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Review

Biology and management of ber fruit fly, *Carpomyia vesuviana* Costa (Diptera: Tephritidae): A review

Karuppaiah Vadivelu

Central Institute for Arid Horticulture (ICAR), Bikaner, Rajasthan-334006, India.

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Ber fruit fly, *Carpomyia vesuviana* Costa (Tephritidae: Diptera) is one of the notorious monophagous pests of ber in India, Pakistan and Middle East countries. The fly infest most of the *Ziziphus* species grown in the world and cause the damage internally and in serious case it causes severe yield loss up to 80% or even upto 100% damage. The external temperature, relative humidity and rainfall and soil moisture, soil temperature and soil depth are found to be critical factors for the activity and the adult fly emergence from soil. The favourable temperature for pupal development and adult emergence is 30°C, pupation at 3 to 6 cm depth of soil was ideal for adult emergence. Alternating rainfall ranging from 20 to 40 mm and 62 to 85% relative humidity also promotes fly activity. Prophylactic measures are the essential components for the successful management of *C. vesuviana*. Field sanitation, destruction of wild bushes, collection of infested fruits and summer ploughing to expose the overwintering pupa to hot summer breaks the reproduction cycle of fly. Growing of resistant cultivars like Tikidi, Umran, Mundia, Banarasi, Sanaur-1, Safeda selection, Illaiciihi, Mirchia, Zg-3 and Chhuhara would give better yield and also reduces the protection cost. However, synthetic chemicals are presently employed as major tools against fruit fly, organophosphate and synthetic pyrethroid insecticides are in extensive use. Availability of potential biocontrol agents and botanic pesticides are very limited. Therefore, it is necessary to incorporate the all available tactics in integrated manner and incorporation of neem based formulations and biological pesticide, spinosad, bait application, male annihilation technique are essential to manage the *C. vesuviana* in a successful manner in the scenario of organic cultivation.

Key words: *Ziziphus* sp., *Carpomyia vesuviana*, bio-ecology, integrated pest management (IPM).

INTRODUCTION

Fruit fly, *Carpomyia vesuviana* Costa (Diptera: Tephritidae) is the most destructive pest of ber, a multipurpose tree that supplies fruit, timber, fuel wood and also fodder (Joshi and Shinde, 1971; Lakra, 1998; Muhammad, 2006; Kavitha and Savithri, 2002; Zavitha et al., 2002; Balikai et al., 2013). It is the monophagous pest that infesting only on *Zizyphus* species growing under arid and semi arid region in Oriental Asia India also in,

E-mail: karupsciah@gmail.com
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Table 1. Host range.

Species	References
Z. zizyphus	Sohi et al. (1990)
Z. mauritiana	Ahmed et al. (2005), Farrer et al. (2004), Singh (1984), Lakra (1984), Bagle (1992)
Z. spina-cheresti ; Z. numularia; Z. lotus	(Lakra (1984), Farrer et al. (2004)
Z. jujube	(Joshi and Shinde (1971), Berdyeva (1978)
Z. sativa	(Bagdavadze (1971), Giray (1979)
Z. rotuntifolia	Lakra and Singh (1984)

Middle East, Temperate Asia, China and South Europe (Kapoor, 2005; Kirichenko, 1940; Stonehouse et al., 2002; Hu et al., 2010; Farrar et al., 2004). The pest contributes towards low yield and poor quality of fruits and it causing loss up to 80% under severe infestation (Batra, 1952; Cherian and Sundaram, 1941; Karuppaiah et al., 2010). The incidence of *C. vesuviana* reduces the yield from 13 to 20% per plant (Bagle, 1992), 90 to 100% (Joshi and Shinde, 1971). In Georgia the *Carpomyia* attacking *Z. sativa* causes more than 70% losses (Bagdavadze, 1977). The ber species *Z. jujube* was infested severely by *C. vesuviana* and it causes up to 60 to 70% fruit damage in Turkmenia (Berdyeva, 1978). In Iran the intensity of damage was 30 to 100% (Farrar et al., 2003).

The brownish yellow adult flies are emerges from the soil and starts to infest on ber fruits at pea stage. Adults inserts the eggs on the young developing fruits by making puncture with small cavity using protrusive ovipositor just below the epidermis of the immature fruits (Lakra and Singh, 1983; Dashad et al., 1999). Thus, newly emerged maggots' starts to feed on the pulp and making the galleries with accumulated excreta. In severe case infestation may cause the fruit deformation and finally leads into fruit drop (Lakra and Singh, 1989). Since the maggots causing internal damage, the curative measures using chemical insecticides are showing unsatisfied results. Therefore, it is essential to explore prophylactic and curative measures together to manage this pest successfully. Besides the synthetic insecticides, incorporation host plant resistance along with bio-control agents and botanical pesticides would give satisfactory control than single approach. Hence, the documented information about *C. vesuviana* has been reviewed in this paper to explore the available technologies for the successful management.

