

Morphological separation of *Tomicus piniperda* and *T. destruens* (Coleoptera: Curculionidae: Scolytinae): new and old characters

MASSIMO FACCOLI

Department of Environmental Agronomy and Crop Protection, University of Padua, Viale dell'Università 16/a, 35020 Legnaro (PD), Italy; e-mail: massimo.faccoli@unipd.it

Key words. Coleoptera, Curculionidae, Scolytinae, *Tomicus*, *Blastophagus*, identification, morphology

Abstract. *Tomicus piniperda* and *T. destruens* are sibling species which are extremely difficult to separate by morphological characters. Although several papers report differences between the two species, many characters need confirmation or better description. Moreover, new morphological characters are required for correct species determination. For these purposes, eight populations of *T. destruens* from Italy, Greece, Spain and Algeria, and ten of *T. piniperda* from Finland, Poland, Czech Republic, Austria, Sweden and Italy, were investigated considering eleven morphological characters. The morphological differences most useful for the species separation include four previously described characters (colour of the elytra, colour of the antennal club, distribution of the antennal setae, distribution of the punctures along the elytral declivity), and four new characters (body proportions, setation of the first antennal club suture, sculpture of the elytral declivity and striae density of the pars stridens). Distribution of the two species is discussed and an illustrated key is included.

INTRODUCTION

The species of the genus *Tomicus* Latreille, 1802 (= *Blastophagus* Eichhoff, 1864; = *Myelophilus* Eichhoff, 1878) belong to the most dangerous pine pests in Eurasia, playing a major role in the decline of many pine forests (Eichhoff, 1881; Escherich, 1923; Postner, 1974; Långström & Hellqvist, 1991; Ye, 1991; Ye & Lieutier, 1997; Dajoz, 2000). Of the six *Tomicus* species known to the world (Wood & Bright, 1992), only *T. piniperda* (Linnaeus, 1758), *T. destruens* (Wollaston, 1865) and *T. minor* (Hartig, 1834) occur in Europe (Pfeffer, 1995). *Tomicus piniperda* is widespread in Eurasia and it has recently been introduced to North America (Haack & Kucera, 1993; Haack & Poland, 2001; Haack et al., 2000). *Tomicus destruens* is found in all circum-Mediterranean regions and Madeira Islands, whereas *Tomicus minor* occurs in Europe and Asia (Pfeffer, 1995).

For a long time, *T. piniperda* and *T. destruens* have been considered as synonymous (Schedl, 1932, 1946), rejecting the conclusions of Wollaston (1865), who described *T. destruens* as a separate species based on specimens collected in Madeira. Wollaston (1865) described *T. destruens* as “different from *T. piniperda* in being on the average a little larger and thicker, and its elytra, which are more coarsely rugulose, being always more or less ferruginous. Its antennae are totally pale (brown in *T. piniperda*) with their clubs somewhat longer and more acute”. Reitter (1913), apparently unaware of Wollaston's paper and finding differences in the elytra colour, reported *T. piniperda* var. *rubripennis* (elytra reddish) as a Mediterranean variety of *T. piniperda* (elytra brown). The same character was also used by Krausse (1920), who described *T. piniperda* var. *rubescens* as having reddish elytra. Later, Russo (1940) studied both morphology and biology of some populations of *T.*

piniperda var. *rubripennis* Reitter occurring in central Italy, without adding new characters. However, these varieties have no taxonomical value as they were described only on the basis of different colours, and not supported by morphological or genetic differences. Not until 1971 did Lekander, who was looking for new morphological characters of the larvae, accept *T. destruens* as a different species having three pairs of epipharyngeal setae instead of the four pairs found in *T. piniperda*. Lekander (1971) briefly commented also on the size and proportions of the two species, but did not provide measurements or other numerical data. Kerdelhué et al. (2002) described the declivity of *T. piniperda* elytra with one row of small and deep punctures occurring between the main punctures of the second interstria, whereas two to three rows can be observed in *T. destruens*. Kohlmayr et al. (2002) reported that three rows of setae occur on the antennal club of *T. destruens* between the second and third suture, whereas *T. piniperda* has only one row of setae. In addition, on the elytra of *T. destruens* the same authors found types of setae not occurring on the elytra of *T. piniperda*. The descriptions of Wollaston and Lekander were recently supported by genetic analyses, which confirm that *T. destruens* and *T. piniperda* are two different species (Gallego & Galian, 2001; Kerdelhué et al., 2002; Kohlmayr et al., 2002; Faccoli et al., 2005).

However, despite the morphological characters reported in the literature, separation of the two *Tomicus* species is still extremely difficult. No illustrated key is available, and the differences described in the literature very often include unstable characters such as elytral or antennal colour, which can change with insect age. As a result of the uncertain identification of the species, most scientific papers published in Mediterranean countries, where *T. destruens* is more common, report *T. piniperda* as the investigated species (Eggers, 1929; Schedl, 1932; Russo,

