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INSECT PESTS OF *EUCALYPTUS* PLANTATIONS IN SARDINIA (ITALY) ⁽¹⁾

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Floris I., Cocco A., Buffa F., Mannu R., Satta A. – Insect pest of *Eucalyptus* plantations in Sardinia (Italy)

In Sardinia (Italy), *Eucalyptus* plantations cover approximately 23,000 hectares, above all in the southern part of the island. There is a complex of phytophagous insect pests that is threatening the health status of *Eucalyptus* trees. The most recent invasions include the sap-suckers, *Glycaspis brimblecombei*, *Blastopsylla occidentalis*, and the bronze bug, *Thaumastocoris peregrinus*. Other pest species have also been reported, including the gall wasps, *Ophelimus maskelli* and *Leptocybe invasa*, the longhorn beetles, *Phoracantha semipunctata* and *P. recurva*, and the weevils, *Gonipterus scutellatus* and *Polydrusus* (= *Metallites*) *parallelus*. Defoliation caused by the gypsy moth, *Lymantria dispar*, have also been frequently observed in various *Eucalyptus*-planted areas of Sardinia.

KEY WORDS: *Eucalyptus*, pests, Sardinia, monitoring, biological control.

INTRODUCTION

In Italy, the first introduction of a *Eucalyptus* (*E. robusta*) species dates to 1803 in the English garden of the royal palace at Caserta (Campania). A few years later, several other species were introduced and cultivated in the Botanical Gardens in Naples and in the *Hortus Camaldulensis*. The latter was an acclimatization garden created by the Count of Camaldoli, to whom Dehnhardt dedicated the species *E. camaldulensis* in 1832 (BRUNDU, 2017). In the early decades of the 19th century, *Eucalyptus* was only of ornamental interest and, according to some estimates, 78 different species were introduced for this purpose (BRUNDU, 2017). In 1869, the trappist monks of the Abbey of the Three Fountains in Rome started a *Eucalyptus* cultivation, believing that it had antimalarial properties due to both the presence of essential oils and its ability to reclaim wetlands. The seeds were brought from Australia by Monsignor Good, Bishop of Melbourne, who attended the First Vatican Council in Rome in December 1869.

At the beginning of the 20th century, extensive forestry programs were started, including wide plantations in land reclamation areas, along railway lines in Sicily, and for the production of the timber poles used in mines in Sardinia. Between 1930 and 1940, eucalypt species were widely used as windbreaks in the Agro Pontino area (Lazio region, central Italy) and in Sardinia (BRUNDU, 2017).

In the 1950s, extensive reforestation projects were carried out in Sicily and Sardinia, often without taking into account the ecological requirements of the species introduced. In the same period, Italy contributed to the knowledge of *Eucalyptus* species and played a prominent role in their

diffusion; for example, in October 1956 in Rome the 1st World Congress on *Eucalyptus* was organized. The large number of species and the wide adaptability to different environments make it difficult to generalize the ecological characteristics and potential uses of the *Eucalyptus* species (BRUNDU, 2017).

Today, in addition to serving as windbreaks and as melliferous and polliniferous species, *Eucalyptus* species are also used to produce paper pulp, firewood, coal, and poles (DEIDDA *et al.*, 2016; BRUNDU, 2017).

In recent years, there has been a renewed interest in these species all over the world. For example, in 2015 Brazil authorized the use of transgenic *Eucalyptus* plants in reforestation. In Europe, *Eucalyptus* species are defined as exotic species by the European Regulation (EU) No. 1143/2014. Thus, both the introduction of new species and new plantations have to be carried out in compliance with legislation and good sustainable agricultural and forestry management practices. In Sardinia, *Eucalyptus* plantations are estimated to cover about 23,000 ha, excluding windbreaks and plantings smaller than one hectare, and are mainly located (90%) below 400 m a.s.l. in the southern part of the island (DEIDDA *et al.*, 2016).

The most widely cultivated species in the Mediterranean basin is the river red gum, *Eucalyptus camaldulensis* Dehnh., followed by *E. globulus* Labill. and *E. gomphoccephala* DC.

