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Biological and Morphometric Studies of Fruit Flies Infesting Fruit Crops with Special Reference to *Bactrocera dorsalis*: A Review

Manoj Kumar Jena[1*], Sachin R. Patel[2] and Satikanta Sahoo[3]

[1]ICAR PG Research Scholar, [2]Assistant Professor, [3]Jr. Lectuerer

[1, 2] Department of Entomology, Navsari Agriculture University, Navsari-396 450, Gujarat, India

[3] Department of Botany, N.C. (Autonomous) College, Jajpur- 755007, Odisha, India

***Corresponding author: jenamanoj401@gmail.com**

Abstract

Fruit flies are one of the major threats to the horticulture sector in the world. They cause significant losses in the quality and yield of fruits and vegetable crops. They have attained the status of quarantine insect pest worldwide. Among them, the oriental fruit fly *Bactrocera dorsalis* (Hendel) is a very serious pest causing huge economic losses. The incubation period, maggot period, pupal period, adult male longevity, adult female longevity, total development period and mean fecundity are 1.5-3.5 days, 7.8-11.3 days, 10.3-12.6 days, 18.3-20.6 days, 20.4-23.9 days, 19.8-27.5 days and 132.7-189.5 eggs per female (12.4 ± 2.54 eggs/day) respectively. Average length and breadth of egg, full-grown maggots and pupae were about 1.36 ± 0.12 mm and 0.25 ± 0.13 mm, 8.18 ± 0.84 mm and 2.25 ± 0.70 mm, 4.08 ± 0.58 mm and 1.82 ± 0.69 mm respectively and the length of adult male and female flies measured about 6.20 ± 0.73 and 8.13 ± 0.69 mm respectively.

Keywords- Quarantine, biology, biometrics, *Bactrocera spp.*, tephretidae

Introduction

Fruit flies are economically important; their favourable hosts are mango, guava, peach as well as other fruits (Gafoor *et al*., 2010). The annual loss of fruits and vegetables by fruit flies are about 144.4 million US dollars (Stone house *et al*., 2002. The major pest species belong to the genus *Bactrocera* are *B. cucurbitae*, *B. dorsalis* and *B. zonata*, while other species, such as *B. correcta*, *B. diversa* and *B. latifrons*, are still localized in their distribution (Kapoor, 2005). The oriental fruit fly, *Bactrocera dorsalis* (Hendel) was first reported in Taiwan Island. It is the most destructive pest of horticultural crops around the world (Wei *et al*., 2017) and is a serious pest on a wide range of fruit and vegetables in the Indian subcontinent (Kamala Jayanthi *et al*., 2011). David and Ramani (2011) reported 325 species, of which 243 families and 79 genera are from India alone. The stage of ripening in the fruit provides the required choice for female flies to find the site at the time of oviposition (Ratna et *al*., 2016). According to Messina and Jones (1990), fruit firmness and the degree of fruit ripeness is considered to be a likely indicator of host quality for female flies.

B. dorsalis causes 100.0, 87.0, 78.0 and 61.0% fruit damage on guava, mango, peach and pear respectively in rainy season (Sharma *et al*., 2011). The females of *B. dorsalis* are usually attracted to oviposit eggs into ripe fruit (Vargas *et al*., 1995). For example, about 32% of *B. dorsalis* females preferred ripe guavas (Ratna *et al*., 2016) while Mohd Nur *et al*. (2011) showed that the ripened fruit is more suitable for larval development of *B. dorsalis* which allows easier penetration of ovipositor (Yashoda *et al*., 2007). However, a small number of *B. dorsalis* can also oviposit eggs into unripe fruits (Rattanapun *et al*., 2009).

Fruit fly menace is difficult to manage because of the fact that these are polyphagous, multivoltine, adults with high mobility, fecundity and all the developmental stages are unexposed (Sharma *et al*., 2011). Hence in order to prevent its spread and reduce damage, great efforts have been made to clarify its ecological adaptation and to develop methods to manage them without causing adverse effects on agroecosystem (Wei *et al*., 2017). So to know the advancement of damage and its distribution in different crops, there is enormous scope for gaining the knowledge on life cycle of this pest.

