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The oak buprestid beetle, *Agrilus biguttatus* (F.) (Col., Buprestidae), a recent factor in oak decline in Europe

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Abstract

During last years, the populations of the oak buprestid beetle *Agrilus biguttatus* (Fab.) in Europe have increased. In several countries, the beetles' attacks have become a new component in oak dieback. The larvae excavate galleries under the bark of weakened trees, which are killed through the girdling. Because of the difficult diagnosis it is necessary to draw more attention to the infestations. Therefore, this paper presents a review on the literature concerning the recognition of the infestations by the insect and its bionomics.

1 Introduction

In Europe, oak decline is in general associated with a complex of biotic and abiotic stress factors, such as repeated insect defoliation, fungi, late winter frost and drought. Some of these primary stress factors are reversible and oaks may recover when these negative factors have been diminished or stopped. However, during a period of weakening, oaks may become attacked by secondary pest insects such as the buprestid beetle, *Agrilus biguttatus* (F.) (syn. *A. pannonicus* (Pill. et Mitt.). This insect may kill the trees before they are able to recover. The larvae excavate galleries under the bark of weakened trees, which are killed through girdling. It is quite easy to overlook *Agrilus*-galleries, unless the bark is removed systematically. The insect is much more common than many people think. Recently, the populations of *A. biguttatus* in Europe have increased. In several countries, the beetles' attacks have become a new component in oak dieback. Because of the difficult diagnosis it is necessary to draw more attention to the infestations. Therefore, this paper presents a review on literature concerning the recognition of the infestations and the ecology of the insect.

2 Geographical distribution and host plants

The buprestid beetle, *A. biguttatus* is a palearctic, euro-siberian species, present all over Europe, except Finland (Bily, 1982; Curletti, 1994). Outside Europe, the insect is occurring in the Middle-East, Northern-Africa and Siberia (Hellrigl, 1978; Curletti, 1994). Host plants are *Quercus robur, Q. petraea, Q. pubescens, Q. ilex, Q. suber, Q. cerris* and occasionally *Fagus sylvatica* and *Castanea sativa* (Hellrigl, 1978). Records of incidence of *A. biguttatus* on *Populus* sp. are doubtful according to Hellrigl (1978), although certain authors (Weidlich, 1989) still reported *Populus* sp. as a host tree of this buprestid. Infestations on *Q. rubra* are very rare (Hartmann, pers. comm.). In the United States, *Quercus rubra* is attacked by the closely related nearctic species *A. bilineatus* (Web.) (Johnson & Lyon, 1988). This species is not present in Europe.

3 Bionomics

In May(June)-July, the 8–13 mm long beetle deposits groups of 5–6 eggs, preferably on the south-side of the bark (Wachtendorf, 1955). Beetles prefer big sized trees (average DBH 30–40 cm) over 80 years old, with thick bark (Starzyk, unpubl. data). The cream-coloured and legless larvae are relatively long and flat, with a pronotum that is a bit wider than the rest of the body. They have a unique tail segment that terminates in a pair of minute black-brown horns. The larvae of *A. biguttatus* posses morphological features typical for larvae living in moist material (Mamaev & Semenova, 1961), this indicates the association of the species with fresh, moist wood. In accordance with this, we learned from all the literature that the larvae do not develop in dry dead trees. Klausnitzer (1994), presented a detailed description of the larva. The larvae excavate, up to 155 cm long, zigzagging galleries under the bark. The insect may have an one-year cycle, but a two-year cycle is more common. In Northern-Germany the larvae hibernates twice. The mean length is about 10 mm for those from the current year and 25–43 mm for the 1 1/2-year-old larvae (Hartmann, pers. comm.; Kolk & Starzyk, 1996). Hibernation of the larvae takes place inside the bark (Hartmann & Kontzog, 1994; Wachtendorf, 1955), in the pupal chambers of the size 10.4–14.8 by 3.0–4.5 mm (Kolk & Starzyk, 1996). During its complete development, larvae have 5 instars. The young beetles leave the tree by gnawing characteristic, D-shaped exit holes of about 2.5–4 by 2–3 mm (Kolk & Starzyk, 1996). Very heavily infested trees have shown up to 38 exit holes per 0.5 m^2 bark (Wachtendorf, 1955). In Poland from a 28 m long oak trunk (DBH 65 cm), infested as standing tree, more than 700 specimens of adults emerged (Hilszczanski, unpubl. data). Adults provide supplementary feeding in the crowns of oaks, on parenchymal tissue of leaves (Kolk & Starzyk, 1996; Wachtendorf, 1955).

