Peach Fruit Fly, *Bactrocera zonata* (Saunders): the coming danger to the Mediterranean fruit trees, how serious this pest is and how to minimize its impact

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Abstract
Fruit flies (Diptera: Tephritidae) are among the world's most serious agricultural pests, causing significant economic losses in fruit production globally and posing a major quarantine concern for most countries. The family Tephritidae contains more than 4,400 - 5000 species. *Bactrocera* is the genus, with approximately 440 described species, and includes the majority of economically important fruit flies, such as *B. zonata*, *B. invadens*, and *B. dorsalis*, among others, which infest a wide range of hosts, particularly fleshy fruits. *B. zonata* is a serious pest of tropical and subtropical fruits. In India alone, it causes damage to 100 percent of peach, apricot, guava, and fig crops, and in Pakistan, it causes 25-50 percent damage to guava crops. This genus is globally recognized to be a frequent invader and aggressive colonizer of new environments. Due to the expansion in the international trade, tourism, beside the weakness of the phytosanitary measures *B.zonata* introduced into Egypt in 1998 and Libya in 2007 and becomes one of the major concerns to the plant protection authorities in all Mediterranean regions. The EPPO and FAO/IAEA organized workshops, conferences, and sponsored projects to increase awareness among farmers, operators, and related authorities about how to contain this invasion. IAM-Bari also participates in these initiatives by facilitating basic research on the biology, ecology, and control of fruit flies. The potential distribution of the peach fruit fly has been investigated by many scientists based on the potential climate change impact using CLIMEX; they found that B. zonata is able to establish itself in new regions, and the potential for expanding peach fruit fly in southern Europe is possible.

Keywords: *Bactrocera zonata,* Peach Fruit Fly, Mediterranean region, IAMB

Introduction

Increased attention has been given to the subject of invasive pests in the last two decades due to the economic damage caused on crops. The fruit fly expansion is attributed to international trade in agricultural crops between different countries, inadequate sanitary measures, and excessive pesticide use. Over the past twenty years, numerous pest outbreaks have occurred in economically important pests, resulting in a significant impact on the agricultural market and affecting food security, as well as the socioeconomic status of many farmers. Among the most destructive invasive pests introduced from Asia to the rest of the world are citrus leaf minor, *Phyllocnistis citrella* on many citrus varieties, the red palm weevil (RPW), *Rhynchophorus ferrugineus* on palm trees, and recently *Drosophila suzukii* on many fruit trees. Tomato borer, *Tuta absoluta* is the last challenge to all the implemented phytosanitary measures which introduced from South America into Europe, North Africa, Middle East and Gulf, and still threatens other countries. Fruit flies have provoked different plant protection organizations globally to be more alert facing the danger of tephritid flies after the invasion of the Mediterranean fruit fly, *Ceratitis capitata* which has high dispersive ability to different parts of the world on a wide range of hosts.

Fruit flies (Diptera: Tephritidae) include some of the world's most serious agricultural pests causing billions of dollars indirect losses to a wide variety of fruit, vegetable and flower crops (e.g., citrus, apple, mango, sunflower), they limit the development of agriculture in many countries because of the strict trade quarantines imposed to prevent their spread. Of the more than 4,400 species known worldwide (Norrbom, 2004), around 350 species are of economic importance (Plant Health Australia, 2011). The *Bactrocera*, as Vargas (2011) said, is a tephritid fly genus comprising at least 440 species, primarily distributed in tropical Asia, the South Pacific, and Australia. However, these species have been spreading rapidly worldwide over the past 15 years. The Oriental fruit fly, *B. dorsalis,* has become established and is spreading throughout French Polynesia. The carambola fruit fly (*Bactrocera carambolae*) is established and spreading throughout areas of South America. *B. invadens*, *B. latifrons*. The melon fly (B. cucurbitae) is found in Africa and the Mediterranean region, and the peach fruit fly (B. zonata) is found in Africa.

Globally, out of approximately 5,000 tephritid fly species, about 1,400 species develop in fruits; of these, about 250 species are considered pests. In Africa, out of 915 native fruit fly species, 299 species develop in fruits (Mohamed *et al*.2012).
One of the main research lines of CIHEAM/IAMB is to strengthen Mediterranean phytosanitary networking through a comprehensive database of native and invasive pests in the Mediterranean region. The institute builds its data from research results conducted within the institute or through cooperation with local and international experts. Regarding the fruit fly pest, the institute initiated the project in 2011, following the proposal of two master's projects. The first study focused on the economic importance and control of *Ceratitis capitata* in Tunisia (Boagga, 2012), while the second examined the spotted wing drosophila, *Drosophila suzukii*, in Italy (Jasim, 2012). Another three students prepared their theses on the evaluation of male annihilation techniques and 'attract and kill' measures for controlling mixed populations of *Bactrocera zonata* and *Ceratitis capitata* on mango and peach in Egypt (Al-Jazar, 2013). The second researcher is investigating the biological, ecological, and control aspects of the African fig fly, *Zaprionus indianus*, in Jordan (Alawamleh, 2013). This species was first recorded by Al-Jboory and Katbeh-Bader (2012) on date palms. The outcomes resulting from the above-mentioned four topics will target the main objective of IAMB, which is to "develop and harmonize a pest alert system in the Mediterranean region."