Biology

Fruit flies go through developmental stages; eggs, larvae (Three larval instars), pre-pupa, pupae and adult (White and Elson Harries, 1992). The adult female fly lay eggs in batches in groups of 4 to 5 under the skin of fruits with a needle-like ovipositor (egg laying tube at the tip of abdomen). While puncturing the fruit, the fly pushes bacteria from the skin into the flesh. These bacteria cause fruit decay, which results in a substrate in which the larvae feed (Drew and Lloyd, 1989; Fletcher, 1987). The role of these bacteria are complex and not yet fully understood and many authors regard their role as symbiotic although that is doubted by the others (Drew and Lloyd-1989; Girolami, 1983; Howard, 1989). Eggs hatch in 1 to 2 days under tropical conditions (24-270 C, 70% RH) (Sauers-Muller, 1991) to produce larvae that feeds on the fruits flesh, causing more decay and, in some cases, premature fruit fall. The larvae grows in size by moulting twice, defining three larval stages (instars). The larvae develops in the fruit for approximately 6 to 9 days (Sauers-Muller, 1991). When fully grown, the larvae escapes from the fruit, drops on the ground, burrows into the soil or organic matter for a short distance and its skin thickens and hardens to form a shell called a puparium, inside which the larvae transforms itself into the adult (White and Elson-Harries, 1992; Andrew and Anthony, 2006; Frias *et al*. 2006; Daniel *et al.* 2009).The adult flies emerge from the puparium and digs its way out of the soil or organic matter. Shortly after females emerge, they search for a protein meal to mature eggs. Studies have shown that plant surface bacteria are very important source of nutrients for the female flies (Drew, 1989; Drew and Lloyd, 1989; Lloyd, 1991). During this phase, flies may disperse quite large distances in search for protein sources. Females mate within 7 to 10 days of emergence and are ready to lay eggs when these become mature.

Eggs

Site and pattern of egg laying

Amur *et al.* (2017) revealed that the eggs of *B. dorsalis* on mango were laid in cluster form, which are embedded in the pulp of fruit vertically or slightly angled and twisting with each other.

Size, shape and colour of egg

The mean length and width of eggs of *B. dorsalis* were 1.30 ± 0.07 mm and 0.24 ± 0.04 mm (Singh *et al*. 2010), whereas these were 1.36 ± 0.12 mm and 0.25 ± 0.13 mm (Naik *et al*. 2017) respectively. The size of eggs were 0.5 mm - 0.6 mm reported for *B. dorsalis* (Kalia, 2015; Amur *et al.* 2017)

The eggs of *B. dorsalis* were white, shiny, rice shaped, slightly curved in to elongate tapering at anterior and posterior end on mango (Amur *et al.* 2017) while, these were elliptical, smooth, elongated, slightly curved and tapering at one end on custard apple. The posterior end is broadly rounded and the anterior end was found to be pointed and shiny white in colour and turned dark brown colour as they are nearer to the hatching (Naik *et al*. 2017).

Dale (2002) recorded that the length and breadth of eggs of *Bactrocera zonata* varied from 0.75 mm to 1.01 mm and 0.16 mm to 0.25 mm, whereas Leghari (2013) reported that the size of eggs varied from 0.5 mm to 0.6 mm for both *B. dorsalis* and *B. zonata*.

Incubation period

The incubation period of eggs of *B. dorsalis* was 1.5 ± 0.02, 2.32 ± 0.16 and 2.39 ± 0.01 days on mango varieties, Chunsa, Sindhri, Beganpali respectively (Kalia, 1992) while it was 1.3 ± 0.41 days (Singh *et al*. 2010). The observed average incubation duration of *B. dorsalis* was 2.0 to 3.25 days on different varieties of mango (Kalia, 1992) and 1.5 days on mango (Kalia and Yadav, 2005).The mean incubation period of the eggs of *B. dorsalis* on custard apple was 1.50 ± 0.48 days (Naik *et al*. 2017), whereas the laying and hatching period was 1-2 days reported for *B. dorsalis* (Leghari, 2013; Kalia, 2015; Amur *et al*. 2017).

According to Abu-Ragheef and Al-Jassany (2018), the incubation period were 8.7, 17.8 and 19 days at 30 ± 2^0 C, 20 ± 2^0 C and field conditions respectively. Ashoka and Javeregowda, (2019) found that the incubation period of the eggs of *B. dorsalis* on mango fruit under laboratory conditions was significantly maximum on Dasheri (3.5 days) followed by Neelum (3.0 days) and Rajgira, Pairi and Mallika (2.5 days). The mean incubation period was significantly lowest on Alphonso (1.5 days) followed by Benishan fruits (1.6 days).