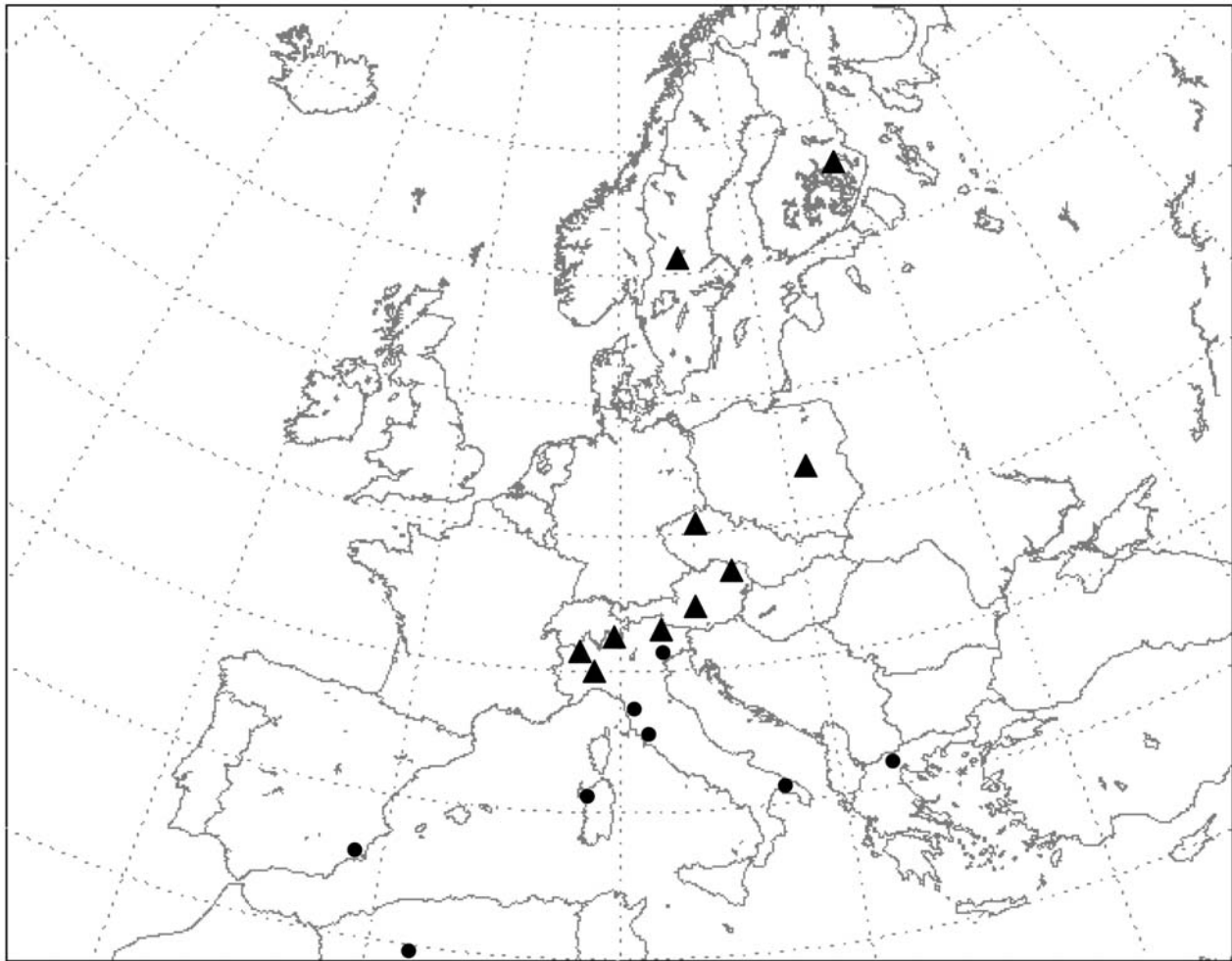


Fig. 1. *Tomicus* populations sampled in the present study. Dots: *T. destruens*; Triangles: *T. piniperda*. Information about the sampled populations is given in Tables 1 and 2.

1940, 1946; Balachowsky, 1949; Chararas, 1962; Masutti, 1969; Carle, 1975; Triggiani, 1983, 1984; Gil & Pajeras, 1986; Ferreira & Ferreira, 1986). In the scientific literature these two *Tomicus* species have been often confused, which results in mixing of data from biological and control studies. From this point of view, correct identification of the species remains one of the main problems for *Tomicus* investigations carried out in southern Europe.

The aims of the present paper were to investigate the validity of the morphological characters reported in the

literature (Reitter, 1913; Krausse 1920; Pfeffer, 1995; Kerdelhué et al., 2002; Kohlmayr et al., 2002), and to look for new characters useful for *Tomicus* species identification.

MATERIAL AND METHODS

Insect collection

Callow and mature adults of *T. destruens* and *T. piniperda* were collected in eighteen localities from Europe and North Africa for a total of 230 specimens (Fig. 1, Tables 1 and 2). The

TABLE 1. Analysed populations of *Tomicus destruens*. Host: P.p. – *Pinus pinaster*; P.d. – *P. pinea*; P.h. – *P. halepensis*. * Populations investigated by Kohlmayr et al. (2002). Countries are reported using the international abbreviation code.

Population	N of callows	N of matures	Country	Region/Locality/City	Lat. N	Long. E	M a.s.l.	Host	Collected by
1	–	19	I	Valle Vecchia	45°54′	12°36′	4	P.p.	M. Faccoli
2	–	19	I	Poggio, Valicaia	43°34′	11°13′	47	P.p.	R. Tiberi
3	20	–	I	Alberese	42°40′	11°06′	300	P.d.	A. Battisti
4	–	20	I	Ginosa	40°34′	16°45′	3	P.h.	O. Triggiani
5	–	6	I	Platamona	40°43′	8°34′	27	P.d.	M. Faccoli
6	2	3	E	Murcia*	37°58′	1°07′	50	P.h.	J. Galian
7	2	3	G	Thessaloniki*	40°39′	22°38′	300	?	N.D. Avtzis
8	–	20	AL	Osella	34°40′	3°14′	?	P.h.	G. Chakali

TABLE 2. Analysed populations of *Tomicus piniperda*. Host: P.s. – *P. sylvestris*; P.n. – *P. nigra*. * Populations investigated by Kohlmayr et al. (2002). Countries are reported using the international abbreviation code.

Population	N of callows	N of matures	Country	Region/Locality/City	Lat. N	Long. E	M a.s.l.	Host	Collected by
1	–	3	FIN	Joensuu*	62°36′	29°46′	100	P.s.	M. Robbo
2	–	6	PL	Sekocin*	52°06′	20°52′	100	P.s.	J. Hilszczanski
3	4	1	CZ	Stará Boleslav*	50°12′	14°44′	250	P.s.	M. Knížek
4	8	–	A	Kühnsdorf*	46°37′	14°36′	440	P.s.	C. Stauffer
5	5	–	A	Mattesburg	47°44′	16°24′	280	P.s.	C. Stauffer
6	20	–	I	Villasantina	46°25′	12°55′	363	P.s.	F. Stergulg
7	–	19	I	Sonico	46°11′	10°23′	1.010	P.s.	A. Ducoli
8	20	–	I	Rocciamelone	45°10′	7°80′	1.600	P.s.	I. Currado
9	–	20	I	Passo del Bocco	42°38′	11°05′	1.100	P.n.	A. Battisti
10	–	10	S	Fredriksberg	60°08′	14°22′	40	P.s.	M. Faccoli

insects were collected from pine shoots found in the litter (mature adults), sampled from pine stems at the beginning of the bark colonisation (mature adults), and from breeding cages containing infested pine logs (callow adults). Some of the populations sampled from central and north Europe were the same as those investigated by Kohlmayr et al. (2002) for genetic purposes (Tables 1 and 2).

Morphological investigations

Six characters reported in the literature and four new morphological characters were tested for separation of *T. piniperda* and *T. destruens*. In particular, according to the specimen availability (Tables 1 and 2), the following characters were investigated:

(1) Colour of elytra

The character was investigated for 149 mature adults, 90 of *T. destruens* and 59 of *T. piniperda* (Tables 1 and 2). Many authors have reported differences in elytral colour between these *Tomicus* species (Reitter, 1913; Krausse 1920; Pfeffer, 1995). However, as is difficult to describe a colour or its intensity in different specimens, in the present paper we investigated if the elytra are similar in colour or lighter than the pronotum, which is always black in mature adults.

(2) Colour of antennal club

The colour of the antennal club, yellow in *T. destruens* and brown in *T. piniperda* (Wollaston, 1865; Pfeffer, 1995), was

tested in 90 *T. destruens* and 59 *T. piniperda*, comprising both callow (81) and mature specimens (149) (Tables 1 and 2).

(3) Setation of antennal club

Kohlmayr et al. (2002) suggested separating the two *Tomicus* species by the density of setae occurring on the surface of the third segment of the antennal club, where *T. piniperda* has only a few setae and *T. destruens* many more. The character was investigated for 98 *T. destruens* and 84 *T. piniperda*, considering both callow and mature adults.

(4) Type and distribution of setae along the elytral interstriae

Kohlmayr et al. (2002) reported three different types of setae (A, B and C) occurring on the elytra of *T. piniperda* and *T. destruens*. The setae A and B were found on both the species, whereas the setae of type C were only found in *T. destruens*. To investigate this character, 298 elytra of mature adults (90 *T. destruens* and 59 *T. piniperda*) were analysed by stereoscope and S.E.M.

