بسم الله الرحمن الرحيم

Hebron University
College of Graduate Studies
M.Sc. Program in Plant Protection

Field Studies on Biology, Ecology and Management of Olive Fruit fly, *Bactrocera oleae* (Rossi) [Diptera: Tephritidae], in the Central Highlands of West-Bank, Palestine

By:

Mohammad Ibrahim ALqorneh

Supervisor:

Dr. Abdul-Jalil Hamdan

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This thesis was successfully defended on 19th June 2013 and approved by:

Examination Committee		Signature
1. Dr. Abdul-Jalil Hamdan	(Supervisor)	
(Assistant Prof. Entomology)		
2. Dr. Resq Basheer-Salimia	(Internal Examiner)	
(Associate Prof. Plant Physiology)		
3. Dr. Raed Alkowni	(External Examiner)	
(Associate Prof. Plant Virology)		

Dedication

I dedicate this work to my family and friends. A special feeling of gratitude goes to my loving parents, whom words of encouragement and push for tenacity ring in my ears. I also dedicate this work to my friends who have supported me throughout the preparation of this work. I appreciate all they have done. Finally, I dedicate this work to my wife as well as to my kids.

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Abstract

Olive (*Olea europaea* L.) is one of the most important fruit trees in Palestine. Olive fruit fly, *B. oleae* is the most dangerous pest that affected olive trees in the Mediterranean basin including Palestine.

This research was conducted in Bethlehem during 2011-2012 and had three objectives: to monitor the seasonal flight activity of the *B. oleae* in Bethlehem governorate; to record the rate of fruit infestation on olive cultivars (Nabali and Baladi) and to investigate the effect of mass trapping techniques on management of *B. oleae.*

Throughout this research, it was clear that the start of the flight activity of *B. oleae* began in early July and continued until the end of November with three peaks. The first peak was recorded in August-September, the second was in October and the third one was in the mid of November. Indeed, it was observed that the flight activity was affected mainly by temperature and humidity that affected the beginning of the flight activity as well as the insect generation. This research confirmed that, throughout the season, the sticky yellow traps were more effecient in captuering *B. oleae* than the green sticky traps, however, red and blue traps rarely captured olive fruit flies.

For the second objective, both Nabali and Baladi olive cultivars were found to be susceptible to fruit fly infestation. However, rate of infestation on both cultivars was higher in OFF production year (2011) than in ON production year (2012).

Sex pheromone traps were the best in mass-trapping of male flies, meanwhile, putrescine was the most effective one in capturing females. For

that, the use of both sex-pheromone and putrescine traps together starting from July until November for mass-trapping of *B. oleae* in olive fields, were highly recommended.

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List of abbreviations

AA	Ammonium Acetate
BC	Before Christ
CON	Control
PA	Paste
PHE	Sex-pheromone
PUT	Puterscine
TRIM	Trimethylamine Hydrochloride
-ve	Negative
+ve	Positive

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Introduction

Olive (*Oleae europaaea* L.) is one of the most important fruit trees in Palestine. The number of olive trees reached 11.3 million trees in Palestine, cultivated in an area of 45,140 hectares, and constituted about 67% of the total planted area with fruit trees in Palestine (Palestinian Central Bureau of Statistics. 2010).

Bethlehem governorate is located in central highlands of West Bank, described with hot summer and cold winter. The number of olive trees reached about 327 thousands trees, cultivated with an area of 1700 hectares, constituted about 32% of the total area planted to fruit trees in Bethlehem (Palestinian Central Bureau of Statistics, 2010).

The olive fruit fly *Bactrocera oleae* (Rossi) [Diptera: Tephritidae] is the most serious insect pest of olive trees in the world. It is known primarily from the Mediterranean area of Southern Europe, and is also found in North Africa, the Middle East, and along the east coast of Africa to South Africa. It is generally agreed among olive fly researchers that this insect can survive and develop in any area of the world where olive trees are grown.

However, in Arab countries, such as Palestine, olive fruit flies have become a serve and regional problem with high economic importance. In the central highlands of West-Bank including Bethlehem governorate, the olive fruit fly is considered as the most damaging pest on olive fruit, and the damages level reached more than 70% on olive fruits (Ministry of agriculture-Palestine).

If it is not controlled, crop losses may reach 80% in the oil producing areas and 100% in areas growing table olive varieties (Broumas, *et al.*, 2002)

During the last decade, olive fruit fly has been managed mainly by conventional insecticide bait or cover sprays from the ground. However, the ecological and toxicological side-effects of the extensive use of such chemicals, as well as the growing interest in organic olive production, have turned attention to alternative control methods.

The most widely used technique of this kind is mass trapping, which refers to the use of toxic, sticky or liquid containing traps of various designs to attract and kill olive fruit fly adults of both sexes. Several food attractants (Zervas, 1982; Broumas and Haniotakis, 1994; and Broumas *et al.*, 1998); sex attractants (Broumas and Haniotakis, 1994; Broumas *et al.*, 1998); killing agents (Broumas and Haniotakis, 1994; Broumas *et al*,. 2002) and trap deployment systems (Neuenschwander and Michelakis 1978; Broumas *et al*., 1998, 2002) have been thoroughly studied in the field for the control of olive fly.

This research study was conducted to monitor the seasonal flight activity of the *B. oleae* in Bethlehem governorate; to record the rate of fruit infestation on olive cultivars (Nabali and Baladi) and to investigate the effect of mass trapping techniques on management of *B. oleae.*

Chapter One: Literature Review

Chapter 1: Literature Review

1.1: Biology of Olive Fruit Fly, *Bactrocera oleae*:

The olive fruit fly, *Bactrocera oleae* (Rossi) (formally *Dacus oleae* (Gmelin), belongs to Tephritidae (Diptera) family. It is a serious pest of olives that was believed to originate in almost countries around the Mediterranean Sea (Vossen *et al*., 2006). The larvae are monophagous; they eat just olive fruit; the adult feeds on nectar; honey dew; and other sources of liquid and semi-liquid food (Weems and Nation, 2009).

Olive fruit flies are distinguished from other fruit flies by black spots on the wingtips and the lack of wing banding seen on other tephritid specie (Collier and Steenwyk, 2003). Also, immature stages are similar in appearance to those of other tephritid fruit flies; the olive fruit fly is one of the smaller species in the genus (Weems and Nation, 2009); their life cycle includes four stages: adult; egg; larvae and pupa (AL-Zaghal, 1985).

1.2: Distribution

Historically, the olive fruit fly was dispersed from the Mediterranean region where there were records of infestations dating back to the third century BC (Vossen and Varela, 2006). The olive fruit fly was first recorded in California in October 1998 (Zalom *et al*., 2003). It was also recorded in the Indian, North Africa, Mexico, Middle East, and Mediterranean areas of Southern Europe (Rice *et al*., 2003).

Also, the olive fruit fly was distributed in Albania, Algeria, Caary Islands, Corsica, Cyprus, Egypt, Etruria, France, Greece, Israel, Italy, Jordan, Lebanon, Libya, Mexico, Morocco, Pakistan, Portugal, Sardinia, South Africa, Spain, Syria, Tunisia, Turkey, United States, and Yugoslavia (Rice, 2000). Thus, olive fruit flies distributions are primarily limited to

regions where cultivated and wild olive trees are found (Daane and Johnson, 2010).

1.3: Identification of Olive Fruit Fly

1.3.1: Adult

The adult olive fruit fly resembles house flies in the general shape; approximately 5 mm long (AL-Zaghal, 1985); it is reddish-brown in color with some yellow-white patches on each side of thorax (Vossen *et al*., 2006); antennae are as long as head and chestnut; brown compound eyes are large with a green metallic sheen (AL-Zaghal, 1985). The thorax is black, with a silvery pubescence dorsal surface stripped with three narrow parallel black lines (Weems and Nation, 2009). The abdomen is brown with darker areas on sides of each segment (Rice, 2000). The female can be distinguished from male by the presence of an ovipositor, a dark colored pointed structure at the end of the abdomen (Zaloam *et al*., 2003).

1.3.2: Egg

The egg of olive fruit fly is milky white colors; lengthy shape; it is average measurements 0.8 mm long * 0.18 mm wide with micropyle at one end (Avidov and Harpaz, 1969; Mustafa and Sharaf, 1994). The female laid the eggs under the skin of the olive fruit on a depth of 1mm by it's ovipositor (AL-Momane and AL-A'ntare, 2008).

1.3.3: Larva

Larvae of olive fruit fly are yellowish white; legless maggots with pointed heads; have three larval instars **(**Mustafa and Sharaf, 1994**;** Zaloam *et al*., 2003**)** and it's length from 7-8 mm (AL-Zaghal, 1985; AL-Momane and AL-A'ntare, 2008). When the larvae hatched, they are tiny and hard to see and the larvae stage is spent entirely within the fruit (Zaloam *et al*., 2003).

1.3.4: Pupa

The pupa of olive fruit fly is yellow-brown color and it is measurements 4 mm long * 2 mm wide (AL-Zaghal, 1985); barrel-shape; cylinder because of the presence sheath around it (Mustafa and Sharaf, 1994; AL-Momane and AL-A'ntare, 2008).

1.4: life Cycle of Olive Fruit Fly

In the Mediterranean region, two to five generations of flies occur yearly (Weems and Nation, 2009). The duration of the different stages of olive fruit fly depends on temperature and humidity in the microclimate within the olive canopy, and on availability and quality of olive fruit (AL-Zaghal, 1985; Burrack and Zalom, 2008).

1.4.1: Adult

The olive fruit fly spent the overwintering either as an adult or as pupa in the soil or in hidden places, and leaf litter. Therefore, overwintered adult populations decrease to low levels during the winter season. However, the adult start emerging in March and April (AL-Momane and AL-A'ntare, 2008).

Adult longevity and fecundity depend mainly on temperature and humidity (AL-Zaghal, 1985), also the adult feeds on variety of organic resources (Tsiropoulos, 1977). Furthermore, adult flies can be found on many different plants where adult food sources are found (Ather, 2005). Thus, adult flies can live from 2 to 6 months depending on temperature and food availability (Vossen *et al*., 2006).

1.4.2: Egg

The female of olive fruit fly may lay from 50 to 400 eggs in it's lifetime, about 10-12 eggs daily and also one egg per olive fruit (Weems and Nation, 2009). But multiple eggs may be laid in varieties that produce large fruit (Colier and Van Steenvwyk, 2003). When the pits of olives begin to harden, eggs are laid under the fruit's skin in the ripening fruit, often creating a dimple or brown spot (Zalom *et al*., 2003).

Egg hatching required 2-3 days in summer and 18-20 days in autumn. In Jordan and Libya, the female laid from 200 to 250 eggs, (Abo-Yamen, 1963 and Sharaf, 1980), but in California, it laid is from 200 to 500 eggs in lifetimes (Zalom *et al*., 2003). No eggs hatch when occurred at the temperature treatment of 18.3-37.8°C (Wang *et al*., 2009).

1.4.3: Larvae

After egg incubation, larvae start penetrating the tissues of the fruit; they then dig a feeding tunnel toward the stone in the center (AL-Momane and AL-A'ntare, 2008). Larval stage needs about 20 days of development (Zalom *et al*., 2003). Larval development depends on the presence of olive fruit (Daane and Jonhson, 2010); and on temperature largely (Genc and Nation, 2008). In east and south of the Mediterranean Sea, under summer condition larval development need 2 to 3 weeks, and about 4 weeks or more in autumn (Talhouk, 1969).

1.4.4: Pupa

Pupal development requires 8 to 10 days during summer, but may take as long as 6 months in winter (Zalom *et al*., 2003). In the last larvae stage, the pupation stage takes place within the fruit under the skin, but in the autumn and winter the pupa leaves the fruit to ground, then pupation

takes place within the range of 3 to 6 cm in soil of saw of dust substrate or leaf litter (Talhouk, 1969; Arambourg, 1984; Vossen and Varela, 2006).

In addition, when the pupae exposed to 26°C it needs 10 days to convert to adult, but at 14°C it needs up to 70 days (Avidov and Harpaz, 1969).

1.5: Population Studies

1.5.1: Generations

In Syria, Lebanon, and in almost countries of the Mediterranean region, the olive fruit fly has 4-5 generations yearly depending on local conditions (Avidov and Harpaz, 1969; Vossen and Varela, 2006). The first generation appears as early as June that coincides with pit hardening; the second generation appears in August; and, the additional generations of flies are produced during the late summer and fall months into December depending on fruit availability. The last generation larvae leave the fruit to pupate in the ground where they may overwinter for 5 to 6 months (Vossen and Varela, 2006)

In summer, the olive fruit fly can complete a generation in 35 to 40 days in Jordan (Abo-Yamen, 1963), and in Lipya (Sharaf,1980), but from 30 to 35 days at optimum temperatures (20°C to 30°C) in California (Zalom, 2003).

1.5.2: Mating Behaviors

Males of the olive fruit fly mate frequently with females, the mating process depends upon the origin of the flies, their age, previous sexual activity, dietary factors, environmental conditions, host fruit availability, and male mating pressure (Tzanalikis *et al*., 1968; Economopulos, 1972; Raspi *et al*., 2005).

Moreover, the light plays an important role in mating (Hanitotakis, 1973) mainly happened during the evening hours. Light intensity is considered to be a key factor for high egg maturation (Tzanakakis *et al*., 1975).

Females of the olive fruit fly produce a multicomponent pheromone, and are the only tephritid females known to produce a sex pheromone (Weems and Nation, 2009). Some researches indicate that the olive fruit fly males produce odors that attract females these odors were highly attractive to virgin females when tested during the last two hours of the photophase (Mavragnis *et al*., 2010).

Under ambient summer temperature, the females readily laid eggs when provided water and food (Wang *et al*., 2009). Therefore, the fly lays eggs singly in the mesocarp of green or ripe olive fruits (Tzanakakis, 1986).

In southern Europe and the middle East given its lack of ovarian maturation during late spring and early to mid-summer, when days are long (Mazomenos, 1984; Daane and Johonson, 2010). Therefore, the effect of temperatures on the reproductive success of adult *B. oleae* (e.g. egg maturation and ovipositional activity) and offspring survival remains unknown (Wang *et al*., 2009).

1.5.3: Activity Behavior

The flight activity of adult olive fruit fly is mainly depended on temperature, fruit availability and seasonal phonology (Rice *et al*., 2003), also based on their attraction to yellow-panel sticky traps with food and pheromone lures in California.

Flight ability is dramatically reduced when resources are unavailable (Daanee and Johnson, 2010). The adult is strong flyers, using a custom-designed flight mill to research of food and water (Wang *et al*., 2009). In the mild, coastal areas of California, the adult flies are active all year (Weems and Nation, 2009).

Olive fruit fly become active enough to feed during the warmer hours of the days, but tend to return to the same sheltered foliage when temperature fall (Bateman, 1972) however, the adult flight activity is high in late winter and early spring but decline in April and May, low activity in June, and decline to very low during hot summer months (July to early September), after that, fly activity begins to increase when the weather is cool and continues to last November (Rice *et al*., 2003).

In addition, in Greece, it is reported that when average temperature was below 9 °C, the olive fly did not show flight activity (Economopoulos *et al*., 1982) fly adult activity declined as temperatures rose above 32 °C, but increased when temperatures were between 21°C and 29°C. (Rice *et al*., 2003) also, as temperatures surpass 29°C, adult flies become increasingly agitated and egg laying is halted and above 35°C they are motionless (Johnson *et al*., 2011).

1.5.4: Dispersal and Migration

The adult olive fly is moderately mobile (up to few hundred meters), and commonly dispersed over long distances (several kilometers) (Neuenschwander and Michelakis, 1981).

Reports of olive fly movement range from 180 m in the presence of an olive host to as much as 4000 m to find hosts (Vassen and Varela, 2006). However, since the flies are very mobile they have the ability to

seek out cooler areas of the orchard and urban trees (Vossen and Varela, 2006).

The olive fruit fly is known to disperse from areas without olive fruit to areas with a new season's crop; from olive trees to other trees; or from plain to mountain olive groves and vice versa (Fletcher and Kapatos, 1981; Michelakis and Meuenschwander, 1981). Other workers suggested that the mean distance for dispersal was found to be over 400 m per week, when flies were released to grove with no new season fruit crop, but in other results, the mean distance of dispersal was low, only 180 m per week (Fletcher and Kapatos, 1981).

Flies have been trapped in other plants or crop orchards where the adults search for food or refuge (Vossen and Varela, 2006).

