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Barbara Manachini & Franco Palla

What does happen when an insect pest follows its host plant and viceversa?

Abstract

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Invasive species are usually well known but only make up a small percentage of the European's alien plants and insects. The ways these exotic species interact with our natural and cultural heritage are very complex and even some species considered invasive had and could have positive aspects on some European landscape and culture. A close look at the complicated relationship between non-native and native plants and insects in the Mediterranean areas reveals some unexpected twists in the story. Here are some cases of when aliens can threaten our cultural heritage or being part of it.

Key words: alien invasive species, cultural heritage, landscape, natural heritage, silkworms, rice.

The roots of the problem

Italian's cultural and natural heritages are under invasion. Since the earliest days of European trade and colonization, forest, woodland, artworks and ecosystems and more in general heritage have fallen victim to introductions of exotic insects, disease causing agents, plants and animals. The primary reasons for this invasion is human movements and trade. Different settlers in past and in more time brought with seeds and plants from different lands. New seeds, plants or transformed products were sometimes contaminated with seeds of other plants, pathogens, insects or nematodes. Some of these new organisms became established and spread over large areas, displacing the native flora and/or fauna (Andaloro & al. 2009). Some introduced organisms also escaped cultivation and displaced native species. Insects and disease causing organisms arrived on plants, imported logs, packing materials. They established themselves on native hosts that did not co-evolve with these agents. In the absence of natural enemies to regulate their numbers, they became widespread and damaging. Some invasive species have been with us for so many years that we have almost forgotten their origins. Today, the rate of introduction of invasive species is higher than ever, due to a global community with increased world trade and a highly mobile human population capable of traveling to the far corners of the world in high-speed

aircraft in a matter of hours. The effects of human activities on the world ecosystems and on the landscape are pervasive. Historical approaches are increasingly used to better understand the structure and function of contemporary ecosystems and landscapes that have been affected by human activities for centuries or even millennia (Swetnam & al. 1999). The introduction of alien species was accidental, causing a lot of damages including loss of biodiversity (Elton 1958) but also was deliberated to growth species that could improve food, feed and fibber supplies (Hoyt 1992), as the case of the plant imported in Europe before the 1492 (approximately considered 1500) and named Archeophyta. Some of them became even the symbol of the landscape as the case of as the *Cupressus sempervirens* L. that is now the landmark of Tuscany (Fig. 1) (Guarrera 2006) or the case of palm trees, probably brought by Arabian, that is the symbol of the cultural heritage of Sicily (Italy) (Manachini & al. 2012, 2013). For the same region other exotic plants are Sicilian Flags like several species of Citrus (Calabrese 2004) and the prickly pears (Raimondo & al. 2005 a, 2005b). There are exotic species that draw the landscape also in the north of Italy as the case *Oryza sativa* (Cerina & al. 2007; Bao-Rong & al. 2007). Since its introduction rice has become more and more important not only as food but also in culinary, in poetry, music, fine arts and in the cultural heritage (Bao-Rong & al. 2007; Cerina & al. 2007).

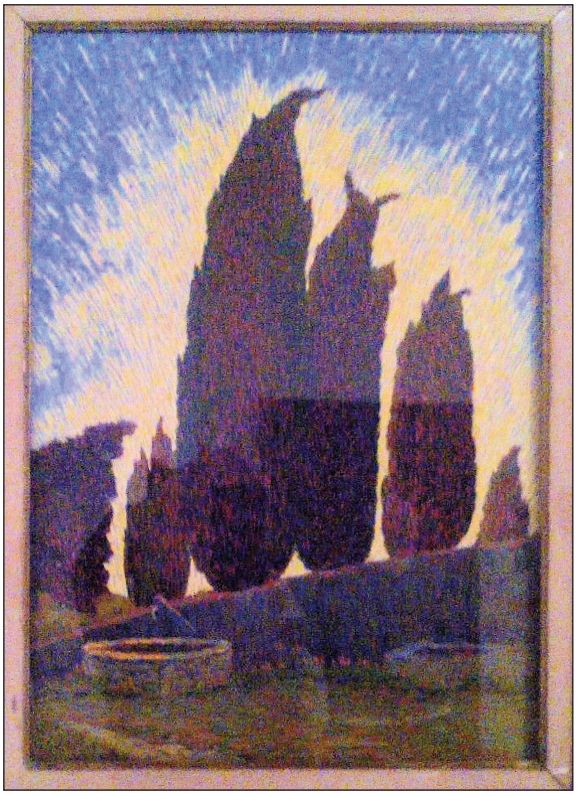

Fig. 1. Benvenuto Benvenuti in " I cipressi" shows how *Cupressus sempervirens* L.is now a landmark of Tuscany.

