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The impact of sap-sucking insect pests (*Blastopsylla occidentalis* Taylor and *Glycaspis brimblecombei* Moore, Hemiptera: Psyllidae) on unifloral eucalyptus honey

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Abstract - *Eucalyptus* species are important worldwide as melliferous plants, as a source of nectar and pollen, and contribute to the production of large quantities of honey, especially in summer when *E. Dehn.*, the most common eucalyptus species in the Mediterranean area, flowers. Its honey yield potential exceeds 200 kg/ha, sometimes accounting for more than 50% of total apiary production. In Italy, eucalyptus plantations cover at least 50,000 hectares, corresponding to a potential production of 10,000 tons of honey per year. Since 2000 several invasive eucalyptus pests have spread and settled in the Mediterranean. Of these, psyllids *Blastopsylla occidentalis* Taylor and *Glycaspis brimblecombei* Moore have become major threats to eucalyptus plantations. The main objective of this study was to verify the impact of sup-sucking insects on unifloral eucalyptus honey production and quality in Northern Sardinia (Italy). Our results show that a pronounced decrease in honey production occurred after 2011, with no production at all in 2012 and 2013, partial recovery in 2014-2016 and a further increase in 2017 and 2018. Moreover, the incidence of honeydew produced by psyllids has led to modifications in the chemical-physical characteristics and pollen spectrum of unifloral eucalyptus honey.

Keywords - eucalyptus, insect pests, honeydew, honey production.

Introduction

Eucalyptus spp. are native to Australia, Indonesia, Philippines and New Guinea and are now the most widely planted hardwood timber species in the world (Paine et al. 2011). This genus consists of over 800 species, but the number is continuing to grow as new taxa are described (Coppen 2002). The multipurpose nature of eucalyptus and its cultivation for such end-uses as timber, pulp and fuelwood have been well documented in the literature. It is considered the tree of the future because it takes root easily, grows quickly - even on poor soils without irrigation - and can be cultivated intensively, with many advantages over other hardwood plantation species. Consequently, vast eucalyptus plantations are to be found in South America (Brazil, Chile and Argentina), sub-Saharan Africa (Republic of South Africa, Zambia and Malawi) and the Mediterranean (Spain, Portugal, Italy, Tunisia, Algeria and Israel) (Doughty 2000). In addition to its value as a commercial species, eucalyptus is planted in many temperate and subtropical regions as an ornamental tree, particularly in urban and tourist contexts (FAO 1981).

Eucalyptus is also renowned for its profuse flowering and production of nectar and pollen suitable for honey bees (Clemson 1985). Some eucalyptus species flower at times of the year when pollen is in short supply, thus benefiting bee populations. According to Crane (1975), eucalyptus honey production potential varies widely from species to species, but in general this melliferous plant gives high honey yields. Some studies have assessed the nectar production of eucalyptus (Davis 1997). For instance, under favourable growth conditions, a single *Eucalyptus erythrosis* plant can bear approximately 2,000 flowers yielding more than 8 litres of nectar containing 970 grams of sugar. Under good conditions, in a low-density plantation (6 x 6 m) with 28 trees per 0.1 ha, a sugar yield of 25 kg/0.1 ha can be expected, whereas in more dense plantations (4 x 4 m) with 62 trees per 0.1 ha a sugar yield of 60 kg/0.1 ha can be expected (Lupo and Eisikowitch 1990). In Italy, a honey yield potential of 200 kg/ha has been reported for *Eucalyptus* (Ricciardelli D'Albore and Persano Oddo 1978).

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Eucalyptus plants are attacked by a very large number of leaf-eating, sucking and boring insects in their native habitats (Ohmart and Edwards 1991). Many trees moved around the globe as seeds, thus escaping the diverse community of herbivores found in their native range for many decades. However, over the last 30 years a number of insect pests from native areas have invaded many *Eucalyptus*-growing regions in Europe, Africa, Asia, North and South America (Paine et al. 2011). Based on trends observed for global dissemination of eucalyptus-feeding insects, pest introduction rates have increased nearly fivefold since the 1980s (Paine et al. 2010). In Europe, especially in the Mediterranean area, new threats to eucalyptus have been recorded over the last decade (Floris et al. 2018), such as eucalyptus psyllid *Blastopsylla occidentalis* Taylor (Laudonia 2006) and, more recently, red gum lerp psyllid *Glycaspis brimblecombei* Moore (Laudonia and Garonna 2010) and the bronze bug *Thaumastocoris peregrinus* Carpintero & Dellapé (Deiana et al. 2018, Laudonia and Sasso 2012). These sap-sucking insects have had a significant impact on eucalyptus's health status, with negative effects for honey production in Sardinia, too (Floris et al. 2017).