HOST RANGE AND DISTRIBUTION

The infestation of *C. vesuviana* has been observed in all wild and cultivated species *viz*., *Z. zizyphus, Z. mauritiana, Z. spina-cheresti, Z. numularia, Z. lotus, Z. jujube, Z. sativa* and *Z. rotuntifolia* (Table 1). The distribution is found in all the ber growing region of India and world. The occurrence of this pest is reported in many countries like India, Pakistan, Iran, Georgia, Bangladesh, Turkey, Turkumenia, Mauritius, Indian Océan Island, Uzbekistan, Temperate Asia, China and South Europe and Oman (Table 2).

NATURE AND EXTENT OF DAMAGE

The infestation starts at onset of fruiting, adult fly lays eggs singly in the young developing fruits after 2 to 5 days. Upon hatching, the maggots feed on the pulp and create galleries with accumulated excreta and results in rotting of fruits. The infested fruits are become deformed and their growth gets retarded in severe cases such fruits are drop off (Singh, 2008). The fruit fly damages flowers and fruits and the adults puncture the ripening fruits and lay their eggs inside the epidermis the young maggots feed on the fleshy and juicy pulp of fruits (Gupta and Sharma, 2006; Lakra and Singh, 1989). The maggots burrow in to the flesh around the centre leaving excreta that give fruits a bitter taste (Bagdavadze, 1977). The full grown larvae come out by making hole in the fruit skin and drop to the ground for pupation.

Variations in the damage intensity found to be associated with external factors like, rainfall, relative humidity and temperature (Lakra and Singh, 1985). However, the physical factors like soil moisture, soil temperature and soil depth also found to play a crucial role in the adult fly emergence from soil. The optimum temperature for pupal development was 30°C leading to high adult emergence (74%) and short pupal duration (15.65 days) at 10, 16 and 40°C no adult emergence up to 50 days and 3 to 6 cm pupation depth was ideal for adult emergence (Sangwan and Lakra, 1992). High temperature >40ºC and low relative humidity <20 to 30% was unfavorable and prolonged immature stage occurs at temperature beyond 5°C. The intermittent light rainfall ranging from 20 to 40 mm also promotes fly activity and moderate and heavy rainfall, 50 to 120 mm per week curtails the activity (Lakra and Singh, 1985). The incidence of fruit fly was high when the relative humidity was 62 to 85% and temperature ranging between 17 and

Table 2. Geographical distribution of *C. vesuviana.*

Country	References
India	Batra (1953), Cherian and Sundaram (1941), Basha (1952), Saen (1986), Jothi and Tandon (1995), Patil et al. (1997), Balikai (1999), Kavitha and Savithri, (2002), Balikai et al. (2013)
Pakistan	Abhasi et al. (1994), Stonehouse et al. (2002), Ahmed et al. (2005), Sarwar (2006)
Iran	Farrar et al. (2004), Farrar and Chou (2000)
Georgia	Bagdavadze (1977)
Turkey	Giray (1979)
Turkmenia	Berdyeva (1978)
Mauritius	(Sookar et al. (1998), White et al. (2000)
Indian ocean islands (Rodrigues, Seychelles)	White et al. (2000)
Uzbekistan	Kimsanboev et al. (2000)
Oman	Azam et al. (2004)

25.5°C and minimum at 2.3 to 4.8°C (Dashad et al., 1999). The relationship between the pest incidence and temperature was positive and it was negative with relative humidity, wind speed and cloud cover (Nandihalli, 1996). The intensity of damage is influenced by the surviving pupa of preceding years (Dashad, 1999). The early maturing varieties had higher infestation than late maturing verities (Singh, 2002). The larvae bore down into the soil up to a depth of 2 to 12 cm where it pupates (Batra, 1953).

STATUS OF *C. VESUVIANA* IN INDIA

In India, the time of activity and number of generations found to be varies with season from region to region (Table 3). In northern states of India, the infestations occur from November to April and activity was very high during fruit maturity. There may be a 2 to 3 generation per year (Batra, 1953) and incidence was most abundant in December and least in March (Lakra and Singh, 1983) and it was 6 to 9 overlapping generation per year (Larka and Singh, 1986). The pupa hibernates in soil during April to August lead to the unusual activity of fly during off season fruits of *Z. zizyphus* at Punjab (Sohi et al., 1990). The shortest generation time 23 days was recorded in the eggs laid on September (Larka and Singh, 1986). In the central part of India (Gujarat) the fruit fly infestation starts around mid October and increased suddenly in mid November, continuing till December (Bagle, 1992). In the Southern state, Karnataka*, in Z. mauritiana* the activity of *C. vesuviana* is prevalent from fortnight of December to fortnight of February (Nandihalli, 1996).

