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Problems and perspectives for the use of exotic predators and parasitoids in biological control

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ABSTRACT The accidental introduction of alien organisms potentially harmful to agriculture can cause extensive damage to vegetable crops and fruit plants and is favoured by the global mobility of people, trade of goods and the ongoing climate change. The use of alien predators and parasitoids is well known in the agricultural field, where they are often used for biological control to protect fruit and horticultural plants. The management of invasive species is and will be one of the key issues for preserving biodiversity and the profitability of crops, the latter can now count on an effective, consolidated and lasting strategy: Integrated Pest Management (IPM). The legislation on this subject is complex and articulated and is continuously being updated. It allows for the development of specific skills in biological control and the availability to use quarantine chambers where it is possible to breed and study the behaviour of antagonists (predators and parasitoids), even exotic ones. If successful, their subsequent release to targeted biological control interventions of infestations of the IAS 'Invasive Alien Species' can be carried out. This contribution highlights the risk that such practices may involve and takes into account the following points: 1. The behaviour of an alien species can be very different in different contexts, being able to be a real IAS or not showing any character of invasiveness; 2. The behaviour of an alien species can vary over time in the same context, diversifying and also expanding its trophic niche; 3. A good number of indigenous predators and parasitoids can over time adapt to new alien prey/hosts and could potentially be used for biological control. In future, biological control will be increasingly used given that EU funds reward and support this type of approach and the intentional introduction of alien natural predators and parasitoids into agroecosystems, although subject to strict protocols, cannot exclude spontaneous colonisation by these last of natural environments with currently not assessable consequences on their biocoenosis. In conclusion, the rigorous risk analysis alone does not currently seem sufficient to exclude potential damage to local biodiversity, and programs for the release of exotic predators and parasitoids should be associated with mandatory monitoring of at least five years to verify the behaviour of these aliens in nature and their possible impact on ecosystems.

KEY WORDS Alien predators; alien parasitoids; integrated biological control; IAS.

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INTRODUCTION

The use of alien predators and parasitoids is well known in the agricultural field, where they are often used for integrated biological control to protect fruit and horticultural plants, both in the open field and in a protected area. The group of predators includes mainly species belonging to the Coleoptera Coc-

cinellidae, the Diptera Syrphidae and numerous Neuroptera; the parasitoid group is mainly represented in importance by the Hymenoptera Chalcidoidea (Aphelinidae, Encyrtidae, Eulophidae, and Pteromalidae) and by some families of Diptera.

The positive role that predators and parasitoids play in agroecosystems is fundamental as they are capable of strongly limiting the populations of phytophagous as aphids, scale insects, whiteflies and mites.

These predators and parasitoid insects are massively bred in real industrial laboratories, the so-called biofactories, and released into the field following tested protocols. In Italy, one of the few active biofactories is present in Sicily in the province of Catania, in the Ramacca area, capable of 'producing' millions of insects a year useful in the fight against the most feared pests of Italian citrus groves.

Despite the positive role that these predators and parasitoids play in agroecosystems, it is also necessary to carefully evaluate the negative effects that can occur when exotic insect species are introduced to control phytophages, most of which are also aliens.

IAS (INVASIVE ALIEN SPECIES) AND THEIR IMPACT

The accidental introduction of alien organisms potentially harmful to agriculture can cause extensive damage to vegetable crops and fruit plants when they manage to adapt to the climatic and environmental conditions of the invaded areas. This happens because in newly colonized areas the lack of specialized indigenous natural antagonists, capable of containing the infesting populations, leads to the occurrence of demographic explosions. The intensification of the mobility of people and goods on a planetary scale, together with ongoing climate changes, are considered the main causes of the introduction of alien insect species into new areas, with serious impacts on natural ecosystems, agricultural activities and human health. Today the presence of alien species, both plant and animal, is increasingly noticed also by the community, i. e. by "non-specialist" people, who, thanks to the spread of the Citizen Science approach, can easily recognize them through images and simple descriptions of the species, alien or not, present in an environment and report them to the authorities.

