. It is subcylindrical, longer than the head and not very arched. The antennae are brown to copper, with very hairy flagella, increasingly hairy towards their extremities, bearing numerous minute and thin white hairs especially on the clavae and the distal joints. The funicles have seven segments, the first two longer than the others. The eyes are black, round and bulging. Legs are lighter, metallic copper and bright pinkish to light green on the underside, with tarsa slightly darker than the other parts. The femora are claviform. The base of femora and coxae are light green, the same color as the abdomen. However, the general appearance of *C. repandus* is reddish dark brown, darker than the similar - in shape and dimensions - *C. tamarisci*. This species is highly mimetic with its host plants, whether the adults are on the branches or

Figure 1. Adult of *C. repandus*.
(In colour at www.bulletinofinsectology.org).

on the bark. Adult males are slimmer and smaller than females. Also, the rostrum is shorter in males. In field collected samples of natural populations males averaged 4.11 ± 0.22 mm length (range 3.66 - 4.75 mm; n = 30) by 1.58 ± 0.11 mm width (range 1.42 - 1.75 mm; n = 30) and females 4.96 ± 0.32 length (range 4.25 - 5.33 mm; n = 30) by 1.91 ± 0.10 mm width (range 1.67 - 2.00 mm; n = 30).

Ethology, physiology and development

Both adults and larvae (figure 2) of *C. repandus* are phyllophagous and anthophagous. During February - March, when *T. gallica* is in the bud swelling stage and does not have leaves, yet, the adults of *C. repandus*, similarly to those of *C. tamarisci*, after overwintering start feeding on swollen buds. This feeding limits considerably the growth of the plants (figure 3), preventing the growth of new stems and the production of flowers at a critical time for the plants' physiology and reproduction, since the plants have limited resources after the winter season and *T. gallica* has one main flowering period at this time of the year. Also, adults prefer feeding on the most tender leaves and stems at the tip of branches (figure 4) and in this way they often cut off the tip of stems (figure 5), thus preventing further growth of those branches. This damage is of particular interest in view of the use of this weevil as an exotic organism in classical biological control programs where its host plant became a noxious weed.

C. repandus is a poor flyer. Adults move walking from branch to branch and seldom fly short distances. Also, they usually do not move to other plants, unless it is needed to find another food source, mate, or because of unfavourable climatic conditions. This is rarely the case in their habitat, where they spend most of the time motionless on the leaves of *Tamarix*, resting and feeding. They prefer the trees and branches less exposed to winds and - during the summer - the most shaded plants, to protect from excessive heat. They are fairly gregarious and prefer plants with a dense vegetation. The diel rhythm of activity of adults is determined by climatic conditions and sunlight. The natural photoperiod in their habitat in Montpellier is reported in figure 6. Adults are inactive during the night. Feeding and mating take place during the day, from mid - morning to sunset. Adults feed on buds, leaves and flowers of *T. gallica*. They usually mate on the plants, during the warmest hours of the day and in absence of strong winds. Adults show thanatosis and easily fall if disturbed. However, they are extremely rapid and react instantly during the fall, usually catching other leaves before reaching the ground. Also, they show a mimetic behaviour, keeping still on the leaves they are feeding on, or moving suddenly and hiding on the opposite side of the twig, when an animal gets close to them. The adults overwinter in bark crevices on the host plants, or in the soil. At the end of February - beginning of March they resume their activity, usually when the temperature during the warmest hours of the day rises above about 18 °C. However, if later it is cold again, they stop their activity and hide again in their shelters until milder temperatures. Adults are fully active until the end of September and gradually reduce

Figure 2. Third instar larva of *C. repandus*.
(In colour at www.bulletinofinsectology.org).

Figure 3. Stem of *T. gallica* fed upon by adults of *C. repandus* (without leaves) and normal stem when the plants resume their vegetative phase at the end of winter.
(In colour at www.bulletinofinsectology.org).

Figure 4. Adult of *C. repandus* feeding at the tip of a stem of *T. gallica.*
(In colour at www.bulletinofinsectology.org).

Figure 5. Tip of stems fallen on the ground following adult feeding.
(In colour at www.bulletinofinsectology.org).