The incubation period of *Daucus zonata* on guava ranged from 2 to 4 days in May-June as recorded by Atwal (1976). Kalia (1992) reported that the incubation period of *B. zonata* was 3.25, 3.00, 2.25 and 2.00 days on mango varieties, Dashehari, Amrapali, Mallika and Bangalora whereas, 3.50 and 2.25 days on guava cultivars, Allahabadi Safeda and Lucknow-49, respectively. The incubation period of eggs of *B. zonata* varied from 1 to 4 days on guava (Rana *et al*. 1992), whereas it varied from 1 to 2.5 days on mango (Dale, 2002). It was 10.16, 3.46, 2.04, 1.42, and 1.54 days at 15, 20, 25, 30 and 35^0 C respectively (Duyck *et al*. 2004). The laying and hatching period was 1-2 days reported for *B. zonata* (Leghari, 2013).

Hatching Percentage

The hatching percentage of *Bactrocera zonata* was 85 to 98 per cent (Rana *et al*., 1992) and 51-93.3 per cent (Quershi *et al.*, 1993) on guava; whereas on mango it was 66.67 to 91.67 per cent (Dale, 2002).Kumar and Agarwal (2005) revealed that the hatching percentage of *Bactrocera dorsalis* was 88.75 per cent.

Maggot (Larvae)

Number of instars

The larvae of *B. dorsalis* pass three instars with different size and morphology (Christenson and Foot, 1960; Weems *et. al*., 2015; Amur *et al*., 2017).

Colour, shape and size

According to Amur *et al.* (2017) the 1st instar was inactive and small in size as compared to two other instars. The 2nd instar had a distinguishing characteristic i.e. presence of externally visible alimentary canal. The fully grown 3rd instar larvae had visible characters. Third instar feed rapidly in the pulp of mango, formed the tunnels and holes in the fruit pulp and peel, come outside the fruit by holes of peel, fast move and Jump. Black mole on anterior and caudal side (Amur *et al*., 2017). Naik *et al*. (2017), revealed that the matured maggots were cylindrical, apodous, frugivorous with an elongated body, pointed anteriorly or cephalic end and blunt posteriorly. The black coloured mouth hooks were retractile and extended outside the body at the time of feeding. The freshly hatched maggot was pale white in colour with translucent body and later instars are turn to brownish yellow in colour

Kalia and Yadav (2005), recorded that the mean body length and width of the freshly hatched maggot and full grown maggot was 2.87 ± 0.74 and 0.40 ± 0.18 and 8.18 ± 0.84 to 2.25 ± 0.70 mm respectively, while Singh *et al*., (2010), reported that these were 3.8 ± 0.074 mm x 0.55 ± 0.10 mm and 8.02 ± 1.02 mm x 1.55 ± 0.17 mm for fresh and full grown maggots respectively.

Total larval period

Kalia, (1992) reported that the maggot period of *D. dorsalis* was 6.50, 6.00, 6.00 and 7.75 days, on varieties Dashehari, Amrapali, Mallika and Bangalora respectively, while Kalia and Srivastava (1992) showed that the maggot period was 9.25, 9.00, 8.50 and 6.0 days on fruits of four, three, two and one week before maturity of Amrapali variety. However, it was 9.50, 9.0, 8.25 and 6.0 days on variety Mallika. The larval development period was 7.75 days (Kalia *et al*., 1992) and 6.0 days (Kalia and Yadav, 2005) on mango.

Kalia and Yadav (2005), recorded the larval period of *B. dorsalis* as 7.5 ± 0.16 and 8.4 ± 0.33 days on mango and sapota, respectively, whereas Amur *et al*. (2017) inferred that the larval development duration was 6.51 ± 0.2 days on Chunsa variety and 7.5 ± 1.6 days on Beganpali and Sindhri variety. The variation in development of larvae on Chunsa variety was due to rich nutrients and the most sugary nature among all varieties.