Peach fruit fly or guava fruit fly, *Bactrocera zonata*
The genus *Bactrocera* is globally recognized to be a frequent invader and aggressive colonizer of new environments. Due to the globalization of trade and the ever-growing tourism industry, coupled with the fragile nature of quarantine facilities and a lack of phytosanitary expertise in Africa and Middle Eastern countries, these regions continue to be under continuous threat of invasion by species belonging to this genus (Mohamed *et al*., 2012). The peach fruit fly, *Bactrocera zonata* (Saunders), is a polyphagous species, but it is particularly a pest of peaches, mangoes, and guavas. It also infests some vegetables as a secondary pest; around 400 species belonging to the genus *Bactrocera* are widely distributed in tropical Asia, South Pacific and Australia regions, but very few species of such genus were recorded in Africa (Drew and Hancock, 1994).

Many features have been employed to differentiate species based on morphological characteristics. For instance, Iwahashi and Routhier (2001) distinguished between *Bactrocera dorsalis*, *B. correcta*, and *B. zonata* using measurements of aedeagal length. Additionally, Tan *et al*. (2011) conducted a comparison of the profiles of phenylpropanoid volatile metabolites accumulated by three species of significant economic and quarantine importance, *Bactrocera invadens*, *B. zonata*, and *B. correcta,* against those of B. dorsalis as a means of species identification. While morphological identification is effective, especially for early larval stages, eggs, and incomplete adults, molecular techniques can enhance or support these findings (Plant Health Australia, 2011). Furthermore, research by Abd-El-Samie and El-Fiky (2011) has examined the genetic structure and phylogeny of the Egyptian peach fruit fly using total RNA.

Distribution

B.zonata is widespread in South Asia, from Pakistan, India, and Sri Lanka to Southeast Asian countries such as Thailand, Laos, Vietnam, and Indonesia. It was introduced and established in the Arabian Peninsula in 1982 and has been well established in Egypt since the late 1990s, as well as in Libya since 2007. It is also present on the Indian Ocean island of Mauritius. It has been detected numerous times in California since 1984, most recently in August 2010, but its establishment there remains uncertain (White & Elson-Haris, 1992; EPPO, 2005; Steck, 2010; Kafu, 2012).

Host plants

The host plants of *B. zonata* have been listed by many researchers, including more than 50 different fruit, vegetable and wild plants belonging to 22 families. The major hosts are mango, guava, and peach, as well as other soft, fleshy fruits. (White |& Elison-Harris, 1992; Allwood, 1999; EPPO, 2005; Delrio and Cocco, 2012).

Biology

The biological and economic importance of *B. zonata* has been extensively reviewed in India, Pakistan and Egypt (Qureshi *et al*., 1993; OEPP/EPPO, 2005; Khalil, 2010; Fetoh *et al*., 2012). Aleryan *et al.* (2006) investigated the natural oviposition stimulants on egg deposition under laboratory conditions of 23 ± 0.8°C and 69.32% ± 1.73 RH. Results showed that the number of eggs harvested from perforated cups supplied with mandarin juice was significantly higher than that from cups supplied with other stimulants, such as banana, orange, guava, and mango juices. The total number of eggs per female was 92.41 and 235.21 for females collected from guava and mandarin fruits, respectively. Elnagar *et al*. (2010) found that, based on the seasonal abundance of both *B. zonata* and *C. capitata*, milder climate conditions are favorable for C. capitata, whereas high temperatures support the survival of *B. zonata.*

Damage

The punctures made by ovipositing insects in fruit are typically called "stings." These stings are usually identified by making a shallow cut through the skin of the fruit. In fruits like peaches, the stings are often not very noticeable. However, in pale, smooth-skinned fruits, the sting mark can be easily seen and may disfigure the fruit, especially if accompanied by a condition known as "gum bleed" (Plant Health Australia, 2011). Fruits with high sugar content, such as peaches, tend to release a sugary liquid that often solidifies near the oviposition site (EPPO 2005).

