Studying the peach fruit fly: bactrocera zonata

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Abstract

The peach fruit fly, Bactrocera zonata (Saunders) is one of the most harmful species of Tephritidae. It is a polyphagous species attacking more than 40 species of fruit crops and has also been recorded from wild host plants. The peach fruit fly is a serious pest of peach, guava and mango; secondary hosts include apricot, fig and citrus. It causes serious economic losses, either by direct damage to fruits or indirectly by warranting the need for quarantine and phytosanitary measures. Bactrocera zonata is native from India and is present in numerous tropical countries of Asia. However, this pest has been established in Egypt since the late 1990s and is now largely widespread throughout the country. Therefore, it demonstrated its ability to establish outside tropical climates and its adaptability to local temperate conditions.

In Egypt, B. zonata is active throughout the year when temperatures exceed 10°C and can complete several generations per year, apparently overwintering also in temperate climates.

Bactrocera zonata is well adapted to hot climates and shows higher low-temperature thresholds than those of the Mediterranean fruit fly, Ceratitis capitata, which is widespread in the Mediterranean countries. Pest risk analysis suggests that the peach fruit fly is capable to establish and spread in coastal areas of the Mediterranean region, causing significant damage on fruit production. of entering, establishing, spreading and causing significant impacts on fruit production in other countries of the Mediterranean region.

INTRODUCTION

Tephritid fruit flies (Diptera: Tephritidae) have a major impact on world agriculture, causing yield losses and reducing the quality and marketability of agricultural crops. Control of fruit flies mostly relies on the application of broad-spectrum insecticides, which could cause food contamination, side effects on beneficials and pest resistance to insecticides.

Tephritid fruit flies are among the most invasive species of fruits and vegetables in the world.

Establishment of exotic flies would cause direct and indirect economic losses due to damage to fruits and strict quarantine regulations imposed by importing countries to avoid introductions of invasive pests.

The family Tephritidae, comprises nearly 4500 species distributed over most of the world and include several species that pose a potential threat to Mediterranean horticulture, mainly of the wide-ranging genus Bactrocera, native to South East Asia and Australasia, the genus Anastrepha, originated from Central and South America, and the genus Ceratitis, indigenous to Africa.

The genus Bactrocera is considered a serious threat of fruit crops because of the wide host range of its species and the invasive power of some species within the genus (White and Helson-Harris 1992; Clarke et al., 2005).

Several Bactrocera species established outside of their native Asian range: Bactrocera carambolae Drew and Hancock in Surinam and northern Brazil, Bactrocera cucurbitae (Coquillet) in Hawaii, East and West Africa, Bactrocera dorsalis Hendel in Polynesia and Hawaii, Bactrocera invadens Drew, Tsuruta and White in Sub-Saharan Africa and Bactrocera zonata (Saunders) in the eastern Mediterranean basin (Vayssières et al., 2008).

The two polyphagous fruit flies presently established in the Mediterranean region are the Mediterranean fruit fly (medfly) Ceratitis capitata (Wiedemann), the most dangerous and widespread species, and the peach fruit fly B. zonata, which has been detected in Egypt in1998 and spread throughout the country (Amro and Abdel-Galil, 2008). The peach fruit fly was intercepted at the port of Valencia in 2005 by quarantine officials on citrus fruits imported from Egypt. Therefore, a Pest Risk Assessment (PRA) was carried out by Spain and submitted to the European Food Safety Authority (EFSA) for a scientific opinion. The PRA pointed out that the peach fruit fly can establish and spread in southern Europe, causing considerable damage to fruit yield. However, the pest risk assessment can be improved by defining the potential climatic range of the pest in Europe and identifying fruit crops potentially at risk (EFSA, 2007). Bactrocera zonata is listed as Dacus zonatus in Annex IAI of Directive 2000/29/EC, which includes harmful organisms whose introduction in EC countries are banned.

In the present paper we review the life history, host range, influence of climatic factors and provide a tentative distribution map of the peach fruit fly in the Mediterranean region along with control methods.

DISTRIBUTION

The peach fruit fly is native to tropical Asia and is widely distributed in Bangladesh, Bhutan, India, Indonesia (Sumatra), southern Iran, Laos, Myanmar, Nepal, Oman, Pakistan, Saudi Arabia, Sri Lanka, Thailand, United Arab Emirates, Viet Nam, Yemen. It also occurs on the Indian Ocean islands of Mauritius and Reunion (EPPO, 2005).