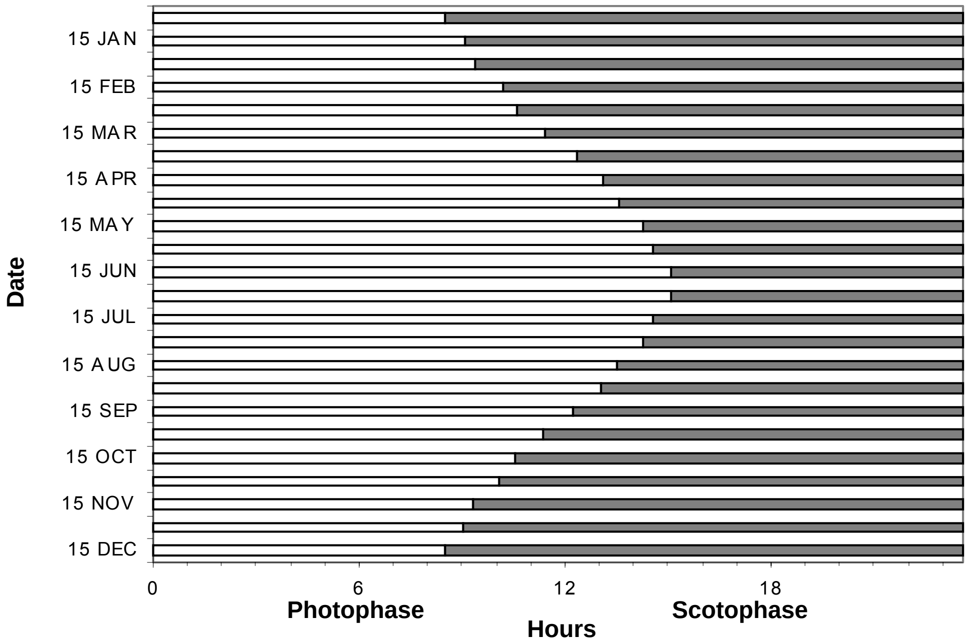

Figure 6. Natural photoperiod in the study area, Montpellier (43°36'N, 3°53'E), France.

their activity during the following months, although some of them are active throughout the winter (figure 7), except during cold days (e.g. when the daily minimum temperature is below 0 °C and the maximum temperature is below 18 °C).

The larvae feed on the tender, young leaves at the tip of stems. In case of wind, they feed and move spirally around the leaves of *Tamarix*, twisted around the stems. This is likely an adaptation that, as observed for the congeneric *C. tamarisci* (Fornasari, 1998), allows them to resist strong winds, that are frequent near the sea. Shortly before pupation mature larvae let themselves fall on the ground, or walk down the trunk to the ground, where they dig a cell a few cm deep in the soil, near the trunk of the host plant. In the cell they make a loose silk cocoon, where they pupate (figure 8).

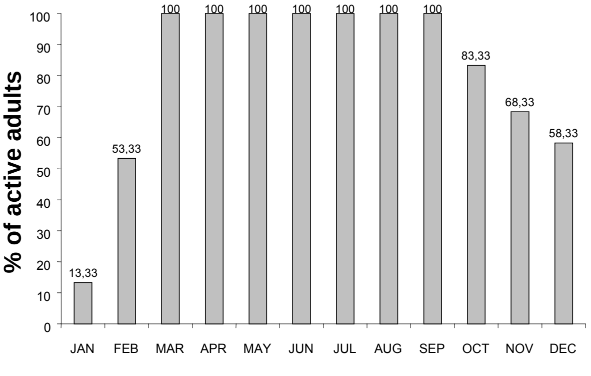

Figure 7. Percentage of active adults during overwintering, in a group of 120 adults (sex ratio 1:1) of *C. repandus*.

Figure 8. Cocoon of *C. repandus* artfully exposed to show its structure.
(In colour at www.bulletinofinsectology.org).

Figure 9. Mature larva of *C. repandus.*
(In colour at www.bulletinofinsectology.org).