Many of these exotic species were introduced to supply new production or for ornamental reasons and they were particularly welcome in the new environment as they did not have pests and pathogens that could affect them and decrease the yield or the quality (Manachini & al. 2013). However with the globalization the opportunity for the pests to meet again its host become more and more higher. There are many example of how the pests of the introduced archaeophyta were introduced in the new territory and meet again their native hosts. Some time they can even prefer the new host species that they have never met before. This is the case of the Red Palm Weevil (RPW, *Rhynchophorous ferrugineus*, *Coleoptera: Curculionidae*), which was not a host of the palm species *Phoenix canariensis;* however in the new introduced area (Mediterranean area) RPW prefers the new host rather than the Date palms (Fig. 2). The introduction of these insects has dramatically changed the landscape and the aesthetic of historical squares and boulevard (Longo & al. 2008; Giovino & al. 2009; Manachini & al. 2013). Although it is interesting to notice that in Australia and in New Zealand the *P. canariens* is considered an alien invasive species accidentally introduced in 2001.

Changes in the landscape could happen also in the rice landscape due to the Alien invasive insect Rice Water Weevil (RWW *Lissorhoptrus oryzophilus*). RWW is native of the United States, where the beetle reproduces sexually. In Italy the insect was first detected in 2004 in Ticino Park. Since then, only parthenogenetic female were found in our country (Lupi & al. 2007). As rice arrived in USA (South Carolina), in 1694 (Cerina & al. 2007; West 2007), its native hosts were different species than *O. sativa*, mainly monocots herbaceous plants as *Poaceae* and *Cyperaceae* weeds. However since this insect has been associated with rice from the time the crop had been introduced in the United States, where it is now the primary pest of the culture. To contrast this pest a part of chemical pesticides the other management control practices is to growth rice (e.g. some varieties) without water puddles. Consequently the famous "waterland" landscape will change in a normal grass-field (Lu Bao-Rong & Manachini 2007).

Well known is also the case of the phylloxera. This small, sap-eating, greenish insect, *Daktulosphaira vitifoliae,* closely related to the aphid, is a worldwide pest of commercial grapevines. It is originally native to eastern North America and was accidentally introduced in Europe in1860. In the late 19th century the phylloxera epidemy destroyed most of the vineyards for wine grapes in France, in Italy and in several countries of Europe. The first report of phylloxera in Italy was near the Lake of Como, but the regions struck hardest were Sicily and Calabria. In 1885 the *New York Times* reported that the Italian Consul estimated lost wages in Sicily over thirty million dollars ('Phylloxera Ravages Italy'). How the *Phylloxera* was introduced to Europe remains debated: American vines had been taken to Europe many times before, for reasons including experimentation and trials in grafting, without consideration of the possibility of the introduction of pestilence. Italy, along with many other European countries, enacted a temporary ban on plants that might carry the phylloxera into their vineyards. Vineyards found infected early on were burned at the expense of the state in order to slow the spread (Ordish 1972). Netherless there were many riots as the destruction of vineyards lead to loss employment.

Because phylloxera is native to North America, the native grape species are at least partially resistant. By contrast on *Vitis vinifera* L., it causes deformations on roots and secondary fungal infections can girdle roots, and gradually cut off the flow of nutrients and

water to the vine. At significant amount of research was devoted in the late 19th century to finding a solution to the phylloxera problem, and two French wine growers, suggested the possibility that if *V. vinifera* vines could be combined, by means of grafting, with the aphid-resistant American vines, then the problem might be solved (Pastena 1990). Once grafting was accepted as a solution the ban on imported vines was lifted in order to supply Italian vineyards with resistant rootstocks subsidized by the Italian government (Cocco 1907). There is still no remedy, as such, for the *Phylloxera*, or the disease it brings with it, and it still poses a substantial threat to any vineyard not planted with grafted rootstock. In fact only few European varieties are resistant to *Phylloxera*.

When the insect meets a new host

The briefcase of RPW previously reported is just an example of the complexity of the phenomena (Manachini & al. 2012) and the possibility of a phytophagous to shift versus a new plant host species. RPW became pest of related species of palm trees of the *Arecaceae* but in other case the phytophagous can even attack plant that has not relative species in the new area or that are phylogenetically really far. *P. canariensis* is the most suitable host of Red Palm Weevil in the Mediterranean countries has never met this insect pest before the human trade of palm trees (Fig. 2).