In Pakistan, this fruit fly is abundant in coastal and sub-coastal areas of Baluchistan and Sind, and in semi-desert areas and northern plains of Punjab. However, it has also been recorded as rare from foot hills of Islamabad and Peshawar valley of North Western Frontier Province (Hussain, 1995).

In Sri Lanka, this species is distributed throughout the island in wet and dry zones and has been recorded up to the elevation of 1800 m (Tsuruta et al., 1997).

In the last decades, the peach fruit fly has spread westward and has established in the Arabian Peninsula and Egypt. Bactrocera zonata was identified in 1998 on infested guavas collected in Agamy and Sabahia, near Alexandria. In 1999, monitoring traps showed high capture rates in Alexandria and Cairo. In October 2000, the pest was detected in North Sinai and is at present widespread in all the fruit-growing areas of Egypt (EPPO, 2008). California has been invaded multiple times (1989, 2001 and 2006) by the peach fruit fly, but it has been successfully eradicated (EPPO, 2005).

LARVAL HOST RANGE

The peach fruit fly has been recorded infesting over 40 cultivated and wild plant species, mainly those with fleshy fruits (Table 1).

In Pakistan, B. zonata is a serious pest of guava, mango, peaches, papaya, persimmon and citrus. Damage of 25-50% has been reported in guava, of 10-15% in mango and of 40% in persimmon (Syed et al., 1970; Qureshi et al., 1992; Stonehouse et al., 2002).

The relative susceptibility of the most common cultivated fruits in New Valley Oases (Egypt) was determined in field on the basis of adult emergence from infested fruits. Sour orange appeared to be the highest susceptible host, followed by orange and guava, whereas mandarin, apple, mango and fig were more resistant/showed some sort of resistance (Amro and Abdel-Galil, 2008). In Egypt, the highest number of pupae and the highest percentage of adult emergence were recorded under laboratory conditions from pear fruits, followed by guava, peach, apple and apricot (Shehata et al., 2008). Bactrocera zonata seems more adapted to attack citrus fruits than C. capitata. In fact, in 2002/2003 at Fayoum Governatorate (Egypt), the two species infested 15. 5 and 0. 35% of Navel orange, 10. 0 and 0. 9% of grapefruit, 8. 7 and 3. 7% of mandarin, 5. 7 and 3. 4% of sour orange, 0. 6 and 0. 3% of lemon and 0. 6 and 0. 3% of Valencia orange, respectively (Saafan et al., 2005).

Restrictions by overseas markets are inevitable if research funding actions show that the peach fruit fly is established in Mediterranean countries.

LIFE HISTORY

The peach fruit fly is anautogenous, i. e. it emerges from puparia as sexually immature adult that needs to feed to survive and reproduce. Adults obtain sugars from honeydew and other plant exudates, protein from bird feces and phylloplane bacteria and moisture from dew and rain. Adults are attracted by some plant-derived phenyl propanoids (e. g., methyl eugenol), that might play a role in the mating behaviour. Mated females pierce the skin of host fruits with their ovipositor and lay a batch of 2-9 eggs. The eggs usually hatch in a few days and the young larvae feed upon the fruit pulp destroying the fruit. Tunnels created by larval feeding also allow the entry of secondary pathogens causing secondary fruit rot. The mature larvae leave the fruit and pupate in the soil where they emerge two weeks later as young adults.

Bactrocera zonata is a non-diapausing and multivoltine species with overlapping generations. In Pakistan and Egypt, adults are present throughout the year except in January and February (Hussain, 1995; Farag et al., 2009). Overwintering mostly occur in the larval or pupal stage.

Adults a strong flier, capable of dispersing more than 24 km in search for host plants (Qureshi et al., 1975). Passive dispersal is mainly by means of winds and transportation of infested fruits. Adults live for 30-60 days and the pre-oviposition period (including sexual maturation of 8-16 days, ranges from 10 to 23 days. A female can lay up to 93 eggs/day, and as many as 564 in its lifetime (Qureshi et al., 1974). Under favourable conditions, the eggs hatch into larvae within 2 days. The larvae feed in the fruits for 4 to 30 days, depending on temperature (Duyck et al., 2004). Mature larvae burrow 2. 5 to 12. 5 cm in the ground to pupate. The pupal period varies from 4 days in summer to over 6 weeks in winter. Full development takes from 5 to 8 weeks, depending on the season and type of fruit infested (Shehata et al., 2008).