Over the last few decades, a number of phytophagous insects and pathogenic fungi have threatened *Eucalyptus* species in the Mediterranean area. Among the most recent exotic invasive species, the red gum lerp psyllid, eucalyptus psyllid, and bronze bug have caused extensive damage to eucalypt plantations in consecutive years. In addition, gall wasps and some beetles, such as eucalyptus longhorned borers and weevils have also been reported. In some areas, the gypsy moth, *Lymantria dispar* (L.), has also caused defoliation.

This paper presents a comprehensive review of the

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Eucalyptus insect pests and their impacts on eucalypt plantations in a Mediterranean context (Sardinia, Italy).

THE MAIN PHYTOPHAGOUS INSECTS

PSYLLIDS

The invasive red gum lerp psyllid, *Glycaspis brimblecombei* Moore (Hemiptera: Psyllidae), is the most serious *Eucalyptus* pest in the Mediterranean area (Fig. I, 1) (MENDEL *et al.*, 2016), especially for *E. camaldulensis*, which has been shown to be extremely susceptible to *G. brimblecombei* infestations (DEIDDA *et al.*, 2016). The red gum lerp psyllid was recorded for the first time in Italy in 2010 (LAUDONIA and GARONNA, 2010) and spread rapidly in central and southern regions, including the islands. It was reported for the first time in Sardinia in spring 2010 (BUFFA, 2015).

Eggs are laid on the leaf surface, where nymphs develop under protective white conical coverings (lerps) composed of lipids, proteins and carbohydrates (Fig. I, 2) (MORGAN, 1984). Adults and nymphs are phloem feeders and produce large amounts of honeydew, thus promoting the development of sooty mold (MENDEL *et al.*, 2016; CUELLO *et al.*, 2018). The damage resulting from leaf feeding includes foliar discoloration, and, in cases of heavy infestations, dieback, early leaf fall and reduced plant growth (BRENNAN *et al.*, 1999, 2001; DAANE *et al.*, 2005, 2012). Defoliation in consecutive years can lead to the death of young plants or susceptible clones (DAANE *et al.*, 2005).

In March 2012, a monitoring program was started in Sardinia in 12 sites located in the main areas of *Eucalyptus* cultivation (BUFFA, 2015; DEIDDA *et al.*, 2016; MANNU *et al.*, 2018). Adults and preimaginal stages were monitored by yellow sticky traps and leaf samples, respectively, in order to estimate the pest population density and natural mortality. Adult captures increased steeply from May-June and reached the highest values in late June-mid July, depending on the year, decreasing significantly from September onwards (MANNU *et al.*, 2018). Egg and nymph dynamics showed a similar pattern (Fig. II).

The specific koinobiont parasitoid *Psyllaephagus bliteus* Riek (Hymenoptera: Encyrtidae) (Fig. I, 3) has been effectively used in classical biological control programs in Mediterranean-climate areas (DAANE *et al.*, 2005, 2012; DAHLSTEN *et al.*, 2005; FERREIRA FILHO *et al.*, 2015). The parasitoid oviposits preferentially on third- and fourth-instar nymphs and develops inside late fourth and fifth instars (DAANE *et al.*, 2005; 2012). In 2015, the rate of *P. bliteus* parasitism was similar throughout the island, although an earlier peak was observed in July both in southern and central Sardinia (Fig. III).

The eucalyptus psyllid, *Blastopsylla occidentalis* Taylor (Hemiptera: Psyllidae) (Fig. I, 6), is native to Australia and was first reported in Italy in 2006 (LAUDONIA, 2006). However, *B. occidentalis* has established itself in other countries outside its native area, including New Zealand (TAYLOR, 1985), California (TAYLOR, 1985), Mexico (HODKINSON, 1991), Brazil (BURCKHARDT *et al.*, 1999; SANTANA and BURCKHARDT, 2007), Chile (BURCKHARDT and ELGUETA, 2000), Argentina (BOUVET *et al.*, 2005), South Africa (ANONYMOUS, 2007), Cameroon (DZOKOU *et al.*, 2009), Turkey (AYTAR *et al.*, 2011), Spain and Portugal (PÉREZ OTERO *et al.*, 2011), and Uruguay (MARTÍNEZ *et al.*, 2014).