INTEGRATED BIOLOGICAL CONTROL AND THE USE OF ALIEN SPECIES

The management of invasive alien species (IAS) is, and in the future will be increasingly, one of the main topics for preserving biodiversity and crop profitability. This last aspect today relies on an effective, consolidated and long-lasting agroecological crop management strategy: integrated Biological Control (BC). The legislation on this topic, complex and detailed, is continuously updated, allowing the development of specific techniques and skills in the field of biological control. In the European context, a recent aspect is that of the use of "quarantine chambers" where it is possible to breed and study the behaviour of exotic antagonists (predators and parasitoids) before their possible subsequent release for targeted interventions for the biological control of IAS infestations.

For example, a project of the autonomous province of Trento, carried out by the Edmund Mach Foundation, plans to work simultaneously on two of the most feared invasive species recently found in Europe: the Brown marmorated stink bug, *Halyomorpha halys* (Stål, 1855) (Hemiptera Pentatomidae) and the Diptera Drosophilidae, *Drosophila suzukii* Matsumura, 1931, both polyphagous species native to East Asia. Although in different ways, both phytophagous species damage the fruits of a wide variety of trees, shrubs and herbs of economic interest.

In Italy, a fundamental role in these projects is played by the Council for Agricultural Research and Economics (CREA) and specifically by the Research Centre for Plant Protection and Certification of Florence, which in the case of the *H. halys* produced the risk assessment study and coordinates the monitoring and selection activities of the release sites and the distribution of the multiplication nuclei of the Hymenoptera Scelionidae, *Trissolcus japonicus* (Ashmead, 1904), Asiatic parasitoid, imported and bred to be subsequently released in the orchards of various Italian regions.

It should be noted that populations of *T. japonicus*, commonly known as the Samurai wasp, were initially reported in North America and Europe in 2014, subsequently in Switzerland in 2017 and in north-western Italy in 2018, following the spread of the host. In 2016, *T. mitsukurii* (Ashmead, 1904), another ovoparasitoid of *H. halys*, was reported from various regions of north-eastern Italy (Sabbatini Peverieri et al., 2018). How and when these exotic parasitoids arrived in Europe remains unclear, most likely they were introduced unintentionally with the same Asian bug.

Regarding *D. suzuki* the tests concern the microhymenopteran parasitoid *Ganaspis brasiliensis* (Ihering, 1905) (Hymenoptera Figitidae), the natural enemy of this dipteran in its native area. 'Quarantine experiments' are currently underway at the Mediterranean Agronomic Institute (CIHEAM) of Bari (Apulia region) to study the risk of introducing the parasitoid into orchards, even though it is currently foreign to Italian fauna.

INVASIVE ALIEN SPECIES: CONTEXTS AND THEIR COMPETITORS

The voluntary introduction of alien predators and parasitoids in the integrated biological fight against IAS may involve potential risk if the ecology, biology and behaviour of the various alien species are little or often not considered at all.

In our opinion, the main factors to take into consideration are the following:

1. The behaviour of an alien species can vary in the different Mediterranean-European areas. In fact, in a specific geographical context, an alien species can behave invasively or show no invasive character at all. Interesting cases, for example, the numerous alien species that arrived in the Mediterranean basin in recent decades living on essences of the *Eucalyptus* and *Ficus* genera. These species have become more or less invasive depending on: 1. the abundance of the host species, 2. its diffusion, 3. the microclimate conditions, 4. the cultivation techniques, and 5. the presence of natural antagonists. The latter can be indigenous (therefore linked to species native to the invaded territories) or allochthonous, often coming from the same areas of their hosts who followed into the new territories.

