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CHESTNUT-ASSOCIATED INSECTS ALIEN TO EUROPE

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The genus *Castanea* comprises 12 species worldwide. *Castanea sativa* Miller, *C. mollissima* Blume and *C. crenata* Siebold & Zucc. are the most important providing a relevant supply of either timber or edible fruits. In particular, *C. sativa*, because of the high economic value of its fruits, is widely cultivated as pure species or hybrids. The accidental introduction in Italy of the East Asian *Dryocosmus kuriphilus* Yasumatsu, responsible for severe damages to *C. sativa*, stressed the importance of implementing monitoring activities and control strategies in southern Europe. Therefore, in order to provide the phytosanitary services operating at European entry points with a useful monitoring tool, more than 150 phytophagous insect species known to attack *Castanea spp.* in North America and Eastern Asia were listed in this review. The risk of their potential introduction and possible threat to European chestnuts were evaluated on the basis of the available literature. To this end, three risk categories were defined: Low risk (L), Medium risk (M) and High risk (H). All the listed species were included in one of them.

KEY WORDS: *Castanea sativa* Miller, fruits, timber, insect alien pests, phytosanitary measures.

INTRODUCTION

The genus *Castanea* Miller comprises 12 species worldwide. Among them, those with a wider distribution are currently the sweet chestnut *C. sativa* Miller, the Chinese chestnut *C. mollissima* Blume and the Japanese chestnut *C. crenata* Siebold & Zucc. These plants are globally regarded as an essential source of timber and fruits suitable for human consumption. In 2014, the global production of fruits exceeded 2 million tons with China being the main producer accounting for almost 85% of the global output, followed by Turkey and Italy with 63.762 and 51.959 tons per year respectively (FAO, 2017). In particular, sweet chestnut is widely cultivated because of the high economic value of its seeds. From its native range in Southern Europe, North Africa and Asia Minor, it has been spread worldwide either as pure species or hybrids with other congeneric species (generally Chinese and Japanese ones). In some cases, these new hybrids permitted either to improve quantity and quality of food production or to develop plant resistance to pests (JAYNES, 1975).

However, *Castanea spp.*, as well as many other crops, are globally threatened by a wide number of noxious organisms. Among them, insects represent one of the main challenges, particularly in the light of the intensive trade of plants, seedlings, scions and fruits, which play a key role in the spread of pests on a global scale. In this regard, it is worth mentioning the case of the American *Castanea dentata* (Marshall) Borkh., which was strongly affected by the accidental introduction from Asia of *Cryphonectria parasitica* (Murrill) Barr., a pest responsible for chestnut blight that severely compromised the whole American chestnut heritage. More recently the oriental chestnut gall wasp *Dryocosmus kuriphilus* Yasumatsu emerged as a new global threat for some *Castanea* species (YASUMATSU, 1951; EPPO, 2005; RIESKE, 2007; MURAKAMI, 2010). Though irreversible damages in orchards and natural forests have

never been reported, the economic losses due to reduced seed production and wood growth are relevant (DIXON *et al.*, 1986; MALTONI *et al.*, 2012; BATTISTI *et al.*, 2014; SABBATINI PEVERIERI *et al.*, 2016).

On a worldwide perspective, there are many potentially harmful insect species that require a special attention in order to avoid critical scenarios in newly invaded areas. In this context, several countries interested in chestnut production (e.g. Australia and New Zealand) particularly focused on high-risk areas such as entry ports and developed pest risk analyses in order to minimize accidental introductions and spreading of alien species (BERG *et al.*, 2001; MAF, 2011).

MATERIALS AND METHODS

The present review is based on a worldwide selection of scientific and technical documents concerning chestnut-feeding insects recorded outside Europe with a special focus on species reported as actual pests. The survey was performed using the following search engines: EBSCO®, SCOPUS®, Annual Review of Entomology® (from the year 1980 to 2006) and Google-Scholar®. The listed insect species were included in the following ecological and nutritional categories: sap-feeding, defoliating, gall-inducing, xylophagous and seed/fruit-feeding insects. Because some of the species showed different nutritional behaviour during their whole life cycle, they were included in the category where the most severe damages had been previously reported.

Since this report was developed based on a wide variety of sources, raw information was inevitably fragmented and scattered in different types of documents (e.g. scientific papers, technical reports and on-line information). Moreover, pest lists available in literature were sometimes incomplete and/or unreliable or poorly validated. In addi-

tion, though abstracts of every type of documents were always considered, full-text documents were, in some cases, difficult to access and complex to interpret when published in languages other than English.

Therefore, in order to schematically define a phytosanitary risk level for each of the selected species, data from literature

were evaluated focusing on either the severity of damages recorded in their native countries or on the risk of accidental introductions in new areas due to trade. In order to manage all data and information, the following three risk categories were defined: low risk (L) medium risk (M) and high risk (H) (Table 1). Every species was then included in one of the categories.

Table 1 – A worldwide list of chestnut-associated insect species alien to Europe: relative risk of introduction and potential threat (CN = China; JP = Japan; KO = Korea; IN = India; RU = Russia (eastern); CA = Canada; TW = Taiwan; Ind = Indonesia; NE = Nepal; MX = Mexico; USA = United States of America; VT = Vietnam; LA = Laos; MY = Myanmar; MO = Mongolia; TH = Thailand; ML = Malaysia; † = considered extinct taxa; (I) = species that were recently and accidentally introduced in Europe.