The adult females, which are generally darker than males and measure approximately 1.5 mm in length, can lay the

eggs on shoots, leaves, flowers and twigs. As with other sap-sucking insects, the eggs are laid preferentially during the main periods of the flushing rhythm of trees (SOUFO and TAMESSE, 2015). The oviposition activity of *B. occidentalis* is closely related to the water conditions of host plants, as the psyllid population density decreased significantly at lower humidity levels in Cameroon (SOUFO and TAMESSE, 2015). Unlike red gum lerp psyllid juveniles, preimaginal stages of *B. occidentalis* are not characterized by lerps but produce a protective white waxy secretion, on which sooty mould can grow (TAYLOR, 1985; MENDEL *et al.*, 2016). The eucalyptus psyllid completes 5-6 generations under tropical conditions (SOUFO and TAMESSE, 2015).

In the regions where *Eucalyptus* trees are used as windbreaks and for fuelwood production, exploitation as a source of pollen and nectar for honeybees is also common. In such *Eucalyptus* plantations, *B. occidentalis* is considered one of the main concerns of eucalypt health (MENDEL *et al.*, 2016). In fact, field observations carried out in the Mediterranean area have shown that the psyllid infested mainly young sprouts (Fig. I, 7) and inflorescences (Fig. I, 8) in formations of *E. camaldulensis* trees, causing a premature fall of flowers in the following spring period (BUFFA, 2015). Losses caused by *B. occidentalis* attacks can be exacerbated by the simultaneous presence of the red gum lerp psyllid infestations. Concomitant infestations of both psyllids could easily endanger the survival of the delicate floral structures of the *Eucalyptus*, with a subsequent impact on the production of the unifloral honey. In fact, joint attacks of the two psyllids led to a 85% decrease in eucalyptus honey production in Sardinia in the two years following *G. brimblecombei* introduction (BUFFA, 2015). Although a different pattern was not found along a latitudinal gradient, the mean abundance of *B. occidentalis* adults in Sardinia was lower in the southern part of the island, reaching a peak of approximately 20 adults per trap in late July (Fig. IV).

Other psyllid species belonging to *Ctenarytaina* have been introduced in the last few years in Europe: *C. eucalipitii* (Maskell), *C. spatulata* Taylor and *C. peregrina* Hodkinson.

THE BRONZE BUG

The bronze bug, *Thaumastocoris peregrinus* Carpintero & Dellapé (Hemiptera: Thaumastocoridae) (Fig. I, 4) is a sap-sucking pest infesting eucalyptus plantations. It originates from Australia (NOACK and ROSE, 2007; NADEL *et al.*, 2010), where it has been reported as a harmful species since 2002. The bronze bug is now widespread in many other areas: Africa (2003) (Zimbabwe, South Africa) (JACOBS and NESER, 2005; GILIOME, 2011), South America (2005) (Uruguay, Paraguay, Brazil, Chile, Argentina) (CARPINTERO and DELLAPÉ, 2006; NOACK and COVIELLA, 2006; MARTÍNEZ and BIANCHI, 2010; WILCKEN *et al.*, 2010; IDE *et al.*, 2011; SOLIMAN *et al.*, 2012), Europe (2011), and recently the Middle East (2014) and New Zealand (SOPOW *et al.*, 2012). The first report in Europe was recorded in Italy (2011) in the Lazio region (LAUDONIA and SASSO, 2012), followed by Portugal in 2012 (GARCIA *et al.*, 2013), Sicily in 2014 (SUMA *et al.*, 2014) and Sardinia in 2015 (DEIANA *et al.*, 2018), where the first record was reported in the south of the island on *E. camaldulensis*.

The bronze bug is known to attack at least 30 *Eucalyptus* species and three common commercial hybrids (JACOBS and NESER, 2005; CARPINTERO and DELLAPÉ, 2006; NOACK and COVIELLA, 2006). *E. urophylla* and *E. grandis* were found to be the most suitable host species, as nymph development

Fig. 1 – 1) adult male of *Glycaspis brimblecombei*; 2) leaves covered by lerps; 3) adult of *Psyllaephagus bliteus*; 4) adult of *Thaumastocoris peregrinus*; 5) grouping of *T. peregrinus* adults feeding on *Eucalyptus* leaves; 6) adult of *Blastopsylla occidentalis*; 7) *B. occidentalis* infestation on a young shoot; 8) *B. occidentalis* infestation on *Eucalyptus* flowers; 9) *Leptocybe invasa* galls on *Eucalyptus* leaves; 10) damage caused by *L. invasa* infestation; 11) *Ophelimus maskelli* galls on upper side of *Eucalyptus* leaf; 12) *Eucalyptus* young plant damaged by *O. maskelli* infestation.