Tephritid fruit flies are responsible for significant losses in both the fresh fruit and some vegetable industries, which adversely affects trade and economies in many countries (Li et al., 2010; Stephenson et al., 2003). Currently, the estimated annual cost of damage in the Near East is approximately EUR 320 million, necessitating intensive control measures to cultivate susceptible crops commercially.

In Egypt, the species Bactrocera zonata has been linked to an estimated annual damage of 190 million EUR (OEPP/EPPO, 2005). El-Henedy (2012) noted that *B. zonata* poses a significant threat to many of Egypt's export markets, with infestation levels reaching approximately 30-40%, resulting in an estimated annual loss of around $ 177 million. Furthermore, if no control measures are implemented against Ceratitis capitata, annual fruit losses could reach approximately $ 365 million (Lysandrou, 2009).

B. zonata is recognized in India and Southeast Asia as a severe pest affecting tropical and subtropical fruits. It ranks among the three most destructive fruit flies in India, causing crop losses ranging from 25% to 100% in fruits such as peaches, apricots, guavas, and figs. In Pakistan, *B. zonata* alone has caused 25-50% damage to guava fruit (Siddiqui *et al*., 2003, as cited in CABI International, 2010).

Control

The control measures of *B. zonata* are not far removed from the conventional methods used for fruit flies, which include population monitoring, field sanitation, protein bait, the male annihilation technique, biological control, and sterile insect technique (SIT) (Haw-Flypm, 2002). The implementation of conventional insecticides remains the dominant measure for controlling fruit flies in many parts of the world (El-Aw *et al*., 2008; Ahmad *et al*., 2010; Mosleh *et al*., 2011). Resistance was induced, ranging from 3 to 19-fold, in B. zonata against trichlorfon, malathion, lambda-cyhalothrin, and bifenthrin in Pakistan (Ahmad *et al*., 2010). Few biorational insecticide have been used against *B.zonata* such as Neem oil which showed a good efficacy against *B.zonata* in different concentrations (Mahmoud & Shoeib, 2008) and entomopathogenic nematode *Steinernema feltiae* Cross N 33 against second and third larval instars and pupa of 1, 4 and 6 days old of the peach fruit fly (Mahmoud & Osama, 2007). The quarantine threshold for *B.tryoni* varies from country to country. For example, five male catches in the trap indicate an outbreak that requires prompt action. However, other countries consider two males or even one as the threshold for an outbreak (Dominiak *et al.,* 2011). Regulatory action is required if more than five adult flies or an unmated female and a male are found in an area less than 3 km^2 within one estimated PFF life cycle, or one mated female, or larva, or pupa are detected, or a single adult fly is found which is determined to be associated with a current eradication project (FAO/IAEA 2000).

Monitoring with different traps is the first step in detecting fruit flies in the fields. Rodríguez Palomino (2012) described a successful eradication campaign for the Oriental fruit fly, Bactrocera dorsalis, on an island in Chile, where a trapping network was established throughout the area. Malathion/Methyl Eugenol traps and protein-baited traps were checked twice a week to assess the magnitude of the outbreak and potential dispersal. After four months of extensive work, they achieved complete eradication of this pest.

El-Gendy (2012) compared two different colors of Jackson traps, yellow and white, each equipped with the sex attractant methyl eugenol. He found that the white traps, hung about 1.5 meters above the ground in the West, North, or West-North direction, captured more male fruit flies than the yellow traps. Ba Angood and Sunaid (2012) used methyl eugenol to monitor the movement of peach fruit flies in mango and guava fields in Lahij province, Yemen, during the 2010/2011 season. They discovered that the pest was present almost year-round and noted a positive correlation between rising temperatures and the number of adults caught in the traps. Ali *et al.* (2010) evaluated different control methods, including cultural control, bait application technique (BAT), and the Male Annihilation Technique (MAT), against *Bactrocera zonata* in Peshawar, Pakistan, and showed that farmers preferred MAT due to its economic feasibility, environmental friendliness, and high efficiency. In 2010, the World Bank sponsored a project aimed at combating fruit flies in Eastern and Southern Africa, which led to several achievements, including problem assessment, the use of various control techniques such as biopesticides, the establishment of a fruit fly database, the development of identification tools, and advanced training programs (Ekesi, 2010).