Other factors affect olive fruit fly dispersal, such as avoiding overcrowding and seeking for new oviposition sites (Fletcher and Kapatos, 1981). Also, the weather plays an important role in dispersal. In Corfu, Greece marked females dispersed an average of 135m per day during early summer, while males averaged 100m (Flectcher and Economopoulos, 1981).

1.6: Host Plants

1.6.1: Main Host

The larvae are monophagus, and feed exclusively on olive fruits And of the genus *Olea*, including *O. europeae* (cultivated and wild), *O. verrucosa*, and *O. cbryophylla* (Avidov and Harpaz, 1969; Weems and Nation, 2009). Also, the olive fruit fly is associated with wild varieties of olives in Africa (Zohary, 1994).

It is generally agreed among olive fly researchers that this insect can survive and develop in any area of the world where olive trees are grown (Rice, 2000).

Basheer-Salimia, *et al*., (2009) identified several olive cultivars in Palestine including: Roomi; Souri; Improved Nabali; and Barenge K18. In addition, Omar, (2012) reported Nabale baladi; Nabali Mahassen, and K18 cultivars are famous in Palestine.

1.6.2: Alternative Host

Larvae of olive fruit fly develop and live justly in olive fruit, but the adult feeds on variety of organic matter including insect honeydews; plant nectar; plant pollens; and fruit exudates and on nutrient resources such as bird dung; bacteria; and yeast (Athar, 2005). The availability of adult food for reproduction and survival may be critical to olive fruit population's existence during periods when olive fruit are unsuitable for oviposition. For this reason, adult flies can be found on many different plants where adult food sources are found (Tsiropoulos, 1977).

The olive fruit fly was first detected in North America on 19th Oct.1998, in an orange tree in west Los Angeles (Rice *et al*., 2000). The olive fruit flies were also trapped in several fruit trees including walnut, cherry, apple, plum, chestnut, vine trees, grapefruit, tangerine, nectarine, lemone, and avocado (Economopoulos *et al.*, 1982; Rice, 2000).

1.6.3: Host Influences

Olive fruit fly detects the target host from a distance by the color of its foliage (Hanitakis and Voyadjoglou, 1978). Feeding behavior is influenced by the presence of nutrients; the form of the diet (solid and liquid); and whether the solid and liquid are mixed or separated (Tsipopoulos, 1977).

Tzanakakis *et al*., (1968) reported that flies during humid areas that feed on a liquid diet lay more eggs and have a shorter preoviposition period than those feeding on a solid diet. The size of drupes, which is considered by several authors, is one of the most important factors in the choice of olives by *B. oleae* female (Jimenez, 1988).

However, the infestation level on cultivars is characterized by a large drupe size resulted usually higher than that one recorded on cultivars bearing small olives. And, in general larger sizes and olives with higher water content are more susceptible for infestation than olives with lower water content (Rice, 2000). Also, other factors that possibly play a role include fruit size; weight; color; fruit epicarp hardness; surface covering; phonological stage of the crop; and chemical factors (Iannotta *et al*., 2007).

1.6.4: Alternative Bearing (Biennial Bearing) of Olive Trees

The term "alternative and biennial'' bearings are used by horticulturists to designate the production of a heavy fruit crop one year followed by a light crop the next (Crane and Nelson, 1972). Thus, AL-Shdiefat and Qrunfleh, (2008) concluded that alternative or biennial bearing of olive trees often occurred in Jordan, where fruit production alternates between high fruit production during ON year (MASSI year) followed by low production during the OFF year (SHALTONI year).

However, the alternative bearing cycles of olive tree for two successive might be affected by several factors including cultural and environmental factors, such as pruning, drought, inadequate chilling, and light intensity that may influence flower bud formation and contribute to alternative bearing (Bactir, *et al.*, 2004)

1.7: Damage

After egg hatching, the larva feeds on the mesocarp of the olive fruit, creating channels inside the fruit while feeding (Avidov and Harpaz,1969; Zygouridis *et al*., 2009), they tunnel throughout the fruit, destroying the pulp and allowing entry of secondary infestation of bacteria and fungi that rot the fruit (Zalom *et al*., 2003;Vossen and Varela, 2006) and decrease the oil quality and quantity, also greatly increase the free fatty acid level (acidity) of the oil olive (AL Dajoee, 1998). European authors have indicated economic losses of table olive crops as high as 100% from infestations that are not controlled; oil losses can range as high as 80% from combined fruit drop; pulp destruction and increased acidity of oil if fruits not harvested in a timely fashion (Rice, 2000).

1.7.1: Content Fruit Damage

During the larva making tunnels in fruit, it produce a brown color in tissues around the larva, which lead to damage the vessels and tissues that affect fruit ripening; fruit weight; and weaken it relates to plants (AL Momanee and Al Antare, 2008).

Olive fruit fly may infest more than 90% of olive fruit (Sharaf, 1980). Larval consumption of fruit pulp has been estimated to range from 50 to 150 mg per larva depending on cultivar (Neuenschwander, and Michelakis, 1978). The real problem occurs when larval feeding introduces fruit rotting organisms that create off flavors (Vossen and Varela, 2006).

1.7.2: Olive Fruit Drop

Feeding damage by larvae olive fruit fly may cause premature dropping of olive fruit (Martinez *et al.*, 2004).

Neuenswander and Michelakis, (1981) observed that the early infected fruit fall on the ground, which increases the crop losses, because of

the link weakness between the fruit and bearer. In addition, Al Antare and AL Momanee, (2008) reported that the infected fruit rate differs from cultivar to another; and, infestation rate and ripening degree affect it.

1.7.3: Olive Oil Damage

The damage of fruit tissue causes the decrease in the amount of oil olive to 30%, and it will not be good for picking (Al Antare and AL Momanee, 2008).

Several factors influence the overall impact of *B.* oleae on olive oil including timing and severity of *B. oleae* infestation, olive cultivar, harvest date, length of storage time prior to pressing, and the presence of microflora (Torres *et al*., 2003; Pereira *et al*., 2004; Tamendjari *et al*., 2004; Tzanakakis, 2006).

1.8: Management of *B. oleae*

In a pest management context, however, it is the practical use of these substances, which is of interest, and their use to date can be divided into two main categories, which are pest monitoring and pest control (Bueno and Jones, 2002).

1.8.1: Pest Monitoring

Monitoring of adult olive fruit fly in traps and observations of larval stage in fruit samples are coupled with climatic data to make predictions of damage and take preventive measures. Traditionally, water based trapping devices baited with olfactory attractants such as Ammonium salts or protein hydrolysates have been used to monitor adult populations of olive fly (Bueno and Jones, 2002).

Trap densities need to be adjusted based on many factors including: trap efficiency; lure/attractant efficiency; location regarding altitude; type

and presence of host; climate; topography; programme phase and type of fruit fly species (IAFA and VIENNA, 2003).

Several types of traps have been used for trapping the olive fruit fly: Pheromone traps; colored traps, several size and shape of traps were used to monitor and control the olive fruit fly, and also used in the studying seasonal fly activity, the population dynamics and the ecology of this fly.

1.8.1.1: Color of Traps

This trap used to detect the presence of fruit fly and measure the strategies of control which should be used in it, and used to reduce the flies' population.

Yellow colored sticky traps baited with a male sex lure (Spiroketal pheromone capsule) and a feeding attractant capsule are used to capture both male and female adult flies (Varela and Vossen, 2006).

One disadvantage of this trap, which is based totally or partially on attraction to color, is that it also attracts non-target insects, and at high trap densities, such traps can cause damage to beneficial insect's population (Neuenschwander, 1982).

Yellow sticky trap was found to attract the fly more than orange, red, green, black, and white color trap (Neuenshwander and Michelakis, 1978).

The following factors are thought to play a role in producing these results: combination of sex pheromones and yellow on the same trap has an additive effect on *B. oleae* (Haniotakis, 1981).

Katsoyannos and Kouloussis, (2001) concluded that the spheres trap used to trap olive fruit flies and that capture vary with the color of the spheres and the sex pheromone. As for males, the two most effective colors

were orange and yellow, whereas for females red and black. From these results, it become clear that yellow and red colors combined with Nulure or Tourla attractants are proper combinations for capturing high numbers of *B. oleae* both males and female (Martinze *et al.*, 2004).

1.8.1.2: Size of Traps

It is clear that trap size had a significant effect on captures, especially of males, when *B. oleae* population is high. As expected in such cases, catches increase with trap surface as small size traps have a limited insect holding capacity. However, the size of sticky pheromone traps has no effect on *B. oleae* catches when insect population densities are low (Haniotakis, *et al.*, 1986).

1.8.1.3: Type of Traps

1.8.1.3.1: Sticky yellow traps

This trap used to detect the presence of fruit fly and determine the schedule of treatment application which should be used in it, and used to reduce the flies' population (IAFA and Vienna, 2003).

Over the last ten years, in Greece and Spain and more latterly in Spain, has been aimed at overcoming the short-comings of mass-trapping using sticky traps through the development of target devices which carry an insecticide for killing the attracted flies instead of adhesives (Bueno and Jones, (2002).

Yellow colored sticky traps baited with a male sex lure (Spiroketal pheromone capsule) and a feeding attractant capsule are used to capture both male and female adult flies (Varela and Vossen, 2006).

1.8.1.3.2: MacPhail -Tephri Traps

The MacPhail-Tephri trap is extensively used in Europe (i.e. Mediterranean coast) for monitoring of Tephritid fruit flies (olive fruit fly, medfly, cherry, etc), but in some cases, it is used for mass trapping (control) as well (IAFA and Vienna , 2003; Vossen and Varela, 2006).

Many attractant materials could be added to the trap. Protein hydrolysate and Ammonium salt were the main attractive substances used (Flectcher and Economopoulos, 1981).

The trap is registered as a "clean" method for pest control. All the flies killed by this method will be reducing the use of insecticide and will improve the chances offering healthy fruit to the consumer (IAFA and Vienna, 2003).

1.8.2: Pest Management

Management of this fly depends on bait sprays, trapping of adult flies, harvest timing, fruit sanitation after harvest, and biological control (Van Steenwky *et al*., 2003).

1.8.2.1: Cultural Control

Cultural control of the olive fruit fly includes several ways: harvesting early to reduce the opportunity population development, removing of infested fruits that falls from the trees. This fruits should be buried or sealed in a bag for landfill disposal (Vossen and Varela, 2006).

Also, removing of all remaining fruit from the tree prior to March 1st will eliminate oviposition sites for flies that return to the trees in the spring (Vossen and Varela, 2006).

1.8.2.2: Chemical Control

Over the last four decades, the management of olive fruit fly has been based on the use of organophosphate insecticides in cover sprays and bait sprays (e.g., dimethoate and fenthion) (kakani and Mathiopolus, 2008; Margaritopoulos *et al*., 2008). During the last several years, there has been an increase in the use of pyrethroids for control (Margaritopoulos *et al*., 2008), and very recently, spinosad has been incorporated into a bait spray (GF-120) to increase the efficacy with less active ingredients (Thomas and Mangan, 2005). However, many disadvantages were resulted from the application of chemical insecticides, such as difficulties in application, pest resistance, increased cost, and difficulty handling treated fruit (Burrack *et al.*, 2008).

Streptomycin was also tested to control this pest in South Europe and proved to be effective against the progeny of the olive fly; and the larva died in the 1s instar after tunneling in the fruit (Hagen, 1966). Also larval growth found to be inhibited when males and females were treated with streptomycin (Tzanakakis and Lambrou, 1975).

1.8.2.3: Mass Trapping

Mass trapping is a managing technique bases on attracting and capturing Tephritid flies in traps using color, food baits, and/or sex pheromones for the purpose of population suppression (Daane and Johnson, 2010).

Therefore, the possibility of insecticidal resistance in *B. oleae* populations was provided as a reason to adopt mass trapping programs as an alternative to organophosphate cover spray (Broumas, 1985).

Traditionally, suppression methods have been based on cover spraying using environmentally not friendly insecticides. Other, more

selective methods, attractive methods, attract and kill and mass-trapping have been developed as ecologically better alternative (Bjelis, 2009).

Mass trapping is preventive control measure, which is based on attraction and killing olive fruit fly adults, before they reached to make infestation. The main advantage of mass trapping method is exclusion of fruits and whole canopy contamination by insecticides (Bjelis, 2009).

The mass trapping methods can be applied by traps of different construction, which need to be set on the tree canopy. The traps are filled by different type of attractants and treated by insecticide, or they could be filled with attractant-insecticide water solution (Hanitokis *et al.*, 1986; Bjelis, 2009)

Visual traps, usually sticky, yellow colored objects, alone or in combination with food attractants has also been tested for population monitoring and control purposes (Economooluos *et al*., 1982; Katsoyannos and Kouloussis, 2001).

In recent years, the mass trapping technique has been used in *B. oleae* control by using Eco-tarp, which comprises deltamethrine-baited traps combining ammonia-releasing salts as a food attractant and a sex pheromone (Petacchi, *et al*., 2003).

The attract- and-kill technique, commonly called Mass Trapping (Petacchi *et al*.,2003), used these material against olive fruit fly including: mixtures of the sex pheromone at a dose of 2.424 ml\hl, food attractant which is protein hydrolisate (Buminal), and Deltamethrin, lead to reduce the infection about 50% (Speranza *et al*., 2004).

1.8.2.3.1: Sex Pheromone

Female *B. oleae* flies release a sex pheromone which functions as a potent long range male attractant (Haniotakis, 1981; Delrio *et al*., 1981). This pheromone was found to be a mixture of the following substances: 1.7-dioxaspiro (5.5) unweans, a-pinene, n-nonanal and ethyl dodecanoate at a ratio of 3:1:0:3:1(Mazomenos and Haniotakis, 1981). 4-Hydroxy-1.7-dioxaspiro [5.5] undecane was isolated by employing a novel asymmetric oxy-Michael addition by these Baker *et al*., (1982) as a minor pheromone component of the olive fruit fly, *B. oleae.*

Mazomenos (1984) found females olive fruit fly began producing sex pheromone on the third day after emergence. The maximal male response to female occurred between the age of 7 to 11 days, and as the female ages, the quantity of sex pheromone produced during the period of high pheromone production decreased (Mazomenos, 1984).

Other worker has shown that a four component pheromone identified from the female olive fruit fly acts as strong male attractant (Mazomenos, *et al.,* 1989).

1.8.2.3.2: Food Attractants

These include various ammonia- releasing compounds, such as aqueous ammonia solutions, ammonium salts, protein or yeast, hydrolysates heterocyclic amines probably responsible for protein attraction and fruit volatiles (Haniotakis *et al*., 1986; Orphanidis *et al*., 1979).

One of the earliest baits that used was molasses in combination with the insecticide lead arsenates. Later baits included protein hydrolysates, torula yeast, and ammonia-releasing salts (e.g., ammonium bicarbonate,

ammonium sulfate, and biammonium phosphate) (Katsoyannos and Kouloussis, 2001; Thomas and Mangan, 2005).

Other food attractants used for trapping olive fruit fly including: ammonium Acetate; putrescine and trimehylamine hydrochloride (Katsoyannos, *et al.,* 2004). Ammonia and acetic acid are also important fruit fly attractants (Bateman and Morton, 1981).

Research on the development of the food-based attractants found that putresine is a synergist to ammonium acetate (Heath *et al*.1995), and that trimethylamine is a synergist to ammoninm Acetate and putrescine (Heath *et al*, 1995).

Katsoyannos, *et al*., (2008) suggested that wet traps perform better for the olive fruit fly than dry ones; therefore, combination of food attractants with strong visual stimuli may result in the development of a powerful lure and kill system for olive fruit fly

1.8.2.4: Biological Control

According to the earlier surveys, it appeared that sub-Saharan Africa might provide a rich source of natural enemies of the olive fruit fly, however, recent surveys were aided by an improved understanding of natural enemy taxonomy and host relationships, which grew from a necessity to understand the parasitoid complexes of invasive fruit fly pests (Copeland *et al*., 2004; Wharton, *et al*., 2000)

The braconids typically provide the highest levels of olive fruit fly suppression: *Pselaphaninae lounsburyi*, *P. dacicida*, and *Bracon celer* as reported in earlier surveys (Silvestri, 1914; Neuenschwander, 1982); the well-known *P. concolor* (Bigler *et al*., 1986; Canard *et al*., 1979; Raspi *et*

al., 2005), and *P. ponerophaga* from Pakistan (Baker *et al*., 1980; Bigler, 1982).