Species name	Order, Family	Origin	Risk level	References
1 <i>Actias luna</i> (Linneo)	Lepidoptera, Saturniidae	USA, CA	L	PAYNE & JOHNSON, 1979
2 <i>Actias ningpoana</i> Fielder	Lepidoptera, Saturniidae	CN, RU	L	WU <i>et al.</i> , 2000b; ZHANG, 2008
3 <i>Adoretus tenuimaculatus</i> Waterhouse	Coleoptera, Scarabaeidae	KO	L	LEE <i>et al.</i> , 1997; ZHANG, 2009
4 <i>Aegeria molybdoceps</i> Hampson	Lepidoptera, Sesiidae	CN	M	JIA <i>et al.</i> , 2001; LIU <i>et al.</i> , 1988; LIU <i>et al.</i> , 2004; PRCMF, 1988; ZHANG, 2009
5 <i>Agrilus bilineatus</i> (Weber)	Coleoptera, Buprestidae	USA	M	CAES, 2007; HAACK & ACCIAVATTI, 1992; MUZIKA <i>et al.</i> , 2000
6 <i>Alsophila pometaria</i> (Harris)	Lepidoptera, Geometridae	USA, CA	L	CAES, 2007; PAYNE & JOHNSON, 1979;
7 <i>Anisota senatoria</i> (Smith)	Lepidoptera, Saturniidae	USA, CA	L	PAYNE & JOHNSON, 1979; YOUNGSTEADT & GURNEY, 2013
8 <i>Anisota virginiensis</i> (Drury)	Lepidoptera, Saturniidae	USA	L	PAYNE & JOHNSON, 1979
9 <i>Anomala corpulenta</i> Motschulsky	Coleoptera, Scarabaeidae	CN, MO	L	WU <i>et al.</i> , 2000b; ZHANG, 2009
10 <i>Anoplophora leechi</i> Gahan	Coleoptera, Cerambycidae	CN	M	WU <i>et al.</i> , 2000b
11 <i>Antheraea polyphemus</i> Cramer	Lepidoptera, Saturniidae	USA, CA	L	PAYNE & JOHNSON, 1979
12 <i>Anthracophora rusticola</i> Burmeister	Coleoptera, Scarabaeidae	CN	L	ZHANG, 2008
13 <i>Apethymus kuri</i> Takeuchi	Hymenoptera, Tenthredinidae	CN	L	HILL, 1987
14 <i>Apoderus nigroapicatus</i> Jekel	Coleoptera, Attelabidae	CN	L	WU <i>et al.</i> , 2000b
15 <i>Apriona germari</i> Hope	Coleoptera, Cerambycidae	Eastern Asia	M	ZHANG, 2009
16 <i>Argyresthia castaneella</i> Busck †	Lepidoptera, Argyresthiidae	USA	L	OPLER, 1977
17 <i>Arnoldia castaneae</i> (Felt)	Diptera, Cecidomyiidae	USA	L	GAGNÉ, 2004
18 <i>Assara exiguella</i> (Caradja)	Lepidoptera, Pyralidae	CN	H	CHEN & HUANG, 2005
19 <i>Aulacophora femoralis</i> (Motschulsky)	Coleoptera, Chrysomelidae	Eastern Asia	L	ZHANG, 2009
20 <i>Balaninus rectus</i> (Say)	Coleoptera, Curculionidae	USA	H	VOSSEN, 2000
21 <i>Batocera horsfieldi</i> Hope	Coleoptera, Cerambycidae	CN, IN	M	WU <i>et al.</i> , 2000b; ZHANG, 2008
22 <i>Batocera lineolata</i> Chevrolat	Coleoptera, Cerambycidae	CN, JP, KO	M	KOTOBUKI <i>et al.</i> , 1982; LEE <i>et al.</i> , 2002
23 <i>Caligula japonica</i> Moore	Lepidoptera, Saturniidae	CN, KO, JP, RU	L	YANG <i>et al.</i> , 2008; ZHANG, 2008
24 <i>Caliroa castanae</i> (Rohwer)	Hymenoptera, Tenthredinidae	USA	L	HILL, 1987
25 <i>Camptoloma interiorata</i> (Walker)	Lepidoptera, Noctuidae	CN, JP, KO, RU	L	WU <i>et al.</i> , 2000b; ZHANG, 2008
26 <i>Cecidomyia chinquapin</i> Beutenmüller	Diptera, Cecidomyiidae	USA	L	GAGNÉ, 2004
27 <i>Chalia larminati</i> Heylaerts	Lepidoptera, Psychidae	CN	L	WU <i>et al.</i> , 2000b
28 <i>Chelidonium gibbicolle</i> (White)	Coleoptera, Cerambycidae	CN	M	ZHANG, 2009
29 <i>Cinalathura folial</i> (Theobald)	Homoptera, Aphididae	CN	L	CSCPRC, 1977; HILL, 1987
30 <i>Clania minuscula</i> (Butler)	Lepidoptera, Psychidae	CN, JP, TW	L	WU <i>et al.</i> , 2000b; ZHANG, 2008
31 <i>Clania variegata</i> Snellen	Lepidoptera, Psychidae	CN, JP, KO, IN, TH	L	ZHANG, 2008
32 <i>Cnidocampa flavescens</i> Walker	Lepidoptera, Limacodidae	CN, JP, TW, RU	L	WU <i>et al.</i> , 2000b; ZHANG, 2008; ZHANG, 2009
33 <i>Coleophora leucochrysell</i> Clemens †	Lepidoptera, Argyresthiidae	USA	L	OPLER, 1977