Fig. II – Mean number of *Glycaspis brimblecombei*: (1) eggs, (2) larvae, and (3) nymphs per leaf observed during 2015 in North, Central and South Sardinia.

was faster and female fecundity higher than on *E. camaldulensis* (SOLIMAN *et al.*, 2012). Adults are light brown in color with darker spots, approximately 3 mm long, with a flattened body. Eggs are black, elliptical in shape and can be found individually or in patches on leaves and twigs. Nymphs develop through five instars to the adult stage in approximately 20 days, whereas adult longevity ranges from 14 to 42 days (NOACK and ROSE, 2007; SOLIMAN *et al.*, 2012). The bronze bug completes multiple generations per year and all life stages can be observed at the same time on leaves.

The damage is caused by the feeding punctures of adults and preimaginal stages on expanded leaves (Fig. I, 5),

causing silvering chlorosis that evolves to leaf bronzing and drying. The canopy turns progressively to a brownish-reddish discoloration, and thus has the common name of “winter bronzing” (Fig. I, 5). In addition to this symptom, early leaf fall and complete defoliation have been observed. Repeated infestations may cause branch dieback, reduce tree growth, and lead to the death of young weak plants (SOLIMAN *et al.*, 2012).

In Sardinia, field surveys were carried out in *E. camaldulensis* plantations in order to study the seasonal occurrence of the pest in two consecutive years (2015: 12 monitoring sites; 2016: three sites). Adults were monitored by yellow sticky traps, whereas egg and nymph density was

Fig. III – Mean rate of *Psyllaephagus bliteus* parasitism on *Glycaspis brimblecombei* nymphs in 2015 in North, Central and South Sardinia.

Fig. IV – Mean number of *Blastopsylla occidentalis* adults per trap captured in 2015 in North, Central and South Sardinia.

determined by sampling twigs (JIMÉNEZ-QUIROZ *et al.*, 2016). The population dynamics in 2015 and 2016 showed high levels of adults in September, with a similar pattern for eggs and nymphs (DEIANA *et al.*, 2018). In addition, both the adults and the juvenile stages were also observed in the winter, suggesting that *T. peregrinus* can also be considered as being well established on the island (DEIANA *et al.*, 2018).

The most promising control strategies are currently based on biological control, in particular using the wasp, *Cleruchoides noackae* Lin & Hube (Hymenoptera: Mymaridae), an egg parasitoid that was recently confirmed as a potential biological control agent of *T. peregrinus* (BARBOSA *et al.*, 2017).

GALL WASPS

The gall wasps *Leptocybe invasa* Fisher & La Salle and *Ophelimus maskelli* (Ashmead) (Hymenoptera: Eulophidae) have been recently considered as serious pests of *Eucalyptus* trees (BRANCO *et al.*, 2016). *L. invasa*,

commonly known as blue-gum chalcid wasp, is native to Australia (MENDEL *et al.*, 2004), and its infestations can cause significant damage and production loss (MENDEL *et al.*, 2004; PETRO *et al.*, 2015; AHMED *et al.*, 2017).

As a rule, *L. invasa* reproduces by thelytoky (MENDEL *et al.*, 2004), although male adults have been found in Turkey (DOGANLAR, 2005) and India (AKHTAR *et al.*, 2012). Females lay eggs in the midrib and petiole of newly-developed leaves and in young stems and shoots, inducing a decrease in shoots and leaf growth of *Eucalyptus* (Fig. I, 9 and 10). The damage caused by the blue-chalcid gall wasp is probably due to changes in the leaf hydraulic architecture, as a reduction of both the development of stomata and a minor vein density have been observed in *L. invasa*-infested trees (TONG *et al.*, 2016). This insect has been reported as a serious pest of various *Eucalyptus* species worldwide (DITTRICH-SCHRÖDER *et al.*, 2012; PETRO *et al.*, 2015), as *E. camaldulensis* are one of the most suitable hosts for its development (BRANCO *et al.*, 2016).