The most important parameters influencing the population dynamics of B. zonata are the favourable environmental conditions for reproduction and survival, and host sequence, suitability and availability. Several generations per year are completed under favourable conditions. In Pakistan, the peach fruit fly complete 8-9 generations per year in the coastal plains, whereas only two generations are completed in 5 months in northern areas (Hussain, 1995). At Giza Governatorate (Egypt), seven overlapping generations were recorded from March to November; the first generation is the longest, occurring from March to May-June, whereas summer generations lasted 4-6 weeks. Populations are usually at their lowest level at the end of the winter due to the slowdown or cessation of development. It may take several generations are needed to reach the highest population density, which was observed during the 5th generation at the end of August (Farag et al., 2009).

Influence CLIMATIC FACTORS AND OF HOSTS

Climate plays a critical role as the determining factor of the peach fruit fly abundance, influencing development and survival, therefore limiting its geographical range. The wide distribution of B. zonata indicates a considerable degree of environmental plasticity. Although the immature stages of Bactrocera sp. can survive short periods of high (> 30°C) or low temperatures (<5°C), adults are able to survive prolonged periods at such conditions. Larvae and pupae of the peach fruit fly can apparently survive winters in temperate climates in Pakistan (Hussain, 1995). Moreover, the species appears to have survived freezing temperatures in Alexandria and North Sinai (Egypt) and in the San Joaquin Valley (California) (EFSA, 2007).

The temperature is the most important factor determining developmental rates of immatures and adult maturation rates. The duration of the peach fruit fly lifecycle is mainly affected by temperature and host fruit species. Development ceases in all stages below 12°C; larvae and pupae are more resistant to cold weather conditions. The developmental thresholds of pre-imaginal stages of a peach fruit fly population in Reunion were determined at constant temperatures. Lower thresholds of eggs, larvae and pupae ranged from 12. 6 to 12. 8°C, which were higher than those of C. capitata (10. 2-11. 6°C). The thermal units required for the development of pre-imaginal stages were estimated in 224 degree day units (Duyck et al., 2004). However, in Egypt, the lower temperature threshold was determined as 11. 84°C and the thermal units required to complete a generation (from egg to egg) were 487 degree days (Sharaf El-Din et al., 2007). Differences on lower developmental thresholds might be due to the different strains and the larval food. However, the existence of cold-hardening ecotypes of the pest can not be ruled out. The upper temperature threshold was estimated as higher than 35°C (Qureshi et al., 1993; Duyck et al., 2004). The optimal temperatures for development and survival of pre-imaginal stages occurs at 25-30°C. The duration of the pre-ovipostion period ranged from 23 days at 20°C to 8. 4 days at 30°C. Fecundity and adult longevity were optimal at 25°C (Qureshi et al., 1993). Reliable temperature thresholds and thermal constants appropriate for each life stage allow the development of phonological models to predict the duration of the life cycle of the peach fruit fly under various climatic conditions. On the basis of thermal units, expressed as cumulative degree days, a number of 6, 7 and 8 annual generations have been predicted in North Sinai, El Beheira and Asyout (Egypt), respectively (Khalil et al., 2010).

Host quality strongly affects development time and survival of pre-imaginal stages and the reproductive parameters of adults. Peach, guava and mango were the most suitable fruits for larval development and fecundity with respect to other fruit species (e. g. apple, pear, plum, orange) (Hussain, 1995).

Climatic factors and host suitability influence coexistence of tephritid fruit flies in some areas. The peach fruit fly was detected in Reunion in 1991 and appears to be displacing C. capitata in warm and dry areas. Ceratitis capitata and B. zonata attack almost the same fruit species, indicating that species niche partitioning is determined by climatic factors rather than host range (Duyck et al., 2008). The peach fruit fly showed displacement ability also over B. dorsalis and Carpomyia vesuviana Costa in some areas of its native geographical range (Agarwal and Kapoor, 1986).

POTENTIAL GEOGRAPHICAL DISTRIBUTION IN THE MEDITERRANEAN BASIN

The potential distribution of the peach fruit fly in the Mediterranean basin has been modelled/predicted with CLIMEX. Based on climatic data, this software compares the geographical distribution of a species in the native area and predict its potential geographical range in other continents using the ‘ Compare Locations’ function (Sutherst et al., 2007).