At this stage the mature larvae transform into eopupae, becoming bent ventrally, with their head almost touching the end of their abdomen, a position that facilitates the making of the cocoon. They are green, ventrally whitish and partially transparent (figure 9). For making the cocoon, eopupae take from the anus a milky fluid secretion very probably of Malpighian tubules and after having stuck it to a support, they pull it, while fresh, making a kind of thread that is stuck to another support in the cell. The thread sets and solidifies quickly as it comes into contact with the air. Then the larvae take from the anus another secretion and repeat these operations many times to form a loose reticulum. Crossing repeatedly this thread and adding a second layer to the first frame the larvae complete the cocoon. The making of the cocoon requires 8 - 12 hours. Then the eopupae transform into prepupae, becoming squat and about one third shorter than their initial length. They become crescent-shaped and are cyphosomatic. The stage of prepupa lasts 1-2 days. After this period the prepupae move rhythmically for the ecdysis, their exuviae remain inside the cocoon and become exarate pupae (figure 10). Newly emerged adults discharge an emerald green meconium inside the cocoon, soon after emergence, or outside, after leaving the cocoon and feeding on the plant.

Figure 10. Pupa of *C. repandus.*
(In colour at www.bulletinofinsectology.org).

Mating

Observations conducted regularly during the day and the night showed that the weevils mate exclusively during the day. The mating behaviour was observed throughout the lifespan of adults and on all generations. The adults mated soon after resuming their activity after overwintering. Matings were observed from the first days of activity, also during February if sunny and mild weather without wind, until September. Mating occurred mainly during the warmest hours of the day, but during the summer it took place from mid morning to the sunset. *C. repandus* did not mate during rainy days, or with strong winds. Usually the adults mated on the plants, on the same branches where they were feeding. Before mating they were very excited, walking rapidly on the branches and - sometimes with short flights from branch to branch - followed females. After the female stopped and showed to be receptive, the male approached and walked on top of her back. Once on the female, it touched with its antennae the antennae of the female and then rubbed its rostrum alternatively from left to right on the pronotum of the female. Shortly after this behaviour, from second to few minutes, the couple mated. During mating the males remained immobile on the females, touching the pronotum and elytra of the females with their antennae. Also females usually did not move during mating, but were often observed feeding on leaves and sometimes walked on the branches. Normally mating lasted from about half an hour to about one hour. Mating took place about one week after emergence. The adults belonging to the last (third) generation did not mate until the following year.

Oviposition

Overwintered adults resumed oviposition at the end of February - beginning of March, when minimum temperatures rose above 11 - 12 °C. They usually laid the eggs (figure 11) singly, at a leaf axil of one-year-old stems, or at the tip of new branches (figure 12). Similarly to the behaviour described for *C. tamarisci* (Fornasari, 1998), females made a niche for the egg at the leaf axil, or at the apex of the twig, destroying the bud at the leaf axil, or at the apex, respectively. In both cases this damage prevented further growth of the plant parts attacked. To do so, females chewed the tissue of the plant and then covered the eggs, after oviposition, with the material chewed. This protected the eggs from predators and injuries and held firmly the eggs in their niches. If the minimum temperatures fell below 8 - 9 °C, *C. repandus* temporarily interrupted oviposition until more favorable climatic conditions were resumed. Unlike *C. tamarisci*, *C. repandus* also interrupted oviposition during the hottest periods of Summer, when maximum temperatures rose above 31 - 32 °C. Also, it seemed to be more cold tolerant, usually ovipositing until the end of September, whereas *C. tamarisci* normally stopped ovipositing at the beginning of September. As a rule *C. repandus* did not oviposit during the night.

Duration of development and life history

The embryonic development of newly laid eggs (≤ 4 hrs) of the first generation required on average 14.06 ± 0.93 days (n = 50), with no mortality. Newly hatched larvae (≤ 4 hrs) reached the pupal stage in 17.66 ± 2.49 days (n = 18). Ten per cent of the larvae died before pupation. Four larval instars were observed. Newly formed pupae (≤ 4 hrs) completed their development to adults in 9.83 ± 1.42 days (n = 18), with no mortality. The average temperature and relative humidity during preimaginal development were 17.23 ± 3.43 °C and 68.27 ± 14.53 %, respectively.

Three generations per year were observed. *C. repandus* overwinters in the adult stage. Overwintering lasted about four months from the end of November to the end of February, with few adults active throughout the winter, especially during milder days (figure 7). When night temperature was below 0 °C, all adults were inactive, also if during the day the temperature arose to 7 - 8 °C. One hundred per cent of activity was observed from March to September and then the number of active adults declined constantly until January (figure 7). The adults of the first generation overwintered and survived until the following summer, overlapping with the emergence of the first generation of new adults (figure 13), while a gap was observed between adults belonging to the second and third generation (figure 13). Overwintering adults in the soil survived minimum temperatures as low as -5 °C. Also considering its behavior described for oviposition, on the whole *C. repandus* appears to be more cold adapted than *C. tamarisci* and this confirms the records in the literature regarding its geographical distribution and presence in cold areas.