(5) Distribution of punctures along the declivity

According to Kerdelhué et al. (2002), the declivity of *T. piniperda* has one row of more-or-less regularly spaced, small, deep punctures occurring between the main punctures of the second interstriae, whereas *T. destruens* has scattered fine punctures occurring in two or three rows. This character has been investigated in 116 *T. piniperda* and 114 *T. destruens*, considering both callow and mature adults (Tables 1 and 2).

(6) Sculpture of elytral declivity

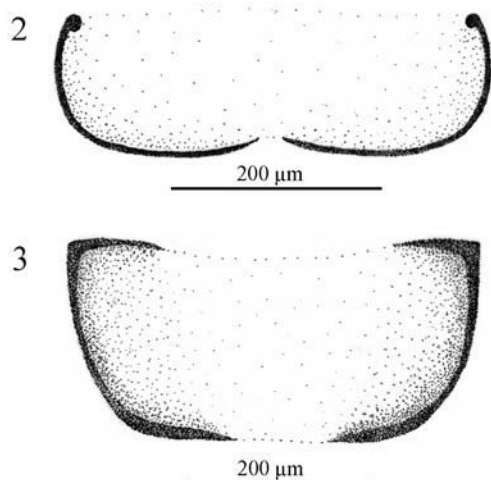
In the original description of *T. destruens*, Wollaston (1865) described the elytral declivity as being duller and more wrinkled than in *T. piniperda*. Sculptures along the second declivital interstriae were analysed in 116 *T. piniperda* and 114 *T. destruens*, using both callow (81) and mature adults (114) (Tables 1 and 2).

(7) Setation of the costal vein

Number, density and distribution of the setae occurring along the costal vein of the membranous wings were analysed for 116 *T. piniperda* and 114 *T. destruens*, considering both wings of each specimen.

(8) Shape of aedeagus and eighth female sternite

The shape of aedeagus, spiculum and eighth female sternite are sometimes useful in scolytid identification (Fuchs, 1912; Butovitsch, 1929). However, in the genus *Tomicus* the eighth sternite of both male and female are very small and composed of two weakly sclerified pieces joined by an unsclerified membrane (Figs 2–3), which easily dissolves or breaks during the extraction procedure. In addition, the eighth sternite is hidden



Figs 2–3: Eighth sternite of *Tomicus destruens*. 2 – male; 3 – female.

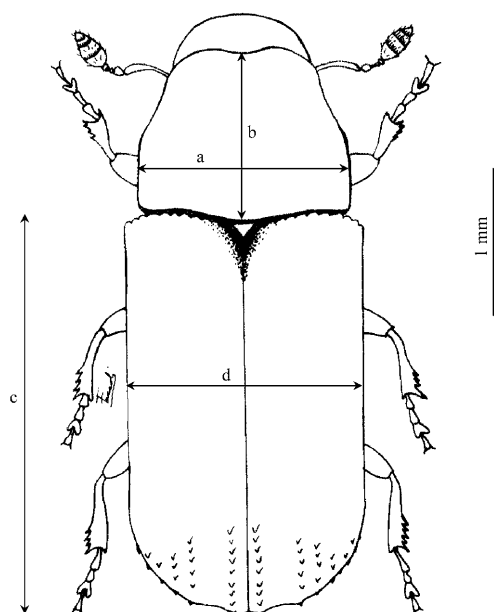


Fig. 4. Body measures taken in *Tomicus destruens* and *T. piniperda*: a – width of the posterior part of the pronotum; b – length of the pronotum; c – length of the elytra; d – width of the elytra.

by the eighth tergite (pygidium) both in males and females. For these reasons, beside the aedeagus and the spiculum, our investigations were focused on pygidium (eighth tergite) (Figs 10–11) and propygidium (seventh tergite) (Figs 12–13) of mature males and females of 59 *T. piniperda* and 90 *T. destruens* (Tables 1 and 2).

(9) Structure of the stridulatory device

Males of *Tomicus* produce sound by a stridulatory device made by a plectrum, two paired conical teeth located on the posterior margin of the propygidium, and a pars stridens occurring on the inner face of the elytra. As in North American species of the genus *Ips*, density and shape of pars stridens are useful for species identification (Lanier, 1970a, b), the structure of the stridulation device was investigated by S.E.M. in 298 elytra of

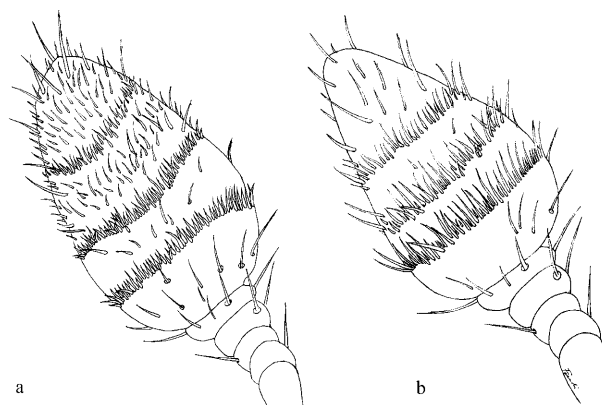


Fig. 5. Antennal clubs of *Tomicus destruens* (a) and *T. piniperda* (b). Note the different setation of the third segment and along the suture of the first segment.

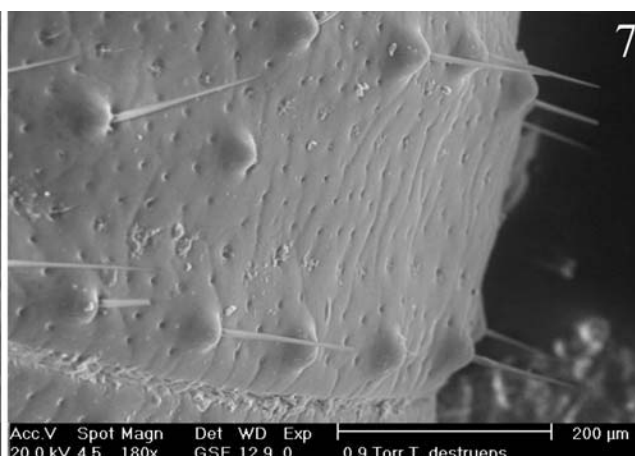
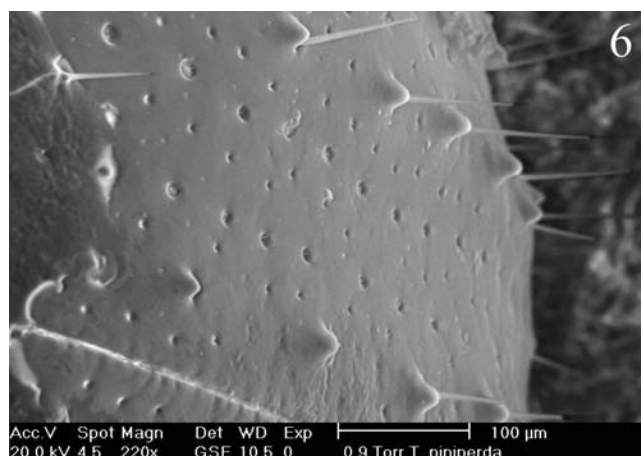
59 *T. piniperda* and 90 *T. destruens*. Only mature adults were used.

