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Osmia cornuta management in pear orchards

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Abstract

Osmia cornuta (Latreille) (Hymenoptera Megachilidae) is a well-known pollinator of pear and several rosaceous plants. If the pollinator cocoons are released in the orchard at the start of pear flowering and the nests are retrieved at petal fall, both its pollinating and reproductive potential are limited. The two-years' study (2004-05) carried out in north-eastern Italy aimed to optimise *O. cornuta* pollinating potential and to enhance its field reproduction. Two aspects have been considered: 1) the use of ecological infrastructures (hedge of *Prunus spinosa* L. and strips of *Brassica* sp.) as complementary food sources in order to anticipate the release of pollinator cocoons in the pear orchard; this technique could allow the female to initiate the nesting/foraging activity before the pear bloom starting; 2) the comparisons among various safety measures to be adopted in order to reduce the impact of noxious treatments; this technique could allow females to extend their activity after pear bloom end. Data showed that both the ecological infrastructures can be functional to anticipate the female activity before pear blooming. The complementary food sources sustained the females and allowed them to increase the number of pedotrophic cells with respect to previous studies concerning females released at the beginning of pear blooming. The most effective safety procedure was: (i) close the nesting boxes after sunset, (ii) store them at cool temperature during the night, (iii) perform the spray treatment in the evening and (iv) relocate the boxes at the same place and orientation.

Key words: *Osmia cornuta*, anticipated release, pear, ecological infrastructure, complementary food source, pollinators conservation, north-eastern Italy.

Introduction

The European mason bee *Osmia cornuta* (Latreille) (Hymenoptera Megachilidae) is a solitary and gregarious cavity nesting species, which proved to be an efficient pollinator of pear (Maccagnani *et al*., 2003a; Monzon *et al*., 2004), apple and of several other rosaceous fruit plants (Bosch, 1994a; 1994b; Pinzauti *et al*., 1997; Vicens and Bosch, 2000a; Bosch and Kemp, 2001; Ladurner *et al*., 2004; Krunić and Stanisavljević, 2006). It is an univoltine species, which overwinters as adult in the cocoon, shows a proterandric emergence in the early spring, during which the female lays nearly thirty eggs. The female (diploid) progeny is reared at the beginning of the reproductive period, while male (haploid) eggs are laid at the end (Tasei, 1973a; 1973b). The most significant research findings have demonstrated that *O. cornuta* appears to be a promising carrier for the direct and the secondary dispersal of microbiological agents against the bacterial fire blight disease (Maccagnani *et al*., 2005; Maccagnani *et al*., 2006).

Italy is the main pear producer in European Union's countries (Deckers and Schoofs, 2005). The well-developed pollen-kit, which envelops the pollen granule, makes pear pollination strictly entomophilous. Cross pollination is a crucial way to obtain proper fruit production, because many varieties are self-incompatible, even though at least partially parthenocarpic (Free, 1993). Pear flowers produce low sugar-content nectar and this is the reason why they fail to attract honeybees. On the contrary, a considerable number of analyses of the pollen masses have showed that *O. cornuta* females collect mainly pear pollen for their provisions (Maccagnani *et al*., 2003a; 2003b). Nepi *et al*. (2005) proved that the pear pollen is highly nutritional for *O. cornuta* larvae. In addition, mason bees are present through the whole flowering period, without significant differences during the day-time. Temperature and relative humidity do not affect *O. cornuta* presence in the pear orchard (Vicens and Bosch, 2000b; Maccagnani *et al*., 2003b). However, foraging flight duration seems to be affected by pollen availability, even if females compensate the quantitative decline of pear pollen with longer foraging flights (i.e. visiting more flowers), and they do not look for other food sources.

Due to the short duration of pear flowering (one week), and the variable weather conditions of the early spring, the timing of the release of *O. cornuta* cocoons is always quite problematic. As *O. cornuta* individuals overwinter as adults in their cocoons (Tasei, 1973a; 1973b), it turns out to be extremely complex to synchronise females emergence and activity with pear blooming, despite the expertise and recent acquisitions concerning the optimal temperature treatments to be adopted during the pre-wintering and wintering periods (Bosch and Blas, 1995; Krunić *et al*., 2001; Bosch and Kemp, 2004).

Furthermore, once males and females have emerged and mated, females need 1-3 days to start collecting pollen for the pedotrophic cells, i.e. to pollinate pear flowers (Bosch, 1994b; Krunić and Stanisavljević, 2006).