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Species name	Order, Family	Origin	Risk level	References
34 <i>Conotrachelus anaglypticus</i> (Say)	Coleoptera, Curculionidae	USA, MX	L	BEERS <i>et al.</i> , 2003; BROOKS, 1924
35 <i>Conotrachelus carinifer</i> (Casey)	Coleoptera, Curculionidae	USA	L	HUNT <i>et al.</i> , 2008; PAYNE & JOHNSON, 1979; PAYNE <i>et al.</i> , 1972
36 <i>Conotrachelus nenuphar</i> (Herbst)	Coleoptera, Curculionidae	USA, CA	L	OLSEN, 2000
37 <i>Coptotriche perplexa</i> (Braun) †	Lepidoptera, Tischeriidae	USA	L	OPLER, 1977
38 <i>Croesus castanae</i> Rohwer	Hymenoptera, Tenthredinidae	USA	L	HILL, 1987
39 <i>Cryptotympana atrata</i> (Fabricius)	Heteroptera, Cicadidae	CN, KO, TW, Indo-China	L	HAYASHI, 1987; WU <i>et al.</i> , 2000b
40 <i>Culcula panterinaria</i> (Bremer et Grey)	Lepidoptera, Geometridae	CN, IN, NP, VT, TH	L	ZHANG, 2008
41 <i>Curculio bimaculatus</i> Faust	Coleoptera, Curculionidae	CN	H	HOU <i>et al.</i> , 1993; LUO <i>et al.</i> , 1991; MASAKI, 1985; ZHAO <i>et al.</i> , 2008
42 <i>Curculio caryatrypes</i> (Boheman)	Coleoptera, Curculionidae	USA	H	BROOKS, 1929; CAES, 2007; HUNT <i>et al.</i> , 2008; PAYNE & JOHNSON, 1979; OLSEN, 2000; YOUNGSTEADT & GURNEY, 2013
43 <i>Curculio davidi</i> (Fairmaire)	Coleoptera, Curculionidae	CN	H	FAO, 2007a, 2007b; GAOPING <i>et al.</i> , 2001; LIU, 2001; WANG, 1998; ZHANG, 2008; ZHANG, 2009
44 <i>Curculio dentipes</i> (Roelofs)	Coleoptera, Curculionidae	CN, JP, RU	H	FAO, 2007a; LIANG, 1997; MORIMOTO, 1981; CHENG & HSU, 1959; WANG, 2000
45 <i>Curculio nigromaculatus</i> Voet	Coleoptera, Curculionidae	CN	H	MASAKI, 1985
46 <i>Curculio sayi</i> (Gyllenhal)	Coleoptera, Curculionidae	USA	H	BROOKS, 1929; CAES, 2007; HUNT <i>et al.</i> , 2008; PAYNE & JOHNSON, 1979
47 <i>Curculio sikkimensis</i> (Heller)	Coleoptera, Curculionidae	CN, JP, IN	H	KIM <i>et al.</i> , 2008; KYU & CHONG, 1984; LEE, 2009
48 <i>Cydia glandicolana</i> (Danilevsky)	Lepidoptera, Tortricidae	CN, KO, JP, RU	H	BROWN & KOMAI, 2008; GILLIGAN & EPSTEIN, 2012; KOMAI & ISHIKAWA, 1987
49 <i>Cydia kurokoi</i> (Amsel)	Lepidoptera, Tortricidae	CN, KO, JP	H	BROWN & KOMAI, 2008; GILLIGAN & EPSTEIN, 2012; KOMAI & ISHIKAWA, 1987; ZHANG, 2008
50 <i>Cydia latiferreana</i> (Walsingham)	Lepidoptera, Tortricidae	USA, MX, CA	H	GILLIGAN & EPSTEIN, 2012; VOSSEN, 2000
51 <i>Cyllorhynchites ursulus</i> (Roelofs)	Coleoptera, Rhynchitidae	CN, JP, KO, RU	H	FAO, 2007a; LIU, 2001; NI, 1998; WANG, 1998; ZHANG, 2009; Zhang <i>et al.</i> , 1999
52 <i>Cyrtepistomus castaneus</i> (Roelofs)	Coleoptera, Curculionidae	JP	H	JOHNSON, 1957; PAYNE & JOHNSON, 1979
53 <i>Dasineura dentatae</i> (Stebbins)	Diptera, Cecidomyiidae	USA	L	GAGNÉ, 2004
54 <i>Dasychira thwaitesii</i> Moore	Lepidoptera, Lymantriidae	CN	L	ZHANG, 2008
55 <i>Datana ministra</i> (Drury)	Lepidoptera, Notodontidae	USA, CA	L	HUNT <i>et al.</i> , 2008; PAYNE & JOHNSON, 1979; YOUNGSTEADT & GURNEY, 2013
56 <i>Dichocrocis chlorophanta</i> Butler	Lepidoptera, Tortricidae	CN	M	WU <i>et al.</i> , 2000b
57 <i>Dichocrocis punctiferalis</i> (Guenée)	Lepidoptera, Tortricidae	CN, KO, JP, IN	H	CHOI, 2004; GAOPING <i>et al.</i> , 2001; FAO, 2007a, 2007b; LEE, 2009, 2011; NI, 1998; YANG <i>et al.</i> , 2002; ZHANG, 2008; ZHANG, 2009; ZHANG <i>et al.</i> , 2009; ZHU <i>et al.</i> , 2000
58 <i>Dryophanta japonica</i> Ashmead	Hymenoptera, Cynipidae	CN, JP	L	WU <i>et al.</i> , 2000b
59 <i>Dryocosmus kuriphilus</i> Yasumatsu (I)	Hymenoptera, Cynipidae	CN	-	YASUMATSU, 1951; PAYNE & JOHNSON, 1979; EPPO, 2005; RIESKE, 2007
<i>Dryocosmus zhui</i> Liu et Zhu	Hymenoptera, Cynipidae	CN	H	ZHU <i>et al.</i> , 2015
60 <i>Eacles imperialis</i> (Drury)	Lepidoptera, Saturniidae	USA, CA	L	PAYNE & JOHNSON, 1979
61 <i>Ectoedemia castanae</i> Busck †	Lepidoptera, Nepticulidae	USA	L	OPLER, 1977
62 <i>Ectoedemia phleophaga</i> Busck †	Lepidoptera, Nepticulidae	USA	L	OPLER, 1977
63 <i>Elaphidionoides villosus</i> (Fabricius)	Coleoptera, Cerambycidae	USA, CA	L	CAES, 2007
64 <i>Endoclitia sinensis</i> (Moore)	Lepidoptera, Hepialidae	CN, JP, KO, TW	L	ZHANG, 2009
65 <i>Eriogyna pyretorum</i> Westwood	Lepidoptera, Saturniidae	Eastern Asia	L	WU <i>et al.</i> , 2000b; ZHANG, 2008
66 <i>Euhampsonia cristata</i> (Butler)	Lepidoptera, Notodontidae	CN, KO	L	ZHANG, 2008