The model combines a weekly population growth index (in response of temperature, rainfall and relative humidity) with 4 stress indices (cold, hot, wet and dry) into an Ecoclimatic Index (EI), which indicates the potential propagation and persistence of the species as determined by climate. A database of 30-year climatic data for meteorological stations irregularly located in the Mediterranean basin was used. Climatic parameters used were modified from available data of other tephritid fruit flies (C. capitata and B. dorsalis) (Vera et al., 2002; Stephens et al., 2007), also considering the climatic requirements of B. zonata (Duyck et al., 2004). Then, values were adjusted to fit the distribution of B. zonata in Egypt. To provide a more realistic prediction of the pest range, the ‘ Irrigation’ option in CLIMEX was used. Figure 1 shows a tentative distribution map of B. zonata based on Ecoclimatic Index. Under current climate conditions, the model predicts the establishment and persistence of the peach fruit fly in coastal areas of North Africa and Near East. The suitability of European countries to B. zonata establishment was limited to southern areas of Portugal, Spain, Greece and all the main Mediterranean islands (Balearic Islands, Sardinia, Corsica, Sicily and Crete). The potential geographical distribution of the peach fruit fly appears to be narrower than that of C. capitata, which is more adapted to cool temperatures. Moreover, the predicted range of B. zonata seems to coincide with most of the Mediterranean citrus-growing areas.

CONTROL METHODS

Biological control of the peach fruit fly is ineffective, because young larvae feed into the fruit flesh and are protected from parasitoids. The most common hymenopterous parasitoids recovered from B. zonata in the native area are the braconid Diachasmimorpha longicaudatus (Ashmead) and the eulophid Aceratoneuromyia indica (Silvestri) (Kapoor 1993). In Egypt, Dirhinus giffardii Silvestri (Hymenoptera: Chalcididae) and the pteromalids Spalangia cameroni Perkins and Pachycrepoideus vindemiae Rondani have been recorded on peach fruit fly pupae (Badr El-Sabah and Afia, 2004). Recently, biological control efforts have been focused on augmentative release of D. longicaudatus and Fopius arisanus (Sonan) (Hymenoptera: Braconidae) (Rousse et al., 2006).

Bactrocera zonata males are attracted to citronella oil and to its active compound methyl eugenol (Howlett, 1915). This parapheromone, which is present in many plants, has both olfactory and phagostimulatory action and attracts peach fruit fly males from up to 800 m (Roomi et al., 1993). Methyl eugenol proved to be very effective in early detection of peach fruit fly males and has been used in several suppression programs (Qureshi et al., 1981; Sookar et al., 2006). The male annihilation technique (MAT) employs methyl eugenol to attract most of the males of B. zonata populations. Extermination of males in a population severely reduces the frequency of fertile matings, minimizing the chances of successful reproduction and consequently lowering the infestation on fruits. Peach fruit fly males are caught/killed by plastic traps baited with methyl eugenol (‘ mass trapping’ technique) or attracted to wooden blocks soaked with parapheromone and insecticide (‘ attract and kill’ technique). MAT is the standard technique to eradicate the peach fruit fly from areas newly-invaded areas and has successfully been applied in several eradication programs (California, Israel) (Spaugy, 1988; EPPO, 2008). A large eradication program based on the massive use of bait stations (wooden blocks) has been very successful in Egypt: B. zonata populations have been reduced about 4-fold from 2008 to 2009 in all the country's fruit-producing areas (FAO/IAEA, 2010).

A number of insecticides used against fruit flies are effective, flexible and low toxic to non-target arthropods. In the European Union, chemicals registered against the medfly include organophosphates (chlorpyrifos-methyl and phosmet) and pyrethroids (lambda-cyhalothrin and deltamethrin). In addition, some naturally-derived insecticide are accepted in organic agriculture, such as spinosad, that is less toxic to beneficials than traditional insecticides, and a Neem formulation/azadirachtin, that showed sterilant and oviposition deterrent activities on the peach fruit fly (Mahmoud and Shoeib, 2008).