(10) Body proportions

The body proportions can vary among species as observed by Wollaston (1865), who described *T. destruens* a “little larger and thicker than *T. piniperda*”. Lekander (1971) confirmed the description made by Wollaston (1865), measuring 44 *T. destruens* from France and 44 *T. piniperda* from Sweden, but no values were reported in his paper. In this regard, total length and width of elytra and pronotum were recorded in 116 *T. piniperda* and 114 *T. destruens* (Tables 1 and 2). The measurements concerned the width of the posterior part of the pronotum (Fig. 4a), the length of the pronotum (Fig. 4b), the length of the elytra (Fig. 4c), and the width of elytra (Fig. 4d).

Insect handling and sample preparation

The analyses were carried out using a Wild® stereoscopic dissecting microscope (50×) and a Wild® microscope (100×), except for the studies concerning density of pars stridens and elytral setation where a S.E.M. was used. The samples analysed by microscope (antennal clubs, membranous wings and genitalia) were prepared by leaving the insect in a KOH solution for 30 minutes at 80°C; then, the body was dissected and the



Figs 6–7. 6 – Punctures of the second interstriae along the declivity of the elytra of *Tomicus piniperda*. Note the uniseriate small punctures running between the two rows of the main punctures. The tegument is smooth, with no evident crenulation. 7 – Punctures and transverse crenulation of the second interstriae along the declivity of the elytra of *T. destruens*. Note the small and deep punctures scattered between the two rows of the main punctures.

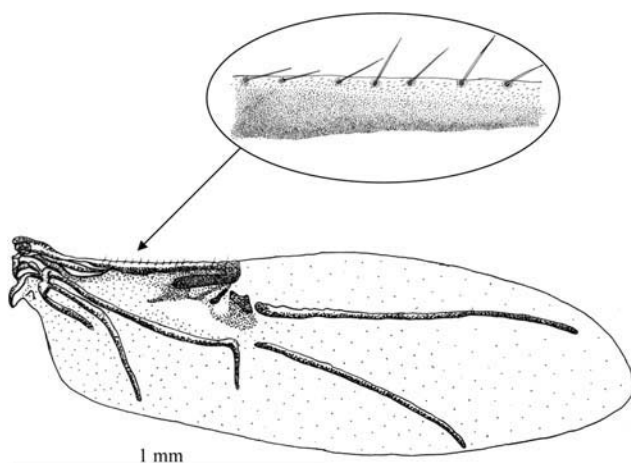


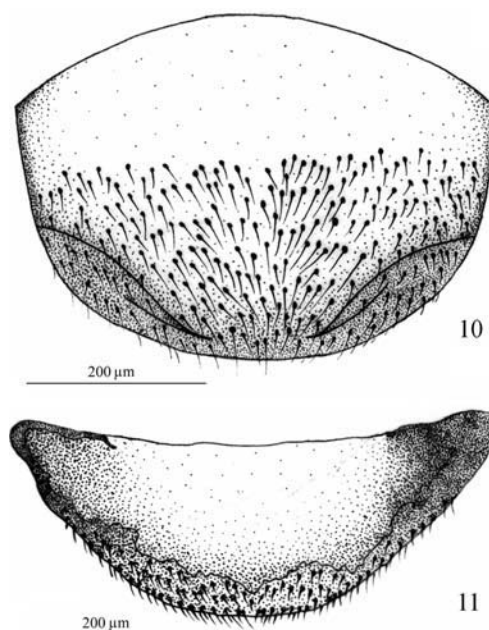
Fig. 8. Membranous wing of *Tomicus destruens* and magnification of setae occurring along the costal vein.

investigated samples were left for few seconds in ethanol 75%, ethanol 90% and pure xylol successively. Finally, the samples were fixed on slides in Canada balsam.

Statistical analysis

Data were subjected to analysis of variance (ANOVA test) by the General Linear Model for randomised block designs (Zar, 1999) for determination of differences between the mean values.

Homogeneity of variance was tested using Cochran's test and, when necessary, data were log-transformed [$X' = \log(x + 1)$] or arcsin-transformed ($X' = \arcsin\sqrt{P_x}$) to obtain homogeneous variances. Where significant differences occurred, Tukey's honestly significant difference (HSD) multiple comparison test was



Figs 10–11. 10 – eighth male tergite (pygidium) of *Tomicus destruens*; 11 – eighth female tergite of *T. destruens*.

applied for mean separation (Zar, 1999). Data having a non-normal distribution were subjected to chi-square (χ^2) analysis. Differences at 0.05 level of confidence were considered significant. Analyses were performed by the STATISTICA® per WINDOWS® software.

RESULTS AND DISCUSSION

(1) Colour of elytra

Mature adults of the two species had different elytral colour (Table 3). In this respect, *T. destruens* always had elytra lighter and more reddish than the pronotum, whereas *T. piniperda* had elytra dark-brown or black with a colour similar to that of the pronotum. Therefore, besides to that previously reported (Wollaston, 1865; Reitter, 1913; Krausse, 1920), the comparison between elytral and pronotum colour is also useful for *Tomicus* identification. However, callow adults of both species have a similar homogeneous yellow colour, thus for young specimens other characters must be used for identification.

(2) Colour of antennal club

Overall, 97.5% of *T. piniperda* specimens had the antennal club browner than the funicle, whereas 96.2% of *T. destruens* had both antennal club and funicle pale (Table 3). In a few cases the character was not recognizable. The character was easily visible in both mature and callow adults, without statistical differences (Tables 5 and 6). The colour of the antennal clubs is one of the differentiating characters reported in the original description made by Wollaston in 1865. Moreover, in a more recent key for identification of Palaearctic bark beetles, Pfeffer (1995) reported club colour as the only character useful for separation of these two *Tomicus* species.