The extensive landscape simplification and the lack of flowered plants in the pear orchards can be considered the main reasons why it is necessary to wait the beginning of pear blooming for the release and the establishment of *O. cornuta* in the field. The association of pear trees with early blooming crops or wildflower strips could allow an early *O. cornuta* release before the pear starts blooming. Moreover, the availability of sufficient

food sources, after pear flowering, would allow *O. cornuta* to complete the egg laying period with the production of males.

This study aims to evaluate two aspects: 1) the use of two early flowering ecological infrastructures as complementary food sources in order to introduce the cocoons in the field before the start of the pear flowering (anticipated release); this technique could allow the female to initiate the nesting/foraging activity before the starting of the pear flowering; 2) to test the efficacy of safety measures which both prevent and reduce the impact of insecticide treatments applied against *Hoplocampa brevis* (Klug) (Hymenoptera Tenthredinidae) at petal fall; this technique could allow females to extend their activity several days after petal fall.

Materials and methods

Field set-up and complementary food sources

The research was carried out during 2004-2005 in an organic farm in Ferrara surroundings (located in north-eastern Italy). In two pear 'Abate Fétel' orchards which were 500 m far one from each other, cocoons of *O. cornuta* were introduced in presence of two different ecological infrastructures with early blooming plants: 1) hedge of *Prunus spinosa* L.; 2) strips of *Brassica oleracea* L. convar. *botrytis* (L.) Alef. var. *cymosa* Duch. (with different ripening times from 30 to 120 days) and of *Brassica napus* L. var. *oleifera* Del. (= *B. n.* cv. *napus*), sowed during the previous autumn. In both sites, four nesting boxes (white plastic box, cm 55 length, 40 width, 27 height) were placed (B1-B4 nearby the *Brassica* spp. strips; P1-P4 nearby the *P. spinosa* hedge); 520 nesting tunnels of 4 types (130 tunnels each) were provided in each nesting box: drilled wooden nests, bundle of common reeds [*Phragmites australis* (Cav.) Trin.], cardboard tubes and cardboard assembled nests. Two hundred females of *O. cornuta* and 400 males were released in each nesting box. The populations were left in the orchards after the end of pear blooming till the end of the egg laying period of the females.

O. cornuta nesting activity

In 2004, the reproduction activity of females during pear blooming was calculated by counting the number of the completed and sealed tunnels (labelled with permanent colours), at 50% and at the end of pear blooming. The former data was considered as an estimation of the number of nesting females. Nests were retrieved in May 12 and opened in September, and the number of cells produced till the above indicated periods was counted.

In 2005, ten females per box were caught and marked on the thorax through a different combination of non toxic water resistant coloured inks; the tunnels completed by the marked females were monitored every two-three days and identified with the same colours. At the end of the reproductive period (May 7) nests were retrieved. In September, the marked tunnels were counted and carefully opened to determine the total number of cells produced per female, the number of males and females (based on cocoon size). For a descriptive purpose, the latter parameter is presented in comparison to previous findings obtained during researches conducted in same localities and 'Abate Fétel' orchards (1998, 1999, 2001), in which *O. cornuta* had been introduced at the beginning of pear flowering and retrieved at petal falls (Maccagnani *et al*., 2003a; 2003b).

Preserving *O. cornuta* from noxious treatments

Due to the presence of the pest *H. brevis*., it was scheduled a treatment with a mixture of rotenone and pyrethrum (2004 – Derrot, a.i rotenone, dose 6.5 kg/ha; Pyrethrum Plus, a.i. pyrethrum, dose 2 l/ha; 2005 – Derrot, 7 kg/ha; Biopiren Plus, a.i. pyrethrum, dose 2 l/ha) at the end of pear blooming.

Before the treatment, ten females per box were caught at the exit of their tunnel and marked on the thorax. The paper tubes were extracted from the wooden nest and marked with the same colour of the female. Through the inspection of the internal cavity, it was feasible to measure the position of the pedotrophic cell produced on the day of the treatment, as well as to label it with a permanent colour on the paper tube.

Different safety measures were adopted for preserving the nesting females (and their progeny) from the insecticide treatment in order to let them complete their reproductive cycle after pear blooming.

In 2004, in April 26, after sunset, when the females were inside their nests, the boxes were closed and removed from the field, and the insecticide was sprayed on the crop. The efficacy of the following safety measures were compared: (i) two boxes were stored at cool temperature (6 °C) till the next morning and relocated around 11 a.m. in the same orchard and position than before; (ii) two boxes were stored at cool temperature (6 °C) till next morning and placed in another pear orchard, with the same orientation; (iii) four boxes were transported 70 km far, placed in a *B. napus* field, and opened the same night.