The more emblematic example is the relationship among the maize and the lepidopteran pest *Ostrinia nubilalis* (*Lepidoptera*: *Crambidae*).

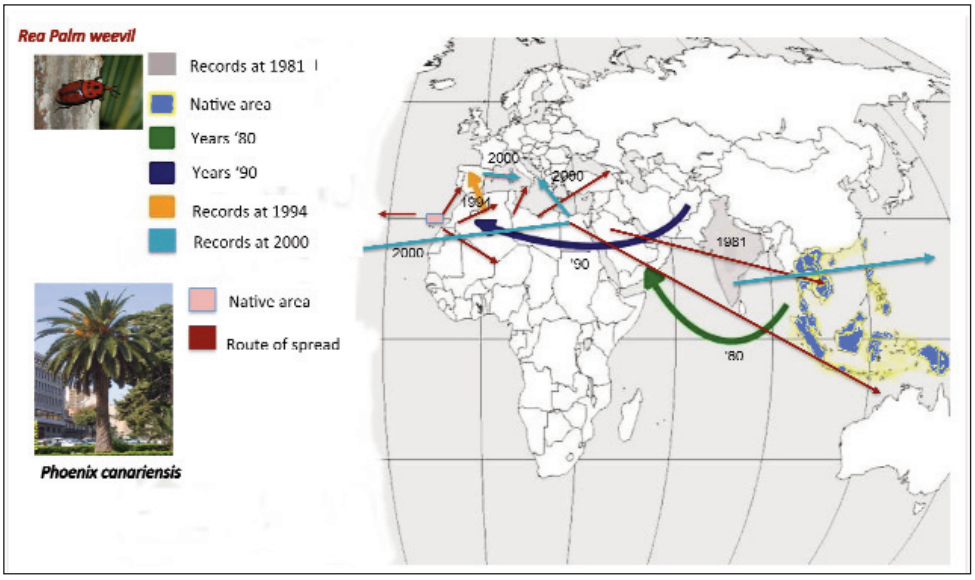

Fig. 2. Schematic view of the native areas and routes of spread of *Phoneix canariensis* and invasion routes of its new pest the coleopteran *Rhynchophorous ferrugineus*.

After European contact with the Americas in the late 15th and early 16th centuries, explorers and traders carried maize back to Europe and introduced it to other countries. Maize spread to the rest of the world because of its ability to grow in diverse climates. *Polenta*, made in the North of Italy is one of the typical recipes and was the major food available during the II World War.

O. nubilalis is the key pest of maize, being native to Europe is known as European corn borer (EBC). It is a pest of grain, but it shows a highly polyphagia. Before the introduction of *Zea mays* in Europe, ECB presumably ate on several herbaceous plants e.g, millet. The ECB was first reported in North America in 1917, but it was probably introduced from Europe several years earlier. Since its initial discovery in the Americas, the insect has spread even into Canada and many other regions becoming the major pest of corn. But ECB was found infesting also the *Oryza sativa*, *Artemisia* sp., *Humulus lupulus* L. and more than 200 plants can serve as hosts. The susceptibility of maize to the ECB and the resulting large crop losses, which are estimated at a billion dollars worldwide, led to the development of transgenic organisms, expressing the *Bacillus thuringiensis* subsp. *kurstaki* entomotoxin. "Bt maize" is widely grown in the United States and has been approved for release in other countries (Manachini 2006). Figure 3 gives a schematic view of the complex relationship among *Zea mays* - *Ostrinia nubilalis* and human trades. All these relationship have drastically changed not only the environment and the landscape, but also the our cultural heritage and culinary recipes!