Figure 11. Egg of *C. repandus* artfully freed from its protective cover.
(In colour at www.bulletinofinsectology.org).

Figure 12. Egg laid at the tip of a branch of *T. gallica*.
(In colour at www.bulletinofinsectology.org).

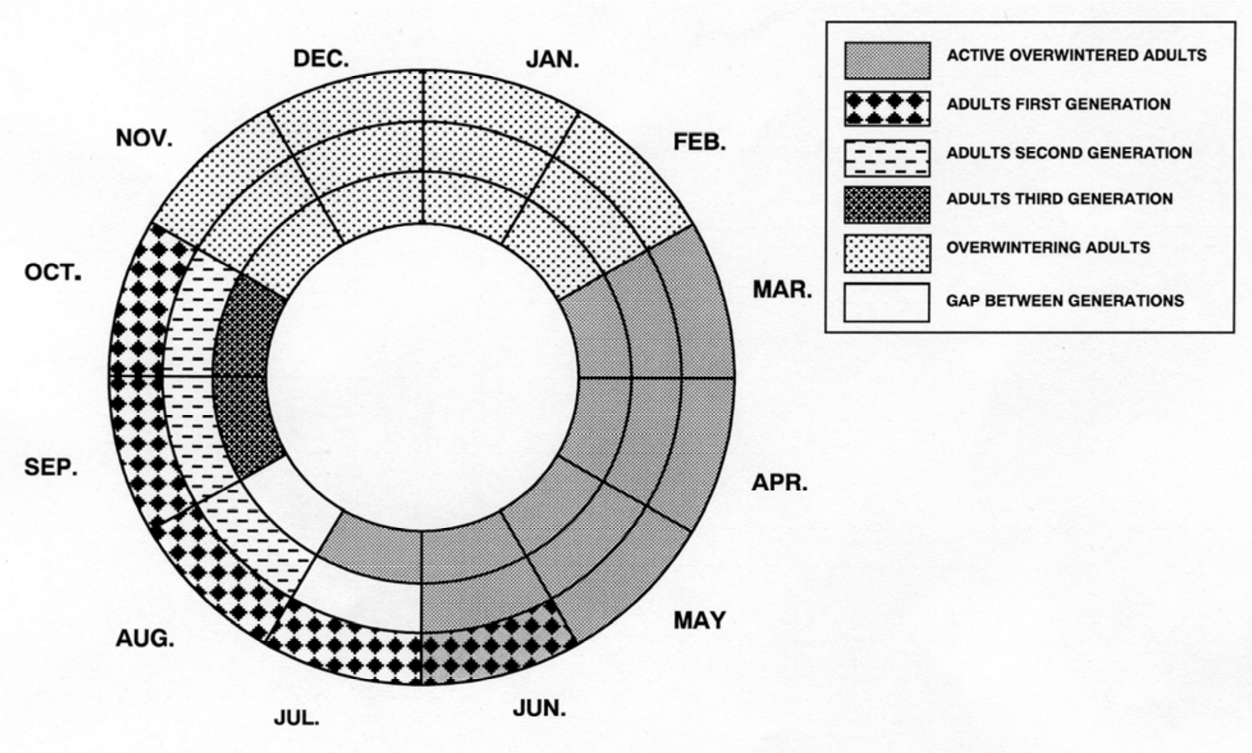

Figure 13. Seasonal occurrence of the generations of adults of *C. repandus*.

Figure 14. Ant predating a mature larva of *C. repandus* fallen on the ground before pupation.
(In colour at www.bulletinofinsectology.org).

Mortality factors

Nabis viridulus Spinola (Rhynchota: Heteroptera, Nabidae), spiders and coccinellids were observed as predators of recently laid eggs of *C. tamarisci*. Ants, such as *Crematogaster scutellaris* (Oliver) (figure 14), and insectivorous birds were observed as predators of young larvae of the weevil. Predation by ants occurred especially when mature larvae fell on the ground before pupation.