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Species name	Order, Family	Origin	Risk level	References
67 <i>Euproctis flava</i> Fabricius	Lepidoptera, Lymantriidae	CN, JP	L	ZHANG, 2008
68 <i>Eurostus validus</i> Dallas	Heteroptera, Tesseratomidae	Eastern Asia, Indo-China	L	FAO, 2007; ZHANG, 2008; ZHANG, 2009
69 <i>Erthesina fullo</i> Thunberg	Heteroptera, Pentatomidae	CN, JP, VT, TW	L	WU <i>et al.</i> , 2000b
70 <i>Garella ruficirra</i> Hampson	Lepidoptera, Noctuidae	CN, JP, IN, Borneo	H	GAOPING <i>et al.</i> , 2001; FAO, 2007a; Ni, 1998; WU <i>et al.</i> , 2001; ZHANG, 2008; ZHANG, 2009
71 <i>Fibuloides aestuosa</i> (Meyrick)	Lepidoptera, Tortricidae	IN, CN, KO, JP	M	BROWN & KOMAI, 2008; GILLIGAN & EPSTEIN, 2012; KOMAI & ISHIKAWA, 1987; ZHANG & LI, 2011
72 <i>Halyomorpha halys</i> (Stål) (I)	Heteroptera, Pentatomidae	Asia	-	ZHANG, 2008
73 <i>Halyomorpha picus</i> (Fabricius)	Heteroptera, Pentatomidae	CN	H	ZHANG, 2008
74 <i>Harmandiola amisae</i> Gagné	Diptera, Cecidomyiidae	USA	L	GAGNÉ, 2004; GAGNÉ & PAYNE, 1992
75 <i>Harmandiola castanae</i> (Stebbins)	Diptera, Cecidomyiidae	USA	L	GAGNÉ, 2004; GAGNÉ & PAYNE, 1992
76 <i>Holotrachia oblita</i> Faldermann	Coleoptera, Scarabaeidae	CN	L	ZHANG, 2009
77 <i>Holotrachia parallela</i> Motschulsky	Coleoptera, Scarabaeidae	CN	L	ZHANG, 2009
78 <i>Homona coffearia</i> (Nietner)	Lepidoptera, Tortricidae	Eastern Asia	L	ZHANG, 2008
79 <i>Kermes flavus</i> Liu	Homoptera, Kermesidae	CN	L	LIU & SHI, 1995
80 <i>Kermes nakagawae</i> Kuwana	Homoptera, Kermesidae	CN, JP, KO	H	LI <i>et al.</i> , 2006
81 <i>Kermes nawae</i> Kuwana	Homoptera, Kermesidae	CN, JP, KO	H	FAO, 2007b; JIA <i>et al.</i> , 2001; LIU, 2004; Ni, 1998; WU <i>et al.</i> , 2000a, 2000b; YANG <i>et al.</i> , 2001; ZHANG, 2009 °
82 <i>Kunugia yamadai</i> Nagano	Lepidoptera, Lasiocampidae	KO	L	PARK & BYUN, 1997
83 <i>Lachnus tropicalis</i> Van Der Goot	Homoptera, Lachnidae	CN, JP, TW, KO, ML	M	FAO, 2007; LIU <i>et al.</i> , 2004; Ni, 1998; PRCMF, 1988; WANG, 1998; YANG <i>et al.</i> , 1998; ZHANG, 2008; ZHANG, 2009
84 <i>Latoia hilarata</i> (Staudinger)	Lepidoptera, Limacodidae	CN	L	ZHANG, 2008
85 <i>Lebeda nobilis</i> Walker	Lepidoptera, Lasiocampidae	CN, IN, TW, NE, IND	L	WU <i>et al.</i> , 2000b
86 <i>Lithocolletis ringoniella</i> Matsumura	Lepidoptera, Gracillariidae	CN, KO, RU, JP	L	ZHANG, 2008
87 <i>Longistigma caryae</i> (Harris)	Homoptera, Aphididae	USA, CA	M	BERG <i>et al.</i> , 2001; CAES, 2007; HILL, 1987; PAYNE & JOHNSON, 1979
88 <i>Lophocampa caryae</i> Harris	Lepidoptera, Arctiidae	USA	L	CAES, 2007
89 <i>Lycoroma delicatula</i> White	Homoptera, Fulgoridae	CN, Sub-tropical Asia	L	ZHANG, 2008
90 <i>Lymantria mathura</i> Moore	Lepidoptera, Lymantriidae	CN, JP, KO, RU	M	ZHANG, 2008
91 <i>Magisicada neotredicim</i> (Marshall et Cooley)	Heteroptera, Cicadidae	USA	L	YOUNGSTEADT & GURNEY, 2013
92 <i>Magisicada septendecim</i> (Fisher)	Heteroptera, Cicadidae	USA	L	YOUNGSTEADT & GURNEY, 2013
93 <i>Magisicada septendecula</i> (Alexander et Moore)	Heteroptera, Cicadidae	USA	L	YOUNGSTEADT & GURNEY, 2013
94 <i>Magisicada tredecassini</i> (Alexander et Moore)	Heteroptera, Cicadidae	USA	L	YOUNGSTEADT & GURNEY, 2013
95 <i>Magisicada tredecim</i> (Walsh et Riley)	Heteroptera, Cicadidae	USA	L	YOUNGSTEADT & GURNEY, 2013
96 <i>Magisicada tredecula</i> (Alexander et Moore)	Heteroptera, Cicadidae	USA	L	YOUNGSTEADT & GURNEY, 2013
97 <i>Magisicada neotredicim</i> (Marshall et Cooley)	Heteroptera, Cicadidae	USA	L	YOUNGSTEADT & GURNEY, 2013
98 <i>Maladera orientalis</i> Motschulsky	Coleoptera, Scarabaeidae	CN, RU, TW, MO	L	ZHANG, 2009
99 <i>Marumba sperchius</i> (Ménétriés)	Lepidoptera, Sphingidae	CN, IN, JP, KO	L	WU <i>et al.</i> , 2000b
100 <i>Massicus raddei</i> (Blessig)	Coleoptera, Cerambycidae	JP, CN, KO,	M	WU <i>et al.</i> , 2000b; YANG <i>et al.</i> , 2013; ZHANG,