Naik *et al.* (2017) observed that the larval development period was 8.50 ± 0.84 days while, Abu-Ragheef and Al-Jassany (2018) reported that the larval period were 8.2, 19.3 and 13.6 days at 30 ± 2^0C, 20 ± 2^0C (when the larvae feeds on artificial diet) and field conditions (when the larvae feeds on mandarin fruit) respectively. According to Ashoka and Javeregowda (2019) the mean maggot period of *B. dorsalis* was 11.3, 10.6, 10.2, 9.8, 9, 8.7, 8 and 7.8 days on Dasheri, Neelum, Rajgira, Pairi, Mallika, Totapuri, Alphonso and Benishan varieties respectively.

Duyck *et al*. (2004) revealed that the maggot development period of *Bactrocera zonata* was 30, 10, 5, 4 and 4 days at 15, 20, 25, 30 and 35^0 C respectively.

Pre-pupa

The full grown maggot of *Bactrocera dorsalis* came out from the fruit and become inactive before pupation. The pre-pupal period of *Bactrocera zonata* was 16 to 23 hours on mango (Dale, 2002).

Pupa

The pupation of *B. dorsalis* occurs in the moist sand (Naik *et al*. 2017) and that of *Dacus dorsalis* occurs in soil (Shah *et al*. 1948; Narayan and Batra, 1960; Christenson and Foote, 1960)

Colour, shape and size

The presence of black dot on the posterior portion of pupae of *B. dorsalis* (Kalia, 1992; Kalia and Yadav, 2015). According to Naik *et al*. (2017), the pupae were segmented, barrel shaped or cylindrical and yellowish white to deep brownish yellow when freshly formed. Later on, the colour changed into light brown to brownish grey with 11 distinct segments. They were of about 4.08 ± 0.5 mm in length and 1.82 ± 0.69 mm in width. Kalia, (1992) reported that size of pupae varied not only between different fruits like guava and mango but also among cultivars of mango.

Pupal period

Kalia (1992), recorded that the pupation period was 7.5, 8.0, 8.75, 9 days when reared using the mango varieties, Mallika, Amrapali, Bangalora, Dashehari respectively, whereas Kalia and Srivastava (1992) reported the pupal period as 8 to 10.50 days on Amrapali and 7.50 to 10.75 days on Malika. Kalia and Yadav (2005), reported the mean pupal period of *B. dorsalis* as 10.4 ± 0.30 and 11.7 ± 0.15 days on papaya and banana respectively. Jiji *et al*., (2006) reported that the pupal period of *B. dorsalis* was 10.50 and12.75 days on varieties, Neelum and Bangalora respectively, while ranged from 8-9 days, 8-11 days, 12 days on mango varieties, such as, Chunsa, Sindhri, Beganpali, of mango (Amur *et al*., 2017; Kalia *et. al*., 1992) and 12 days on banana (Kalia and Yadav, 2005; Jayanthi and Varghese, 2002).

Mohamed *et al*. (2017) revealed that there is a high number of pupae recovered from fully-ripe fruits (27.60 ± 8.87 pupae) followed by ripe (18.20 ± 7.59 pupae) and unripe fruits (4.60 ± 3.03 pupae). Abu-Ragheef and Al-Jassany (2018) reported that the pupation period were 10.8, 23.9 and 22.3 days at 30 ± 2^{0}C, 20 ± 2^{0}C and field conditions respectively, whereas The mean pupal period of *B. dorsalis* was 12.6, 12.3, 11.5, 11.4, 10.9, 10.8, 10.5, 10.3 days on Dasheri, Neelum, Rajgira, Pairi, Totapuri, Mallika, Alphonso and Benishan respectively (Ashoka and Javeregowda, 2019).

According to Rana and his co-workers (1992) the pupal period of *B. zonata* ranged from 7 to 10 days; However, it was found to vary from 7.03 to 40.9 days (Mohamed, 2000) on guava and 7.40 to 8.80 days on mango (Dale, 2002). Duyck *et al*. (2004) revealed that the pupa development period of *Bactrocera zonata* was 53, 20, 10, 8 and 8 days at 15, 20, 25, 30 and 35^0 C respectively.

Effect of Depth of Pupation Substrate on Adult Emergence:

Shehata *et al*. (2008) indicated that about 93, 90, 84.4, 75.4, 34.7, 0 % of peach fruit flies adult flies emerged at depth of 5, 10, 15, 20, 30 cm of sand respectively. Also, the percentage of malformed adults increased by increasing the depth, it ranged between 2.6 % to 20.6 % at depths from 5 to 30 cm.