In 2005, the treatment was done in April 23. The nest boxes were closed early in the morning (7 a.m.), and the treatment was immediately applied. The first two procedures, above mentioned for the year 2004, were repeated; the remaining four boxes were left in the orchard, closed to protect the nesting materials from the direct spray, with a very little space to ensure some aeration. The nesting boxes were opened at 11 a.m.

In both years, two days after the treatment, observations were made to register the percentage of marked females still actively nesting. To assess the possible side effects on the larvae feeding on contaminated provisions, the marked paper tubes were extracted and carefully opened with a thin pair of scissors. The presence and vitality of the larvae nearer the tunnel exit with respect to the pedotrophic cell labelled before the treatment was examined.

Statistical analysis

The effect of the two complementary food sources *(P. spinosa* hedge *vs Brassica* sp. strips) on the reproductive parameters (number of occupied tunnels, pedotrophic cells, males and females) was tested by means of

one-way ANOVA, followed by the Tukey's test ($p < 0.05$) for means' separation. When the assumption of homogeneity of the variances was not respected a non parametric analysis of variance (Kruskal-Wallis test) was adopted, and the Dunn' test ($p < 0.05$) based on the sums of ranks was applied.

Results

O. cornuta nesting activity

2004 – As soon as *P. spinosa* and *Brassica* spp. started flowering (while pear blossoms were still completely closed) cocoons of *O. cornuta* were released (March 29) under good weather conditions. The first pear flowers opened in April 14, due to the low temperatures and the 7 rainy days. For the same reasons, the emergence from the cocoons occurred gradually. Data concerning the number of pedotrophic cells produced on average by each female during the first part of the pear flowering (till 50% blooming, April 17) showed that females nesting near to the *P. spinosa* hedge produced a significantly higher number of pedotrophic cells (mean ± sd; 5.62 ± 2.71) with respect to those nesting near to the *Brassica* spp. (mean ± sd; 4.56 ± 2.31) (Kruskal-Wallis test: $p < 0.05$; Dunn's test: $p < 0.05$).

Nevertheless, as long as the pear flowering proceeded, the number of cells produced at the end of blooming, in April 24, became similar between the two sites ('*P. spinosa* females': 8.16 ± 1.96; '*Brassica* females': 8.23 ± 2.20; Kruskal-Wallis test $p > 0.05$) (figure 1). At the end of the egg laying period, also the other measured parameters of the females nesting activity (number of occupied tunnels, males and females) resulted not statistically different between the two sites (figure 1), showing that both the two considered ecological infrastructures can play a valuable role as complementary food sources.

The establishment of the released females was quite uniform among the nesting boxes, without statistically significant differences in the measured parameters (figure 2).

2005 – *O. cornuta* cocoons were introduced into the orchards in April 1, and the females began to forage on the flowers of the two complementary food sources in a few days. Pear flowering started in April 12, and, as happened the previous year, no statistically significant difference was found in the measured nesting parameters among the sites (figure 3) and the nest boxes (figure 4) at the end of the females egg laying period.

Comparison of the nesting activity of *O. cornuta* in pear orchards over 5 year of study

In the previous three year studies (1998-1999-2001), the females released in an 'Abate Fétel' orchard at the beginning of pear flowering produced a few larval provisions, because of the shortness of the activity period (Maccagnani *et al*., 2003a; 2003b). In 2004 and 2005, in both cases of release on *P. spinosa* or on *Brassica* sp., females were already active at the very beginning of pear flowering, and produced a higher number of larval provisions. Figure 5 shows a striking variation in the reproductive success for the females released in 2004-2005 with respect to the previous studies.

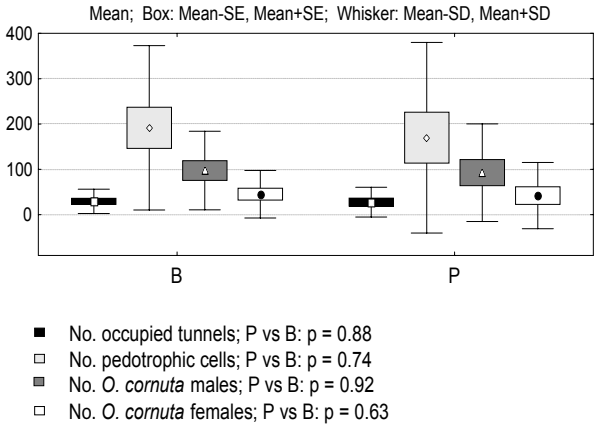

Figure 1. 2004 – Mean reproductive parameters measured at nesting boxes retrieval for the two sites. B: orchard with sowed *Brassica* sp.; P: orchard near to *P. spinosa* hedge. Kruskal-Wallis test.