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Species name	Order, Family	Origin	Risk level	References
101 <i>Mechoris cumulatus</i> (Voss)	Coleoptera, Curculionidae	CN	H	CIESLA, 2011; FAO, 2007A; GAOPING, 2001; WANG, 2000; ZHANG <i>et al.</i> , 2010
102 <i>Melanaspis obscura</i> (Comstock)	Homoptera, Diaspididae	USA	M	HILL, 1987
103 <i>Melittomma sericeum</i> (Harris)	Coleoptera, Lymexylidae	USA, CA	M	CRAIGHEAD, 1950; WHEELER, 1986
104 <i>Moritziella castaneivora</i> Miyazaki	Homoptera, Phylloxeridae	CN, JP	H	JIANG <i>et al.</i> , 2006; MIYAZAKI, 1968; WANG <i>et al.</i> , 2010; ZHANG, 2007
105 <i>Myzocallis kuricola</i> (Matsumura) (I)	Homoptera, Aphididae	JP, CN, KO, TW	-	KAZUO, 2001; MANSILLA <i>et al.</i> , 2001
106 <i>Myzocallis castaneae</i> (Fitch)	Homoptera, Aphididae	USA, MX, CA	L	QUEDNAU & REMAUDIERE, 1987
107 <i>Myzocallis castaneoides</i> (Baker)	Homoptera, Aphididae	USA, MX, CA	L	QUEDNAU & REMAUDIERE, 1987
108 <i>Myzocallis nanae</i> (Tissot)	Homoptera, Aphididae	USA, MX, CA	L	QUEDNAU & REMAUDIERE, 1987
109 <i>Myzocallis tissoti</i> Quednau et Remaudière	Homoptera, Aphididae	USA, MX, CA	L	QUEDNAU & REMAUDIERE, 1987
110 <i>Nematocampa resistaria</i> (Herrich-Schäffer)	Lepidoptera, Geometridae	USA	L	PAYNE & JOHNSON, 1979
111 <i>Neoausterodiaspis castaneae</i> Borchsenius	Homoptera, Asterolecaniidae	CN	H	JIA, 2001; WU <i>et al.</i> , 2000b; CAES, 2007
112 <i>Niphades castanea</i> Chao	Coleoptera, Curculionidae	CN	H	FAO, 2007a, 2007b; GAOPING <i>et al.</i> , 2001; LIU, 2001; WANG, 1998; ZHANG, 2008; ZHANG, 2009; ZHANG <i>et al.</i> , 2010; ZHAO <i>et al.</i> , 2004
113 <i>Orgyia leucostigma</i> (Smith)	Lepidoptera, Lymantriidae	USA, CA	L	CAES, 2007
114 <i>Orgyia thyellina</i> Butler	Lepidoptera, Lymantriidae	CN, JP, KO, RU	L	ZHANG, 2008
115 <i>Orthaga achatina</i> Butler	Lepidoptera, Pyralidae	CN, JP, KO	L	YANG, 1999
116 <i>Oxycetonia jucunda</i> (Falderman)	Coleoptera, Scarabaeidae	CN, JP	L	ZHANG, 2008; ZHANG, 2009
117 <i>Palaearctia vernata</i> (Peck)	Lepidoptera, Geometridae	USA, CA	L	CAES, 2007; PAYNE & JOHNSON, 1979
118 <i>Parasa consocia</i> Walker	Lepidoptera, Limacodidae	CN, JP, KO, TW, RU	L	ZHANG, 2009
119 <i>Parasa sinica</i> Moore	Lepidoptera, Limacodidae	CN	L	ZHANG, 2009
120 <i>Phalera assimilis</i> Bremer et Grey	Lepidoptera, Notodontidae	CN	L	WU <i>et al.</i> , 2000b; ZHANG, 2008
121 <i>Phalera flavescens</i> (Bremer et Gery)	Lepidoptera, Notodontidae	CN, JP, KO, TW	L	ZHANG, 2008; ZHENG & WANG, 2010
122 <i>Phyllonorycter kamijoi</i> (Kumata)	Lepidoptera, Gracillariidae	JP, KO	L	KUMATA, 1963; KUMATA <i>et al.</i> , 1985
123 <i>Phyllonorycter kearfottella</i> (Braun)	Lepidoptera, Gracillariidae	USA	L	PAYNE & JOHNSON, 1979
124 <i>Phylloxera castaneae</i> Haldeman	Homoptera, Phylloxeridae	USA	L	DUNCAN, 1922
125 <i>Popillia gracilicornis</i> Blanchard	Coleoptera: Scarabaeidae	CN, KO	L	ZHANG, 2008
126 <i>Popillia japonica</i> Newman (I)	Coleoptera: Scarabaeidae	JP, CN, KO	-	PAYNE & JOHNSON, 1979; YOUNGSTADT & GURNEY, 2013
127 <i>Popillia quadriguttata</i> Newman	Coleoptera: Scarabaeidae	CN, KO	L	ZHANG, 2008
128 <i>Prionoxystus robiniae</i> (Peck)	Lepidoptera, Cossidae	USA, CA	M	PAYNE & JOHNSON, 1979; GEISEL, 2010
129 <i>Proagoperttha lucidula</i> Faldermann	Coleoptera, Rutelidae	CN	L	ZHANG, 2008
130 <i>Profenusa castaneivora</i> Togashi	Hymenoptera, Tenthredinidae	JP	L	TOGASHI, 1981
131 <i>Pseudaulacaspis kiushiuensis</i> (Kuwana)	Homoptera, Diaspididae	CN, JP	L	LIU <i>et al.</i> , 2004
132 <i>Sesia rhynchioides</i> Butler	Lepidoptera, Sesiidae	CN	H	FAO, 2007b; LIU <i>et al.</i> , 1988; WANG, 1990
133 <i>Setora postornata</i> (Hampson)	Lepidoptera, Limacodidae	CN, IN, NE, TW, VT, LA	L	ZHANG, 2008
134 <i>Stenolechia rectivalva</i> Kanazawa	Lepidoptera, Gelechiidae	CN, JP	L	HOUQING <i>et al.</i> , 1993; ZHOU <i>et al.</i> , 2002
135 <i>Stephanitis nashi</i> Esaki et Takeya	Homoptera, Tingidae	CN, ML, MO, KO, Indo-China	L	WU <i>et al.</i> , 2000b
136 <i>Stigmella castaneae-foliella</i> (Chambers)	Lepidoptera, Nepticulidae	USA, CA	L	PAYNE & JOHNSON, 1979