O. maskelli also originates from Australia and was

accidentally introduced into the Mediterranean region in 1999, where it was initially misidentified as *O. eucalypti* (ARZONE and ALMA, 2000; VIGGIANI and NICOTINA, 2001). After its first report in Italy as *O. eucalypti*, the wasp has been observed in other Mediterranean areas on *E. camaldulensis* trees, including Spain (PUJADE-VILLAR and RIBA-FLINCH, 2004), Greece (KAVALLIERATOS *et al.*, 2006), France (EPPO, 2006), Portugal (BRANCO *et al.*, 2006), and Tunisia (DHAHRI *et al.*, 2010). *O. maskelli* has also been reported in southern Asia (LAWSON *et al.*, 2012), South Africa (HURLEY, 2014), and California (BURKS *et al.*, 2015). Contrary to *L. invasa*, the galls induced by *O. maskelli* occur exclusively on the leaf blade of *Eucalyptus* leaves, forming typical round button-shaped galls (Fig. I, 11) (PROTASOV *et al.*, 2007). Under particular environmental conditions, the surface of the infested leaves can be entirely covered with galls (Fig. I, 12) (BRANCO *et al.*, 2016).

The populations of both gall wasps, as well as the presence of the specific parasitoid of *O. maskelli*, *Closterocerus chamaeleon* (Girault) (Hymenoptera: Eulophidae), were monitored from 2013 to 2014 in a Mediterranean area (BUFFA, 2015), showing a within-year pattern with two peaks of abundance for both *L. invasa* and *O. maskelli*. The highest number of galls per leaf occurred in the early spring and late summer for *O. maskelli* and *L. invasa*, respectively (BUFFA, 2015).

WEEVILS

The leaf-feeding beetle *Gonipterus scutellatus* Gyllenhal (Coleoptera: Curculionidae) (Fig. V, 1) is native to Australia and is probably the most studied weevil species infesting *Eucalyptus* trees worldwide. *G. scutellatus* species, which is also known as *Eucalyptus* weevil or *Eucalyptus* snout-beetle, belongs to a complex of cryptic species, whose revision is still in progress (NEWETE *et al.*, 2011; MAPONDERA *et al.*, 2012). Different species of the *G. scutellatus* complex have been accidentally introduced in Africa, America, Europe and New Zealand (NEWETE *et al.*, 2011; MAPONDERA *et al.*, 2012). *G. scutellatus* was first reported on *Eucalyptus* trees in Italy in 1975 (ARZONE, 1976).

G. scutellatus can cause severe damage to *Eucalyptus* trees mainly outside its native range, in which a rich community of predators and parasitoids has been shown to be able to control weevil infestations (TOOKE, 1953; LOCH and FLOYD, 2001; LOCH, 2008; LOCH and MATSUKI, 2010). In newly introduced areas, a different susceptibility of *Eucalyptus* species to *G. scutellatus* infestations and development has been observed (CORDERO RIVERA and SANTOLAMAZZA CARBONE, 2000; NEWETE *et al.*, 2011). *E. viminalis* is considered the most susceptible species to the snout beetle (TOOKE, 1953), although a variability in the weevil host preference has been reported in different countries (CLARKE *et al.*, 1998; HANKS *et al.*, 2000; LOCH 2006).

Adult females are polygynous and can lay more than 300 eggs during their lifetime (EPPO, 2005). The eggs are laid on leaves in capsules containing approximately 8-10 eggs. The weevil can complete up to four generations per year, even though only two generations have been recorded in Italy (EPPO, 2005). Larvae of *G. scutellatus* attack leaves and twigs (Fig. V, 2), whereas adults feed exclusively on leaf edges leading to a generalized dieback of shoot tips and the development of tufts of epicormic shoots (EPPO, 2005). Successive defoliations negatively affect the tree growth and a stag-headed appearance occurs in the presence of severe infestation. Occasionally, infested-trees may split and die.

The use of natural enemies and tolerant *Eucalyptus*

species is the most sustainable alternative to control *G. scutellatus* infestations, whereas chemical treatments have a potential negative effect on various *Eucalyptus* pollinators (EPPO, 2005). The egg parasitoid *Anaphes (Patasson) nitens* (Girault) (Hymenoptera: Mymaridae) has been used in controlling snout beetle populations in Italy (ARZONE, 1985). Based on preliminary observations, no detectable damage caused by *G. scutellatus* has been observed in Sardinia.