All these compounds are non-systemic, therefore control treatments are targeted to kill adults and prevent egg-laying in the fruit. Bait applications integrate insecticide and attractant formulations to lure male and female adult fruit flies. The most effective control strategy worldwide against fruit flies consists in bait sprays of malathion mixed with hydrolysed protein acting as attractants and phagostimulants. However, malathion has recently been excluded from the list of plant protection products allowed in the European Union, which has also prohibited importation of fruits with malathion residues. Laboratory experiments carried out in Egypt showed that spinosad might effectively replace malathion in bait applications against the peach fruit fly (El-Aw et al., 2008). Bait insecticides are sprayed in spots on the foliage of host plants by ground or aerial applications.

Studies have been carried out to control B. zonata with the sterile insect technique (SIT) (Qureshi et al., 1974), that is widely used in eradication programs against C. capitata and B. dorsalis. However, this technique has never been adopted in the field against the peach fruit fly.

The establishment of the peach fruit fly in Mediterranean countries would prevent export of fruits and vegetables to countries with quarantine regulations or be made conform to their rules and restrictions. Fruit fumigation with methyl bromide is still adopted in several countries, but its use may soon be prohibited. Therefore, alternative fruit sanitation techniques based on temperature manipulation have been developed. Cold treatments consist in holding export products at constant temperatures for a time period sufficient to ensure death of the most resistant peach fruit fly life stages (eggs and larvae).

Alternatively, fruits can be disinfested with high temperature treatments (water dips, dry or vapour heat, forced hair). Heat treatments can cause fruit injury and alteration of colour, aroma, flavour or texture in some citrus fruits.

CONCLUSIONS

The host-plant range of the peach fruit fly is broad, with more than 40 plant species verified as hosts in ; therefore, potential hosts are abundant in the diverse, cultivated and uncultivated flora of Mediterranean region and pose the eventuality of peach fruit fly population cycling. This cycling is characterized by different host-plant species sequentially serving as fruit fly reproductive hosts for parts of the year. Given the lack of diapause in this frugivorous tephritid and its wide host range, population cycling in alternate hosts could play a major role in the potential establishment of Bz and future economic depredations of exotic fruit flies such as the peach fruit fly in Mediterranean region.

Peach fruit fly is a generalist tephritid species infesting many host species throughout the entire geographical range. Locally these generalists may utilize only a few of their potential host species.

However, no absolute statement about plant susceptibility can be made. A good host in one geographic location may not be as good a host in another, and vice versa, as slight environmental changes may occur that influence the plant's desirability as a host. In addition, it is important to analyze the plant species in a given area to identify the competing host range. A desirable host in one area may be less desirable in another because a better host exists.

The population dynamics of such tephritid species are also susceptible to fluctuations in community attributes, i. e., plant diversity, interspecific interactions, and abiotic factors. These allow such tephritids to become pestiferous in some areas, but barely noticeable in other areas, or subject them to localized extinction in still other areas

Rapid transport of infested host fruits through cargo, personal luggage, and mail has complicated efforts to contain peach fruit fly within its present distribution. Efforts should be made to improve exclusion, prevention, detection, and control practices against peah fruit fly, with the aim of decreasing the risk of introduction. Since eradication efforts can be extremely difficult and expensive when peach fruit fly populations become well established, such efforts are started as soon as possible after introductions are detected. Crop yield reductions, control measures, handling processes, and quarantine restrictions on commodity movement are expenses associated with peach fruit fly infestations.

Appropriate phytosanitary measures should be applied to avoid the invasion and establishment of these exotic pests in the Mediterranean region.

We believe that Mediterranean countries can no longer ignore the inevitability of recurrent peach fruit fly populations. The Mediterranean countries must prepare to deal with the eventuality and consequences of permanent peach fruit fly populations.

Economic importance Impact of peach fruit fly on agriculture

Peach fruit fly can have a direct impact on agricultural production in Mediterranean area. One estimate of the direct impact of peach fruit fly in Egypt was million euros, which did not include the costs or impacts of insecticide use to control this pest. A great number of crops in the Mediterranean countries are threatened by the introduction of this pest: including apple, apricot, peach, fig, grapefruit, nectarine, orange, peach, pear, persimmon, plum, pomegranate, tangerine. While the direct loss of production of fruit fly host products can have a significant impact on Mediterranean agriculture, perhaps a more important impact is the loss of potential production and markets due to the threat of fruit flies and the high economic costs for their control.