(Continued)

Continued Table 1

Species name	Order, Family	Origin	Risk level	References
137 <i>Stigmella saginella</i> (Clemens)	Lepidoptera, Nepticulidae	USA, CA	L	PAYNE & JOHNSON, 1979
138 <i>Stigmella latifasciella</i> (Chambers)	Lepidoptera, Nepticulidae	USA, CA	L	PAYNE & JOHNSON, 1979
139 <i>Stigmella similella</i> (Braun)	Lepidoptera, Nepticulidae	USA, CA	L	PAYNE & JOHNSON, 1979
140 <i>Swammerdamia castaneae</i> Busck †	Lepidoptera, Yponomeutidae	USA	L	OPLER, 1977
141 <i>Synanthedon castaneae</i> (Busck)	Lepidoptera, Sesiidae	USA	M	BROWN, 1986; CAES, 2007; VOSSEN, 2000; BROWN & MIZELL, 1993; ENGELHARDT, 1946; SOLOMON, 1995; SNOW & EICHLIN, 1986
142 <i>Synanthedon castanevora</i> Yang et Wang	Lepidoptera, Sesiidae	CN	M	LIU <i>et al.</i> , 1989; WU <i>et al.</i> , 2000b
143 <i>Taihorina</i> sp.	Homoptera, Cercopidae	CN	L	HUANG, 2008; WU <i>et al.</i> , 2000b; ZHANG, 2009
144 <i>Thosea sinensis</i> Walker	Lepidoptera, Limacodidae	CN, KO, TW, Indo-China	L	ZHANG, 2009
145 <i>Tischeria castaneae</i> Chambers	Lepidoptera, Tischeriidae	USA	L	PAYNE & JOHNSON, 1979
146 <i>Tischeria citrinipennella</i> Clemens	Lepidoptera, Tischeriidae	USA	L	PAYNE & JOHNSON, 1979
147 <i>Tischeria quercifolia</i> Kuroko	Lepidoptera, Tischeriidae	CN, JP	L	TAO <i>et al.</i> , 2003
148 <i>Toxoscelus auriceps</i> Saunders	Coleoptera, Buprestidae	CN, JP	L	WU <i>et al.</i> , 2000b
149 <i>Trabala vishnou</i> Lefébvre	Lepidoptera, Lasiocampidae	CN, IN, TW, Indo-China	L	WU <i>et al.</i> , 2000b; ZHANG, 2008
150 <i>Tuberculatus castanocallis</i> Zhang et Zhong	Homoptera, Aphididae	CN	L	ZHANG, 2008; JIA <i>et al.</i> , 2001; ZHANG, 2009; HOU & YANG, 1998
151 <i>Urostylis yangi</i> Maa	Heteroptera, Urostylidae	CN	L	CHEN & JI, 1987; JIA <i>et al.</i> , 2001; ZHANG, 2009; HONG <i>et al.</i> , 2008
152 <i>Xyleborus mutilatus</i> Blandford	Coleoptera, Scolytidae	Eastern Asia	L	ZHANG, 2009; TANG, 2000; YE <i>et al.</i> , 1996
153 <i>Xyleborus semiopacus</i> Eichhoff	Coleoptera, Scolytidae	Asia, Africa	L	ZHANG, 2009

RESULTS AND DISCUSSION

The review of the available literature highlighted the absence of monophagous species (i.e. able to feed exclusively on one species of chestnut). Conversely, oligophagous species, (i.e. capable to exploit more than one species of *Castanea*) were quite common, while the polyphagous ones feeding not only on chestnuts but also on other plants (e.g. *Quercus* spp. and *Fagus* spp.) were the most prevalent. Though species belonging to the last category often exploit chestnut only as a secondary or occasional host, they have been sometimes reported to cause severe damages on a local scale.