Nevertheless, classical biological control programs for olive fruit fly have not been successful yet. To date, *P. concolor* has been the only imported species widely released and established in olive growing regions, and records of this species impact suggest that control is not achieved unless the population is augmented (Daane *et al.*, 2009).

The endogenous hymenoperan bracoind, *Opius concolor* Szepl was discovered in North Africa. It was found that female lays its eggs in the puparium, and, the adult hatches out by cutting hole in the puparium side (Arambourg, 1984).

Insect predators such as lady beetles and lacewings are found in olive orchards. However, the fly's eggs are embedded underneath the fruits epidermis and the flies larvae feed deep inside the fruit (Tzanakakis, 2006).

Reduction in the use of conventional insecticides (e.g. organophosphates and pyrethoids) is a goal in many olive-producing areas as an efforts increased to reduce environmental pollutions; contamination of olive oils; and destruction of beneficial insects (Brounmas *et al*., 2002).

Chapter Two: Materials and Methods

Chapter 2: Materials and Methods

2.1: Research Sites

This research was conducted in Bethlehem area that located in the central highlands of West Bank, throughout 2011and 2012. Bethlehem has a Mediterranean climate, with hot and dry summers and cold winters, and, receives an average annual rainfall of 518.4 mm, with temperature ranging from 28-32°C in summer and 1-13°C in winter. Also, it stands at an elevation of about 775 meters above sea level.

Observations were recorded throughout two successive growing seasons: 1st season was from 1st June 2011 until 30th May 2012 in three villages: Battir, Hindaza, and Tuqu' in Bethlehem area and, the 2nd season was from 1st Jun 2012 until 30th Dec 2012 in Hindaza village (Fig.2.1)

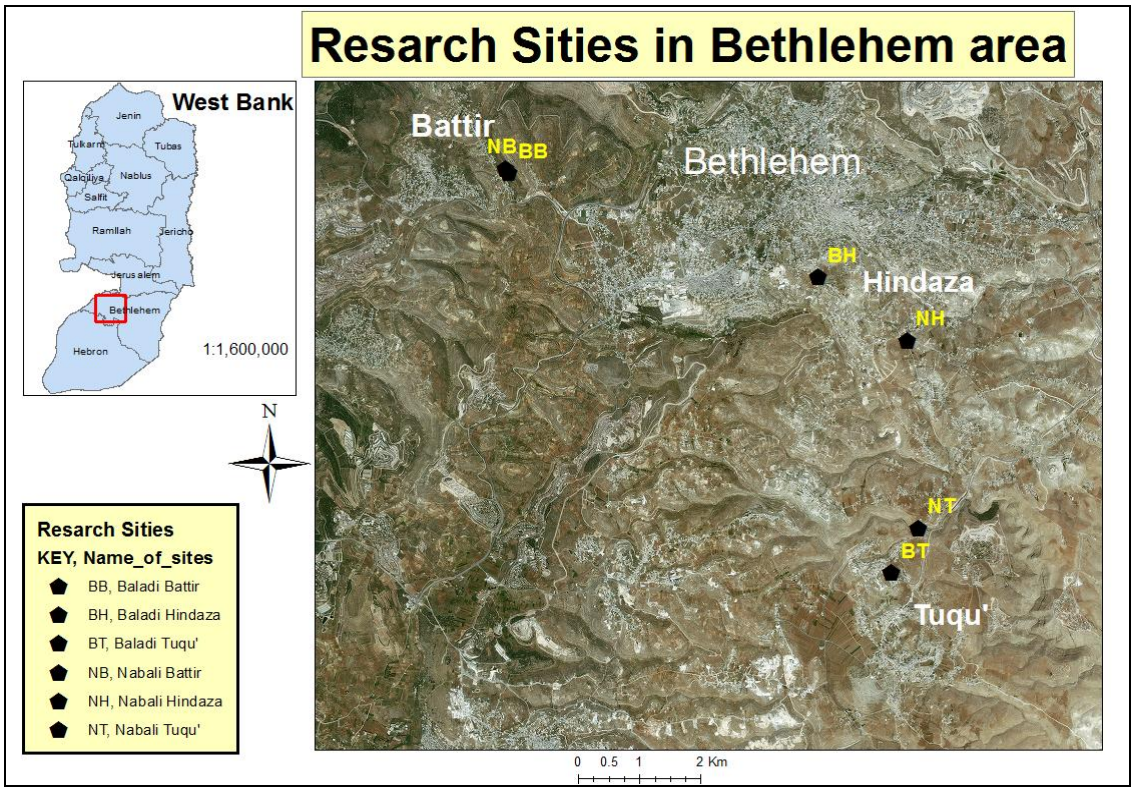

Fig 2.1: Map shows the research sites in Bethlehem area.

2.2: Research Fields

Two fields, three dunums for each were subjected to study in each three villages. One field planted with olive Roomi cultivar (Baladi) and the other field is planted with Improved Nabali cultivar (Nabali).

2.2.1: Battir Village

Battir village (Fig 2.1) located in the western side of Bethlehem area, West Bank -Palestine. Its elevation is about 800 m above sea level, with an average rainfall between 500-650 mm.

In Battir village, the first field planted with 15 years old olive trees of Baladi cultivar, included 5 rows and 7 columns, with 8 m distance between trees in rows and columns. The second field was planted with, 5-15 year old Nabali cultivar, included 4 rows and 6 columns, with 6 m distance between trees.

2.2.2: Hindaza Village

Hindaza village (Fig 2.1) located in the center of Bethlehem area. The elevation of Hindaza is about 750 m above sea level, with an average rainfall average between 400-518 mm.

In Hindaza village, the first field was planted with 15 year old olive trees with Baladi cultivar, included 7 rows and 6 columns, with 5 m distance between trees in rows and columns. The second field was planted with 15 years old Nabali cultivar, included 18 rows and 11 columns, with 5 m distance between trees in rows and columns.

2.2.3: Tuqu' Village

Tuqu' village (Fig 2.1) located in the eastern side of Bethlehem area. The elevation of Tuqu’ is about 670 m above the sea level, with an average rainfall between 250-300 mm.

In Tuqu' village, the first site was planted with olive 15 year old trees of Baladi cultivar, included 4 rows and 6 columns, with 6 m distance between trees. The second site was planted with 15 year old Nabali cultivar, included 4 rows and 7 columns, with 5 m distance between trees.

2. 3: Research Methodology

2.3.1: Monitoring of the Seasonal Flight Activity of Olive Fruit Fly, *B. oleae*

To monitor flight activity, two experiments were carried out as follows:

1st Experiment: Monitoring of the Seasonal Flight Activity of Olive Fruit Fly, *B. oleae* in Bethlehem Area During 2011& 2012.

This experiment was conducted in three sites: Battir, Hindaza, and Tuqu', from 1st June 2011 until 30th Apr 2012 then it continued in Hindaza site only from 1st Jun 2012 until 30th Dec 2012.

One Jackson sticky trap (Fig 2.2) was used in each site. The trap included Yellow colored sticky board, baited with a male sex lure (Spiroketal pheromone capsule), was hanged inside sticky rectangles poster-broad placed on the base of the trap. The upper side of the trap was painted with adhesive (sticky) which is Rinifoot Paste, (Polisobutene 80% PA).

The trapped olive fruit flies were weekly counted and sexed to males or female according to the presence of ovipositor in female fly that distinguish it from male fly (Fig 2.3 & Fig 2.4) . Further the sticky board was weekly changed, and stored in the laboratory. However the sex-pheromone was monthly changed.

Fig 2.2: Jackson Sticky trap used to monitor flight activity *B. oleae*

Fig. 2.3: Adult female *B. oleae*

Fig. 2.4: Adult male *B. oleae*

2nd Experiment: Study on the Effect of Color on the Attracting Efficiency of Sticky Traps Used for Monitoring the Flight Activity of *B. oleae*

This experiment was conducted in three sites in Bethlehem area: Battir, Fig (2.5); Hidaza, Fig (2.6), and Tuqu' Fig (2.7), from 1st Jun 2011 until 30th April 2012. Four sticky colors traps (Yellow, Green, Red, and Blue) were used in each site.

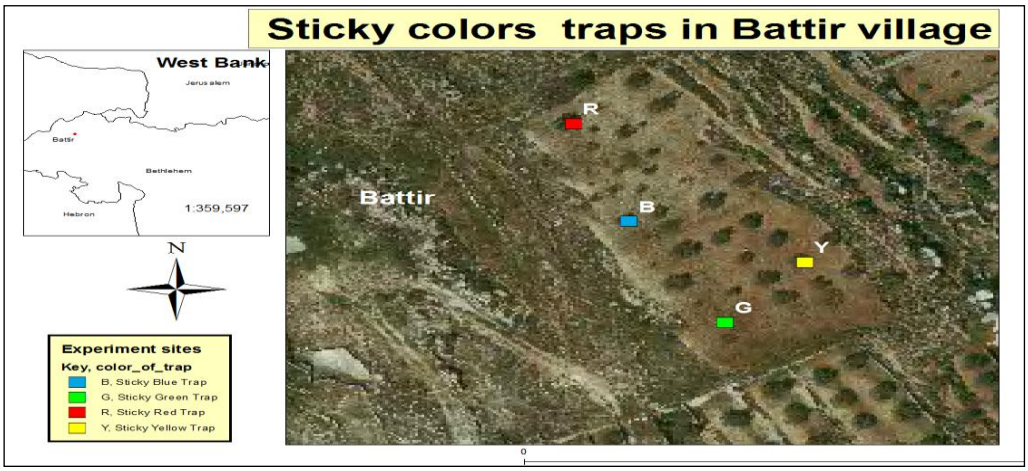

Fig 2.5: Map Shows the Distribution of the Sticky Colored Traps in Battir Site

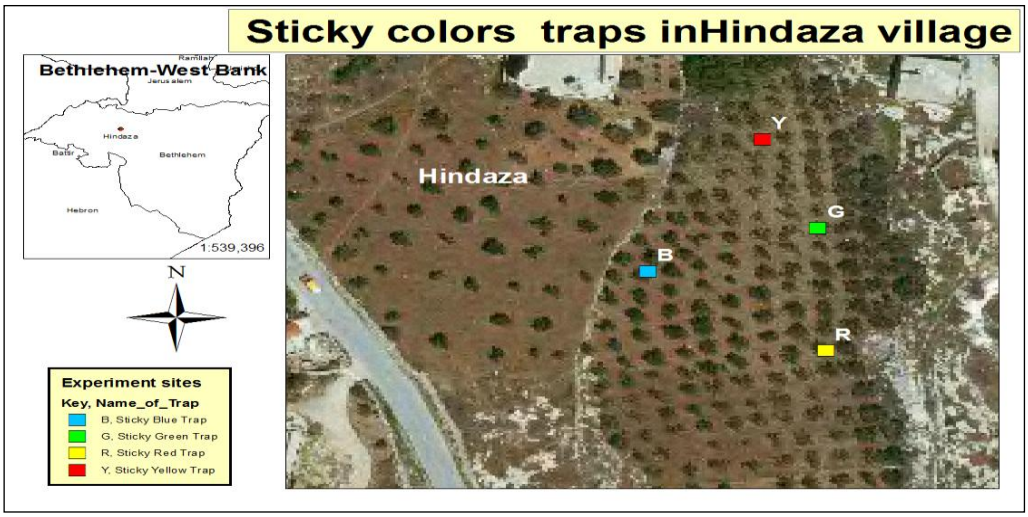

Fig 2.6: Map Shows the Distribution of the Sticky Colored Traps in Hindaza Site

Fig 2.7: Map Shows The Distribution Of The Sticky Colored Traps in Tuqu' site

Sticky rectangles poster-broads, (Fig: 2.8) with 15*25 cm dimension were used in all sites. One side of the trap was painted with adhesive (sticky) which is Rinifoot Paste, (Polisobutene 80% PA).

In all treatments, the traps were hanged on the trees at a height of 1 to 2 m and were distributed in the blocks randomly.

The trapped olive fruit flies were counted and sexed (Male &Female) weekly. And the sticky board was weekly changed, and stored in the laboratory.

Fig 2.8: Sticky colored traps (Yellow, Blue, Green, and Red)

2.3.2: Recording the Rate of Fruit Infestation by Olive Fruit Fly on Two Olive Cultivars (Nabali and Baladi) in Bethlehem Area.

This section includes two experiments

1st Experiment: Rate of Fruit Infestation of Olive Fruit Fly in Three Sites Battir, Hindaza, and Tuqu' During 2011.

This experiment was conducted in three sites Battir, Hindaza, and Tuqu' in Bethlehem area from July up to October 2011 (Fig2.1).

One hundred fruits were weekly and randomly collected from both cultivars in each site. The rate of fruit infestation was weekly recorded on each cultivar/site throughout the season.

Records of the environmental conditions of the area were obtained from the Palestinian Meteorological, and Ministry of Agriculture. In addition, records of fruit production were obtained by personal communication with the owner farmers of the research sites.

2nd Experiment: Rate of Fruit Infestation by Olive Fruit Fly on Two Olive Cultivars (Nabali and Baladi) in Hindaza Village for Two Successive Growing Seasons 2011 and 2012.

This experiment was conducted in two fields in Hindaza village-throughout 2011 & 2012. The eastern field was planted with Nabali cultivar and the western field was planted with Baladi cultivar. Three dunums were used in each field (Fig 2.9).

One hundred fruits were weekly and randomly collected from both cultivars in each site throughout the two successive seasons (2011 & 2012), and the rate of fruit infestation was weekly recorded using human eyes and dissecting microscope to inspect the presence of olive fruit eggs in infected fruits on each cultivar/site.

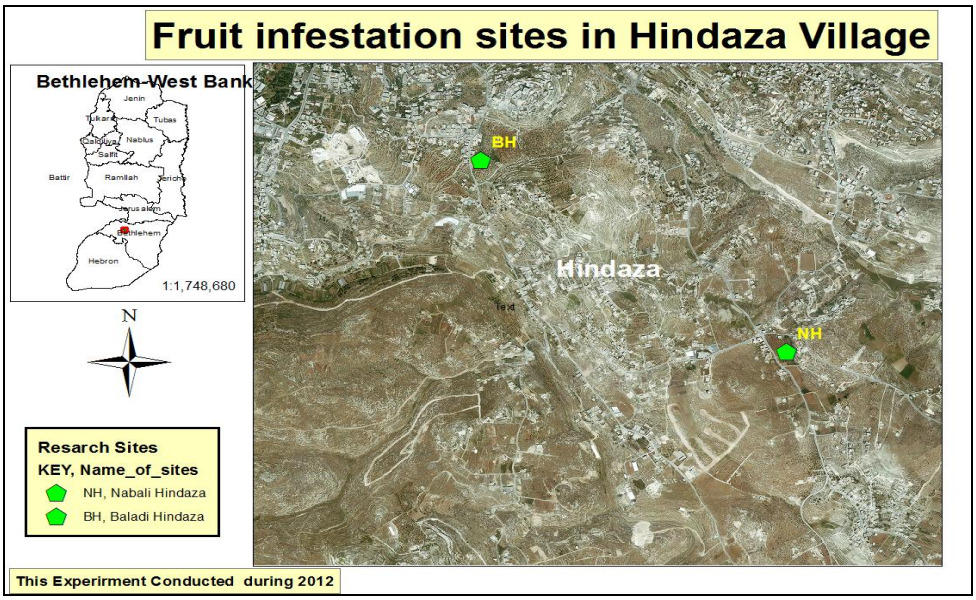

Fig 2.9: Map Shows the sites of Nabali and Baladi fields in Hidaza village.

2.3.3: Investigation on the Use of Mass Trapping Techniques for Management of *B. oleae*

Food attractant baits and sex-pheromone were investigated as mass trapping technique for management of *B. oleae*. This experiment was conducted in Hindaza village in two site cultivars: Nabali (Fig 2.10) and Baladi (Fig 2.11), from 1st Jul 2012 until 30th Dec 2012.