Adult

Colour, size and shape

The adult fruit flies are noticeably larger than house fly, black to orange brown in colour and having a typical T shaped marking on the abdomen. The wings contain fuscous shedding (wing band) on the outer margin. On the apical margin of wing greyish brown patches were noted with black bands on the radio-medial veins (Kalia and Yadav (2015); Naik *et al.*, 2017). Adult size (8.1 mm) was maximum length of adults (Koul and Bhagat, 1994; Amur *et al.* 2017)

Time of Adult Emergence

According to Qureshi *et al*. (1974) *B. zonata* flies started emerging at 5:15 AM and 90% of adult flies were emerged between 7 AM 12 PM at noon, under conditions of 25 ± 2^0 C and 60- 65% R.H. This give an important criterian for choosing the proper time for releasing the irradiated pupae or adults in sterile release programmes. Sauer-Muller, (1993) reported that adult emergence was during morning hours, 9AM to 12 PM while, Shehata *et al.* (2008) indicated that about 26.7%, 23.3%,11.0% and 0% of adults of peach fruit flies emerged on the 1^{st}, 2^{nd}, 3^{rd} and 4th day of emergence. Also, most of adults emerged in the morning between 6 AM to 12 PM. The maximum number of emerged adults (about 83%) took place between 9 AM to 11 AM (during the 1st and 2nd day of observation) while on the 3rd day most of adult emergence took place between 6 to 9 AM.

Host Preference:

Shehata *et al.* (2008) indicated that the highest number of produced pupae and the highest percentage of adult emergence (93%) of peach fruit fly was recorded from pear fruits followed by guava, peach, apple and apricot, respectively. White, (2000) reported that *B. zonata* attacked wide variety of fruits especially peach, guava and mango. On the other hand, Kapoor (1989) stated that mango, guava and peach were the most preferred hosts for *B. zonata* adults.

Male

In adult male, the abdomen was blunt and smaller in size than that of the female. The length and breadth (wing expanse) of the male adult varied from 4.91 to 7.23 mm and 10.10 to 12.65 mm respectively. The longevity of male was 52.4 ± 8.74 in *Bactrocera dorsalis* on custard apple (Naik *et al*., 2017)

Female

Adult females were easily distinguishable by the presence of tapering abdomen extending into an ovipositor and comparatively larger than the males. The length and breadth (wing expanse) of the female adult was found to vary from 6.70 to 8.98 mm and 12.20 to 16.50 mm respectively. The longevity of female was 64.6 ± 9.72 days in *Bactrocera dorsalis* on custard apple (Naik *et al*., 2017)

Sex Ratio

Sex ratio (♂: ♀) among three different cultivars of mango such as, Chunsa, Sindhri, Beganpali was 1:3 (Batra, 1964; Shimada *et al*. 1981; Doharey, 1983; Kalia, 1992; Jayanthi and Verghese, 2002). Rana *et al.* (1992) observed that the sex ratio of male: female of *Bactrocera zonata* was 1:1.10 when reared on guava, whereas, it was 1: 1.11 on mango (Dale, 2002). According to Jayanthi and Verghese (2002) male to female ratio was 1: 1.00, 1: 1.70, 1: 1.10, 1:1.09 and 1:0.92 respectively when *Bactrocera dorsalis* was reared on papaya, mango, guava and Robusta and Ekaki varieties of banana.

Sex ratio may be affected by environmental fluctuations or food availability, and may be its natural phenomena. Sex ratio (♂: ♀) of *Bactrocera dorsalis* on different host such as Bannana, guava, papaya and sapota and mango 1:1.22, 1:1.1, 1:1.06 and 1:1 and 1:3 respectively (Shivyya *et al*., 2007; Waseem *et al*., 2012; Kalia, 2015).

Pre-oviposition period

The pre-oviposition period of *Bactrocera dorsalis* was 18-22 days (Saeki *et al.*, 1980; Qureshi *et al*., 1993; Shivay *et al*., 2007; Shehata, 2008 Kalia and Yadav, 2015 while it was 7 to 13 days on mango (Kumar and Agrawal, 2005).While studying the impact of varieties, Kalia (1992) reported that the pre-oviposition period was lowest (9.0 days) on Dashehari as against 12.66 days on Mallika as well as Bangalora and 17.33 days on Amrapali. However, in guava this period was shorter on Lucknow- 49 (12 days) in comparison to Allahaba Safeda (13.33 days). The variations in oviposition rate may be affected due to different cultivars of crops, or due to some physical parameters such as ripened and unripened fruits as well as the size of peel thickness and colour (Kalia, 2015; Amur *et al*., 2017).