Polydrusus (Metallites) parallelus Chevrolat (Coleoptera: Curculionidae) (Fig. V, 3) is an endemic species of Sardinia, Corsica and Elba which feeds on *Eucalyptus* trees in its distribution range. However, the biology of this insect is unknown. Adults are common in spring and summer, and larvae presumably live underground feeding on plant roots. Damage caused by the feeding activity of *P. parallelus* was detected in Sardinia in April and May 2013 on *Eucalyptus* shoots (Fig. V, 4). The presence of *P. parallelus* was also recorded in the spring of 2014 throughout the island (BUFFA 2015). Damage to *Eucalyptus*, which has never been reported before, appeared to be significant in young plants. Adults feeding on *Eucalyptus* caused annular erosions on young branches, thus determining the break and subsequent drying of the attacked branches (Fig. V, 5).

LONGHORN BEETLES

The two-closely related species of longhorn beetles, *Phoracantha semipunctata* (Fabricius) and *P. recurva* Newman (Coleoptera: Cerambycidae), are above all associated with *Eucalyptus*. *P. semipunctata* (Fig. V, 6) was first detected in Sardinia in the 1970s, representing the first detection of the pest in Europe (TASSI, 1969; PIRAS *et al.*, 1970). A few years after its detection, the species had spread throughout the surrounding area in which *Eucalyptus* trees were growing, particularly in southern Italy (ROMANO, 2007; LONGO, 2009). *P. semipunctata* adult females live one or more months and can produce up to 300 eggs, which are laid in groups of 3-30 under the loose bark of *Eucalyptus* trees.

The eggs hatch 7-14 days after oviposition, depending on the temperature. First-instar larvae can either chew a hole directly in the inner bark or mine the outer bark before making its way to the bark-cambium-xylem interface. Larval development lasts on average 90 days (MENDEL, 1985). Mature larvae excavate pupal chambers in the wood, sealing the chamber entrance with wood shavings and frass. After the pupation period, which lasts approximately 40 days in Mediterranean field conditions (MENDEL, 1985), adult beetles emerge from the same entry holes by chewing through the plugs of frass. The adult beetle can complete its life cycle in 3-4 or 9 months when eggs are laid during early spring or late summer, respectively (MENDEL, 1985). Hence, there are generally 2-3 generations per year.

The longhorn beetle *P. recurva* (Fig. V, 7) was discovered in Sardinia in 2006 (CILLO *et al.*, 2006), although it has been in Italy since 1992 (PALMERI and CAMPOLO, 2006). The life cycle of the insect differs somewhat from that of the other longhorn beetles that infest *Eucalyptus* trees, as *P. recurva* adults can emerge earlier than *P. semipunctata* (ROMANO, 2007). Today, *P. recurva* in Sardinia has almost completely displaced the congeneric species, which was very common until 2004, resulting in a greater number of *Eucalyptus* plantations infested exclusively by *P. recurva* (ROMANO, 2007).

The two longhorn beetle species can cause serious damage to young trees (Fig. V, 8), and are considered a potential threat to *Eucalyptus* reforestation (MENDEL, 1985; ROMANO, 2007). The presence of both *P. semipunctata* and

Fig. V – 1) adult of *Gonipterus scutellatus*; 2) leaf damaged by feeding activity of *G. scutellatus* larvae; 3) adult of *Polydrusus parallelus*; 4) and 5) young shoots damaged by *P. parallelus* infestations; 6) adult of *Phorachanta semi-punctata*; 7) adult of *P. recurva*; 8) galleries of *Phorachanta* species on *Eucalyptus* tree; 9) mature larva of *Lymantria dispar*; 10) windbreak of *Eucalyptus* trees defoliated by *L. dispar*; 11) complete defoliation of *Eucalyptus* young trees caused by *L. dispar*.

P. recurva coupled with other pests threatens the sanitary status of *Eucalyptus* trees and makes the control of longhorn borers necessary, especially by enhancing the physiological status of *Eucalyptus* trees or using resistant *Eucalyptus* species (PAINE and MILLAR, 2003).