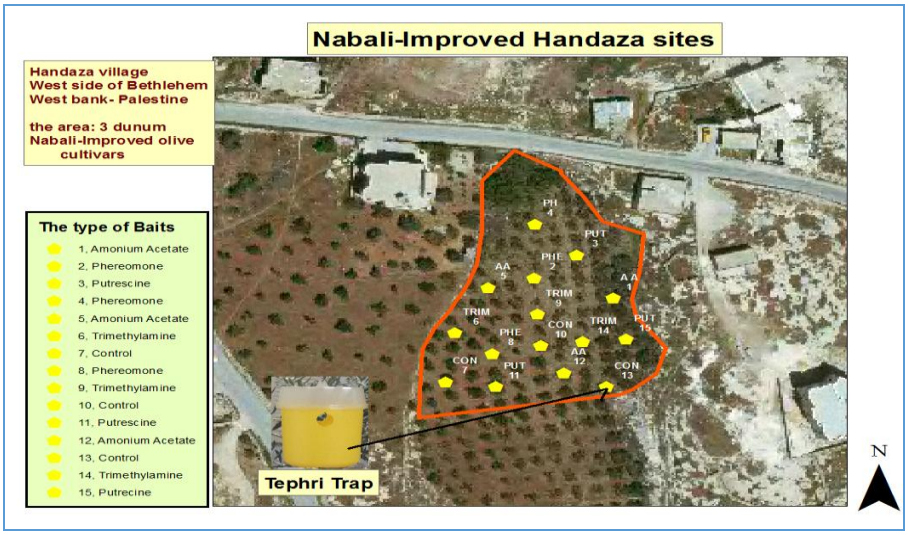

Fig 2.10: Map shows the distribution of different baits and sex-pheromone tephri traps in Nabali cultivar site

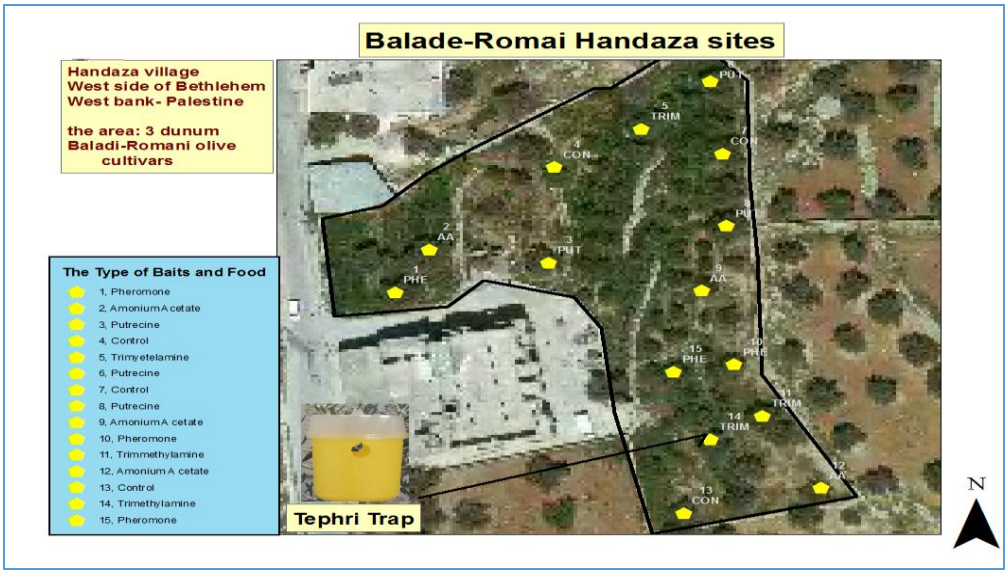

Fig 2.11: Map shows the distribution of different baits and sex-pheromone tephri traps in Baladi cultivar site

MacPhil-Tephri traps (Fig 2.12) were used in this experiment. The trap was consisted of a yellow base and a clear top, which could be separated to facilitate servicing. That trap had entrance holes around the top of the periphery of the yellow base, and an invaginated opening in the bottom. Inside the clear top, there was a platform to house the attractant (bait or Pheromone lure) treatments. The trap fluid was consisted of 300 ml water, 0.5ml fairy soap, and 2 ml Diettol, which was placed in the basal part of the trap. MacPhil-tephri traps were set up and placed randomly in each site. The traps were hung from 1.5m to 2m ground level, and separated by 30m between each other.

Fig 2.12: MacPhil -Tephri Trap hanged on Olive Tree

Five treatments were used with three replicates in each site consist of the following:

1- Ammonium Acetate (AA): its molecular formula is: CH_3COONH_4 (Environmental Health and Safety, 2001). Ammonium acetate percentage in the package was 100% and was used as a bait.

2- Putrescine (PUT): its molecular formula is: $\underline{NH_2}(\underline{C}H_2)_4NH_2$ (1,4-diaminobutane or butanediamine) (Gold Biotechnology. Inc, 2011). Putrescine percentage in the package was100% and it was used as a bait.

3- Trimehylamine Hydrochloride (TRIM): its molecular formula is:

C_3H_9N.CLH. It's percentage in the package was 98% and used as a bait.

4- Sex-pheromone (PHE): Spiroketal male attractant pheromone capsule: Molecular formula is: 1, 7-dioxaspiro [5, 5]-Undecane, and its formula is $C_9H_{16}O_2$. It was used as male attractants in this experiment and plastic pheromone emitting device as product form (Fig 2.13).

5- Control treatment (CON): Macphil-tephri traps those contain the trap fluid but do not contain any attractant material.

Food attractants and sex pheromone packages were stocked on the special platform of the trap that located inside the clear top of each trap.

Respectively, AA, PUT, and TRIM are solid attractants that are easier to handle than liquid ones. In addition, it was one single diffuser which was placed directly inside and under the surface of the cover of the trap. These baits consisted of adhesive connected with surface of the trap cover. Spiroketal male attractant pheromone capsule was used as male attractants in this experiment, and plastic pheromone emitting device as product form.

Traps were checked every week, and trap fluid filtered, adult flies were collected, recorded and sexed (Male & Female). And the bait packages and the sex pheromone dispensers were monthly replaced.

Fig 2.13: Sex- Pheromone dispenser and its barrier.

2.4: Statistical analysis

Statistical analysis for the data of this research was done by using Minitab Package as shown under each table of results. Mintiab 16 was developed at the Pennsylvania State University by researches Barbara F. Ryan, Thomas A. Ryan, Jr., and Brian L. Joiner in 1972. It was published in 1986. It is often used in conjunction with the implementation of six-sigma, and other statistics-based process improvement methods.

2.5: Meteorological Data

Records of the environmental conditions of the area were obtained from the Palestinian Meteorological Department, and Ministry of Agriculture.

2.6: ArcGIS Maps 10.1

GIS Maps were obtained from the Land Research Centre, and Ministry of Agriculture- Bethlehem Agriculture Directorate. ArcGIS is software that is used for creating and using maps. These maps are used by the researcher.

Chapter Three: Results

Chapter 3: Results

3.1: Flight Activity of Olive Fruit Fly, *B. oleae* in Bethlehem Area During 2011 & 2012.

3.1.1: Seasonal Flight Activity of Olive Fruit Fly, *B. oleae* in Bethlehem Area During 2011& 2012.

The results in (Fig 3.1) show the flight activity of *B. oleae* in Battir, Hindaza, and, Tuqu' villages during 2011 season. It was found that *B. oleae* started its seasonal flight activity in Battir, Hindaza and Tuqu' sites at the beginning of Jul 2011, and then continued until late of November in Battir and Hindaza, and up to early January in Tuqu'.

Also, results showed that olive fruit fly had three generations in Battir, Hindaza, and Tuqu'. In Battir, results presented in Fig (3.1-A) showed that the peak of 1st generation recorded about 12 flies/trap/week at the beginning of August; the second generation recorded in early September and the peak of the third generation recorded in late October.

However, in Hindaza site, results presented in Fig (3.1-B) show that the peak of the 1st generation with 12 flies/trap/week was recorded in mid of August; the peak of the 2nd generation with 129 flies/trap/week was recorded in early October and the peak of the 3rd generation with 99 flies/trap/week was recorded in mid of November.

But, in Tuqu' site, results presented in Fig (3.1-C) show that the peak of the 1st generation with about 5 flies/trap/week was recorded in mid of Augest, the peak of the 2nd generation with 126 flies/trap/week was recorded in early November and as for the peak of the 3rd generation, 54 flies/trap/week were captured in early December.

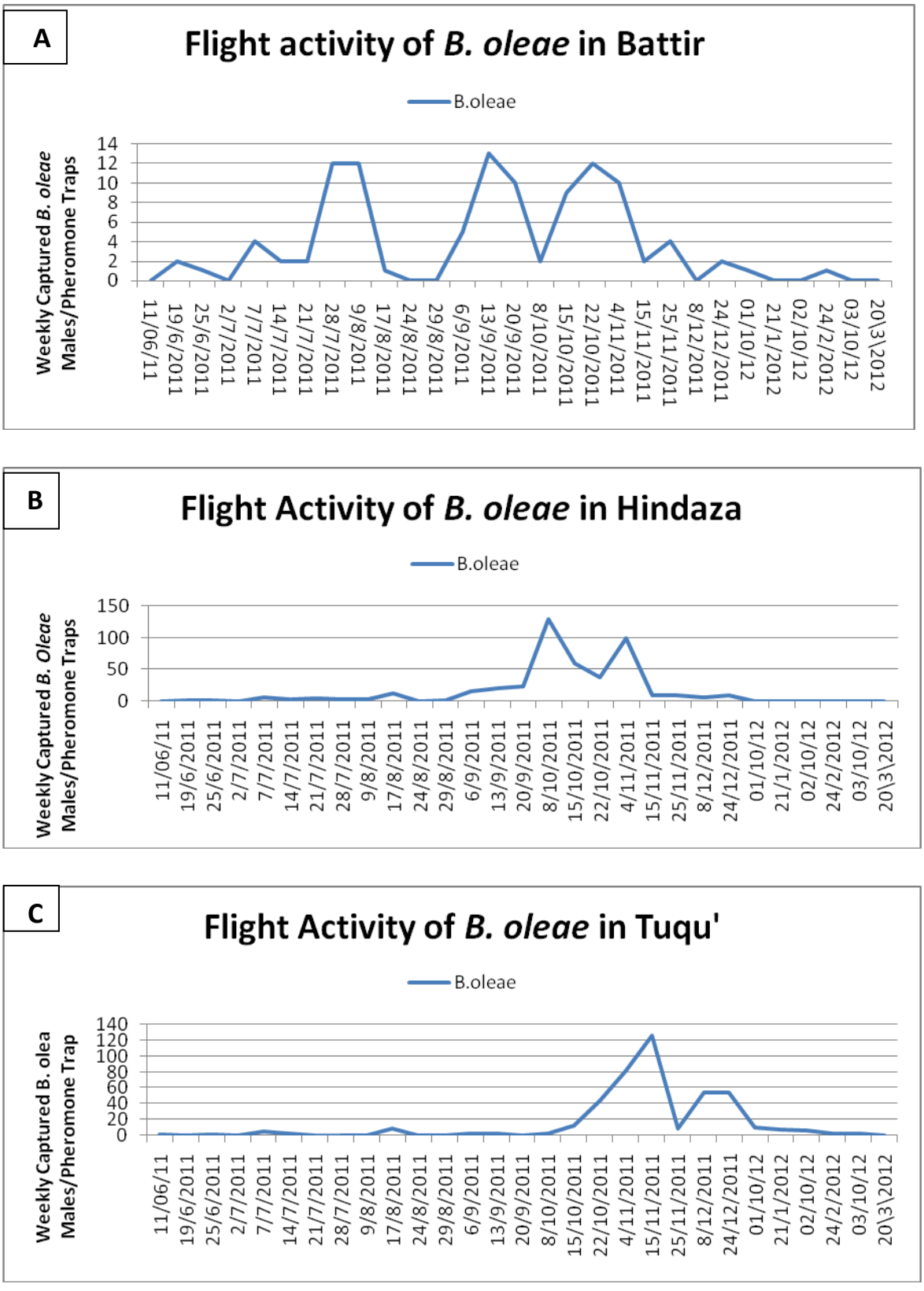

Fig 3.1: Flight activity of *B. oleae* in Bethlehem area during 2011 season (A: Battir, B: Hindaza, and C: Tuqu').

In addition, the results in Fig (3.2) summarized the flight activity of *B. oleae* in the three sites of Bethlehem, and showed that the seasonal flight activity was affected by temperature as well as rainfall, and thus, no flight activity observed at temperature ≤ 10°C or ≥ 30°C, and, very low flight activity was recorded during the rainy periods.

Furthermore, results presented in Fig. 3.2 showed that, the average numbers of *B. oleae* males that were weekly captured on sticky pheromone traps in Battir site were less than that in Hindaza and Tuqu' throughout the season. And, the greatest numbers of flies were caught between late September and mid-December. At this time, the captured males ranged from 90 to 130/pheromone trap/week, and few adults were caught/trap from early January up to early July.

But in Tuqu', flight activity continued until the end of January of the following year, when the environmental condition were suitable for the flight of *B. oleae* in this site.

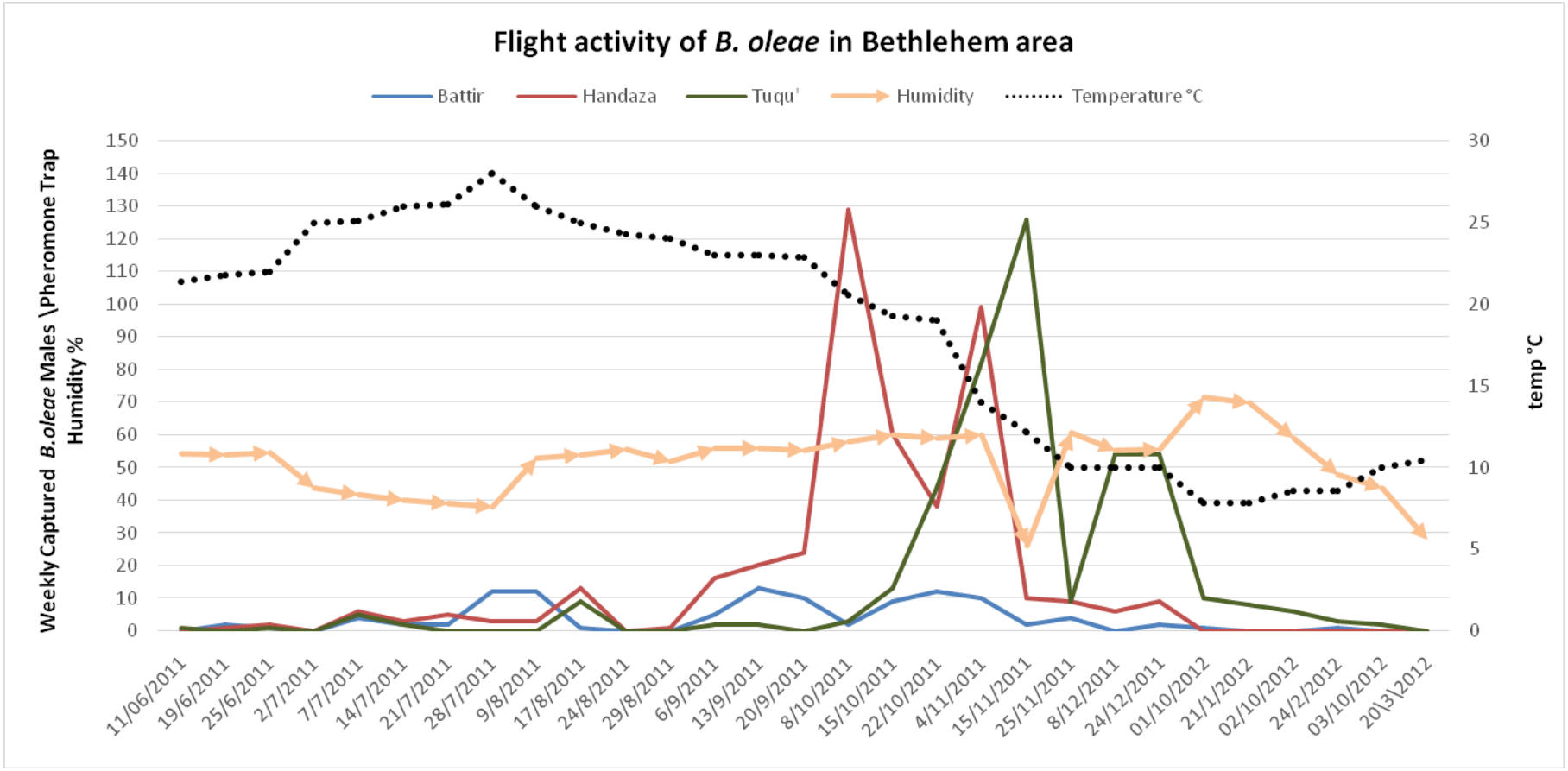

Fig 3.2: Flight activity of *B. oleae* in three sites in Bethlehem area during 2011.