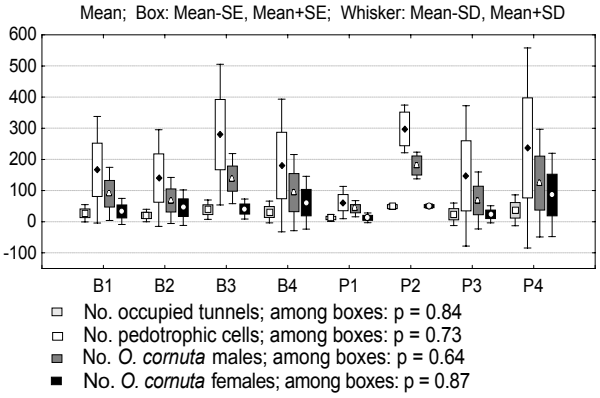

Figure 2. 2004 – Comparison among *O. cornuta* nesting activity in the 8 nesting boxes: B: *Brassica* sp.; P: *P. spinosa*. Kruskal-Wallis test.

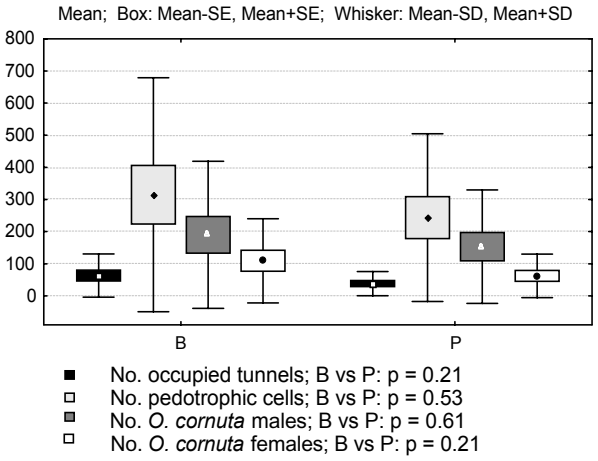

Figure 3. 2005 – Reproductive parameters measured for the two orchards: B: *Brassica* sp.; P: *P. spinosa*. Factorial ANOVA.

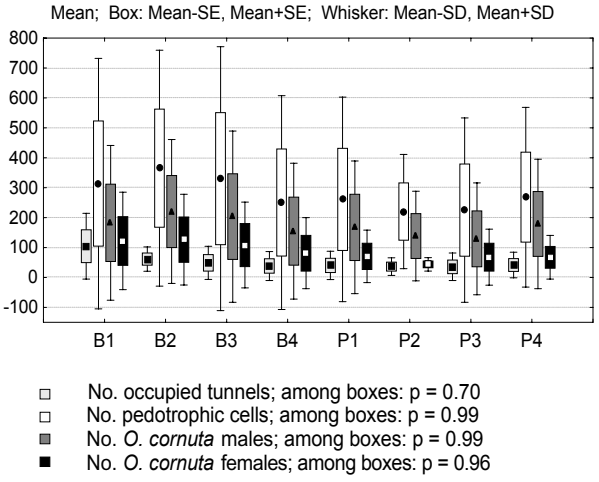

Figure 4. 2005 – Comparison among *O. cornuta* nesting activity in the 8 nesting boxes: B: *Brassica* sp.; P: *P. spinosa*. One-way ANOVA.

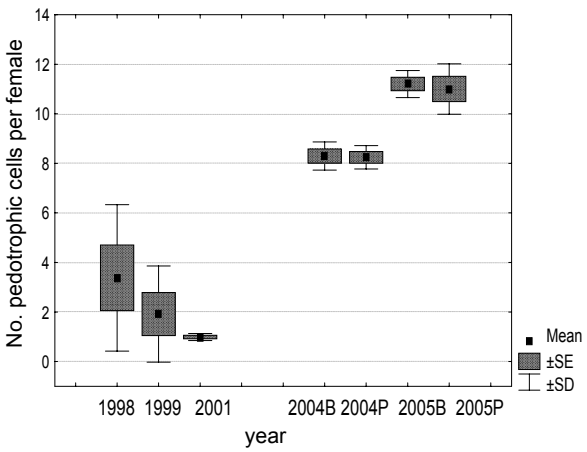

Figure 5. *O. cornuta* reproductive success. Release at pear bloom starting (1998-1999-2001) *vs* anticipated release (2004-2005) on pear orchard with early flowering ecological infrastructures: B = *Brassica* sp.; P = *P. spinosa*.

Preserving *O. cornuta* from noxious treatments

Table 1 reports the results of the measures adopted in the two years of study in order to reduce the impact on *O. cornuta* adults and larvae of the insecticide sprayed against *H. brevis*.