The natural enemy complex of *A. biguttatus* is not rich. The most spectacular are birds such as woodpeckers feeding on the larvae overwintering inside the bark. Among insects only few species of parasitic braconids are known to be associated with this buprestid: *Spathius curvicaudus* Ratz. This gregarious species, is recorded as a parasitoid of *A. biguttatus* in Russia, Azerbaijan, Czech Republic, England and The Netherlands (Telenga, 1941; Abdinbekova, 1975; Capek et al., 1982; Shaw,

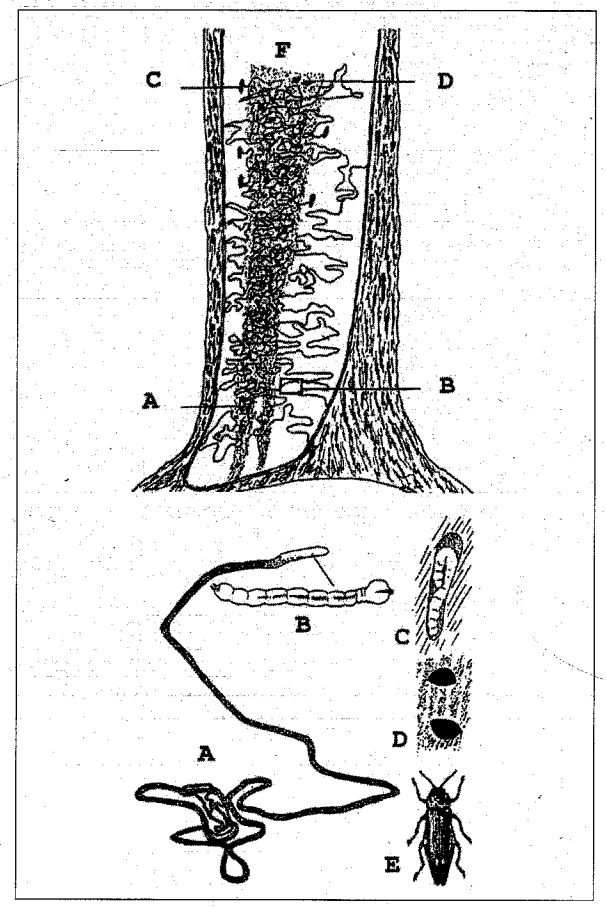

Fig. 1. Schematic development of *Agrilus biguttatus*.
(Source: Hartmann & Kontzog, 1994)
A. Zigzagging larval galleries on the south-side of the tree
B. Larva with two minute brown-black horns on the tail segment
C. Hibernation of the larva takes place within the bark
D. Characteristic, D-shaped, exit holes of the young beetles
E. Adult beetle
F. Bark necrosis

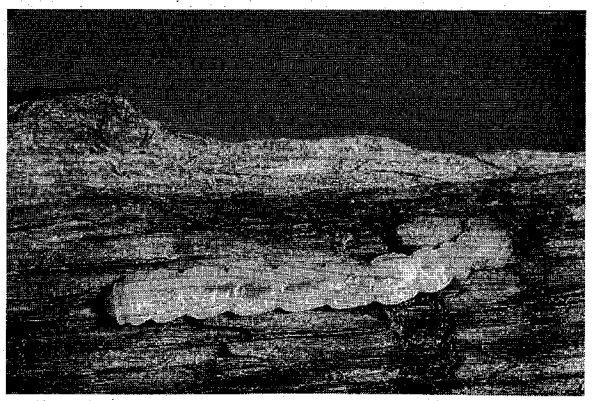

Fig. 2. The larva of *Agrilus biguttatus*; the last abdominal segment terminates in a pair of minute black-brown horns (photo: Alterra/A. van Frankenhuyzen)