Scientific and technical documents concerning chestnut-feeding insects include many species, which may be actual pests, organisms known to infest various crops or insects only relevant from a faunistic point of view. Unfortunately, in the last two cases, there is often no detailed information on their association with chestnut and sometimes only casual records have been reported. Theoretically, the chestnut-feeding insects most frequently recorded worldwide should be also regarded as the most susceptible to introduction in new areas. However, in invaded regions, even apparently less relevant species may have higher negative impacts than it could be expected.

Studies conducted in China on chestnut zoocenosis evidenced the presence of more than 450 insect species (LI *et al.*, 2002; YAN *et al.*, 2005; ZHENG *et al.*, 2005; ZHAO *et al.*, 2008; WANG *et al.*, 2010). However, ZHENG *et al.*, 2005 highlighted that 117 of the 178 species recorded on

chestnuts were actually able to exploit the feeding substrate. In 1977, a US committee had already carried out a specific research in China on insects harmful to agriculture and forest crops, concluding that only six phytophagous species actually represented a threat for chestnuts (CSCPRC, 1977). Moreover, some reports mentioned only few phytophagous species as deserving particular attention (LIU *et al.*, 2004; PRCMF, 1988) whereas REN and CHEN (2009) reported only 2 noxious species out of the 100 recorded on chestnuts. In addition, HILL (1987) identified no harmful organism while a report of FAO (2007a, 2007b) listed 13 noxious chestnut-associated species.

In the USA, more than 60 chestnuts-feeding species have been recorded only among lepidopterans: 10 are associated with the genus *Castanea* while the others, reported to feed only on the American chestnut, are currently considered extinct (OPLER, 1977). Technical documents such as guides for growers mentioned at least 10 different noxious insect species, in addition to generic information on other sap-sucking insects and mites, which were not, though, presented in detail (CAES, 2007; YOUNGSTEADT and GURNEY, 2013). Furthermore, in the same country, PAYNE and JOHNSON (1979) evidenced that more than 50 insect species could attack the American chestnut.

Likewise, in an incursion risk analysis focusing on official reports in Australia, BERG *et al.* (2001) mentioned 57 noxious insect species together with a generic list of mites reported without detailed information. A similar document issued by the New Zealand Ministry of Agriculture and Forestry included all species from the

genera *Cydia* and *Curculio* associated with chestnuts, together with other four species of harmful insects included in the following taxa: Coleoptera, Lepidoptera and Hymenoptera (MAF, 2011).

On the whole, more than 150 phytophagous insects species feeding on *Castanea* spp. were listed in the present review (Table 1). The 62% are native to East Asia, particularly China but also Japan and Korea, while the other 38% live in North America (mainly USA). The majority belong to the order Lepidoptera (46%) followed in order of frequency by Coleoptera (26%) and Hemiptera (13%), while Diptera, Heteroptera and Hymenoptera are much less common. The defoliating insects are the more consistent trophic group (38%), whereas the seed-feeders, the xylophagous, the sap-sucking and all the others are in order less represented being the first two categories respectively 22% and 16% of the total, while the last two groups combined only 24%.

Among the sap-sucking insects able to develop on chestnuts, only few species seem to actually represent a serious issue: in China, the Phylloxerid *Moritzziella castaneivora* Miyazaki, together with *Neoaasterodiaspis castanae* Borchsenius, *Kermes nawae* (Kuwana) and *Lachnus tropicalis* (VAN DER GOOT) may significantly affect cultivations (CHEN *et al.*, 1998; NI, 1998; WANG, 1998; WU *et al.*, 2000a; WU *et al.*, 2000b; JIA *et al.*, 2001; LIU *et al.*, 2004; JIANG *et al.*, 2006; FAO, 2007a; ZHANG *et al.*, 2007; ZHANG, 2008; ZHANG, 2009). Moreover, *Longistigma caryae* (Harris) has been often reported to be harmful in the USA (PAYNE and JOHNSON, 1979; HILL, 1987; CAES, 2007). There is no clear information on the level of association between those species and chestnuts, even though *M. castaneivora* is considered a harmful chestnut-feeding species (MIYAZAKI, 1968). In fact, in the last decades, this pest had a negative impact on production not only in Japan (country of the original description), but also in China where it is was accidentally introduced (JIANG *et al.*, 2006; WANG *et al.*, 2010). Similarly, *N. castanae*, which is reported as only associated with chestnut, is considered in China a severe threat requiring specific quarantine measures (CHEN *et al.*, 1998; JIA *et al.*, 2001).

Defoliators are the most numerous chestnut feeding insects worldwide. However, excluding some monophagous species of North America and all species that became extinct due to the disappearance of American forests, there are no other specialized taxa (OPLER, 1977). In their original countries, most of the chestnut-feeding species belonging to this category, generally exploit chestnut only as a secondary or occasional host. Nevertheless, even in these circumstances severe damages have been sometimes reported. For example, in the USA *Alsophila pomataria* (Harris), *Anisota senatoria* (Smith), *Datana ministra* (Drury), *Lophocampa caryae* Harris, *Orgyia leucostigma* (Smith) and *Paleacrita vernata* (Peck) are sometimes able to cause local infestations requiring adequate control measures (PAYNE and JOHNSON, 1979; CAES, 2007; YOUNGSTEADT and GURNEY, 2013). Likewise, in China, *Phalera flavescens* (Bremer *et Gery*) and *Tischeria quercifolia* Kuroko are reported to cause relevant damages to cultivations (TAO *et al.*, 2003; ZHENG and WANG, 2010).