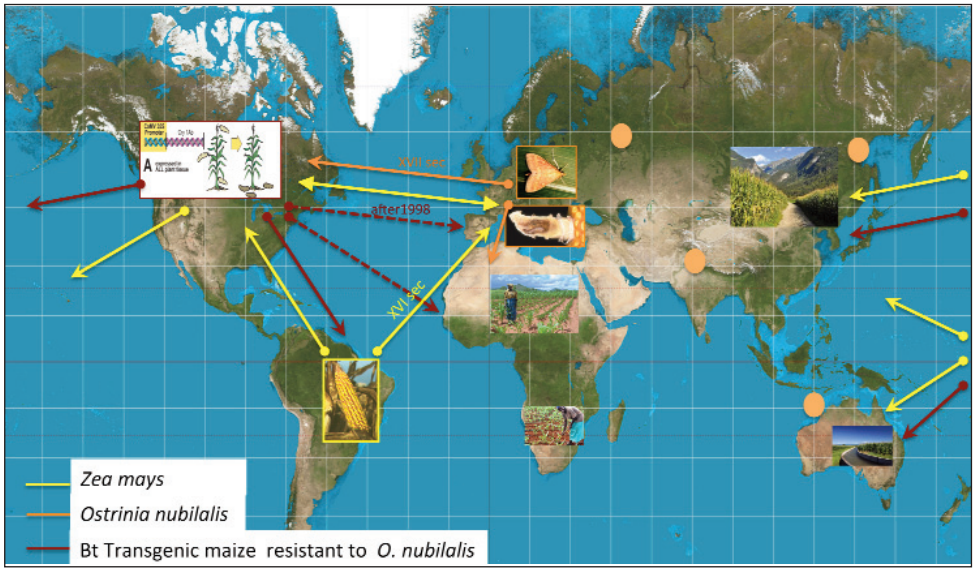

Fig. 3. Schematic view of the complex relationship among *Zea mays* - *Ostrinia nubilalis* and human trades.

When the plant follows the insect

Ailanthus altissima is an invasive species in Italy, where was imported in 1760 (Raimondo & al. 2014). It is a deciduous tree in the *Simaroubaceae* family. It is both native in northeast and central China, as well as Taiwan. The tree has been grown extensively both in China and abroad as a host plant for the ailanthus silkmoth, (*Phylosamia cynthia*) used for silk production. It is a saturniid moth, used to produce silk fabric but not as domesticated as the silkworm. The silk is extremely durable, but cannot be easily reeled off the cocoon and is thus spun like cotton or wool. However *P. cynthia* was unable to adapt at the new condition while *A. altissima* is what was left by this tentative in Europe (Raimondo & al. 2009). In addition the host plant was one of the first trees brought west during a time when *chinoiserie* was dominating European arts, and was initially hailed as a beautiful garden specimen. However, enthusiasm soon waned after gardeners became familiar with its suckering habits and its foul smelling odour. Despite this, it was used extensively as a street tree during much of the 19th century. Nowadays there is awareness of *A. altissima* invasiveness and its impact on forests, urban areas, rangelands and cultural heritage (Raimondo 2009), thus there are several laws addressed to eradicate and ban the use of *A. altissima* (e.g. Regione Toscana, Legge Reg. n.56 del 6/4/2000).

The most known imported insect is certainly the silkworm (*Bombyx mori*), originally existed in the wild throughout Asia, as we rely on their silk for our textile and clothing