BIOLOGY

Life-cycle of the fruit flies varied with environmental factors. Adults are small yellowish brown fly little smaller than the common housefly having brownish bands on hyaline wings and black spots on the thorax. The pre oviposition, oviposistion and post oviposition periods lasted after 2 to 12, 3 to 44 and 0 to 14 days, respectively and about 80% of the females deposited eggs after 3 to 7 days and laid an average of 22.99 eggs. The egg stage was 1 to 4 days with the viability of 70.21 to 94.44%, and the larval period found to be 7 to 24 days and pre-pupal stage was 3 to 8 h (short 5 to 42 days) long (43 to 122 days) cycle pupation occurred in 80 and 20% of pupa, respectively. The pupal duration was more in November, December and April (Lakra and Singh, 1986). The incubation period was 2 to 5 days and of larval and pupal stage was 9 to12 and 2 weeks, respectively (Batra, 1953). The fly larvae enter soil and pupate after 3 to 4 h in puparia that over winter in the soil around the tree trunks and occasionally pupation takes place with infested fruits (Bagdavadze, 1977). Adult emergence from pupa between 9 and 14 h, pairing and oviposition occur during day light hours at night the flies usually rest in the tree canopy and its complete two generation per year at Turkmenia (Berdyeva, 1978). The adult longevity was 3 to 48 days in lab and it varied respect with month. The sex ratio was 1:1 and pre-oviposition, oviposition and post oviposition periods lasted 2 to 8, 3 to 35 and 0 to 12 days. Females laid averagely 19.1 ± 5 eggs, generally 1 to 4 ovipunctures per fruit. About 72% of the egg laying was occurs between 3 to 7 days and higher fecundity during November, February and lower in March. The incubation period was 1 to 4 days and 70.4 to 91.9% of eggs were viable. The larval and pupal period was long during December and short during March and the average was 6 to 22 days and 8 to 320 days. The maggots took 1.8 to 5 h to pupate. The shortest pupal duration 8 days was observed in March to April and longest 320 days in September. The eggs laid during march April and January had shortest life cycle and eggs laid in September October had the life cycle duration of320 days. The fly completes about 8 to 10 overlapping

Table 3. Season of activity of *C. vesuviana* in India.

Month of activity	State	Reference
August-October	Uttar Pradesh	Gupta and Sharma (2006)
October-December	Gujarat	Bagle (1992)
December-February	Karnataka	Nandihalli (1996)
August-September (on *Z. numularia*) 'July - April (on *Z. mauritiana*)	Haryana	Lakra and Singh (1985)
July - February	Andhra Pradesh	Kavitha and Savithri (2002)

Table 4. Resistance cultivars to *C. vesuviana.*

Cultivar	Remarks	Reference
Sanaur-1, Safeda selection,Illacihi, Chinese, Mirchia, Zg-3,Umran	Resistant	Mann and Bindara (1976)
Tikidi	Resistant	Singh (1984)
Gola, Illaichi	Moderately resistant	
Tikidi, Illaichi	Resistant	Sharma et al. (1998)
Umran,Tas bataso, Deshi Alwar, Kismis	Moderately resistant	
Cv. Illaichi, Chhuhara	Resistant	Nandihalli et al. (1996)
Tikidi, Mundia	Moderately susceptible	Pareek et al. (2003)
Tikidi	Highly resistant	Pramanick et al. (2005)

generation in a year (Farrar et al., 2003).

INTEGRATED MANAGEMENT STRATEGIES

Fruit fly, *C. vesuviana* cause damage internally and it is very difficult to manage this pest without insecticides. The egg laying can reduce by prophylactic spraying. The maggot has the low possibilities to expose against key mortality factors like harsh environment, pathogen predators and parasites. The lack of early detection techniques also boosts the pest population built-up. Apart from this, the fruits are harvested with short intervals for consumption and it is consumed directly by consumers. In the consumption point of view it will not be recommended to rely on pesticides as a major component to mange this pest. Hence it is necessary to include eco-friendly soft pesticides with low residual toxicity and short waiting period (Table 4).