Among the gall-inducing insects, which are comparable to defoliators in terms of foliage reduction, *D. kuriphilus* is doubtless the main pest. Originally native to China it was accidentally introduced in many chestnut-growing countries. In Italy, this pest was responsible for the economic collapse of nut production in a time frame of

more than a decade (BATTISTI *et al.*, 2014; SABBATINI PEVERIERI *et al.*, 2016) but its mitigation was successfully achieved by classical biological control using one of its natural antagonists, the parasitoid *Torymus sinensis* Kamijo (FERRACINI *et al.*, 2017). However, among the gall-inducing insects, the newly described *D. zhuli* Liu *et Zhu*, a species associated with *Castanea henryi*, represents a potential new worldwide threat deserving particular attention (ZHU *et al.*, 2015).

Furthermore, a large number of xylophagous species associated with chestnut have been reported in both North America and Eastern Asia. In the USA, the Two-lined chestnut borer *Agrilus bilineatus* (Weber) was one of the main pests causing tree death particularly in plant specimens weakened by adverse factors (HAACK and ACCIAVATTI, 1992; CAES, 2007).

Though damages were mainly reported on timber, the Chestnut timberworm *Melittomma sericeum* (Harris) was also regarded in the past as a dangerous pest in the USA, where up to 90% of old trees were affected by its infestation (SOLOMON, 1995). In China, the species *Aegeria molybdoceps* Hampson, *Sesia rhynchioides* (Butler) and *Synanthedon castanevora* Yang *et Wang*, were also considered responsible for relevant tree damages and thus control measures specifically evaluated (PRCMF, 1988; JIA *et al.*, 2001; LIU *et al.*, 2004).

As regards the seed-feeding insects, East Asia harbours the majority of species, accounting for the 75% reported in the current review. The 62% of the total number of species included in this trophic category are coleopterans, and the genus *Curculio* is the most represented. Similarly to what occurs in Europe, *Curculio* includes in Asia and North America some of the most harmful chestnut-associated seed-feeding insects such as *Curculio bimaculatus* Faust, *Curculio sikkimensis* (Heller) and *Curculio davidi* (Fairmaire) native to East Asia, together with *Curculio caryatrypes* (Boheman) and *Curculio say* (Gyllenhal) recorded in the USA (PAYNE and JOHNSON, 1979; KYU and CHONG 1984; GAOPING *et al.*, 2001; SUN *et al.*, 2004; KIM *et al.*, 2008; ZHAO *et al.*, 2008; YOUNGSTEAD and GURNEY, 2013). In Asia, equally important are also the coleopterans *Niphades castanea* Chao, *Cyllorhynchites ursulus* (Roelofs) and *Mechoris cumulatus* (Voss) responsible for a strong reduction in fruit harvest in China (NI, 1998; WANG, 1998; GAOPING *et al.*, 2001; LIU, 2001; WANG *et al.*, 2001; ZHAO *et al.*, 2004; ZHANG *et al.*, 2010). Moreover, in the same country, the lepidopteran *Cydia glandicolana* (Danilevsky), *Cydia kurokoi* (Amsel) and *Garella ruficirra* (Hampson) were also reported to be noxious pests requiring adequate control strategies (KOMAI and ISHIKAWA, 1987; NI, 1998; GAOPING *et al.*, 2001). Furthermore, in other Asian countries such as Korea, it is worth mentioning the lepidopteran *Dichocrocis punctiferalis* (Guenée), responsible for relevant damages to fruits in chestnut orchards (CHOI, 2004; CIESLA, 2011; LEE, 2011).

In the light of the current trade routes, insects more at risk of accidental introduction and thus potentially dangerous for chestnut in Europe are the seed feeding Coleoptera and Lepidoptera (particularly larvae of weevils and moths) which can be easily vectored due to fruit trade. Moreover, a second threat is represented by chestnut scions that may harbour a wide variety of phytophagous insects. These pests, belonging mainly to the sap-sucking or defoliating groups, can be found in all development stages and in the defoliating species; specimens may be carried as eggs attached to the bark, or buds. Among defoliators, leaf miners are unlikely to be accidentally introduced, while

gall-inducing species belong to a more high-risk category as already evidenced by the introduction and rapid spread of *D. kuriphilus* in new areas. Xylophagous insects colonizing trunks and branches are less relevant in the context of chestnut used for food production (nuts or scions for propagation) though trade of logs or wood poles may represent an important risk factor for European plants.

In fact, the risk of introducing new pests is today at its highest level due to the high amount of merchandise traded worldwide and the practical impossibility for phytosanitary inspectors to fully control every shipment at the entry ports (MACK *et al.*, 2002). In addition, many insects show in certain development stages cryptic behaviours that make them particularly difficult to detect. This is the case, for example, of the oriental chestnut gall wasp, whose first-stage larvae overwinter in buds without showing any evident sign of their presence (EPPO, 2005). In this context, it is worth noting that the recent introductions of the dangerous polyphagous *Anoplophora chinensis* (Forster) and *A. glabripennis* (Motshulsky) (Coleoptera, Cerambycidae) (VAN DER GAAG *et al.*, 2010; HAACK *et al.*, 2012) together with *D. kuriphilus* are only some examples of invasive organisms quickly adapted to new environments.

Therefore, since preventing new pest introductions at the entry points is a hard challenge, the possibility to rely on a list of potentially harmful species is a preliminary step to provide the phytosanitary services with the necessary skills to deal with possible biological invasions. In fact, avoiding accidental introductions at an interception/early-infestation stage is a key element of every control strategy. Therefore, the importance of either the interceptions of infested material at the entry points or the early interventions aimed at controlling and eradicating initial pest outbreaks should be emphasized in order to prevent new negative ecological and economic impacts.

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