2004 – At the closure of the boxes, most females were in their nests, and the vibrations during the transport did not induce them to leave their tunnels. The following morning, females showed a normal behaviour: most of them performed the first flight apparently without re-orienting to the new nest place, and flew away very fast and straight. By contrast, several females of the nesting boxes relocated in the pear orchards, at the opening of the boxes the following morning, were already walking out of their tunnels, attracted by the light that penetrated through the white box walls; most of them flew rapidly away.

The observations made in the following days showed that most of the females displaced to the *B. napus* field abandoned their nest, or were not able to find the way back to the nesting box. The other two safety measures produced better results, with more than 70% of active females for the boxes stored for one night at low temperature and relocated in the same orchard; females in the boxes placed in a different orchard performed better than those transported in the open field, with a percentage of re-oriented females of around 35%.

As far as the possible side effects of the insecticide treatment on the larvae inside the nests is concerned, at the opening of the labelled paper tubes, all the larvae appeared in healthy conditions.

2005 – The safety measures achieved better results if compared with those adopted in 2004, in particular the displacement of the boxes in a different pear orchard. In addition to this, even the partial protection of the females, left in their boxes in the field, offered more protection than expected. The larvae survival was optimal for all the compared measures.

Discussion and conclusions

In 2004, the females released in presence of *P. spinosa* hedge produced at the beginning higher numbers of pedotrophic cells than those released on the strips of *Brassica* sp., probably for its richness in the number and density of the flowers. The total progeny reared in the two sites, leaving the females in the field till the natural conclusion of their activity, was not different. This demonstrated that both the two kinds of ecological infrastructures proved to be attractive for both males and females of *O. cornuta* and to provide enough food to sustain the population until the start of pear flowering.

Table 1. Percentage of active females (mean ± SD) after the adoption of the safety measures.

Safety measure	2004		2005	
	Females survival (%)	Larvae survival (%)	Females survival (%)	Larvae survival (%)
Displacement to *B. napus* var. *oleifera* field	12.5 ± 9.5	-	-	-
Cool storage + relocation in the same pear orchard	70.6 ± 11.9	100	78.8 ± 10.9	100
Cool storage + relocation in a different pear orchard	35.5 ± 14.3	100	72.2 ± 11.2	100
Left slightly opened in the field	-	-	60.8 ± 7.4	100

In the purposely descriptive comparison of the total progeny output obtained in the present study with the data obtained during the previous studies, the latter registered a lower pedotrophic cell production per female. This finding demonstrates that the anticipation of the pollinators release (7-10 days before pear bloom starting) allows the population to become well-established in the pear orchard at the very beginning of pear flowering. This means that *O. cornuta* females reach the maximum of their foraging (i.e. pollinating) activity at the opening of the very first flowers of the bouquets, and this is of particular importance for a good pear production (Sedgley and Griffin, 1989).

In addition, it is likely that the availability of a rich food source during the emergence of the *O. cornuta* population reduces the female dispersal rate in the pre-nesting period (Krunić *et al*., 2001). This aspect was not estimated in the present study, as our purpose was not to evaluate the proper number of females to be released per hectare, but how to maximise the nesting/pollinating potential of each established female.

The possibility to continue the nesting activity after the end of pear flowering can significantly increase the female reproductive rate, and this is important if the *O. cornuta* is not released only for pear pollination, but also for its multiplication and conservation. *O. cornuta* releases in agroecosystems with floral resources may not be sufficient to achieve success in pollination and rearing. The pesticide toxicity can be acute and/or delayed, affecting *Osmia* spp. adults (Ladurner *et al*., 2005) and larval stages (Tesoriero *et al*., 2003). Thus it is necessary to adopt safety measures at petal fall, when usually one treatment against *H. brevis* is required. The closure of the nesting boxes after sunset, storage at cool temperature and relocation in the same place is a worthy preserving technique. It showed that avoiding the direct contact of the females with the insecticide adopted in the organic farming systems (rotenone and pyrethrum) can enable the females to survive up to 90%, without any side effects on larvae survival.

The other preserving measures under investigation had to face with the difficulty of the females in re-orienting themselves when the nesting boxes are displaced (Vicens and Bosch, 2000c). The intermediate results obtained through the displacement of the nest boxes in a different pear orchard, which offered visual cues similar to those of the original orchard, means that the expectation regarding visual landmarks are crucial in the long and medium distance navigation.

The data obtained up to now constitute a starting point to define a strategy in *O. cornuta* management in pear orchards, which maximises its activity as pollinators and its reproductive potential in north-eastern Italian agroecosystems.

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