GYPSY MOTH

The gypsy moth, *Lymantria dispar* (L.) (Lepidoptera: Erebidae), is a univoltine pest species which is considered one of the main risks to oak woods worldwide (LUCIANO and PROTA, 1985; MCFADDEN and MCMANUS, 1991). The adult female gypsy moth is creamy white and flightless, whereas the adult male can fly several kilometers. Egg masses, which are laid on the trunks of trees during the summer, are covered by the abdominal hairs of the female which will protect the eggs until the following spring. Hence, larvae (Fig. V, 9) start feeding on young leaves after hatching, and pass through either five (male) or six (female) instars before the prepupal stage. Gypsy moth populations are characterized by cyclical fluctuations of their population density, which are commonly known as *gradations* (CAMPBELL, 1981). During the first period of gradation (i.e. latency phase), the population density is at a harmless level for several years. After this period, the population density increases gradually in 2-3 years (i.e. progradation), reaches a peak or *outbreak* (i.e. culmination), which can last for two consecutive years, and naturally decreases (i.e. retrogradation) until returning to a latency period. The complete defoliation of over 60,000 hectares of cork oak forests has been recorded in Sardinia during a gypsy moth outbreak (LUCIANO and PROTA, 1985).

Defoliation causes a significant reduction in photosynthetic activity and can negatively affect the tree growth, as well as compromise the health of forest stands when there are other abiotic (e.g. drought) or biotic stresses (e.g. fungal diseases). Moreover, defoliation during the summer tends to discourage tourism in infested areas, resulting in an additional economic loss.

Although in the Mediterranean area the gypsy moth is mainly associated with the *Quercus* tree species (COCCO *et al.*, 2010; MANNU *et al.*, 2017), it is a very polyphagous pest, capable of feeding on more than 300 host plants including some *Eucalyptus* species (LEONARD, 1981; MCFADDEN and MCMANUS, 1991; LIEBHOLD *et al.*, 1995). *L. dispar* larvae feeding on leaves of different *Eucalyptus* species under laboratory conditions have shown a high variability in development and survival, indicating both the variability and limited ability to process some secondary metabolites (MATSUKI *et al.*, 2011). However, the complete defoliation of *Eucalyptus* trees has recently been observed in Sardinia (Fig. V, 10, 11). These occasional infestations are more likely to be due to *L. dispar* populations spreading either actively or passively from close outbreak foci.

CONCLUSION

Sardinia is one of the most important areas of the Mediterranean basin for the cultivation of *Eucalyptus* tree species. In the last few years, several insect pests infesting *Eucalyptus* trees have been reported, including the leaf-feeding insects *G. brimblecombei*, *B. occidentalis* and *T. peregrinus*. These insects increase the complexity of *Eucalyptus* pest fauna already present throughout the entire area, such as gall wasps, longhorn beetles, and weevils. In addition, the defoliations caused by *L. dispar* and the symptoms of decay caused by the fungus *Neofusicoccum*

australe have been recently found in some limited areas (DEIDDA *et al.*, 2016). The health status of *Eucalyptus* trees in Sardinia has severely deteriorated.

A monitoring program carried out from 2012 to 2016 as part of the project “Programma triennale di controllo biologico della Psylla lerp dell’eucalipto *Glycaspis brimblecombei* e monitoraggio delle problematiche fitosanitarie dell’eucalipto in Sardegna” financially supported by the “Regione Autonoma Sardegna - Assessorato Difesa Ambiente, Tavolo Tecnico Difesa Fitosanitaria Piante Forestali”, investigated the health status of *Eucalyptus* in Sardinia (FLORIS and LUCIANO, 2017). The program also evaluated the economic impact of the most important pests on the quality and quantity of unifloral *Eucalyptus* honey, which represents more than 50% of the entire honey production in Sardinia (FLORIS *et al.*, 2016).

As a consequence of the increasing interest in *Eucalyptus* species as forestry and melliferous resources, a specific plan providing information on the most effective and sustainable management strategies for *Eucalyptus* plantations is needed. In line with international standards (IPPC/FAO, EPPO), a “collection field” of the *Eucalyptus* genus could be set up in order to: (1) evaluate the adaptation of different species, subspecies and hybrids to Mediterranean environmental conditions; (2) detect the presence of new pests and pathogens and assess the different susceptibilities of *Eucalyptus* species and hybrids; (3) evaluate the biological and ecological characteristics of different species, subspecies and hybrids of *Eucalyptus* in order to support their potential use as pollen resources for honey production; (4) increase ecological knowledge of plant-rhizosphere interactions focused on the naturalization of species and hybrids and their potential role as “biological invaders”.

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