Additionally, the Sterile Insect Technique (SIT) was successfully employed against *Ceratitis capitata* in South Africa, with plans to expand the program to cover 70 percent of all deciduous fruits and table grapes between 2013 and 2015 (Barnes, 2012). Research on the effects of gamma rays on female pupae of the peach fruit fly revealed that a dose of 40 Gy is suitable for sterilizing *B. zonata* females, with no signs of ovarian recovery observed until seven weeks into the female's lifespan (Younes *et al*., 2007). Cultural control, bait application, the application of the behavioral attraction technique (BAT) and the male annihilation technique (MAT) against *Bactrocera zonata* in Peshawar, Pakistan, showed that farmers preferred MAT due to its economic feasibility, environmental friendliness, and high efficiency. In 2010, the World Bank sponsored a project aimed at combating fruit flies in Eastern and Southern Africa. This initiative resulted in several notable achievements, including problem assessment, the application of various control techniques such as biopesticides, the establishment of a fruit fly database, the development of identification tools, and advanced training programs (Ekesi, 2010).

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Climate change as a parameter for *B. zonata* expansion in the Mediterranean region

Despite its economic importance, *B. zonata* has been insufficiently investigated, and its potential for colonizing new areas has been inadequately estimated (Ni *et al*., 2012). In addition, global climate change is widely accepted as having caused global temperature increases of approximately 0.6 °C throughout the 20th century, with temperatures expected to continue increasing in the 21st century (Christ *et al*., 2002b). Peach fruit fly was previously believed to be found exclusively in tropical regions (e.g., Mauritius and Réunion) (EPPO, 2005); however, following its invasion of Egypt and Libya, the insect's range is expected to extend poleward into cooler areas due to shifts in temperature, soil moisture, and humidity patterns.

The attributes and applications of the CLIMEX modeling software have been thoroughly documented in various publications (Sutherst and Maywald, 1985, 1999; Sutherst et al., 1995, 1999; Sutherst, 1998). This software employs a combination of 'growth' and 'stress' indices to describe species responses across a wide range of climatic conditions experienced in different seasons and locations around the world. Experience with CLIMEX has highlighted the limited understanding that biologists have regarding the role of climate in influencing species distributions.Sutherst et al. (1995) and Kriticos and Randall (2000) compared the various methods used for climate matching. Instead of repeating a description of the models, this text will highlight and elaborate on several features and issues related to CLIMEX and climate matching that are not widely recognized.http://www.ento.csiro.au/climex/climex.htm.

Ni et al. (2012) and Delrio and Cocco (2012) created a map that illustrates the predicted distribution of *Bactrocera zonata*, also known as the peach fruit fly, based on the Ecoclimatic Index under current climate conditions. The model forecasts that the establishment and persistence of this pest will primarily occur in the coastal areas of North Africa and the Near East. In Europe, the climatic suitability for the establishment of *B. zonata* is limited to the southern regions of Portugal, Spain, Greece, and the main Mediterranean islands. The projected geographical range of the peach fruit fly appears to be narrower than that of *Ceratitis capitata*, which is better adapted to cooler temperatures. Additionally, the predicted distribution of *B. zonata* largely overlaps with the primary citrus-growing regions in the Mediterranean.

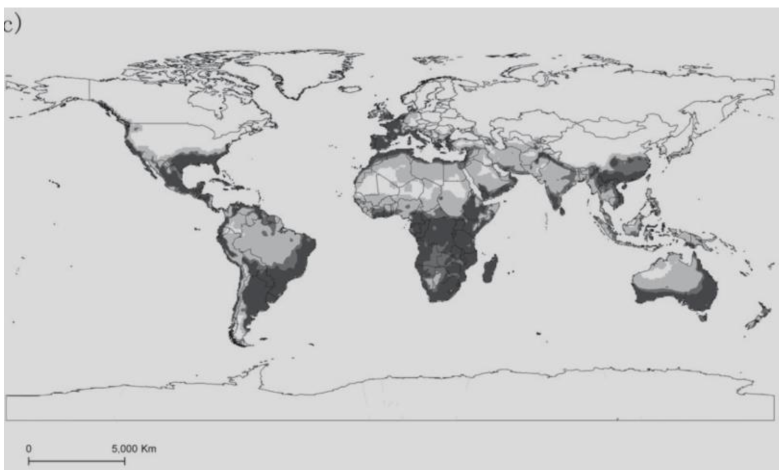

Figure 1. Climatic suitability (EI) for the peach fruit fly in the 2070s, projected using CLIMEX™. Source meteorological data were adjusted using the CSIRO Mark 2.0 GCM, which ran the SRES (Ni *et al*., 2012).

Conclusion

The peach fruit fly poses a significant threat to Mediterranean countries, particularly southern Italy, Spain, Greece, and the Mediterranean islands. According to the findings of Ni *et al*., (2012), this pest is expected to invade many new regions in tropical and subtropical areas, including South Carolina, southern China, and Australia. This forecast predicts such invasions by the year 2070.

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