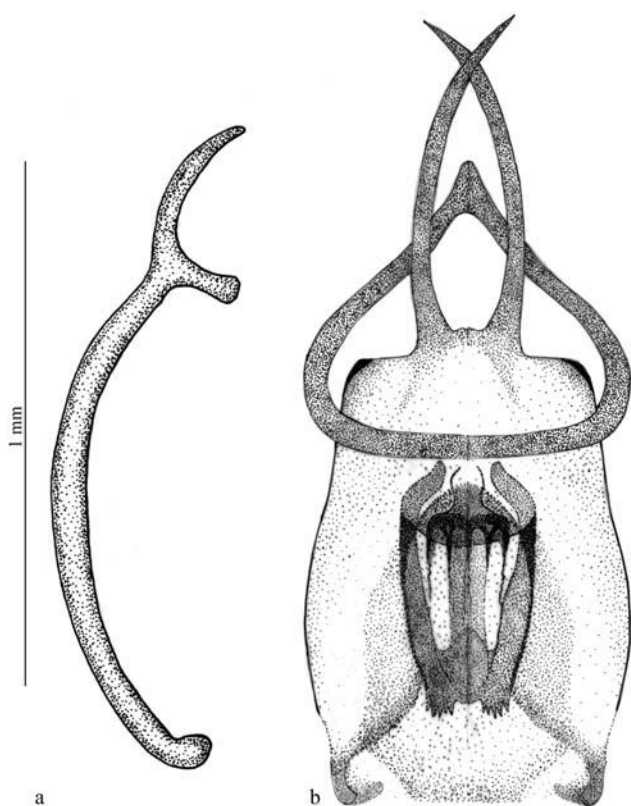
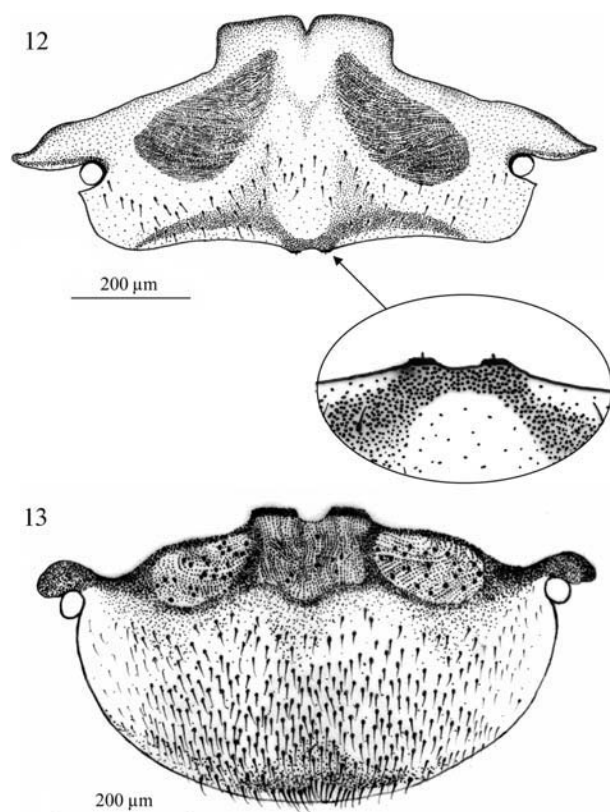


Fig. 9. Spiculum (a) and aedeagus (b) of *Tomicus destruens*.



Figs 12–13: 12 – seventh male tergite (propygidium) of *Tomicus destruens* and magnification of the plectrum; 13 – seventh female tergite of *T. destruens*.

(3) Setation of antennal club

The distribution of setae occurring on the third antennal segment was denser in *T. destruens* than in *T. piniperda* (Table 3), especially in the upper part of the club (Fig. 5). Concerning *T. piniperda*, 69.9% of the specimens showed the character proposed by Kohlmayr et al. (2002), whereas in 27.8% of the adults the character was not visible. For *T. destruens* the character occurred in 82.3% of the specimens but was not identifiable in 13.9% of the adults. Finally, 6.3% of *T. destruens* were similar to *T.*

TABLE 3. Statistical analysis (test χ^2) of non-normal data from the morphological comparison of *Tomicus destruens* and *T. piniperda*. Differences at 0.05 level of confidence were considered significant.

Character	Df effect	Df error	χ^2 value	P level
Colour of elytra	1	148	57.03	0.001
Colour of antennal club	1	217	131.24	0.001
Setae of third club segment	1	181	58.33	0.001
Setae of first club suture	1	181	73.87	0.001
Punctures of declivity	1	229	52.61	0.001
Sculpture of declivity	1	229	28.06	0.001
Elytral length/width	1	229	9.21	0.01
Elytra/pronotum length	1	229	6.99	0.01
Elytral length/pronotum width	1	229	8.84	0.01

TABLE 4. Statistical analysis (ANOVA) of normal data from the morphological comparison of *Tomicus destruens* and *T. piniperda*. Differences at 0.05 level of confidence were considered significant.

Character	Df effect	Df error	F value	P level
Number of setae on costal vein	1	459	0.08	0.66
Density of setae on costal vein	1	459	0.10	0.61
Distance first-last setae on costal vein	1	459	0.18	0.57
Density of the pars stridens	1	297	33.13	0.001

piniperda. There were not statistical differences between callow and mature adults (Tables 5 and 6).

During the present study a new morphological difference was found. In 83.5% of *T. piniperda* the upper margin of the first antennal segment had two different types of setae, one short and one long (Fig. 5b), placed in a single row, whereas 86% of *T. destruens* had only short setae (Fig. 5a) (Table 3). The new character, which has higher accuracy (83.5% of *T. piniperda* and 86% of *T. destruens*) than the character proposed by Kohlmayr et al. (2002) (69.9% of *T. piniperda* and 82.3% of *T. destruens*), occurred both in callow and mature adults (Tables 5 and 6).

(4) Type and distribution of setae along the elytral interstriae

This do not seem to be a good morphological character for *Tomicus* identification as no differences were found in the elytral setae of the two species, neither by stereoscope nor by SEM. The three types of setae (A, B and C) described by Kohlmayr et al. (2002) occurred on the elytra of both the species, with the setae of type C occurring only sporadically.

(5) Distribution of punctures along the declivity

According to Kerdelhué et al. (2002), the distribution of the punctures on the second interstriae along the declivity was different between species (Table 3). *Tomicus piniperda* had uniseriate, small and deep punctures occurring between the large and shallow punctures of the striae (Fig. 6). *Tomicus destruens* had similar punctures, but they were arranged in two or three irregular rows (Fig. 7). Wood also reported this difference in an unpublished key to *Tomicus* genus (pers. comm., 1999). Although the character is usually good for species separation, it did not occur in all specimens, and for both species it was more visible in mature compared with callow adults (Tables 5 and 6).

TABLE 5. Statistical analysis (test χ^2) of non-normal data from the morphological comparison of mature and callow adults of *Tomicus destruens*. Differences at 0.05 level of confidence were considered significant.

Character	Df effect	Df error	χ^2 value	P level
Colour of antennal club	1	105	0.02	0.34
Setae of third club segment	1	97	0.33	0.21
Setae of first club suture	1	97	0.09	0.48
Punctures of declivity	1	113	45.9	0.01