The aim of this study was to monitor the abundance of sap-sucking insects *G. brimblecombei* and *B. occidentalis* in an area dominated by *E. camaldulensis* trees, report on honey bee and other pollinator activity and assess the impact of the above sap-sucking insects on unifloral eucalyptus honey production and quality in Northern Sardinia (Italy).

Materials and Methods

Monitoring sap-sucking insects

In 2015, eucalyptus psyllid *B. occidentalis* and red gum lerp psyllid *G. brimblecombei* adults were monitored in an area of Northern Sardinia in which *E. camaldulensis* Dehn. was widespread (Santa Maria La Palma - Lat. 40°65'27" N, Lon. 8.2905 E, El. 30 m a.s.l.), using four yellow sticky traps (20 cm × 20 cm) placed on four eucalyptus trees during the whole monitoring period. All traps were collected and subsequently replaced monthly throughout the winter and every fifteen days in spring, summer and autumn.

Honey bees and other floral visitors

Honey bees (*Apis mellifera* Linnaeus) and other diurnal anthophiles associated with *E. camaldulensis* flowers were assessed in the same area in which the main sup-sucking insects had been monitored in 2015. Observations focused primarily on the activity of honey bees (*A. mellifera*), other bees (Apoidea) and other nectar-feeding insects (*Diptera*, *Lepidoptera*, *Hymenoptera Formicoidea*, *Coleoptera*, *and Orthoptera*). Insect species were identified from individuals captured with a sweep net after they had been observed visiting *E. camaldulensis* flowers. Bees were identified to genus or species level, whereas taxa other than bees were identified to family or order level. Observations on visitors to *E. camaldulensis* flowers were carried out following Utelli and Roy's procedure (2000) and consisted of three 30-minute periods of observation with two observers per plant, for a total of three hours per day of observations. During the day, three time slots were identified - 9-10 h, 13-14 h and 17-18 h - within which two observations lasting 15 minutes each were conducted on branches of different plants chosen at random. This procedure was repeated once a week for nine weeks, for a total of 54 observation periods, covering a period of about two months. On each branch inflorescence numbers, open flower numbers and pollinator frequency, separated by order, were counted and, only for *A. mellifera*, the number of flowers visited per bee was also determined. To distinguish general visitors from actual pollinators, insect behaviour on flowers was observed, thus verifying the likelihood of contact with anthers and pistils. After observing and recording all pollinating species interacting with *E. camaldulensis* inflorescences, insects were captured, placed in vials in alcohol and marked for subsequent identification. During observation periods, environmental temperature was also measured.

The Pearson correlation coefficient (r) was used to verify correlations between honey bee numbers and environmental temperature and number of open flowers per inflorescence (Sanzana et al. 2012). Data analysis was carried out using Minitab 15 software (2007).

Unifloral honey production and characteristics

Data on honey production from 2011 to 2016 was obtained directly from beekeepers present in the same survey area. Additional information on honey production in 2017 and 2018 was obtained from Osservatorio Nazionale del Miele (2019). A total of 15 eucalyptus honey samples were collected in 2014 and 2015 in five apiaries located in the same area in which phytophagous and antophiles had been monitored in 2015. In each sample, honey characteristics (colour, glucose, fructose and electrical conductivity) were determined using Official Methods (G.U. no. 185, 11 August 2003) and pollen spectrum by melissopalynological analysis using the Louveaux et al. (1978) method to check for any variations in

the qualitative characteristics of eucalyptus honey due to the presence of honeydew.