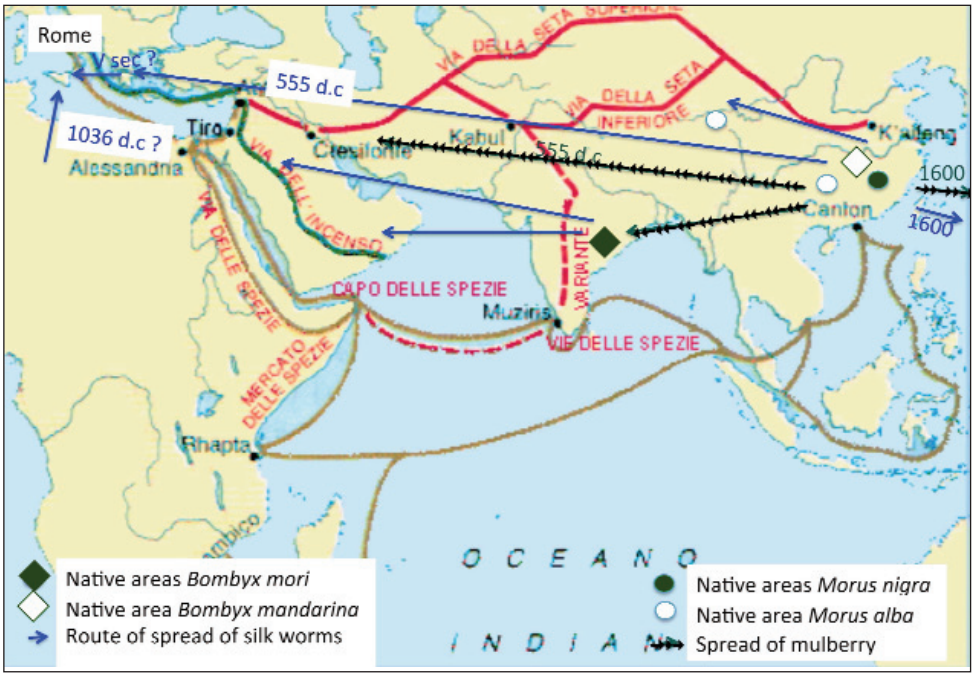

Fig. 4. Schematic view of the complex relationship among *Bombyx mori – Morus spp.* and human trades.

industries. Sericulture in Italy originated in an imprecise period of time between the 10th and 11th century. The silkworm rearing was probably introduced by Arabs to Sicily and by Byzantines to the other regions of the South (Cappellozza 2002).

Though they are believed to no longer exist in the wild, they are in the care of the silk industry world wild. This insect, the foundation of an industry that dates back over 4000 years to China, eats only one thing - the Mulberry and especially the White Mulberry. The silkworm's or Mulberry moth's scientific name, *Bombyx mori* reflects this close relationship with *mori* being derived from *Morus* (*M. rubra* and/or *M. nigra*). Also mulberry, is not native in Europe (Celesti-Grapow & al. 2010). Trees were brought here to support a silk industry, but at the moment silk production is restricted to few areas in Europe (Fig. 4). Thus the mulberry is considered a weed tree in many parts of Europe including urban areas. Nether less, mulberry trees are held in high regard in Sicily. The taste of the fruits is appreciated by most people, and they are used to made the famous "granita di gelsi", jams and jellies or fermented to make something a bit stronger. Wildlife ranging from birds to deer, however, find the fruit most attractive and they frequent the trees in the summer to consume the bountiful crop.

Domestic silk moths are closely dependent on humans for reproduction, as a result of millennia of selective breeding. Each Italian region, where sericulture represented an economic activity, had its own silkworm strains (or geographical races), which belonged to silkworm eggs producers; these races were adapted to live and produce in the particular environmental conditions where they had always been reared.

Conclusion

Increase awareness of invasive species and their impacts

There is a continuing need to increase the awareness of invasive species and their impacts on natural and cultural heritage. While specialists (e.g., entomologists, plant pathologists, weed scientists) at are often actively engaged in management or claim the risk of invasive species, program managers and other stackeholders may not fully appreciate the magnitude of the problem.

Others that must be made more aware of the problems associated with invasive species are the legislators (DAISIE 2015).

In 2008, the cost of controlling invasive species and repairing the damage they cause across the EU reached an estimated €9.6 - €12.7 billion (Anonymous [European Commission] 2009). But this range is certainly an underestimate, as often private costs, are not included and the estimation of damages on cultural heritage is far to be defined. Moreover, many European countries are only starting to count the costs (Anonymous [European Commission] 2009; DAISIE, 2015). However alien species have in several cases brought advantages in the new countries, but the globalisation speeds the potential spread of this phenomena and more precautions are needed than in the past (Manachini & al. 2012).

Differences in the composition of regional alien species are driven by a complex set of filters such as biogeography, socio-economic issues, cultural heritage, global trade dynamics, human populations, cultural acceptance and tradition. Furthermore, the increasing

amount and efficiency, of global trade continues to provide the opportunity for new species to invade new areas.

In our analyses we examined example of patterns associated with different plants and insects species currently established in Italy and we reported how alien species in the past and now have changed culture and landscape, becoming even "symbol flag" of some regions. We recommend that further effort be made towards the formation, and analysis, of regional inventories of alien species that would impact natural and cultural heritage. This will allow a wider range of taxa and regions to be examined for generalisations, and help assess the risk posed by certain taxa to the economy or environment, and which habitats and cultural assets are at greater risk.

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Addresses of the authors:
Barbara Manachini[1] & Franco Palla[2]
[1]Università degli Studi di Palermo - Dipartimento STEBICEF, Sez. Biologia animale ed Antropologia, via Archirafi 18, 90123 Palermo. E-mail: barbara.manachini@unipa.it
[2]Università degli Studi di Palermo - Dipartimento STEBICEF, Sez. Botanica e Ecologia ambientale, via Archirafi 38, 90123 Palermo. E-mail: franco.palla@unipa.it