2. The behaviour of an alien species can vary over time in the same environmental context, also varying and expanding its trophic niche. Glaring and devastating examples are those of the Red palm weevil *Rhynchophorus ferrugineus* (Olivier, 1790) (Coleoptera Curculionidae) (Fig. 1), native to Southeast Asia and of the Lepidoptera Castniidae Palm borer moth, *Paysandisia archon* (Burmeister, 1880) native to South America (EPPO, 2024), whose larvae live inside the stems of the following Arecaceae genera: *Brahea*, *Butia*, *Chamaerops* (*C. humilis*, endemic species of the Mediterranean region), *Howea*, *Jubaea*, *Latania*, *Livistona*, *Phoenix* (*P. theophrasti*, endemic species of Creta), *Sabal*, *Syagrus*, *Trachycarpus*, *Trithrinax*, *Washingtonia*.

3. The alien species could occupy the territory of indigenous useful species, causing the decline of their population.

For example, the Harlequin ladybird *Harmonia axyridis* (Pallas, 1773) (Fig. 2) (Coleoptera Coccinellidae), is a generalist predator, native to Central-eastern Asia. In Europe, it is suspected to cause the decline of native ladybirds through competition and predation. Kenis et al. (2020), in Switzerland, monitored ladybirds for 11 years; these surveys showed that, on broadleaved hedges, the Harlequin ladybird quickly became the most abundant species,

Figure 1. Adult of the Red palm weevil, *Rhynchophorus ferrugineus* (Olivier, 1790) (Coleoptera Curculionidae). Photo by S. Bella.

representing 60–80% of all specimens collected in this habitat. One species, the Two-spot ladybird, *Adalia bipunctata* (Linnaeus, 1758) (Coleoptera Coccinellidae) almost disappeared, whereas it was the most abundant ladybird in that habitat when the study started.

4. Some indigenous predators and parasitoids can subsequently adapt to new alien prey/hosts and could potentially be used for biological control, although they are mainly generalist predators/parasitoids causing low levels of predation/parasitism to the target species.

For example, the Tomato borer *Tuta absoluta* (Meyrick, 1917) (Lepidoptera Gelechiidae), native to Central America, causes extensive damage to tomatoes but can also infest potatoes, aubergines and wild Solanaceae species, in Italy it is attacked by indigenous Hymenoptera belonging to 13 genera and 6 Families (Ichneumonidae, Braconidae, Eulophidae, Elasmidae, Pteromalidae and Trichogrammatidae) (Zappalà et al., 2012). Also, the Citrus leafminer *Phyllocnistis citrella* Stainton, 1856 (Lepidoptera Gracillariidae), native to Asia, infesting citrus trees in the Mediterranean area, and responsible for considerable damage in the citrus orchard, it is attacked in the new areas occupied by over 15 species of indigenous Hymenoptera Eulophidae (Mansour et al., 2021).

Figure 2. The Harlequin ladybird, *Harmonia axyridis* (Pallas, 1773) (Coleoptera Coccinellidae) native to Central-eastern Asia. Photo by S. Bella.

DISCUSSION AND CONCLUSIONS

Brief concluding considerations can be summarised in the following points:

1. Biological control will be increasingly used also because EU funding rewards and supports this type of agronomic management.

2. The voluntary introduction of alien predators and parasitoids into agroecosystems, although subject to strict protocols, cannot exclude their spontaneous colonisation of different natural environments, even very distant from those where they were initially introduced, with consequences on biocoenoses that cannot currently be assessed, given that numerous species of alien natural enemies adapted to live on various native species are known. For example, the two alien Hymenoptera Eulophidae *Semielacher petiolatus* (Girault, 1915) and *Citrostichus phyllocnistoides* (Narayanan, 1960), are considered among the most active controllers of the *Citrus* leaf miner *Phyllocnistis citrella*, were obtained from 9 non-target hosts (leaf miner microlepidoptera and Diptera) living on native plants (Rizzo et al., 2006).