Results

Seasonal sap-sucking insect patterns

Mean psyllid *Blastopsylla occidentalis* Taylor and *Glycaspis brimblecombei* Moore adult numbers per trap captured in 2015 in Santa Maria la Palma (Sardinia, Italy) are shown in Figure 1. Adult captures of the two psyllids increased markedly from June to July, when it peaked, in accordance with the main *E. camaldulensis* flowering period and decreased afterwards, with a significant fall from September to December. Eucalyptus psyllid *B. occidentalis* attacked young *E. camaldulensis* trees sprouts and inflorescences for the most part (Fig. 2), causing premature flower drop, whereas the red gum lerp psyllid *G. brimblecombei* fed on leaves, completing its development underneath white conical shelters secreted by nymphs, commonly called lerps (Fig. 3) and causing honeydew production, sooty mould development and severe defoliation.

Frequency of honey bees and other floral visitors

In the survey area, the most frequent insects visiting *E. camaldulensis* flowers belonged to the Hymenoptera order (87%). The most abundant species was *A. mellifera* (64% of total visitors), followed by other Apoidea (15%) and ant species (8%). Diptera and Coleoptera accounted for 9% and 3% of total floral visitors, respectively. Orthoptera (0.4%) and Lepidoptera (0.1%) were found only sporadically.

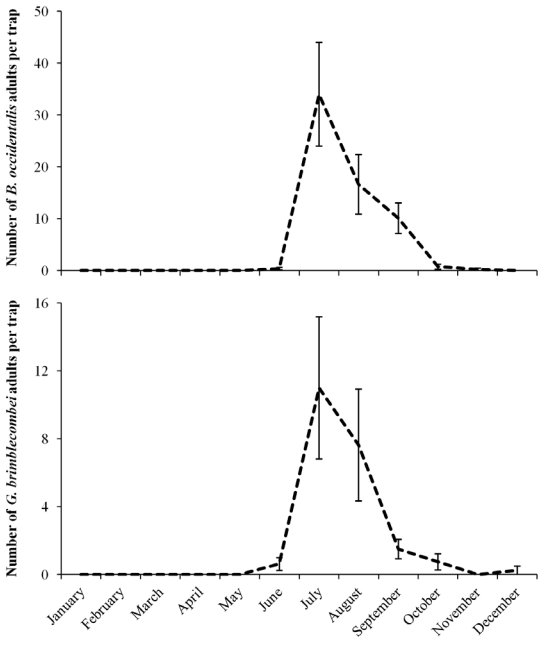

Figure 1 - Mean number of ***Blastopsylla occidentalis*** and ***Glycaspis brimblecombei*** adults per trap captured during 2015 in Santa Maria la Palma (Sardinia, Italy). For each date, bars indicate the standard error of the mean.

Figure 2 - The eucalyptus psyllid ***Blastopsylla occidentalis*** (on the left) and the young sprouts and inflorescences attacked (on the right).

Figure 3 - ***Glicaspis brimblecombei*** (on the left) and the conical shelters secreted by the nymphs, commonly called lerps (on the right).

In the *E. camaldulensis* flowering period a honey bee activity peak was recorded from 21 June onwards, showing a variable pattern over time. Honey bees were more active in the central hours of the day (13-14 h) whereas in June (the first flowering month) other insects were the main pollinators, especially wild bees, mainly belonging to the following species: *Andrena thoracica*, *A. nigroaenea*, *A. flavipes*, *A. morio; Nomiapis diversipes; Lasioglossum villosulum*, *L. pauxillum*, *L. pauperatum*, *L. malachurum*, *L. interruptum; Nomada* sp.*; Ceratina dallatorreana; Hylaeus clypearis*, *H. cornutus*; and *Bombus terrestris sassaricus*.

No correlation was found between honey bee numbers, environmental temperature and the number of open flowers per inflorescence. Pollinator visit frequency to *E. camaldulensis* was highly variable within the sampling period.