Rana *et al*. (1992) reported that the pre-oviposition period of *Bactrocera zonata* was found to be 14- 17 days on guava whereas, on mango it varied from 12-14 days with an average of 13.20 days (Dale, 2002) and it was 10 to 14 days, with a mean duration of 12.1 ± 1.28 days (Naik *et al*., 2017). Abu-Ragheef and Al-Jassany (2018) reported that the pre-oviposition period were 26.4, 43.6 and 29 days at 30 ± 2^{0}C, 20 ± 2^{0}C (when the larvae feeds on artificial diet) and field conditions (when the larvae feeds on mandarin fruit) respectively

Oviposition period

According to Rana *et al*. (1992), the oviposition period of *Bactrocera zonata* on guava was 12-17 days; whereas, it was 13 to 18 days with an average of 15 days on mango (Dale, 2002).

Post-oviposition period

Post-oviposition period of *Bactrocera zonata* was found to be 16-43 days on guava (Rana *et al.* 1992) and it was 21 to 26 days with an average of 22.8 days on mango (Dale, 2002).

Abu-Ragheef and Al-Jassany (2018) inferred that the post-oviposition period of *Bactrocera zonata* were 4.2, 9.4 and 5.3 days at 30 ± 2^{0}C, 20 ± 2^{0}C (when the larvae feeds on artificial diet) and field conditions (when the larvae feeds on mandarin fruit) respectively.

Fecundity

Naik *et al*. (2017) recorded that each female of *Bactrocera dorsalis* laid a mean of 12.4 ± 2.54 eggs/day with a mean total fecundity of 371.9 ± 60.78 eggs/female during its life cycle. According to Ashoka and Javeregowda (2019) the fecundity of *B. dorsalis* varied in the different mango genotypes. Highest fecundity was recorded on Benishan and Alphonso with 189.5 eggs and 187.4 eggs followed by Totapuri (167.9 eggs) which were at par with each other. Mallika recorded 166.3 eggs. Further, Pairi (152.8 eggs) and Rajgira (146.0 eggs) were found at par with each other. Rajgira was at par with Neelum (142.6 eggs). Significantly the lowest fecundity was observed on Dasheri (132.7 eggs).

Narayanan and Batra (1960) recorded on an average 50 eggs of *D. dorsalis*, but under favourable conditions they observed 150-200 eggs per female in a period of one month.

Rana *et al.* (1992) reported that single female of *Bactrocera zonata* laid 191 to 259 eggs, when reared on guava, whereas, it was between 121 to 146 per female on mango (Dale, 2002).

Longevity

Jiji *et al*., (2006) reported adult longevity of *B. dorsalis* in the variety Neelum and Bangalora was 16.50 and 20.30 days respectively. According to Ashoka and Javeregowda (2019) the longevity of *Bactrocera dorsalis* on mango varieties were almost same there is no variation occurred. The adult longevity of male obtained from maggot reared on different mango genotypes varied from 18.3 to 24.0 days. Maximum male adult longevity (20.6 days) was observed on Benishan followed by the Alphonso (20.1 days) Pairi and Rajgira (18.8 days each) both were at par with each other. Minimum male adult longevity was recorded on Dasheri and Neelum (18.3 days) and maximum female adult longevity (23.9 days) was observed on Alphonso followed by Benishan and Mallika (23.4 and 22.1 days). Totapuri and Rajgira recorded 22.0 days and both were at par with each other. Minimum female adult longevity was recorded on Dasheri and Neelum (20.4 and 20.7 days).

Rana *et al.* (1992) revealed that the longevity of *Bactrocera zonata* males varied from 36 to 53 days with an average of 44.3 days, while it was 47 to 72 days with an average of 58.2 days for the females reared on guava. Similarly, the longevity of *Bactrocera zonata* male on mango varied from 37 to 42 days with an average of 51 days for female reared on mango (Dale, 2002).