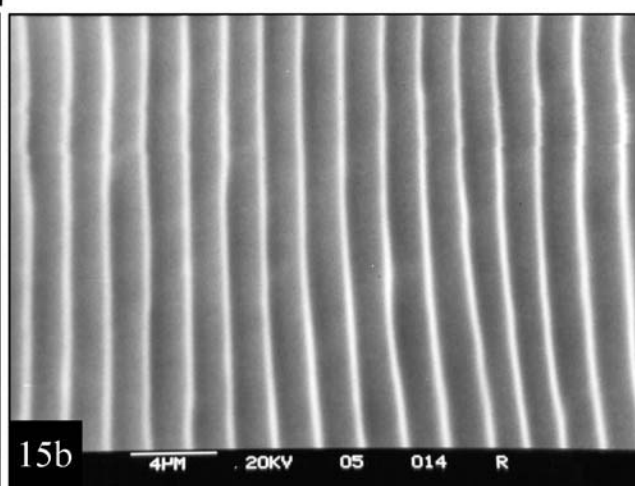
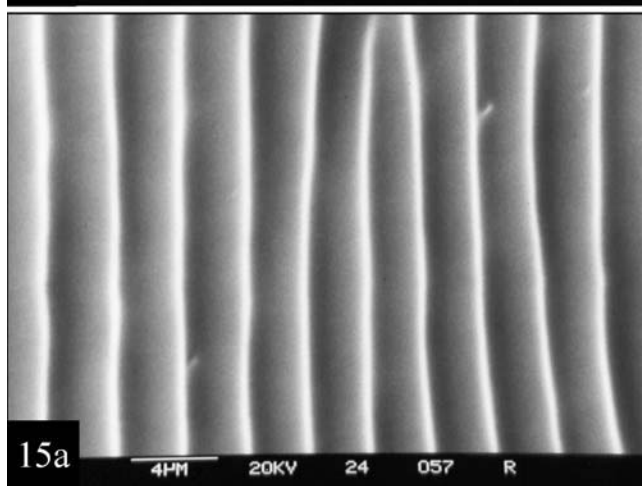
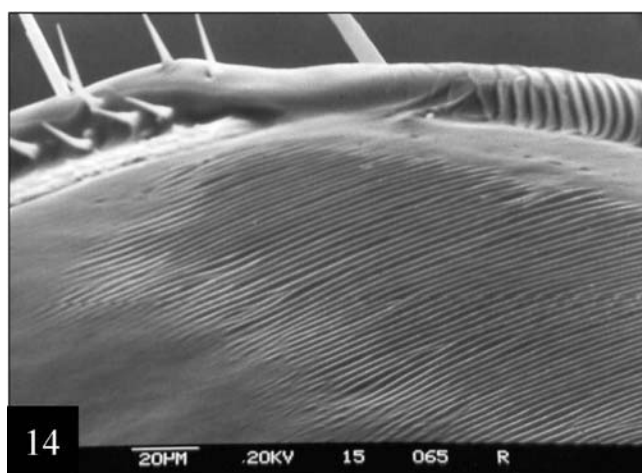


Fig. 14–15. 14 – Pars stridens of *Tomicus destruens*. 15 – Pars stridens of *Tomicus destruens* (a) and *T. piniperda* (b), taken at the same magnification. See the different density of the striae.

(6) Sculpture of elytral declivity

The declivity of both species was weakly, irregularly, transversely wrinkled, most easily seen on interstriae 2 where no setae occur (Figs 6–7), but in most *T. destruens* specimens the sculpture of the second declivital interstriae was more wrinkled than in *T. piniperda* (Table 3).

Our observations partially confirm the character proposed by Wollaston (1865), who described the elytral declivity of *T. destruens* as more “opaque and wrinkled” than in *T. piniperda*. Nevertheless, there were no relevant differences between species in the lustre of the elytral declivity, and the shining of the second interstria was similar in both species. The character was more visible in mature than in callow adults.

TABLE 6. Statistical analysis (test χ^2) of non-normal data from the morphological comparison of mature and callow adults of *Tomicus piniperda*. Differences at 0.05 level of confidence were considered significant.

Character	Df effect	Df error	χ^2 value	P level
Colour of antennal club	1	111	1.33	0.21
Setae of third club segment	1	83	0.06	0.64
Setae of first club suture	1	83	0.69	0.82
Punctures of declivity	1	115	69.3	0.001

(7) Setation of the costal vein

The two species showed no statistical difference in both the number of setae, their density or the distance between first and last setae occurring along the costal vein of the membranous wings (Table 4, Fig. 8). Therefore, this character is not reliable for *Tomicus* identification.

(8) Shape of aedeagus and tergites

The genitalia, which can provide important morphological characters (Fuchs, 1912; Butovitsch, 1929), were similar between the two species. Males of *T. piniperda* and *T. destruens* had aedeagus and spiculum similar in shape and size (Fig. 9). Likewise, pygidium (eighth tergite) (Figs 10–11) and propygidium (seventh tergite) (Figs 12–13) were similar between species, and different between sexes. None of the investigated segments shows morphological differences visible by stereoscope or microscope.

(9) Structure of the stridulatory device

Tomicus males are able to produce sound by a stridulatory device constituted by two conical bristles (pectrum) situated on the central part of the posterior margin of the propygidium (Fig. 12). The pectrum scrapes against tegumental striae (pars stridens), which are situated on the adjacent inner surface of the elytra (Fig. 14), producing sound. Females have a small pars stridens but no

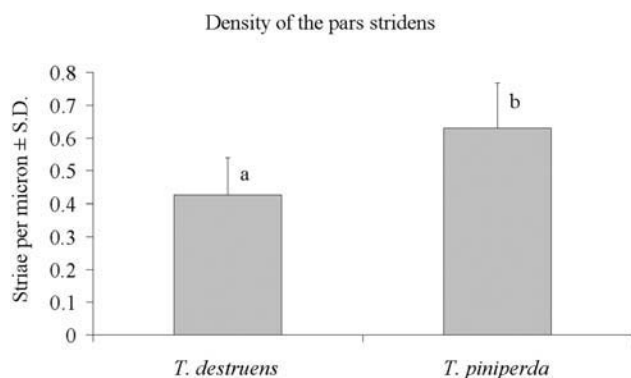


Fig. 16. Density of the pars stridens of *Tomicus destruens* and *T. piniperda* (Different letters indicate statistical differences between species).

plectrum, so they are unable to produce sound. The pars stridens of *Tomicus* males covers a large area along the inner and postero-medial part of the elytra (close to the elytral suture), and no differences were found between species in either shape or size (Fig. 14). However, the density of striae along the pars stridens was higher in *T. piniperda* than in *T. destruens* (Table 4, Fig. 15). The pars stridens of *T. piniperda* had in average 0.63 striae per micron, whereas only 0.42 occurred in *T. destruens* (Fig. 16). No differences were found between species in shape, size and position of the plectrum (Fig. 12). In many bark beetles, stridulation is known to be important for aggregation and mating (Rudinsky et al., 1973; Rudinsky & Michael, 1973; Rudinsky & Ryker, 1976; Rudinsky & Vallo, 1979). Different densities of pars stridens could determine different sound emissions, which can lead to reproductive isolation among closely related species, as *T. destruens* and *T. piniperda*.

(10) Body proportions

The ratio between length and width of the elytra was different between species, higher in *T. piniperda* (>1.7) than in *T. destruens* (<1.7) (Table 3). Also, the ratio between elytra and pronotum length was higher in *T. piniperda* (>2.35) than *T. destruens* (<2.35) (Table 3). Finally, the ratio between elytral length and pronotum width was higher in *T. piniperda* (>1.9) than *T. destruens* (<1.9) (Table 3). Lekander (1971) supported the general observations made by Wollaston (1865) concerning the different size and shape of the two species, describing *T. destruens* as on average a little “larger and wider” than *T. piniperda*. Our measurements give similar results with *T. piniperda* having in general a slimmer silhouette than *T. destruens*. Finally, we found no significant differences between species in shape and proportions of the pronotum, although Lekander (1971) described the form of the pronotum as “more pear-like in the *piniperda* than in *destruens* in which species it is broadest at the base, tapering gradually forwards, and therefore barely pear-shaped”.