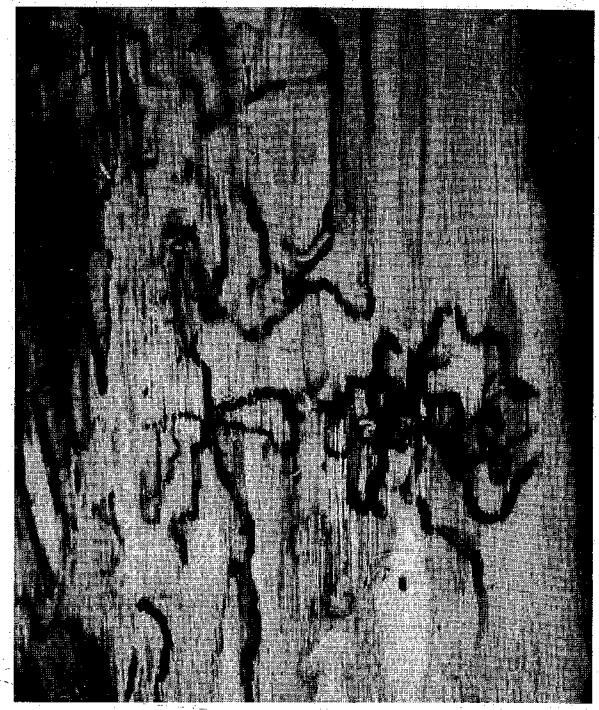

Fig. 3. Living tree with zigzagging galleries under the bark (photo: Alterra/R. Venekamp)

1988; Moraal, unpubl. data). Telenga (1941) recorded also *Spathius ligniarius* (Ratz.) and *S. radzayanus* Ratz. as parasitoids of *A. biguttatus*. The braconid *Atanycolus neesii* Marsh. is also listed as a parasitoid (Medvedev, 1986).

4 Damage

Young larvae make their galleries in a longitudinal direction of the tree. Older larvae produce galleries in irregular twisting, transverse directions. This can lead to partial or complete girdling of the trees. It is known that larvae of the buprestid are involved in the process causing structural abnormalities in cambium tissue of the infested trees (Jacquiot, 1963). As a result of larval activity, twigs and branches in the top of the tree will die. The tree may show a transparent crown with clusters of foliage on the surviving branches. Epicormic shoots are formed on the stem. In a later stage the tree may die.

Relatively vigorous trees can ward off early larval feeding by wound reactions, which show as dark cracks with slime flux (Hartmann & Blank, 1992, 1993). For the recognition of *Agrilus*-infestations can be referred to Hartmann et. al, 1995; see also figures 1–4.

5 Other *Agrilus*-species important as oak pests

In several countries such as Poland, Czech Republic, Ukraine, Austria and Germany, some other *Agrilus*-species play a role in oak decline. These species are *A. sulcicollis* Lacord. and *A. angustulus* (Ill.). There are many similarities in the biology among these species. However, in contradistinction to *A. biguttatus, A. sulcicollis* and *A.*

Fig. 4. Dead tree with old larval galleries (photo: L.G. Moraal)

angustulus prefer to infest upper parts of the stems, branches (diameter 3–20 cm) and smaller size host trees (Kolk & Starzyk, 1996; König, 1996). These usual smaller species (3.5–8.5 mm) are recorded to occur sometimes in high densities in oak stands weakened by different factors. However, the preferences of these buprestids to infest crown layers of distinctly weakened trees, place them rather among secondary factors within the oak decline.