3.1.2 Seasonal Flight activity of *B. oleae* in Hindaza Village for Two Successive Growing Seasons (2011-2012)

Results obtained during 2011 season showed that the numbers of *B. oleae* that were captured on pheromone traps in Hindaza site were significantly higher than that in either Battir or Tuqu' sites. Therefore, the experiment was continued in Hindaza for the second growing season 2012.

Results in figure (3. 3) showed that in Hindaza site, *B. oleae* started its flight activity in early July, and, continued its activity throughout the season till the late of November during 2011. While during 2012, the flight activity started in early July, and continued its activity throughout the season up to late November.

Three generations of *B. oleae* were annually recorded in Hindaza site (Fig 3.3) throughout the two years (2011& 2012). In 2011, the peaks of the three generations were recorded on mid of August; early October and in mid of November respectively, meanwhile in 2012, the three generations were respectively recorded in mid of September; in last October, and in the mid of November.

Results throughout the two successive seasons, the highest numbers were caught between late September and early November, and, few adults were caught by the traps between early of December till late of July.

Furthermore, results showed that the seasonal flight activity was affected by temperature as well rainfall, and thus no flight activity recorded at temperature $\leq$ 10°C and the number of captured males\pheromone trap was observed to increase with increasing temperature from 20-25°C. In addition, very low flight activity was recorded during the rainy periods.

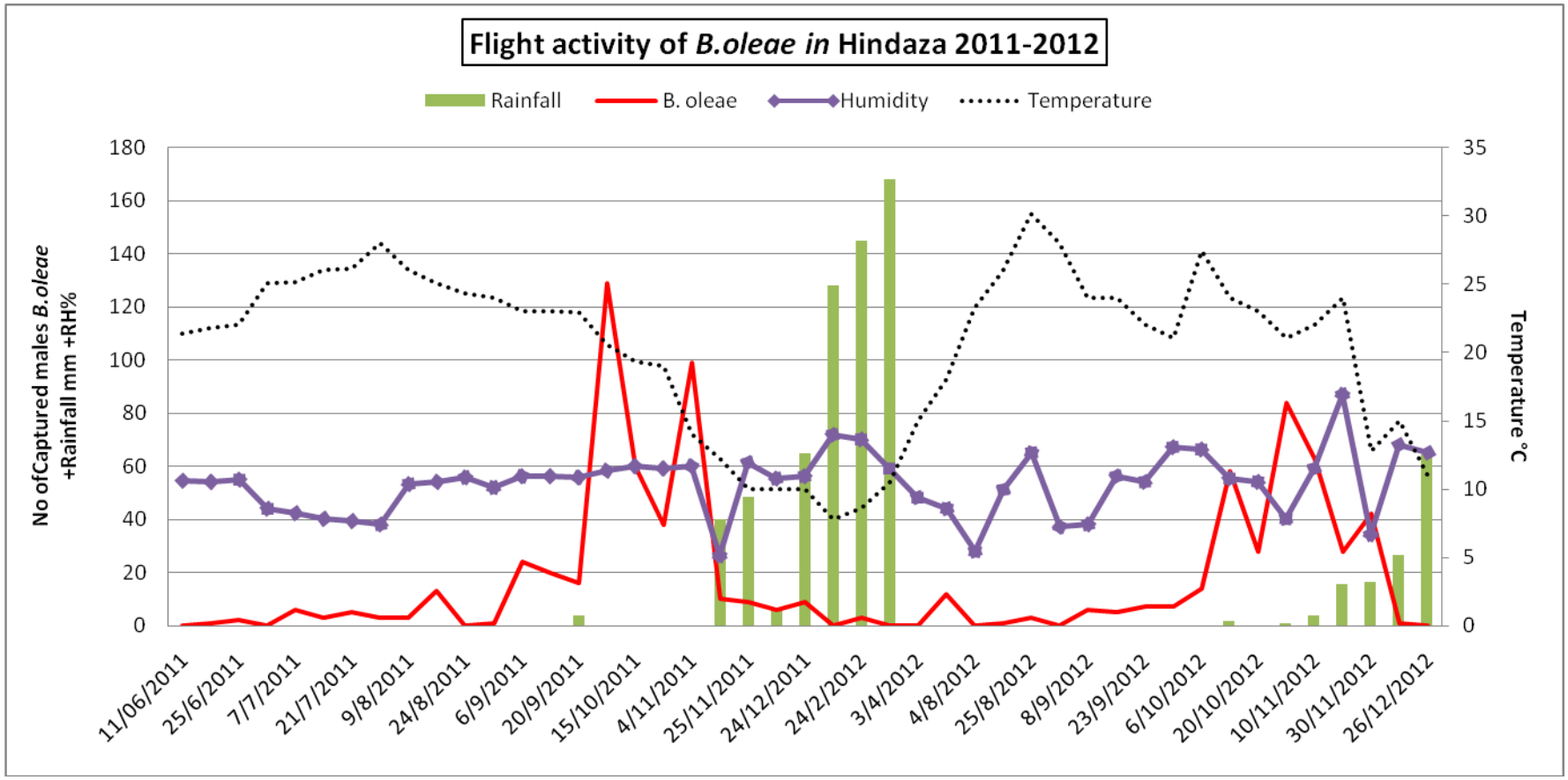

Fig 3.3: Flight activity of *B. oleae* in Hindaza site during 2011 and2012.

3.1.3: Effect of Color on the Attracting Efficiency of Sticky Traps Used for Monitoring the Flight Activity of *B. oleae*

Results of this experiment showed that the color of the sticky trap has an effect on the efficiency of the trap in attracting of adult flies from both sexes.

The results in Table (3.1) showed the monthly distribution of the captured flies (males and females), throughout the growing season from June 2011 to April 2012.

Results show that the significant effect of color was recorded during September 2011, where the yellow sticky traps were significantly higher than green; red; and blue colored traps.

However, the mean total numbers of flies trapped by the four colors during September 2011 were; 3.0 flies/yellow trap; 1.0 fly/green trap; and no flies were trapped by either the red or blue traps. Moreover, during the period from October 2011 till end of January 2012, higher numbers of flies were captured by all colors (during October 2011), but without significant differences between all colors, even though, higher numbers of flies trapped by the yellow colored traps followed by the green ones.

Table 3.1: Mean Numbers Of Monthly Captured Olive Fruit Flies/Colored Sticky Trap. Mean* ± S.E.

Date	Sex	Yellow	Green	Red	Blue	*P value***
JUN 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	-
	F	0.0±0.0	0.33±0.33	0.0±0.0	0.0±0.0	0.441NS
	T	0.0±0.0	0.33±0.33	0.0±0.0	0.0±0.0	0.441NS
JUL 11	M	0.33±0.33	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	-
	T	0.33±0.33	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
AUG 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	-
	F	0.67±0.67	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	T	0.67±0.67	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS

SEP 11	M	2.0^{a}±0.00	0.33^{b}±0.33	0.0^{b}±0.0	0.0^{b}±0.0	0.000
	F	1.0^{a}±0.00	0.67^{b}±0.33	0.0^{b}±0.0	0.0^{b}±0.0	0.006
	T	3.0^{a}±0.00	1.0^{b}±0.577	0.0^{b}±0.0	0.0^{b}±0.0	.012
OCT 11	M	37.3±24.9	12.0±0.78	0.33±0.33	1.0±0.58	0.203NS
	F	13.7±6.69	5.67±0.67	0.000.00	0.67±0.67	0.070
	T	51.0±31.6	17.67±1.20	0.33±0.33	1.67±1.20	0.163NS
NOV 11	M	84.3±70.3	24.3±13.7	0.00±0.00	0.67±0.33	0.362NS
	F	22.3±16.3	7.33±3.76	0.00±0.00	0.67±0.67	0.277NS
	T	106.7±86.4	31.7±15.3	0.0±0.0	1.33±0.88	0.340NS
DEC 12	M	10.0±5.29	7.33±6.84	0.00±0.00	0.00±0.00	0.311NS
	F	2.67±1.76	3.33±3.33	0.33±0.33	0.33±0.33	0.590NS
	T	12.67±6.96	10.7±10.2	0.33±0.33	0.33±0.33	0.389NS
JAN 12	M	3.67±2.03	0.33±0.33	0.0±0.0	0.0±0.0	0.94NS
	F	2.0±1.15	0.33±0.33	0.0±0.0	0.0±0.0	0.130NS
	T	5.67±3.18	0.67±0.67	0.0±0.0	0.0±0.0	0.105NS
FEB 12	M	0.33±0.33	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	-
	T	0.33±0.33	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
MAR 12	M	0.33±0.33	1.0±1.00	0.0±0.0	0.0±0.00	0.528NS
	F	0.33±0.33	0.0±0.00	0.0±0.0	0.0±0.0	0.441NS
	T	0.67±0.67	1.0±1.0	0.0±0.0	0.0±0.0	0.582NS
APR 12	M	0.67±0.33	1.33±1.33	0.0±0.0	0.0±0.0	0.449NS
	F	0.0±0.0	0.33±0.33	0.0±0.0	0.0±0.0	0.499NS
	T	0.67±0.67	1.67±1.67	0.0±0.0	0.0±0.0	0.500NS

*: Means within the same row with different letters significantly differ at *P* value ≤0.05 (Using Fisher's pairwise comparisons)

**: NS=Not significant at *P* value ≥ 0.05 (Using Fisher's pairwise comparisons)

Fig (3.4-A) demonstrates that the captured males of *B. oleae* on sticky traps started at the end of August and continued up to late January, and showed the peak of captured males of *B. oleae* at early November. However, Fig (3.4-B) show that the captured females of *B. oleae* on sticky trap started at the end of September and continued up to late January, and showed the peak of capturing males of *B. oleae* at the mid of November.

Thus, Fig 3.4 shows that the peak of males of *B. oleae* flight is two weeks earlier than that of the females.

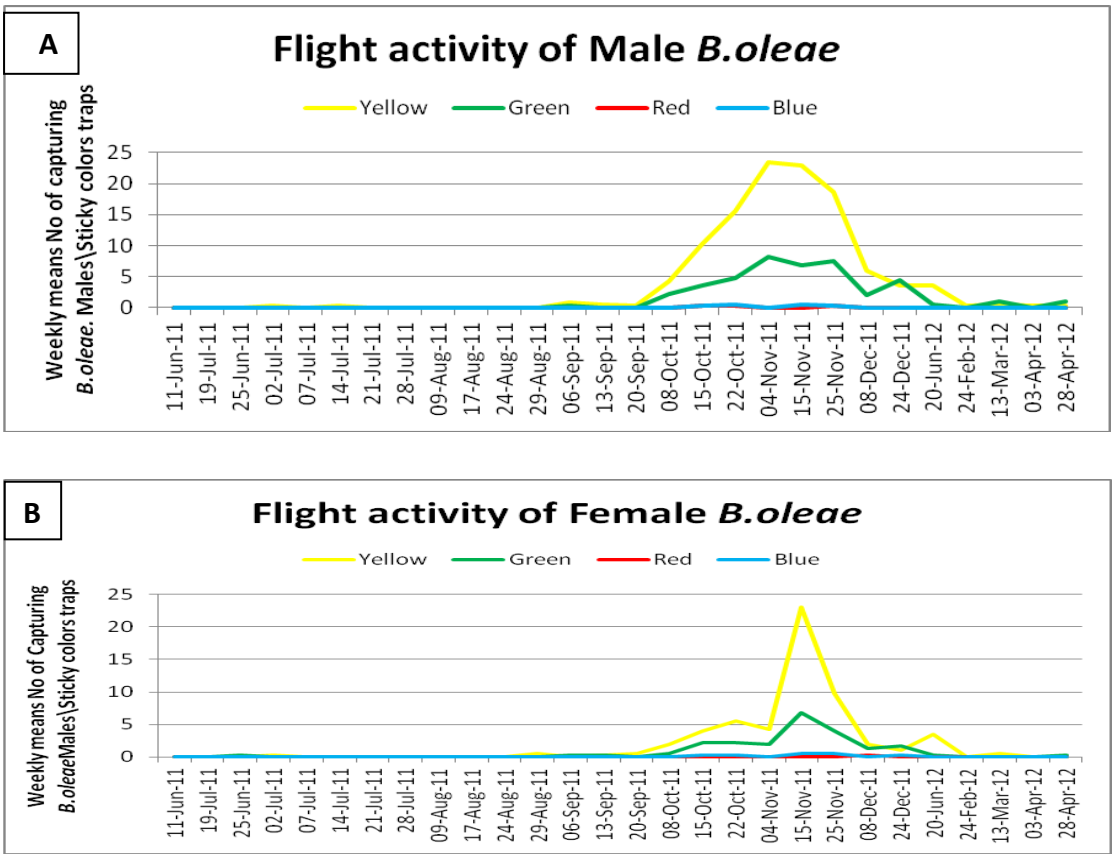

Fig: 3.4: Flight activity of *B. oleae* recorded by colored sticky traps. A: Males, B: Females.

Results presented in Table (3.2) show the means of the total olive fruit flies (of both sexes) that were captured/ sticky trap during the experiment. The sum of 182 fly were trapped/yellow; 64.7/green trap; 3.33 fly/blue trap and 0.67 fly/red trap. Its concluded that yellow color is the most attractive than any other color investigated in this experiment.

Table 3.2: Means of total olive fruit flies that were trapped by various colored sticky traps. Mean* ± S.E

Mean	**Yellow**	**Green**	**Red**	**Blue**	***P value*****
Males	139.0±100.0	46.7±20.5	0.33±0.33	1.67±0.88	0.260NS
Females	42.7±25.10	18.0±5.13	0.33±0.33	1.67±1.67	0.147NS
M + F	182.0±125.0	64.7±25.2	0.67±0.33	3.33±2.40	0.232NS

*: Means within the same row with different letters significantly differ at *P* value ≤0.05 (Using Fisher's pairwise comparisons)

**: NS=Not significant at *P* value ≥ 0.05 (Using Fisher's pairwise comparisons)

3.2: The Rate of Fruit Infestation by Olive Fruit Fly on Two Olive Cultivars (Nabali and Baladi)

3.2.1: Rate of Fruit Infestation of Olive Fruit Fly in Three Sites, Battir, Hindaza, and Tuqu' During 2011

The results in this section illustrated the fruit infestation on two olive cultivars (Nabali and Baladi) in three sites (Battir, Hindaza, and Tuqu') during 2011 season.

Results presented in Fig (3.5) show the rate of fruit infestation on Nabali cultivar throughout 2011 season. In general, results indicated that during 2011 season, fruit infestation stared on the early of July and continued up to harvesting at the end of October 2011.

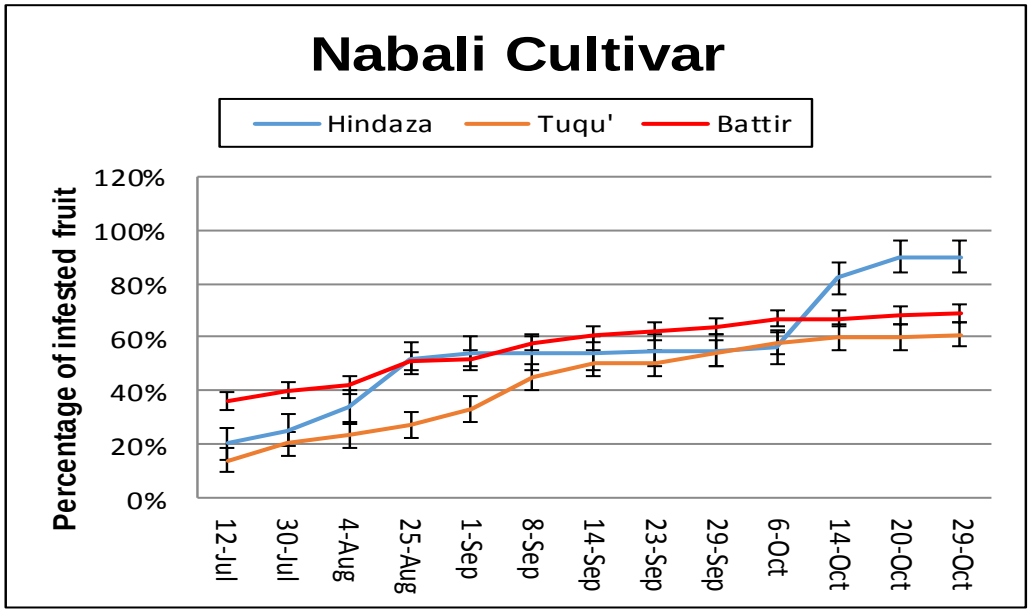

Fig 3.5: Rate of fruit infestation on Nabali cultivar in three sites (Hindaza, Battir, and Tuqu')

Results also showed that, at the beginning of the season, fruit infestation on Nabali cultivar was significantly higher in Battir site (with 37% fruit infestation), than that in Hindaza (with 20%) and in Tuqu` (with 15%). However, throughout the season, rate of infestation increased to

reach 90% in Hindaza, at the end of October, and that level of infestation was significantly higher than that in Battir where it reached 65%; and in Tuqu` with 60% fruit infestation.