Total life cycle

According to Rana *et al*. (1992), the total life cycle of male *Bactrocera zonata* varied from 56.4 to 73.4 days and that of female varied from 67.0 to 92.4 days when reared on guava fruit. The total life cycle of male and female *Bactrocera zonata* varied from 53.05 to 61.35 and 66.27 to 72.92 days, respectively on mango (Dale, 2002). Kalia and Yadav, (2015) recorded that the developmental period of *B. dorsalis* was 20.3 ± 0.44 and 21.6 ± 0.88 days on banana and sapota respectively. The total life cycle from egg to adult emergence of *B. dorsalis* recorded 5 to 11 day on mango (Singh and Teotia, 1970), 3 to 8 days on mango (Doharey, 1983), 15 days on mango (Shivarker and Dumber, 1985). 8 to 10 days on mango (Amur *et al.*, 2017), 18 to 23 days, with a mean of 20.3 ± .82 days on custard apple (Naik *et al*., 2017). The variation in larval developmental time may be because nature, type and variety of host.

The life cycle of *Bactrocera dorsalis* on mango was 16-18 days (Kalia *et al*., 2005; Amur *et al*., 2017). Doharey, (1983) reported shorter life cycle on mango 19.8 days whereas Jayanthi and Verghese, (2002) reported longest life cycle on mango 25.0 day. It may depend on varietal contents because some varieties of mango are very juicy and more sugary, therefore, life cycle rapidly developed, but some were fibrous and less sweet in test, the life cycle of *B. dorsalis* took some time for development in such cases.

The life cycle of *B. dorsalis* took lesser duration on mango variety Mallika (15.75 days) followed by Amrapali (17.00 days), Bangalora (18.50 days) and Dashehari (18.75 days) (Kalia, 1992) while, Abu-Ragheef and Al-Jassany (2018) reported that the life-cycle duration were 16.9, 37.1 and 32.6 days at 30±2^{0}C, 20±2^{0}C (when the larvae feeds on artificial diet) and field conditions (when the larvae feeds on mandarin fruit) respectively. According to Ashoka and Javeregowda (2019) the total developmental period from hatching of maggot to emergence of adults from pupa was significantly longer on Dasheri (27.5 days) followed by Neelum (26.0 days). Remaining mango genotypes to follow were Rajgira (24.2 days), Pairi (23.8 days), Mallika (22.3 days), Totapuri (21.7 days) and Alphonso (20.0 days). However, it was found to be shorter on Benishan (19.8 days). These results indicated that, the unusual nutrients quality of Dasheri and Neelum for *B. dorsalis* might require prolong feeding relative to other mango genotype such as Benishan and Alphonso.

Number of Generations per Year

Saeki *et al*. (1980) mentioned that *B. dorsalis* (Hendel) have three to eight generations per year whereas *Rhagoletis spp.* (Temperate species) are usually univoltine but Tropical pest species of *Anastrepha*, *Bactrocera*, *Ceratitis* and *Dacus* are typically multivoltine (Zwolfer, 1983; Fletcher, 1989). Qureshi *et al*. (1993) stated that *B. zonata* can complete three to nine generations per year in various parts of its range. Again, Mahmoud (2004) recorded that *B. zonata* could complete eight to nine generations per year. Generally, it could be say that *B. zonata* could complete eight to nine generations per year depending upon the environmental conditions all over the year. According to Shehata *et al.*, (2008) *B. zonata* completed eight successive generations per year. The dates of beginning and ending of each generation besides the different biological stages in addition to the averages of temperatures and relative humidities during each generation. The longest period of generation was 56 days; from 1st January to 25th February (from adult to adult); and 49 days from 2nd February to 23rd March (from egg to egg) at temperatures ranged between about 16.76 C° and 21.1° C and average relative humidities between 58.9% and 63.7%. The shortest periods of generation was 34 days, it occupied the months of July, August till the 9th September where the recorded average temperatures was about 29.75 C° and the average relative humidity was about 67.3%. Generally, the shortest periods of generations (5, 6 and 7) were recorded during summer months and the longest periods of generations (1 and 2) were occupied the winter, spring and the beginning of summer months.

Conclusion

India is a major producer of fruits and vegetables in the world and contribute to a greater extent in the world market. So there is a need for accounting the plant protection measures to ensure the better production of the crop as the fruit fly is being threats to the crop in the recent days. Understanding the biology of fruit fly on fruit crops help to know the damaging stages, weak link in the life cycle as well as in making decision regarding the application of crop protection measures.

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