6 Pest incidence of *Agrilus biguttatus* in Europe

In Germany, attacks by *A. biguttatus* have become very common recently. At present they are considered as an important factor for tree mortality. During the annual monitoring of forest health in 1991, *Agrilus* is mentioned only in few cases (Forstschutzsituation 1991/1992). However, in later years more and more attacks are reported. For example in 1996, in Baden-Württemberg, the beetle is present in 1929 ha of oak while 125 ha is heavily infested. In Rheinland-Pfalz these numbers are 953 and 510 ha respectively. The infestations mostly occurred in oak stands which have been previously defoliated by *Lymantria dispar* (L.), *Operophtera brumata* (L.) and *Eranis defoliaria* (Cl.) (Forstschutzsituation 1996/1997). For other reports on the incidence of *A. biguttatus*, Wulf & Kehr (1996) mention several authors. Winterfrost injuries to trees weakened by repeated insect defoliation, and locally by water stress (drought or fluctuating groundwater levels) are assumed to predispose oaks to attack by secondary organisms. *A. biguttatus* is the earliest and most aggressive secondary organism involved. Mortality or survival of predisposed oaks depends largely on whether or not an *Agrilus*-attack occurs. Warm summers in combination with a large supply of weakened trees are assumed to favour this thermophilic insect (Altenkirch & Hartmann, 1995; Hartmann & Blank, 1993).

In France, during 1994/1995, heavy attacks of *A. biguttatus* on oak were recorded in the northern part of Alsace. More than 40.000 m^3 of wood were harvested. Stands of all ages are affected and more than 150 ha had to be reforested. Various site and stand factors play a role. However, the exceptional outbreak of the gypsy moth, *Lymantria dispar*, in previous years, undoubtedly had a strong impact on the incidence of *A. biguttatus* (Landmann, 1996).

In England, as recently as in 1987, *A. biguttatus* was listed in the British Red Data Books as a vulnerable endangered species (Gibbs & Greig, 1997). However, recently it has shown a remarkable revival. In the London area, larvae and exit holes were found in many dying and dead oaks in woodlands and parks (Hackett, 1995). During an examination of dying oaks in southern England, the infestations were found on 14 out of 20 locations (Gibbs & Greig, 1997).

In The Netherlands, insect pests on trees are monitored annually since 1946 (Moraal, 1991). Since then, infestations of *A. biguttatus*, have never been observed. However, in 1997, heavy attacks were noticed in several oak stands on several locations. Oaks with ages varying from 58–110 years old appeared to be attacked (Moraal, 1997). In some stands more than 70 % of the trees were killed. In these trees numerous larvae or exit holes have been found. The intention is to carry out an inventory of the attacks in relation to water stress, defoliation class and soil fertility.

In Austria, relatively many *Agrilus*-larvae were found in trunks and branches of weakened oaks. However, all these larvae were identified as *A. sulcicollis* and *A. angustulus*. Infestations of *A. biguttatus* have not yet been observed (Schopf, 1992).

In Hungary, larval galleries of *A. angustulus* were observed in declining oak trees. Xylem vessels being in contact with the larval tunnels become opened. These openings are probably the gateways for infection with the fungus *Fusarium solani*. This means that the larva could act as a vector for the fungal infection (Bohàr, 1993). In Hungary, also *A. biguttatus* was observed in many dying trees (Hartmann, pers. comm.).

Fig. 5. The young beetles leave the tree by gnawing small characteristic, D-shaped exit holes (photo: L.G. Moraal)