The Harlequin ladybird *Harmonia axyridis* has been used as a biological control agent for various species of aphids and scale insects. In Western Europe, tested since 1982, this predator was released as a biological control agent in 1995, and now is present in almost all of Europe (Brown et al., 2008). The side effects of the use of *H. axyridis* have a notable impact on biocoenoses since it is a generalist predator species that feeds essentially on aphids and scale insects but also preys on larvae of other native coccinellids, Neuroptera Lacewings, mites, eggs and larvae of Lepidoptera and larvae of Diptera. A serious ecological problem!

3. Although the authorization for the breeding and release of alien predators or parasitoids into agroecosystems requires a rigorous risk analysis, it currently does not appear sufficient to exclude potential damage to indigenous biodiversity. It is therefore essential that the release programs should be mandatorily associated with multi-year monitoring to verify the behaviour of these aliens species in nature and their possible impacts on ecosystems.

According to Kenis et al. (2020), long-term

monitoring is necessary. 11-years monitoring in some habitats in Switzerland shows a strong decline of *Adalia bipunctata* and no variation of the predation pressure of ladybird species on aphids in response to *H. axyridis* invasion; this suggests that the biological control function of ladybirds on aphids living in those habitats has not been affected by the arrival of *H. axyridis*. The authors give recommendations to further assess the impact of *H. axyridis* on native ladybirds and aphids.

For example, the case of *Zelus renardii* (Kolenati, 1856) (Hemiptera Reduviidae) (Fig. 3) is significant: can this species be useful for biological control? *Zelus renardii* is an invasive alien species, native to North-Central America. Reported in Europe for the first time in 2010 from Greece and, in a few years, mentioned for almost all Mediterranean regions. In Italy, it was reported in 2013 in Latium and spread in Liguria, Apulia, Campania, Sardinia and Sicily. *Z. renardii* is a general feeder on a wide range of insects, including species of aphids and, unfortunately, among its prey are also useful arthropods (e. g. Coccinellidae). These well-known features indicate that this reduviid is not suitable for classical biological control. In fact, it is a harmful and potentially dangerous species for agroecosystems because it is a generalist and its presence could represent a new threat for indigenous species and human activities (Bella, 2020).

A recent study (Liccardo et al., 2020) investigated the possible effects of a strategy in an olive orchard with *Z. renardii* against *Philaenus spumarius* (Linnaeus, 1758) (Hemiptera Aphrophoridae), vector of Gram-negative xylem-limited bacteria *Xylella fastidiosa* (Wells et al., 1987) (Lysobacteraceae). Results seem encouraging, suggesting that the use of this agent in an augmentative biocontrol strategy could be a "green" solution to the invasions of *X. fastidiosa* (Liccardo et al., 2020). However, there are many factors to consider before deciding if an alien organism can be intentionally released or diffused. In fact, the attitude of *Zelus renardii* as pioneer species, together with biological characters as the short predation and feeding time and the high rate of offspring per mating, could represent a high potential risk to establish in natural areas too (Weirauch et al., 2012; Pinzari et al., 2018).

In conclusion, rigorous risk analysis alone currently does not appear sufficient to exclude potential damage to native biodiversity. The problem remains open, and so do our concerns!

Figure 3. *Zelus renardii* (Kolenati, 1856) (Hemiptera Reduviidae) while preying a specimen of ladybird. Photo by S. Bella.

Finally, it must be remembered that introducing alien species into the national territory is prohibited in Italy(Legislative Decree no. 19 of 2 February 2021) and, below, some of the main legislative regulations adopted in Italy are reported: Legislative Decree 230/2017, which adapts national legislation to the provisions of Regulation 1143/2014 containing provisions aimed at preventing and managing the introduction and spread of invasive alien species; Ministerial Decree 2 April 2020 "Criteria for the reintroduction and repopulation of native species (All. D)"; Presidential Decree n. 102 published on 5/9/2019 (Regulation amending art. 12 of Presidential Decree 8/9/1997 n. 357), which reintroduces in Italy the possibility of carrying out "Classic Biological Control" interventions to defend agriculture and environment through the re-establishment of new natural balances with the use of exotic natural antagonists for the containment below damage thresholds of the populations of the new "Pests".

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