In addition, results presented in Fig (3.6) show that the rate of fruit infestation on Baladi cultivar started at the early of July in the three sites of the study. At the early of July, the recorded rate of the infestation on Baladi cultivar was 35% in both Battir and Tuqu`, but 20% in Hindaza. However, the infestation rate on Baladi cultivar increased through the season to reach high levels of infestation at the end of October 2011 with 82% fruit infestation in Tuqu`; 80% in Hindaza, but 65% in Battir.

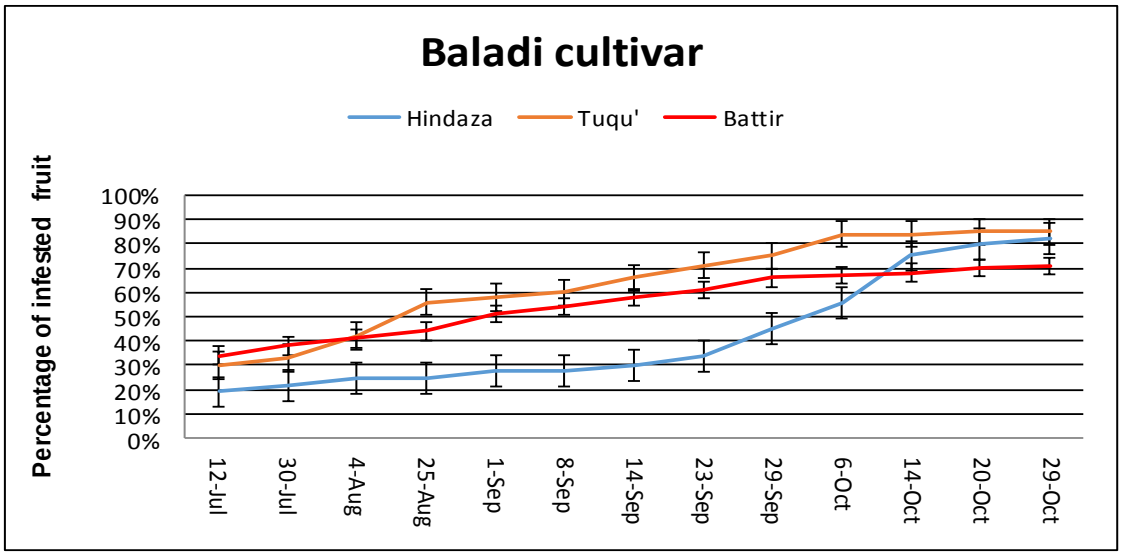

Fig 3.6: Rate of fruit infestation on Baladi cultivar in three sites (Hindaza, Battir, and Tuqu')

Furthermore, results presented in Fig 3.7 showed that the rate of fruit infestation on both Nabali and Baladi in Bethlehem area was without significant differences throughout 2011 production season. Thus, the rate of fruit infestation reached 80% at the end of the season, just before the start of harvesting.

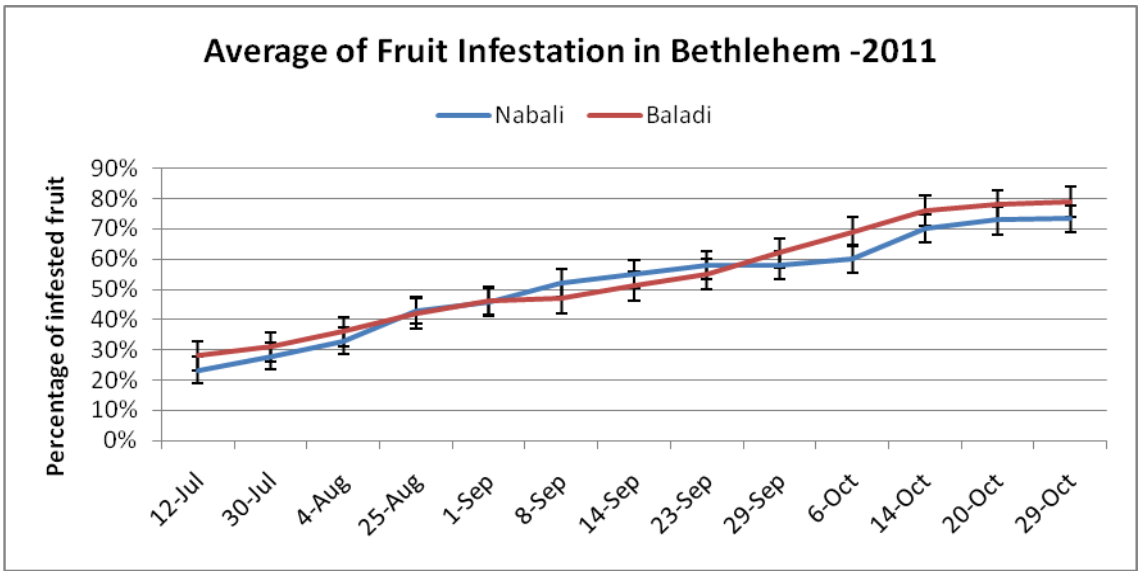

Fig 3.7: Rate of fruit infestation on both Nabali and Baladi cultivars in Bethlehem area during 2011 season.

3.2.2: Rate of Fruit Infestation of Olive Fruit Fly in Hindaza throughout Two Successive Growing Seasons (2011-2012).

The results in 2011 seasons indicated that the rate of fruit infestation and flight activity of *B. oleae* in Hindaza were significantly the highest than that in the other sites of the study. Therefore, observations on both flight activity as well as record of fruit infestation continued in Hindaza throughout the following growing season during 2012.

Results presented in Fig (3.8) reflected the rate of fruit infestation during 2011 and 2012 seasons on the Nabali cultivar in Hindaza site. When comparing between the two production seasons, the percentage of fruit infestation that was recorded on Nabali cultivar at early July of both 2011 and 2012 was 20% at 2011 but about 15% at 2012. However, the rate of fruit infestation on Nabali cultivars rose to reach 90% at the end of October 2011, but only 40% at the end of October 2012. Thus, rate of fruit infestation on Nabali cultivar was significantly lower in 2012 than that in 2011.

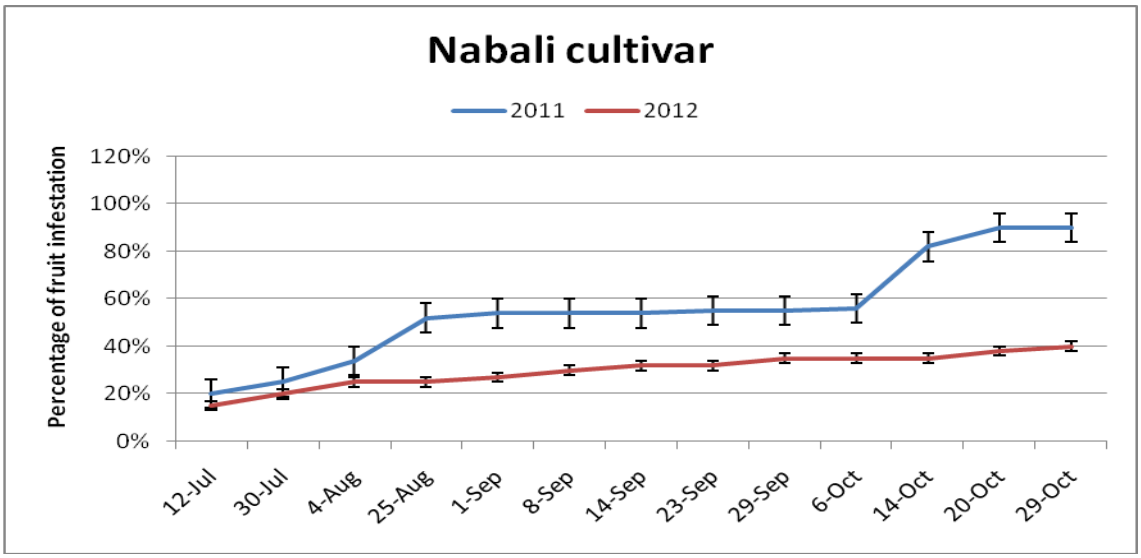

Fig 3.8: Rate of fruit infestation on Nabali cultivar in Hidaza village 2011 and 2012.

However, results presented in Fig (3.9) indicated that the rate of fruit infestation recorded on Baladi cultivar, through the two successive years, in Hindaza site, was with similar levels of fruit infestation throughout the period from early July till beginning of October of both 2011 and 2012. And, later on, the rate of fruit infestation rose to reach 80% at the end of October 2011, but 62% at the end of October 2012. Furthermore, statistical analysis showed that the rate of fruit infestation on Baladi cultivar was significantly higher at the end of 2011 season than that at 2012 season.

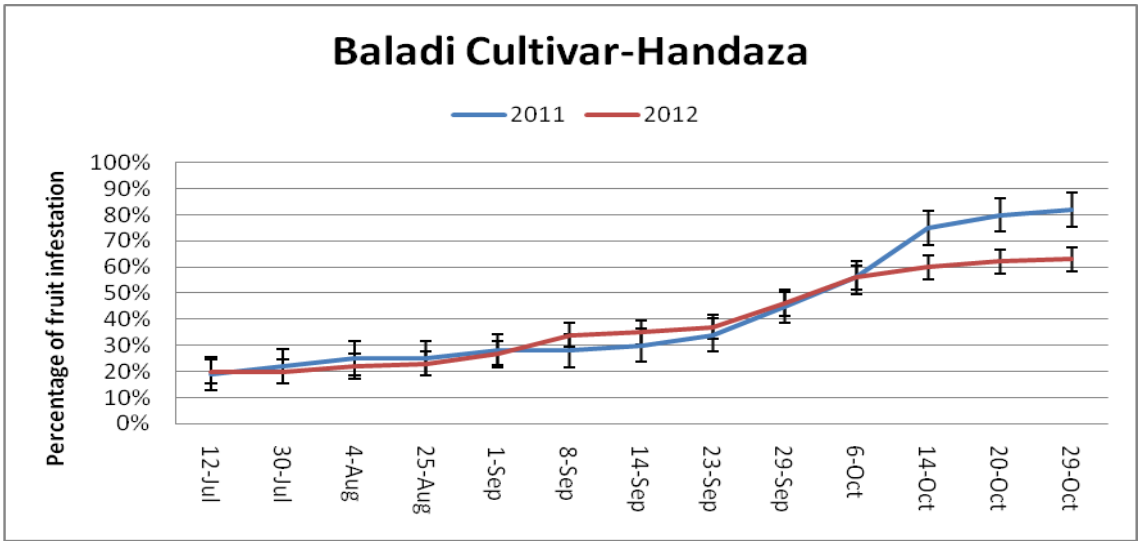

Fig 3.9: Rate of Fruit infestation on Baladi cultivar in Hidaza village during 2011-2012.

3.2.3 Effect of Environmental Condition on Rate of Fruit infestation and Flight activity of *B. oleae*.

Results presented in Fig (3.10) demonstrated the relationships between rates of fruit infestation; flight activity of *B. oleae* and the environmental conditions in Hindaza site throughout 2011and 2012 growing seasons.

Results showed that positive relationships were recorded between the percentage of fruit infestation and the flight activity of *B. oleae* during both 2011 and 2012 seasons. Thus, it was noted that, during 2011 season, when the flight activity of *B. oleae* was high, the rate of the fruit infestation was also higher in comparison with the levels of these parameters in 2012.

Furthermore, the present study noted flight activity declined at temperature $\leq$ 10°C or $\geq$ 30°C, and the number of captured males\pheromone trap was observed to be highest at temperature range from 20-25°C. In addition, very low flight activity was recorded during the rainy periods.

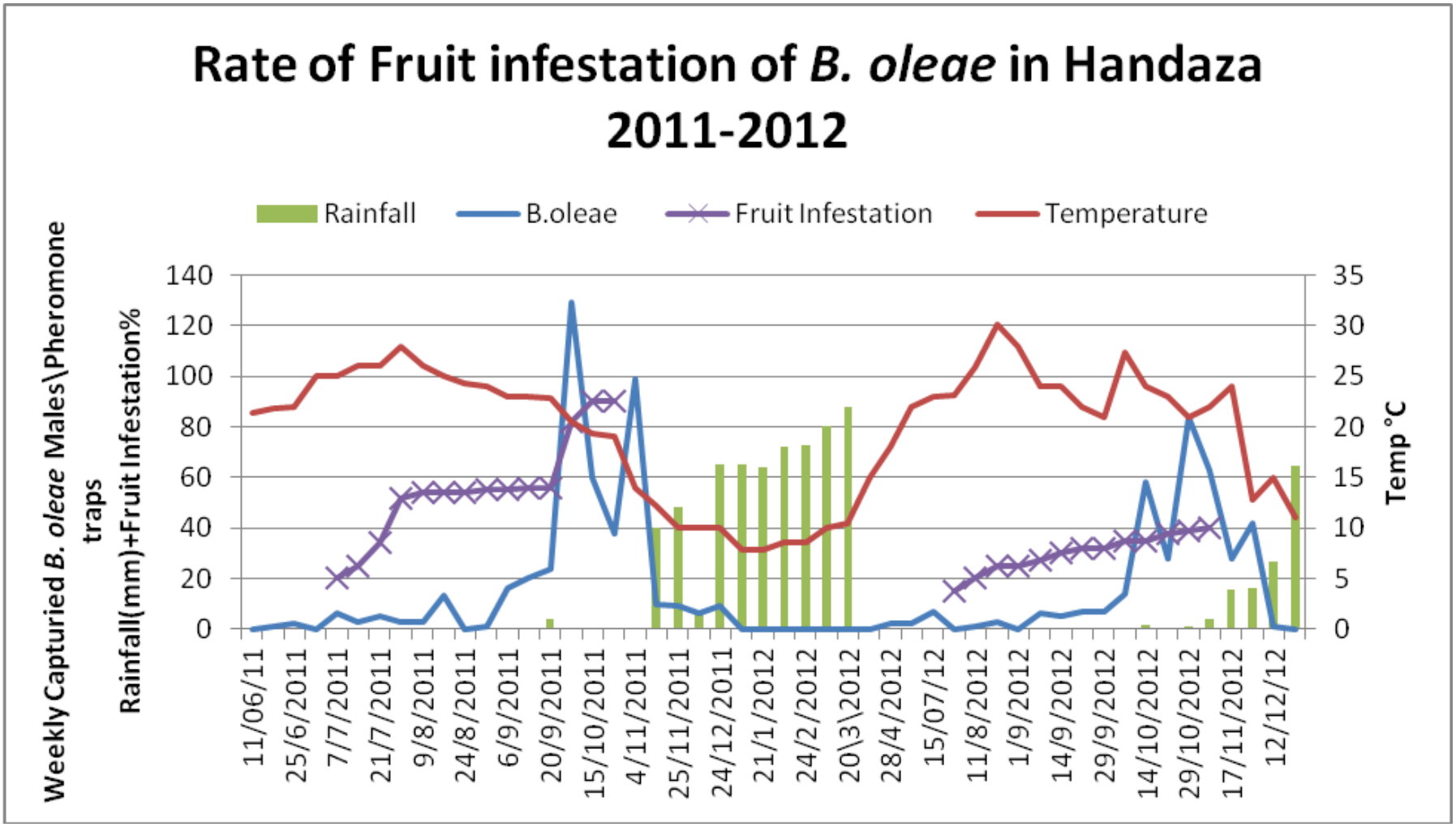

Fig 3.10: Rate of fruit infestation on Nabali cultivar and Flight activity of *B. oleae* in relation to environmental condition in Hindaza' site throughout 2011-2012.

3.2.4: Relationships between Rainfall; Production Yield and Rate of Fruit infestation of B. oleae.