Unifloral honey production and characteristics

In 2011, before the dissemination and establishment of these new pests, honey production reached average values of 35 kg per beehive, whereas in the two subsequent years (2012 and 2013) no production at all was recorded. This was followed by a partial recovery, reaching average values from 3.1

to 6.6 kg/hive in 2014 and about 15 kg/hive in 2015 and 2016 while production increased to about 18 kg/hive in 2017 and 2018. Eucalyptus honey contaminated with honeydew ("blossom + honeydew") sampled during our analysis showed lower glucose (mean±SD: 27.1±1.22 g/L) and fructose (37.0±2.21 g/L) levels than "blossom" honey samples (29.9±1.80 g/L and 41.3±2.23 g/L, respectively), in accordance with White (1975). Similar results were obtained for electrical conductivity, with average values of 0.91±0.18 and 0.51±0.09 mS/cm honeydew contaminated and uncontaminated honey, respectively, in line with values reported in the literature for non-contaminated unifloral *Eucalyptus* honey (Persano Oddo et al. 2000, Terrab et al. 2003).

Average colour values passed from 52.8 to 85 mm Pfund, evidencing a clear darkening of the honey. Melissopalynological analyses evidenced *Eucalyptus* pollen percentages slightly above or below 90%, associated with a slightly higher incidence of honeydew indicators (spores, hyphae, etc.).

Discussion

Eucalyptus spp. are among the most widely planted trees for pulpwood production in the world's temperate regions (Eldridge et al. 1993) but there is scarce information on their importance for honey bees and other anthophiles associated with its flowers (Yates et al. 2005), and the potential effects of the main phytophagous honey production and quality during their flowering period. Generally, eucalyptus is associated with good or excellent nectar production under favourable conditions, which can lead to potential honey yields of 200 kg per ha and, in some cases, up to 600 kg per ha (Lupo and Eisikowitch 1990).

In Mediterranean regions, such as Sardinia (Italy), eucalyptus honey production in apiaries exploiting this important melliferous source can reach or exceed 50% of total production, with yields of up to 40-50 kg per beehive per year (Floris et al. 2007). Moreover, from a beekeeping point of view, especially as regards the most common eucalyptus species (*E. camaldulensis*), the importance of pollen production, characterized by a high protein content (Floris et al. 1993), should not be undervalued when sources of pollen are scarce, as in the Mediterranean in summer.

The phytosanitary problems registered in eucalyptus over the last decade, particularly from 2006 onwards with the introduction of eucalyptus psyllid *B. occidentalis* (Laudonia 2006) and more recently red gum lerp psyllid *G. brimblecombei* (Laudonia and Garonna 2010) and bronze bug *T. peregrinus* (Deiana et al. 2018, Laudonia and Sasso 2012) have had a strong negative impact on plant health with consequences for flowering and honey production, particularly for the concomitant psyllid attacks during the *E. calmadulensis* flowering period.

A marked decrease in average eucalyptus honey production observed in the apiaries of the survey sites from 2012 to 2016 corresponded to the presence of new herbivorous insects (particularly sap-sucking insects). The last high production level year was 2011 (35 kg per beehive), but over the year which followed this production decreased drastically, with no production at all in 2012 and 2013, minimal production in 2014, partial recovery in 2015 and 2016, and a further increase in 2017 and 2018. Nevertheless, production values recorded in 2018 (around 18 kg/beehive) are not comparable to production levels obtained prior to the advent of sap-sucking insects, particularly red gum lerp psyllids. Moreover, based on our preliminary honey quality enquiries, it is extremely likely that the presence of the honeydew produced by sap-sucking insects on the leaves has been responsible for changes in some significant chemical-physical characteristics (colour, glucose, fructose and electrical conductivity) and pollen spectrum in the honey collected in this study as compared to standard unifloral eucalyptus honey (White 1975, Persano Oddo et al. 2000, Terrab et al. 2003). In particular, pollen spectrum changes consisted in a reduction in eucalyptus pollen in honey sediment, with pollen percentages sometimes slightly below ministerial standards (90%) (Persano Oddo et al. 2000), putting the unifloral classification of this honey potentially at risk.

High plant productivity and great consumer popularity makes *Eucalyptus* honey a fundamental source of income for beekeeping farms, especially professional farms. However, new eucalyptus phytosanitary issues have had a negative impact on apiary productivity. Fortunately, production has partially recovered in recent years, partly as a result of a biological control program against the red gum lerp psyllid using the specific parasitoids *Psyllaephagus bliteus* Rick (Floris et al. 2018, Mannu et al. 2018).

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