CONCLUSIONS

One aim of systematic research is to find clear morphological characters useful for species separation. Nevertheless, in many cases the available characters are few and weak. The acceptance of *T. destruens* as a different species from *T. piniperda* has been relatively recent due to the absence of clear diagnostic differences between the two species. In addition, many descriptions were not very useful for taxonomic purposes, as they did not provide figures concerning the differentiating characters (Wollaston, 1865; Reitter, 1913; Krausse, 1920). Although Lekander (1971) reported clear drawings of the larval epipharyngeal setae, his sketches of the adults are not very useful. Only recent genetic analyses have confirmed the validity of *T. destruens* as a separate species (Gallego & Galian, 2001; Kerdelhuè et al., 2002; Kohlmayr et al., 2002; Faccoli et al., 2005). However, the present morphological investigation allowed for the discovery or confirmation of eight characters that differentiate *T. destruens* and *T. piniperda*. They include elytra colour, antennal club colour, density of antennal club setae, setation of the first antennal club suture, punctuation of the second declivital interstriae, structure of stridulatory device, body proportions, and sculpture on the elytral declivity. On the other hand, three of the eleven investigated characters, such as the type of setae of the elytral interstriae, density of setae along the costal vein, and the shape and size of genitalia, were not useful in separating the two species. All morphological differences reported in the literature are good for *Tomicus* separation, except the setation of the elytral interstriae proposed by Kohlmayr et al. (2002), which probably needs a more detailed analysis. In addition, the differences among setae are visible only by SEM. Concerning the original observations carried out in the present paper, the density of the pars stridens, the setation of the first suture of the antennal clubs, and the body proportions are new characters useful for separation of *T. piniperda* and *T. destruens*. Finally, callow adults of *T. destruens* and *T. piniperda* can be easily separated using all the proposed characters, except the colour of the elytra. However, the punctures occurring on the declivital interstriae and the sculpture of the elytral declivity are more difficult to see in callow than in mature adults.

Data from the investigated populations (Table 1 and 2) and from the literature indicated *T. destruens* as a thermophile species living in Mediterranean and Atlantic regions (Fig. 1), which include western localities such as Madeira (Wollaston, 1865; Lekander, 1971), Spain (Lekander, 1971; Kohlmayr et al., 2002) and Mallorca (Lekander, 1971), central Mediterranean including North Africa (Algeria), Italian and Greek coasts (Fig. 1), Sardinia and Tuscany archipelagos (Faccoli & Cecchi, 2003), and finally eastern regions as Turkey, Cyprus and Israel (Lekander, 1971). *Tomicus piniperda* has a larger Eurasian distribution. However, in southern Europe it is possible to find overlapping populations of the two species, especially in southern France, northern Spain, Portugal, and the Balkan peninsula (Kerdelhuè et al., 2002; Gallego et al., 2004). In this respect, it would be interesting to

continue the preliminary experiments of Carle (1974) concerning the interfecundity of the two species. Similar shape and size of genitalia could allow mating between *T. destruens* and *T. piniperda*, although different densities of the pars stridens suggest different sound emissions, which may play a major role in avoiding mating.

Key for *T. piniperda* and *T. destruens* separation

Because some of the described characters do not occur in all specimens, the best way for species separation is through a careful analysis of the specimens, using a combination of all characters reported in the following key:

- 1 Mature colour of elytra dark brown, colour of antennal club darker than antennal funicle, third antennal segment with few isolated setae (Fig. 5b), upper margin of the first antennal club segment with both short and long setae (Fig. 5b), second interstriae of the declivity smooth, with uniseriate, small and deep punctures (Fig. 6), length/width of elytra >1.7, elytra/pronotum length >2.35, elytral length/pronotum width >1.9. Distribution: Eurasia, including Japan; introduced into N. America. Host-trees: Mainly on continental pine species and *Pinus pinaster*. In N America on Scots pine (*P. sylvestris* L.), jack pine (*P. banksiana* Lamb.), red pine (*P. resinosa* Aiton) and eastern white pine (*P. strobus* L.). *T. piniperda* (Linnaeus, 1758)
- Mature colour of elytra reddish, antennal club of the same colour of the antennal funicle, third antennal segment with abundant vestiture of many setae (Fig. 5a), upper margin of the first antennal club segment with only short and regular setae (Fig. 5a), second interstriae of the declivity transversely wrinkled, with 2 or 3 rows of punctures (Fig. 7), length/width of elytra <1.7, elytra/pronotum length <2.35, elytral length/pronotum width <1.9. Distribution: Mediterranean regions of N. Africa, S Europe, and SW Asia. Host-trees: Mediterranean pine species such as *Pinus pinaster*, *P. pinea*, *P. canariensis*, *P. brutia* and *P. halepensis*. *T. destruens* (Wollaston, 1865)

ACKNOWLEDGEMENTS. The author is very grateful to R. Haack, M. Knížek and L. Kirkendall who reviewed the manuscript and provided numerous suggestions for its improvement. Many thanks to all the people listed in tables 1 and 2 for their help in collecting and sending *Tomicus* specimens. Special thanks to C. Stauffer for providing part of his insect collection.

REFERENCES

BALACHOWSKY A. 1949: *Coléoptères Scolytides*. Faune de France 50. Librairie de la Faculté des Sciences, Paris, 320 pp.

BUTOVITSCH V. 1929: Studien über die Morphologie und Systematik der paläarktischen Splintkäfer. *Stett. Entomol. Zeit.* **90**: 1–80.

CARLE P. 1974: Mise en évidence d'une attraction secondaire d'origine sexuelle chez *Blastophagus destruens* Woll. (Col. Scolytidae). *Ann. Zool. Écol. Anim.* **6**: 539–550.

CARLE P. 1975 : Problèmes posés par les ravageurs xylophages des conifères en forêt méditerranéenne. *Rev. For. Fr.* **27**: 283–296.

CHARARAS C. 1962: *Étude Biologique des Scolytides des Conifères*. Enc. Ent. 37, Lechevalier, Paris, 555 pp.

DAJOZ R. 2000: *Insects and Forest: The Role and Diversity of Insects in the Forest Environment*. Techniques and Documentations Editions, Paris, 668 pp.

EGGERS H. 1929: Zur Synonymie der Borkenkäfer (Ipidae, Col.). *Wien. Entomol. Zeit.* **46**: 41–55.

EICHHOFF W.J. 1881: *Die Europäischen Borkenkäfer*. J. Springer, Berlin, 315 pp.

ESCHERICH K. 1923: *Forstinsekten Mitteleuropas. Band II*. Paul Parey, Berlin, 663 pp.

FACCOLI M., PISCEDDA A., SALVATO P., SIMONATO M., MASUTTI L. & BATTISTI A. 2005: Phylogeography of the pine shoot beetles *Tomicus destruens* and *T. piniperda* (Coleoptera: Scolytidae) in Italy. *Ann. Forest Sci.* **62**: 361–368.

FACCOLI M. & CECCHI B. 2003: Contributo alla conoscenza dell'Ipidofauna dell'arcipelago toscano (Coleoptera Scolytidae). *Redia* **86**: 133–138.

FERREIRA M.C. & FERREIRA G.W.S. 1986: Pragas do pinheiro bravo em Portugal – Escolitideos. *Bol. Agric.* **36**: 1–4.

FUCHS G. 1912: *Morphologische Studien über Borkenkäfer – II. Die europäischen Hylesinen*. Reinhardt, München, 53 pp.