Results presented in Table (3.3) demonstrated the relationships between annual rainfall; average yield of two olive cultivars in Battir, Hindaza and Tuqu` and their rate of fruit infestation by *B. oleae* during 2011. Results show that the production yield of the two cultivars has a +ve relation with total rainfall, but it shows a –ve effect on the rate of fruit infestation by the olive fruit fly.

Table 3.3: Annual Rainfall (mm); Average fruit production (Kg/Dun); and % of infested fruit by *B. oleae* in Battir, Hindaza and Tuqu` during 2011.

Site	Rainfall mm	Yield Kg/Dun		% infestation	
		Baladi	Nabali	Baladi	Nabali
Battir	380	120	80	71	69
Hindaza	311	90	55	82	90
Tuqu'	220	80	40	86	61

Furthermore, results presented in Table (3.4), confirmed the conclusion that years with high rainfall that resulted in golden yield has lower % of fruit infestation than that years with low rainfall and also low production yield but with higher rate of fruit infestation.

Table 3.4: Annual Rainfall (mm); Average fruit production (Kg/Dun); and % of infested fruits in Hindaza during 2011and 2012.

Year	Rainfall mm	Cultivar	Olive production Kg/Dun	% of fruit infestation
2011	311	Baladi	90	82
		Nabali	55	90
2012	550	Baladi	130	63
		Nabali	90	40

Furthermore, results indicated that the phenomena of biennial yield alteration of olive is inversely related with fruit infestation, thus, high fruit production in 2012 was accompanied with lower rate of infestation in comparison to high rate of infestation that recorded accompanied to the low fruit production yield in 2011.

3.3: Mass Trapping Technique of *B. oleae* Using Various Baits and Sex-Pheromone

Results in this section show the efficiency of baits and sex-pheromone in trapping the adults of *B. oleae* within two olive cultivars, Nabali and Baladi in Hindaza site during 2012 season.

3.3.1: Means of adult Olive fruit Flies (Male and Female) that were Monthly Captured by Various Attractant Treatments.

Table 3.5: Means of adult Olive fruit flies (male and female) that were monthly captured by various attractant treatments. Mean* ± S.E

Date	Sex	Control	Ammonium Acetate	Pheromone	Putrescine	Trimethylamine Hydrochloride	*P value***
JUL	M	2.83±1.3	20.83±4.9	9.67±3.27	20.8±13.9	2.0±0.58	0.148NS
	F	0.5±0.5	7.67±2.19	1.17±0.65	6±4.07	1±0.26	0.069NS
	T	3.33±1.78	28.5±6.87	10.83±3.5	20.8±17.9	3.0±0.68	0.122NS
AUG	M	0.67±0.67	0.33±0.21	2.83±1.35	2.33±0.99	0.0±0.0	0.074NS
	F	0.17±0.17	0.0±0.0	0.0±0.0	1.33±0.88	0.0±0.0	0.110NS
	T	0.83±0.83	0.33±0.21	2.83±1.35	3.67±1.74	0.0±0.0	0.082NS
SEP	M	0.5^{b}±0.5	0.17^{b}±0.17	7.33^{a}±1.56	1.17^{b}±0.75	0.17^{b}±0.17	0.000
	F	0.50±0.50	0.00 ±0.00	0.17±0.17	0.0±0.0	0.0±0.0	0.507NS
	T	1.0^{b}±1.0	0.17^{b}±0.17	7.5^{a}±1.65	1.17^{b}±0.75	0.17^{b}±0.10	0.000
OCT	M	4.67^{b}±1.84	2.50^{b}±1.31	34.3^{a}±7.59	6.50^{b}±1.91	1.33^{b}±0.67	0.000
	F	0.67±0.33	1.50±1.12	0.50±0.22	2.33±1.38	0.50±0.34	0.457NS
	T	5.33^{b}±1.93	4.0^{b}±2.38	32.8^{a}±7.43	8.67^{b}±3.14	1.83^{b}±0.98	0.000
NOV	M	17.8^{ab}±4.2	4.67^{b}±3.07	31.2^{a}±6.47	30.3^{a}±13.3	9.00^{b}±3.01	0.045
	F	6.0±1.41	2.67±0.80	3.67±0.96	13.83±9.7	5.33±1.50	0.445NS
	T	23.83±5.0	7.33±3.60	34.83±7.1	44.2±21.8	14.33±4.0	0.139NS
Total	M	26.5^{b}±6.55	28.5^{b}±6.63	85.3^{a}±15.7	61.2^{a}±14.6	12.5^{c}±3.37	0.000
	F	7.83±2.06	11.83±3.5	5.50±1.61	23.5±11.0	6.83±1.92	0146NS
	T	34.0^{b}±8.2	40.33^{b}±9.6	90.8^{a}±17.1	84.7^{a}±24.3	19.3^{c}±4.81	0.005

*: Means within each row with different letters significantly differ at *P* value ≤0.05 (Using Fisher's pairwise comparisons)

**: NS=Not significant at *P* value ≥ 0.05 (Using Fisher's pairwise comparisons)

Results in Table (3.5) showed that both males and females of olive fruit flies were captured by the various food attractants and sex-pheromone traps, throughout the season from beginning of July till end of November 2012.

Statistical analysis indicated that during the period from early September till end of November, sex-pheromone traps were significantly higher in capturing adult males than all other investigated treatments.

Results also showed that the attractant baits can be significantly classified into three groups according to their efficiency in trapping of the adult males of *B. oleae* throughout the season as follow: 1st group including both sex pheromone and putrescine that are significantly with high efficiency in trapping adult males with an average total of 85.3 males captured/pheromone trap; and 61.2 males captured/putrescine trap; followed by the 2nd group of baits with medium efficiency in trapping adult males including both ammonium acetate and the control treatment with an average total of 28.5 males captured/ammonium acetate trap; and 26.5 males captured/control trap; and the 3rd group with the lowest efficiency in trapping the adult males included the trimethylamine hydrochloride trap that captured an average total of 12.5 males/trap which is even significantly lower than that trapped by the control treatment.

3.3.2: Proportion of Adult Males and Females of *B. oleae* Captured by Various Attractants

Results presented in Fig (3.11) show proportion of either males or female *B. oleae* that captured by each attractant bait traps throughout the growing season.

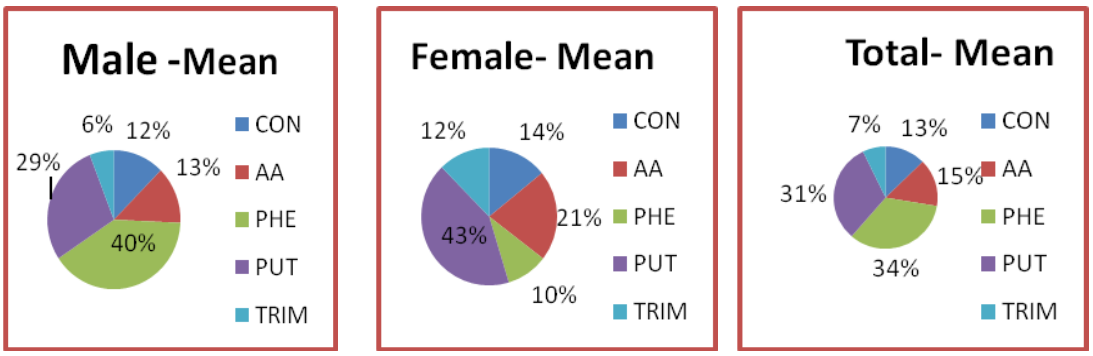

Fig 3.11: Proportion of adult *B. oleae* captured by various attractants: Control (CON); Ammonium Acetate (AA); Sex-Pheromone (PHE); Putrescine (PUT); and Trimehylamine Hydrochloride (TRIM) throughout 2012 season.

Results show that 40% of males captured by the sex pheromone traps followed by puterscine that captured 29% of adult males. Meanwhile, ammonium acetate traps captured 13% of the adult males; control treatment captured 12% of adult males and finally, Trimethylamine Hydrochloride traps captured half the ratio of the control treatment with only 6% adult males/trap.

However, concerning the captured females of *B. oleae*, results indicated that putrescine bait captured 43% of the trapped females throughout the season; followed by the ammonium acetate baits that captured 21%; control treatment captured 14%; trimethylamine hydrochloride baits that captured 12%; and sex pheromone traps that captured only 10% of the trapped females.

Finally, concerning the total flies from both sexes that were trapped throughout the season, sex pheromone and putrescine baits together captured approximately two third of the trapped flies with a total proportion of 34% captured by the pheromone traps; and 31% captured by the putrescine traps.

Thus, pheromone traps were found to be the most effective treatments for mass trapping of males, and putrescine is the most effective for mass trapping of females.

3.3.3: Efficiency of Mass Trapping Attractant Baits of *B. oleae* in Relation to the Cultivar Olive Plants.

Table 3.6: Average Total Flies of *B. oleae* Captured/Bait Trap In Two Olive Cultivar Fields (Balade and Nabali). Mean* ± S.E.

Olive Cultivar	Sex	CK	AA	PHE	PUT	TRIM	*P value***
Nabali	M	20.33^{c}±6.7	36.0^{c}±6.43	117^{a}±11.7	64.3^{b}±23.1	12^{c}±3.51	0.001
	F	5.67±2.67	18±3.46	8.33±2.19	31±21.3	6.67±2.03	0.371NS
	T	26^{b}±8.19	54^{b}±8.33	125.3^{a}±12.8	95.3^{ab}±42.5	18.67^{c}±5.36	0.019
Baladi	M	32.7±11.5	21±11.1	53.67±9.84	58±22.9	13±6.66	0.153NS
	F	10±3.06	5.67±3.28	2.67±0.33	16±9.54	7±3.79	0.442NS
	T	42.7±14.2	26.7±14.3	56.3±10.1	74±32.0	20.0±9.29	0.276NS

*: Means within each row with different letters significantly differ at *P* value ≤0.05 (Using Fisher's pairwise comparisons)

**: NS=Not significant at *P* value ≥ 0.05 (Using Fisher's pairwise comparisons)

Results presented in Table (3.6) showed that significant differences between the investigated attractant baits for mass trapping of *B. oleae* in Nabali fields, but no significant differences recorded in Baladi fields. Thus, in Nabali fields, sex pheromone demonstrated to be significantly, the highest attractant treatment to adult males of *B. oleae*, followed by putrescine, but, all other investigated attractants were with low efficiency in trapping males of *B. oleae*. However, no significant differences between the investigated attractants recorded in Baladi cultivar.

Chapter Four: Discussion

Chapter 4: Discussion

4.1: Flight Activity of *B .oleae*

Results of the present study showed that throughout two years of study (2011and 2012), the seasonal flight activity of *B. oleae* started in early July, and continued its activity throughout the season till the mid of November during 2011. While during 2012, the flight activity also started in early July, and continued its activity up to late November.

Present results also demonstrated three peaks of *B. oleae* flight activity were annually observed throughout the two years (2011& 2012), and those peaks were respectively recorded on August-September; October and finally in mid of November. In addition, the population of *B. oleae* was very high in the second peak of flight activity which coincides the repining period of olive fruits and before the harvesting.

Those results are similar to that concluded by Al-Zaghal, (1985), in Jordan, who also reported three generations, the first with a peak that appeared in late July, the second with a peak which appeared in early October and the third appeared near the end of October. Furthermore, In Syria, Lebanon, the olive fruit fly had 4-5 generations yearly depending on local conditions (Avidov and Harpaz, 1969; Vossen and Varela, 2006).

Furthermore, the present study noted the relationship between flight activities of *B. oleae* and the climatic conditions including temperature as well as humidity and rainfall, and thus, flight activity declines at temperature $\leq$ 10°C or $\geq$ 30°C, and the number of captured males\pheromone traps were observed to be highest at temperature range from 20-25°C. In addition, very low flight activity was recorded during the rainy periods. Thus, results of the present study were in agreement with those found by Rice *et al*., (2003), who reported that the flight activity of

adult *B. oleae* was mainly depended on temperature, fruit availability and seasonal phonology, and their attraction to yellow-panel sticky traps. In addition, Rice *et al*., (2003), found that also in the south California coast, flight activity declined as maximum daily temperatures rose above 32°C, but, it increased when temperatures were between 21°C and 28°C.

In addition, Economopoulos *et al*., (1982) reported that in Greece, when average temperature was below 9 °C, the olive fly did not show flight activity; also, as temperatures surpass 29°C, adult flies become increasingly agitated and above 35°C they are motionless (Johnson *et al*., 2011).

This research confirmed that throughout the season, the sticky yellow traps were more effecent in captuering *B. oleae* than the green sticky traps, but, both red and blue traps rarely captured olive fruit flies.

According to other workers, Yellow sticky trap was found to attract the fly more than orange, red, green, black, and white color trap (Neuenshwander and Michelakis, 1978). In addition, Katsoyannos and Kouloussis, (2001), reported that the yellow and orange spheres trapped the greatest number of males of *B. oleae.*

4.2: Rate of Fruit Infestation by *B. oleae*

Results of the present study demonstrated the relationships between rate of fruit infestation; flight activity of *B. oleae* and the environmental conditions throughout the two successive (2011and 2012) growing seasons. Thus, results showed that positive relationships were recorded between the percentage of fruit infestation and the flight activity of *B. oleae* during both 2011 and 2012 seasons. In addition, results indicated that the rate of fruit infestation is inversely related with the phenomena of biennial yield alteration of olive, and thus, high fruit production yield in 2012 (ON year = Massi) was accompanied with lower rate of infestation and high rate of

infestation was recorded to accompany the low fruit production yield in 2011 (OFF year = Shaltoni).

However, results of the present study show that, at 2011 which was with low fruit production (Shaltoni year), the rate of fruit infestation on Nabali cultivar was higher (90%) than that on Baladi cultivar (82%), but at 2012 which was with high production (Massi year), the rate of fruit infestation inversed to be higher on the Baladi cultivar (63%) than that on Nabali cultivar (40%).

Rice, (2000) explained that the infestation level on cultivars is characterized by a large drupe size (such as the Nabali cultivar) resulted usually higher than that one recorded on cultivars bearing small olives (such as the Baladi cultivar). In general, larger sizes and olives with higher water content are more susceptible for infestation than olives with lower water content. Also, olive hardness was proved to be another important factor in determining the choice of drupes for oviposition by *B. oleae* female (Martin, 1948; Orphanidis *et al*., 1958).

Other factors that possibly play a role include fruit size; weight; color; fruit epicarp hardness; surface covering; phonological stage of the crop; and chemical factors (Iannotta *et al*., 2007).

4.3: Mass Trapping *B. oleae*

In this study, five treatments were investigated in mass trapping technique using the MacPhil- tephri traps, to figure out which one is the best to attract *B. oleae.* Attractants were: ammonium acetate, putrescine, trimehylamine hydrocholoride which was used as food attractant baits; in addition to sex-pheromone traps, a control treatment (without attractant material) was uesd.

The results of this research indicated that the sex-pheromone was significantly higher in capturing of male of *B. oleae* than the other treatments, while putrescine was the most attractive baits to female of *B. oleae*. However, ammonium acetate was similar to control traps in attracting either males or females of *B. oleae*; and finally, trimethlymaine hydrochloride was not attractive to *B. oleae* and its rate of trapping to both sexes was even lower than that of the control treatment.

The results of the present study agreed with that of Vossen and Varela,(2006) who concluded that, yellow colored sticky traps baited with a male sex lure (Spiroketal pheromone capsule) and a feeding attractant capsule, were best to capture both male and female adult flies. In addition, food attractants used for trapping olive fruit fly including: ammonium acetate; putrescine and trimehylamine Hydrochloride were studied by Heath *et al*.(1995); and Katsoyannos, *et al.*, (2004) and found that putresine was a synergist to ammonium acetate, and that trimethylamine is asynergist to ammonium IAFA and VIENNA , 2003 acetate and putrescine. In addition, Papadopoulos, (2004) suggested that wet traps perform better for the olive fruit fly than dry ones, therefore, combination of food attractants with strong visual stimuli may result in the development of a powerful lure and kill system for olive fruit fly.

Conclusions and Recommendations

Conclusions:

- Flight activity of olive fruit fly was found to start at early July and continued until the end of November in Bethlehem area.

- *B. oleae* had three generations: the first generation was in August-September, the second one was in October and the third one was in mid of November.

- The climate changes (temperature and humidity) determined the beginning of the flight activity.

- The sticky yellow traps were more efficient in capturing *B. oleae* than the green sticky traps, but, both red and blue traps rarely captured olive fruit flies.