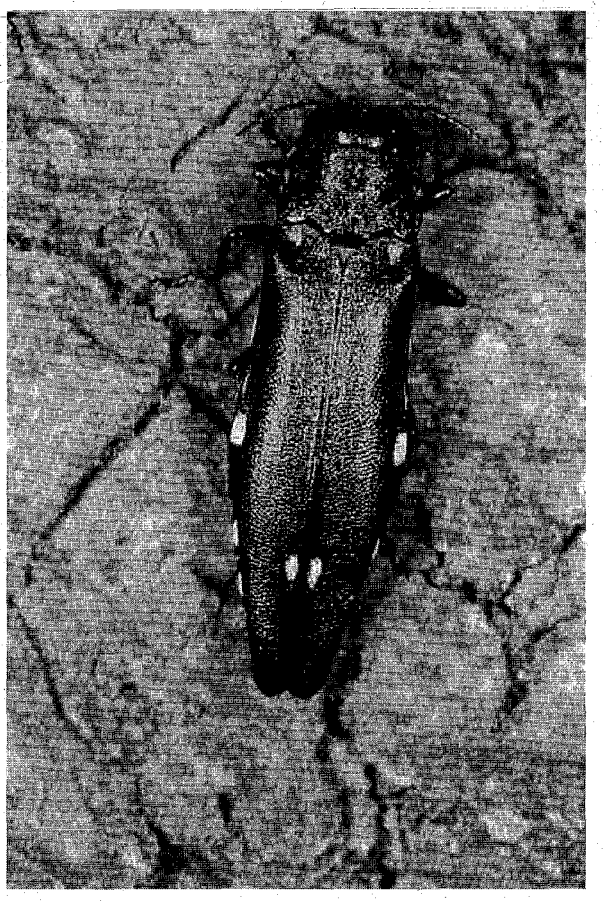

Fig. 6. Agrilus biguttatus shows several white spots, two of them are located on the elytra (photo: C. Bystrowski)

In Poland *A. biguttatus* occurs in many oak stands all over the country except in mountains (Burakowski et al., 1985). The species is regarded as the first cambiophagous insect infesting weakened oaks, preferring trees over 80 years old, but recorded also on 20 years old hosts (Starzyk, unpubl. data). In oak stands of Niepolomice Forest District (near Krakow), weakened by industrial air pollution, the high incidence of *A. biguttatus* is also the effect of heavy defoliation caused by *Tortrix viridana* L. and other defoliators (Starzyk, unpubl. data). During 1997, flood in Lower Silesia created forest edges with many weakened oaks. *A. biguttatus* was the main insect infesting and killing these oaks in the following years (together with accompanying *Agrilus sulcicollis*, cerambycids such as *Plagionotus* spp. and the oak bark beetle, *Scolytus intricatus* Ratz.). As a result in 1998–1999, about 40 thousand m^3 of infested oaks were harvested from two Forest Districts in the Odra river valley.

In Russia, Ukraine and Belarus the buprestid is recorded as one of the main pests of oaks, weakened by ground water fluctuations and defoliators (Zakharov & Levkovych, 1951; Anishchenko et al., 1988). In Ukraine *A. biguttatus* was observed attacking slightly weakened trees and being much more aggressive then *Armillaria* species (Mezencev, 1993).

7 *Armillaria*-infection follows on *Agrilus*-attack

In the past, many authors have contributed an important status to honey fungus, *Armillaria* spp., in relation to oak decline, as this fungus was observed in the roots and stems of dead trees. However, there are several *Armillaria* species; some of them are pathogenic while others are saprophytic. On the richer soils, in The Netherlands and Northern-Germany, where most oaks are cultivated, pathogenic *Armillaria*-species do not occur (de Kam et al., 1990; Hartmann, 1996). Infections with *Armillaria* mostly occur, after the trees have been infested by *Agrilus* (Hartmann, 1996; Hartmann & Blank, 1992; Seemann, 1996). In Ukraine, larvae *of A. biguttatus* were observed to develop abnormally on trees infested with *Armillaria* sp. The most numerous larvae were found above the fungus layer (Mezencev, 1993).

8 Sylvicultural measures

To reduce the population of the beetle, a feasible countermeasure might be the removal of those stems which are heavily infested with larvae. The branches may be left in the stand because *A. biguttatus* mainly breeds in the stems. Non-infested trees, which are already dead for more than one year, or dead trees with already the beetles' exit holes, may be left in the stands for their contribution in the development of dead wood fauna. Long-term measures includes increasing age structure, and developing the shrub and underwood layers providing shade on stems, decrease the susceptibility of the trees for infestation.

9 Conclusions

The buprestid beetle, *Agrilus biguttatus* is nearly present all over Europe. During last years, the populations of this secondary pest insect have increased remarkably. In several countries the beetles' attacks have become a new and significant component in oak dieback. The insect may kill trees which are weakened by repeated insect defoliation, water stress and late winter frosts, before they are able to recover from temporary drawbacks for tree vitality. As the infestations of *A. biguttatus* so far have been underestimated in most monitoring programs, further insight in population dynamics is needed.

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