Host suitability test

A test was conducted to assess the host suitability and the comparative ability of the weevil to develop on *T. gallica, T. africana*, *T. parviflora* and *M. germanica*, whose classification is reported in table 1. Neonate larvae reared outdoors during May - June under natural conditions of light (figure 6), temperature (16.26 ± 2.81 °C) and humidity (RH 71.08 ± 15.81 %), on the above mentioned species, completed their development to adults, but with a high mortality, especially on *T. parviflora* and *M. germanica* and in significantly smaller numbers, compared to *T. gallica* (table 2). The mortality

Table 1. Classification[a] of plant species selected for studies on *C. repandus*.

Order	Family	Section	Series	Genus - Species	Common name
Violales	*Tamaricaceae*	*Tamarix*	*Gallicae*	*Tamarix gallica* L.	Tamarisk
"	"	*Oligadenia*	*Anisandrae*	*Tamarix africana* Poiret	Tamarisk
"	"	"	*Arbusculae*	*Tamarix parviflora* De Candolle	Tamarisk
"	"	---	---	*Myricaria germanica* (L.) Desvaux	---

[a] According to Baum (1978).

Table 2. Survival and development of neonate larvae of *C. repandus* on selected plant species[a].

Plant Species	Number of Adults Emerged [Mean ± S.D. (No.; range)]	Total Number of Adults Emerged Total (Males; Females)	Duration of Development [Mean Days ± S.D. (No.; range)]	Mortality (%)
Tamarix gallica	16.83 ± 0.75 (101; 16-18)a	101 (48; 53)	41.11 ± 2.92 (101; 37-47)a	15.83
Tamarix africana	12.83 ± 0.75 (77; 12-14)b	77 (34; 43)	44.12 ± 2.33 (77; 38-47)b	35.83
Myricaria germanica	4.50 ± 1.05 (27; 3-6)c	27 (12; 15)	41.70 ± 2.48 (27; 37-47)ac	77.50
Tamarix parviflora	0.50 ± 0.84 (3; 0-2)d	3 (1; 2)	43.67 ± 2.08 (3; 42-46)bc	97.50

Means within columns followed by the same letter are not significantly different (based on Fisher's protected LSD test at $\alpha = 0.05$). One hundred and twenty larvae per plant species.

[a] Six replicates were used per plant species and twenty neonate larvae were used per replicate.

observed on these species was 15.83 %, 35.83 %, 77.50 % and 97.50 %, respectively. From 120 larvae reared on each species, a total of 101 adults (48 males and 53 females) reached the adult stage on *T. gallica* and 77 adults (34 males and 43 females) on *T. africana*, while only 27 adults (12 males and 15 females) on *M. germanica* and three adults (one male and two females) on *T. parviflora*. ANOVA revealed statistically significant differences among treatments ($F = 458.485$; df = 3, 20; $P \leq 0.0001$). The number of adults emerged from *T. gallica* was significantly greater than from *T. africana*, *M. germanica* and *T. parviflora* (table 2). The development of neonate larvae to adults required about 41 days (n = 120) on *T. gallica* and *M. germanica*, while it took about 44 days on *T. africana* and about 43 days on *T. parviflora* (table 2). ANOVA showed significant differences among the treatments for the number of individuals that completed their development ($F = 19.582$; df = 3, 204; $P \leq 0.0001$). The duration of development was significantly shorter in *T. gallica* and *M. germanica* than in *T. africana* (table 2). The different suitability, besides *M. germanica*, of *T. africana* and *T. parviflora* for *C. repandus*, may be considered also in light of its taxonomic position and the fact that these species belong to different Series, *Anisandrae* and *Arbusculae*, within the Section *Oligadenia*, while *T. gallica* belongs to the Series *Gallicae* of the Section *Tamarix* (table 1). Therefore this ability to select for very closely related species would suppose an extremely high host specificity of *C. repandus*.

Acknowledgements

I thank A. Ghedini for technical assistance.

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Author address: Luca FORNASARI, Clos de l'Ermitage, 636, Av. du Prof. E. Jeanbrau, 34090 Montpellier, France (e-mail: lgpm.fornasari@libertysurf.fr).

Received April 14, 2004. Accepted October 15, 2004.