- Both olive cultivars were susceptible to olive fruit fly, and the rate of infestation was higher during the [(OFF season) year (2011)] than that during the [(ON season) year (2012)].

- Pheromone traps are the most effective for mass trapping of males, and putrescine is the most effective for mass trapping of females.

Recommendations:

- It is recommended to use Mass-Trapping Technique from the beginning of the flight activity starting from early July till end of November.

- It is recommended to conduct further studies on use of sex pheromone and putrescine together for the Mass-Trapping Technique against olive fruit fly.

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Appendixes

Appendixes

Appendix 1: Weekly Record of Captured Olive Fruit Flies (Male, Female, And Total) According To Color Of Traps. Mean ± S.E

Date	Sex	Yellow	Green	Red	Blue	*P value*
11 Jun 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
19 Jun 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
25 Jun 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.33±0.33	0.0±0.0	0.0±0.0	0.441NS
	T	0.0±0.0	0.33±0.33	0.0±0.0	0.0±0.0	0.441NS
2 Jul 11	M	0.33±0.33	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	F	0.33±0.33	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	T	0.67±0.67	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
7 Jul 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
14 Jul 11	M	0.33±0.33	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.33±0.33`	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
21 Jul 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
28 Jul 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
9 Aug 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
17Aug 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
24 Aug11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
29Aug 11	M	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	F	067±0.67	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	T	0.67±0.67	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
6 Sep 11	M	1.0±0.58	0.33±0.33	0.0±0.0	0.0±0.0	0.193NS
	F	0.0±0.0	0.33±0.33	0.0±0.0	0.0±0.0	0.441NS

	T	1.0±0.58	0.67±0.67	0.0±0.0	0.0±0.0	0.344NS
13 Sep 11	M	0.67±0.67	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	F	0.33±0.33	0.33±0.33	0.0±0.0	0.0±0.0	0.596NS
	T	1.00±1.00	0.33±0.33	0.0±0.0	0.0±0.0	0.528NS
20 Sep	M	0.33±0.33	0.0±0.0	0.0±0.0	0.0±0.0	0.441NS
	F	0.67^{a}±0.33	0.0^{b}±0.0	0.0^{b}±0.0	0.0^{b}±0.0	0.052
	T	1.00±0.58	0.0±0.0	0.0±0.0	0.0±0.0	0.95NS
8 Oct 11	M	5.33±2.73	3.00±3.00	0.0±0.0	0.0±0.0	0.258NS
	F	2.33±1.45	0.67±0.67	0.0±0.0	0.0±0.0	0.208NS
	T	7.67±3.84	3.67±3.67	0.0±0.0	0.0±0.0	0.209NS
15 Oct 11	M	12.67±7.75	4.00±1.53	0.00±0.00	0.33±0.33	0.163NS
	F	4.33±2.85	2.33±0.88	0.0±0.0	0.33±0.33	0.222NS
	T	17.0±10.6	6.33±2.33	0.00±0.00	0.67±0.67	0.180NS
22 Oct 11	M	19.3±15.3	5.00±2.31	0.33±0.33	0.67±0.33	0.333NS
	F	7.00±4.04	2.67±0.88	0.0±0.0	0.33±0.33	0.142NS
	T	26.3±19.33	7.67±2.19	0.33±0.33	1.0±0.58	0.275NS
4 Nov 11	M	29.7±26.2	8.33±5.84	0.0±0.0	0.0±0.0	0.409NS
	F	4.33±3.38	1.33±0.33	0.0±0.0	0.0±0.0	0.300NS
	T	34.0±29.6	9.67±5.67	0.0±0.0	0.0±0.0	0.392NS
15 Nov	M	30.0±24.6	6.67±4.06	0.0±0.0	0.67±0.33	0.347NS
	F	6.33±5.36	0.67±0.67	0.0±0.0	0.0±0.0	0.342NS
	T	36.3±30.0	7.33±4.67	0.0±0.0	0.67±0.33	0.346NS
25 Nov	M	24.7±19.4	9.33±4.81	0.00±0.00	0.00±0.00	0.324NS
	F	11.67±7.62	5.33±3.53	0.0±0.0	0.67±0.67	0.257NS
	T	36.3±27.0	14,67±7.4	0.00±0.00	0.67±0.67	0.292NS
8 Dec 11	M	7.0±4.36	1.33±0.88	0.0±0.0	0.0±0.0	0.159NS
	F	2.33±1.86	1.0±1.00	0.33±0.33	0.0±0.0	0.467NS
	T	9.33±6.17	2.33±1.86	0.33±0.33	0.0±0.0	0.223NS
24 Dec 11	M	3.00±1.73	6.00±6.00	0. ±0.0	0.0±0.0	0.506NS
	F	0.33±0.33	2.33±2.33	0.0±0.0	0.33±0.33	0.526NS
	T	3.33±2.03	8.33±8.33	0.0±0.0	0.33±0.33	0.524NS
20 Jan 12	M	3.67±2.03	0.33±0.33	0.0±0.0	0.0±0.0	0.94NS
	F	2.0±1.15	0.33±0.33	0.0±0.0	0.0±0.0	0.130NS
	T	5.67±3.18	0.67±0.67	0.0±0.0	0.0±0.0	0.105NS
24 Feb 12	M	0.00±0.00	0.00±0.00	0.0±0.00	0.0±0.0	*
	F	0.00±0.00	0.00±0.00	0.0±0.00	0.0±0.0	*
	T	0.00±00.0	0.00±0.00	0.00±0.00	0.0±0.0	*
13 Mar12	M	0.33±0.33	1.0±1.00	0.0±0.0	0.0±0.00	0.528NS
	F	0.33±0.33	0.0±0.00	0.0±0.0	0.0±0.0	0.441NS
	T	0.67±0.67	1.0±1.0	0.0±0.0	0.0±0.0	0.582NS
3 Apr 12	M	0.33±0.33	1.0±1.000	0.00±0.00	0.0±0.00	0.441NS
	F	0.0±0.00	0.0±0.000	0.00±0.00	0.0±0.0	*
	T	0.33±0.33	1.0±1.000	0.00±0.00	0.0±0.00	0.441NS
28 Apr	M	0.33±0.33	1.33±1.33	0.0±0.0	0.0±0.0	0.508NS
	F	0.0±0.0	0.33±0.33	0.0±0.0	0.0±0.0	0.441NS
	T	0.33±0.33	1.66±1.66	0.0±0.0	0.0±0.0	0.495NS

Appendix 2: Weekly Record of Captured Olive Fruit Fly (Male, Female, and Total) According To Food Attractant. Mean ± S.E

Date	Sex	CK	AA	PHE	PUT	TRIM	*P value*
2 July 12	M	2.0±1.44	13.5±4.33	6.17±2.81	13.67±2.81	1.17±0.54	0.253NS
	F	0.50±0.50	3.67±1.12	0.33±0.33	3.33±2.56	0.833±0.17	0.202NS
	T	2.50±1.93	17.17±5.36	6.50±2.99	17.5±12.5	2.0±0.63	0.248NS
7 July 12	M	0.33^{b}±0.21	5.67^{a}±1.76	0.50^{b}±0.34	2.83^{ab}±2.29	0.67^{b}±0.33	0.036
	F	0.0^{b}±0.0	3.0^{a}±1.03	0.83^{b}±0.40	0.50^{b}±0.50	0.17^{b}±0.17	0.005
	T	0.33^{b}±0.21	8.67^{a}±2.73	1.33^{b}±0.615	3.33^{b}±2.78	0.83^{b}±0.31	0.016
12July 12	M	0.0±0.0	1.33±0.49	0.0±0.0	1.83±1.83	0.7±0.17	0420NS
	F	0.0±0.0	1.0±0.82	0.0±0.0	1.17±1.17	0.0±0.0	0.492NS
	T	0.0±0.0	2.33±1.05	0.0±0.0	3.0±3.0	0.17±0.17	0.407NS
30 July 12	M	0.50±0.21	0.33±0.21	3.0±0.93	2.5±1.91	0.0±0.0	0.121NS
	F	0.0±0.0	0.0±0.0	0.0±0.0	1.0±0.68	0.0±0.0	0.105NS
	T	0.50±0.34	0.33±0.21	3.0±0.93	3.5±2.54	0.0±0.0	0.16NS
4 Aug 12	M	0.0^{b}±0.0	0.17^{ab}±0.17	1.3^{a}±0.56	1.3^{a}±0.71	0.0^{b}±0.0	0.042
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.83±0.83	0.0±0.0	0.426NS
	T	0.0±0.0	0.17±0.17	1.3±0.56	2.17±1.45	0.0±.0	0.132NS
11 Aug 12	M	0.0±0.0	0.0±0.0	0.67±0.494	0.33±0.33	0.0±0.0	0.316NS
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.67±0.494	0.33±0.33	0.0±0.0	0.316NS
25 Aug 12	M	0.67±0.67	0.17±0.17	0.83±0.48	0.67±0.67	0.0±0.0	0.687NS
	F	0.17±0.17	0.0±0.0	0.0±0.0	0.50±0.50	0.0±0.0	0.507NS
	T	0.83±0.83	0.17±0.17	0.83±0.477	1.17±1.17	0.0±0.0	0.716NS
1 Sep 12	M	0.17^{b}±0.17	0.0^{b}±0.0	1.50^{a}±0.62	0.33^{b}±0.21	0.17^{b}±0.17	0.015
	F	0.17±0.17	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.426NS
	T	0.33^{b}±0.33	0.0^{b}±0.0	1.50^{a}±0.62	0.33^{b}±0.21	0.17^{b}±0.17	0.033
8 Sep 12	M	0.17±0.17	0.0±0.0	0.83±0.40	0.67±0.42	0.0±0.0	0.113NS
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.17±0.17	0.0±0.0	0.83±0.40	0.67±0.42	0.0±0.0	0.113NS
14 Sep 12	M	0.0±0.0	0.0±0.0	0.17±0.17	0.0±0.0	0.0±0.0	0.426NS
	F	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	*
	T	0.0±0.0	0.0±0.0	0.17±0.17	0.0±0.0	0.0±0.0	0.426NS
23 Sep 12	M	0.0±0.0	0.17±0.17	1.67±1.12	0.0±0.0	0.0±0.0	0.111NS
	F	0.17±0.17	0.0±0.0	0.17±0.17	0.0±0.0	0.0±0.0	0.567NS
	T	0.17±0.17	0.17±0.17	1.83±1.14	0.0±0.0	0.0±0.0	0.09NS
29 Sep 12	M	0.17^{b}±0.17	0.0^{b}±0.0	3.17^{a}±0.54	0.17^{b}±0.17	0.0^{b}±0.0	0.000
	F	0.17±0.17	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.43 NS
	T	0.33^{b}±0.33	0.0^{b}±0.0	3.17^{a}±0.54	0.17^{b}±0.17	0.0^{b}±0.0	0.000
6 Oct 12	M	1.0±0.52	0.33±0.33	1.50±0.76	0.67±0.21	0.17±0.17	0.27 NS
	F	0.17±0.17	0.33±0.21	0.0±0.0	0.17±0.17	0.17±0.17	0.71 NS
	T	1.17±0.60	0.67±0.49	1.5±0.76	0.67±0.33	0.33±0.21	0.54 NS
14 Oct 12	M	0.17^{b}±0.17	0.50^{b}±0.342	13.33^{a}±5.7	0.0^{b}±0.0	0.3^{b}±0.3	0.003
	F	0.0±0.0	0.50±0.50	0.17±0.17	0.0±0.0	0.0±0.0	0.51NS
	T	0.17^{b}±0.17	1.0^{b}±0.82	11.50^{a}±6.2	0.0^{b}±0.0	0.33^{b}±0.33	0.031

20 Oct 12	M	0.67^{b}±0.94	1.33^{b}±0.67	5.3^{a}±1.93	2.0^{b}±0.78	0.33^{b}±0.21	0.012
	F	0.17±0.17	0.67±0.67	0.17±0.17	1.17±0.98	0.0±0.0	0.54 NS
	T	0.83^{b}±0.48	2.0^{ab}±1.26	5.5^{a}±1.95	3.17^{ab}±1.68	0.33^{b}±0.21	0.07 NS
29 Oct 12	M	2.83^{b}±1.2	0.33^{b}±0.33	14.2^{a}±3.46	3.83^{b}±1.14	0.50^{b}±0.22	0.000
	F	0.33±0.33	0.0±0.0	0.17±0.17	1.0±0.37	0.33±0.33	0.09 NS
	T	3.17^{b}±1.45	0.33^{b}±0.33	14.33^{a}±3.51	4.83^{b}±1.42	0.83^{b}±0.40	0.000
10 Nov 12	M	14.0^{ab}±4.49	3.83^{b}±2.62	26.5^{a}±6.78	29.2^{a}±13.4	8.0^{b}±3.02	0.77 NS
	F	4.50±0.89	2.17±0.95	3.17±0.65	13.50±9.44	4.17±1.38	0.370NS
	T	18.5±4.90	6.0±3.28	29.67±7.15	42.7±21.5	12.7±4.09	0.145NS
17 Nov 12	M	1.50±0.96	0.0±0.0	3.00±1.84	0.50±0.50	0.83±0.48	0.261NS
	F	0.33±0.21	0.33±0.21	0.0±0.0	0.17±0.17	1.0±1.0	0.634NS
	T	1.83±1.08	0.33±0.21	3.0±1.84	0.67±0.49	1.83±1.45	0.543NS
30 Nov 12	M	2.33±1.12	0.83±0.48	1.67±0.56	0.67±0.33	0.17±0.17	0.137NS
	F	1.17±0.54	0.167±0.17	0.50±0.34	0.17±0.17	0.17±0.17	0.140NS
	T	3.5^{a}±1.41	1.0^{b}±0.45	2.17^{ab}±0.48	0.83^{b}±0.48	0.33^{b}±0.21	0.05

Abstract in Arabic

دراسة حقلية حول بيولوجيا و بيئة و مكافحة ذبابة ثمار الزيتون (*Bactrocera oleae*) في المناطق الجبلية الوسطى في الضفة الغربية – فلسطين

الملخص باللغة العربية

تعتبر شجرة الزيتون من أهم أشجار الفاكهة المزروعة في فلسطين. و تعتبر ذبابة ثمار الزيتون من أهم الحشرات التي تنتشر في منطقة البحر الأبيض المتوسط ومن أهم الحشرات الرئيسية التي تصيب أشجار الزيتون حيث تبلغ نسبة الإصابة حوالي 80%.

تم تنفيذ هذه الدراسة في منطقة بيت لحم في الفترة 2011-2012، وقد هدفت الدراسة إلى مراقبة نشاط طيران ذبابة ثمار الزيتون ونسبة الإصابة في الصنفين ألنبالي والبلدي ,بالإضافة إلى دراسة استخدام تقنية المصائد مع الطعوم السامة والفيرومون في مكافحة الحشرة.

بالنسبة للهدف الأول للدراسة، أظهرت النتائج أن نشاط الحشرة بدأ خلال شهر تموز واستمر حتى شهر تشرين الثاني. كما تبين أن للحشرة ثلاثة أجيال: الجيل الأول ظهر في شهر آب وأيلول والجيل الثاني ظهر في شهر تشرين الثاني وظهر الجيل الثالث في وسط تشرين الثاني. كما تم الاستنتاج أن المصائد اللاصقة الصفراء كانت الأعلى فعالية في صيد الحشرة تلاها اللون الأخضر بينما ظهر أن كلا اللون الأحمر و الأزرق لم تكن جاذبة للحشرة.

بالنسبة للهدف الثاني للدراسة، أظهرت النتائج أن كلا الصنف من الزيتون البلدي (الرومي) و ألنبالي المحسن كانت حساسة للإصابة بذبابة ثمار الزيتون كما تبين أن نسبة الإصابة ترتفع في السنة الشلتونية (2011) عنها في السنة الماسية (2012).

أما بالنسبة لدراسة استخدام المصائد بالطعوم الجاذبة فقد أظهرت النتائج أن المصائد الفرمونية كانت فعالة في صيد الذكور بينما الطعم (Putrescine) كان الأعلى فعالية في صيد إناث ذبابة ثمار الزيتون.

و عليه يمكن التوصية باستخدام المصائد الفرمونية بالإضافة إلى الطعم الجاذب (Putrescine) معا و ذلك للسيطرة على آفة ذبابة ثمار الزيتون و ينصح بالبدء في نشر المصائد اعتبارا من بداية شهر تموز و لغاية نهاية موسم الحصاد في تشرين الثاني.