GALLEGO D. & GALIÁN J. 2001: The internal transcribed spacers (ITS1 and ITS2) of the rDNA differentiate the bark beetle forest pests *Tomicus destruens* and *T. piniperda*. *Ins. Mol. Biol.* **10**: 415–420.

GALLEGO D., CÁNOVAS F., ESTEVE M.A. & GALIÁN J. 2004: Descriptive biogeography of *Tomicus* (Coleoptera: Scolytidae) species in Spain. *J. Biogeog.* **31**: 2011–2024.

GIL L. & PAJERAS J.A. 1986: *Los Escolitidos de las Coníferas en la Península Ibérica*. Publicaciones del Ministerio de Agricultura, Pesca y Alimentación – Secretaría General Técnica, Madrid, 194 pp.

HAACK R.A. & KUCERA D. 1993: *New Introduction – Common Pine Shoot Beetle, Tomicus piniperda (L.)*. USDA Forest Service, Northeastern Area, Pest Alert NA-TP-05-93.

HAACK R.A., POLAND T.M., PATRICE T.R. & GENNRICH M.A. 2000: Range expansion of *Tomicus piniperda* since 1992 and notes on other new exotics. *Michigan Entomol. Soc.* **45**: 9–10.

HAACK R.A. & POLAND T.M. 2001. Evolving management strategies for a recently discovered exotic forest pest: the pine shoot beetle, *Tomicus piniperda* (Coleoptera). *Biol. Invas.* **3**: 307–322.

KERDELHUÉ C., ROUX-MORABITO G., FORICHON J., CHAMBON J.-M., ROBERT A. & LIEUTIER F. 2002: Population genetic structure of *Tomicus piniperda* (Curculionidae: Scolytinae) on different pine species and validation of *T. destruens* (Woll.). *Mol. Ecol.* **11**: 483–494.

KOHLMAYR B., RIEGLER M., WEGENSTEINER R. & STAUFFER C. 2002: Morphological and genetic identification of the three pine pests of the genus *Tomicus* (Coleoptera, Scolytidae) in Europe. *Agr. For. Entomol.* **4**: 151–157.

KRAUSSE A.M. 1920: Die Arten, Rassen und Varietäten des grossen Waldgärten (genus *Blastophagus* Eich.). *Z. Forst. Jagdw.* **52**: 169–178.

LÄNGSTRÖM B. & HELLQVIST C. 1991: Spatial distribution and crown damage and growth losses caused by recurrent attacks of pine shoot beetles in pine stands surrounding a pulp mill in southern Sweden. *J. Appl. Entomol.* **110**: 261–269.

LANIER G.N. 1970a: Biosystematics of North American *Ips* (Coleoptera: Scolytidae). Hopping's group IX. *Can. Entomol.* **102**: 1139–1163.

LANIER G.N. 1970b: Biosystematics of North American *Ips* (Coleoptera: Scolytidae). Hopping's group III. *Can. Entomol.* **102**: 1404–1423.

LEKANDER B. 1971: On *Blastophagus destruens* Woll. and a description of its larva (Col. Scolytidae). *Entomol. Tidskrift* **92**: 271–276.

MASUTTI L. 1969: Pinete dei litorali e *Blastophagus piniperda* L. – Una difficile convivenza. *Monti e Boschi* **3**: 15–27.

PEFFER A. 1995: *Zentral- und westpaläarktische Borken- und Kernkäfer (Coleoptera: Scolytidae, Platypodidae)*. Pro Entomologia, c/o Naturhistorisches Museum Basel, 310 pp.

- POSTNER M. 1974: Scolytidae Borkenkäfer. In Schwenke W. (ed.): *Die Forstschädlinge Europas. Bd. 2, Käfer*. Paul Parey, Hamburg und Berlin, pp. 334–487.
- REITTER E. 1913: Bestimmungstabelle der Borkenkäfer (Scolytidae) aus Europa und den angrenzenden Ländern. *Wien. Entomol. Zeit.* **32**: 1–116.
- RUDINSKY J.A. & MICHAEL R.R. 1973: Sound production in Scolytidae: Stridulation by female *Dendroctonus* beetles. *J. Insect Physiol.* **19**: 689–705.
- RUDINSKY J.A. & RYKER L.C. 1976: Sound production in Scolytidae: rivalry and premating stridulation of male Douglas-fir beetle. *J. Insect Physiol.* **22**: 997–1003.
- RUDINSKY J.A. & VALLO V. 1979: The ash bark beetles *Leperisinus fraxini* and *Hylesinus oleiperda*: stridulatory organs, acoustic signals, and pheromone production. *Z. Ang. Entomol.* **87**: 417–429.
- RUDINSKY J.A., MORGAN M.E., LIBBEY L.M. & MICHAEL R.R. 1973: Sound production in Scolytidae: 3-methyl-2-cyclohexen-1-one released by the female Douglas-fir beetle in response to male sonic signal. *Environ. Entomol.* **2**: 505–509.
- RUSSO G. 1940: Il blastofago del pino (*Blastophagus* (*Myelophilus*) *piniperda* L. var. *rubripennis* Reitter). *R. Lab. Entomol. Agr. Fac. Agr. Portici* **19**: 1–13.
- RUSSO G. 1946: Scolitidi del Pino del litorale toscano. *Boll. Ist. Entomol. "G. Grandi" Univ. Bologna* **15**: 297–314.
- SCHEDL K.E. 1932: Scolytidae, Platypodidae. In Winkler A. (ed.): *Catalogus Coleopterorum Regionis Palaearcticae*. Wien, pp. 1632–1647.
- SCHEDL K.E. 1946: Bestimmungstabellen der palaearktischen Borkenkäfer, II – Die Gattung *Blastophagus* Eichh. *Zentr. Ges. Entomol.* **1**: 50–58.
- TRIGGIANI O. 1983: Sensibilità del *Tomicus* (*Blastophagus*) *piniperda* L., (Col., Scolytidae) ai nematodi della famiglia Steinernematidae e Heterorhabditidae. *Entomologica* **18**: 215–223.
- TRIGGIANI O. 1984: *Tomicus* (*Blastophagus*) *piniperda* (Coleoptera, Scolytidae, Hylesininae): biologia, danni e controllo nel litorale ionico. *Entomologica* **19**: 5–21.
- WOLLASTON T.V. 1865: *Coleoptera Atlantidum, Being an Enumeration of the Coleopterous Insects of Madeiran, Salvages and Canaries*. Voorst, London, 526 pp.
- WOOD S.L. & BRIGHT D.E. 1992: *A Catalogue of Scolytidae and Platypodidae (Coleoptera). Part 2: Taxonomic Index. Great Basin Naturalist Memoirs 13*. Brigham Young Univ., Provo, Utah, 1553 pp.
- YE H. 1991: On the bionomy of *Tomicus piniperda* (L.) (Col., Scolytidae) in the Kuming region of China. *J. Appl. Entomol.* **117**: 190–194.
- YE H. & LIEUTIER F. 1997: Shoot aggregation by *Tomicus piniperda* (L.) (Col., Scolytidae) in Yunnan, Southwestern China. *Ann. For. Sci.* **54**: 635–641.
- ZAR J.H. 1999: *Biostatistical Analysis*. Prentice Hall Press, Upper Saddle, NJ, 660 pp.

Received April 17, 2005; revised and accepted September 23, 2005