PROPHYLACTIC MEASURES

Clean cultivation

Field sanitation is an effective preventive measure in fruit fly management and need to be done systematically as a primary component to break the reproduction cycle and minimize the population built up and infestation (Singh, 2008). The residual pupae are the major source of infestation, which is present in the surrounding of the tree trunk through the physiological adaptation like aestivation and hibernation (Singh et al., 1973). The collection of all fallen, bird damaged and infested fruit at regular interval that is twice in a week from fruit setting to harvest and proper destruction and feed such fruits to sheep goats, camels or other farm animals or bury them at least on one meter deep in compact soil can avoid the fly's emergence (Srivastava and Nanda, 1983; Lakra, 1998). Birds attack on unripe and semi ripped fruits results in a built up of initial population of tephritids causing heavy losses at later stage of crop (Grewal and Kapoor, 1986). Harvesting of matured fruits before the colour change (green to yellow), deep and through raking up of soil and ploughing the orchards during hot summer and winter months expose the pupae to drastic environment and natural enemies. Cultural operation also been destroy the over wintering pupae through mechanical injury during the operations (Lakra, 1998). Clean cultivation surrounding the areas of orchard by destroying burning and destroying the pruned parts of cultivated as well as the wild bushes (*Z. numularia, Z. mauritiana* var. *rotundifolia*) which serve as a good source of multiplication and help in carrying over of fruit fly to cultivated ber species (Chauhan and Yadav, 2000). The early fruit setting and off season fruit bearing of wild bushes provide link to breed and switch over to main crop. Early harvesting of fruits at colour change stage,

avoiding the over ripening of fruits on trees also promote less survival of fruit fly (Lakra, 2004). Cultivation of orchards soil during spring (Singh et al., 1973a), summer (Chundawat and Srivastava, 1978) and rainy season (Bakhshi and Singh, 1974) destroy the hibernating pupae by exposing them to bright sunlight and birds making the considerable reduction in the infestation. Heating of soil by burning grass and irrigation during summer also kill the pupae (Singh, 2008).

Host plant resistance

Host plant resistance promotes cumulative protection against fruit fly without any environmental hazards with least management cost (Singh, 1984; Singh and Vashistha, 1985; Sharma et al., 1998). The success of developing varieties which is resistance against the fruit fly has the limitations like crossable barriers, heritability of quality characters and less availability of resistance source etc. Use of biotechnological tools to transfer the resistance gene from the source genotypes to cultivated genotypes could be a better option. However, in India some successful work has been reported in the resistant breeding programme (Table 4). Faroda (1996) attempted cross between Seb x Tikidi and obtained F_1 generation showed 90% resistant with poor fruit quality and backcrossed BC_1 line showed 87 to 90% resistance and desirable fruit characters. None of the *Z. mauritiana* cultivars were immune to the fruit fly but it has wide range of susceptibility from 10 to 50% damage (Sharma et al., 1998). The expression of resistance also depends up on the bio physical and bio chemical characters of fruits. The cultivar with moderate sugar content and hard texture of fruit coupled with resistant to fruit fly (Pramanick et al., 2005). The adult flies avoid egg laying in the fruits which are less than 9 × 4.5 mm size and lay more than 50% of the eggs in 20 × 9 mm size fruits (Lakra and Singh, 1983). The mechanism of resistance such as antibiosis and non preference in ber genotypes against fruit fly has been studied by and certain cultivar for egg laying and no significant variation among them respect to egg laying, same time significance variation was observed in the larvae hatching indicate the antibiosis (Singh, 1984). The infestation of fruit fly was positively correlated with fruit weight, pulp stone ratio, total soluble solids and total sugars and negatively correlated to acidity, vitamin C and total phenol (Arora et al., 1999). Fruit size, fruit weight and pulp ratio showed positive correlation with fly infestation and cultivar with round fruits and early varieties contributing higher infestation (Singh and Vashishtha, 2002). The early maturing cultivar with moderate to bigger fruit size, sweet soft and thin skinned, more juicy and attractive flavoured pulp are more susceptible to fruit fly (Saxena and Rawat, 1968). Varieties such as Kakara, Umran, Mundia, Banarasi and Chhuhara exhibited fewer incidences of *C. vesuviana* and Gola, Kaithali and Ajmeri showed higher incidence.

Biological control

There is no successful record of parasitoids, predators and pathogens against the *C. vesuviana.* Singh (1989) reported that the braconid *Biostres vandenboschi* Fullaway as a parasitoid of *Carpomyia* from India but the proportion was very negligible. The parasitoids *Bracon fletcheri, Opius carpomyia* and *Omphalia* sp. were also noticed (Kavitha and Savithri, 2002). However, the population reduction of pest was not insignificant (Saxena and Rawat, 1968). The wasp parasitoid *Fopus carpomyia* was found at larval stage of fruit fly and the ovipositor is very suitable to parasitize the hidden host in fruits. The rate of parasitization was 21 to 26.7% (Farrar et al., 2004). The successful suppression of *C. vesuviana* with parasitoid can made through the augmentative release. The lack of mass culturing and efficacy testing techniques should be developed to overcome this bottleneck by generating new ideas for the practical application in the integrated management programme.

Chemical control

Management of ber fruit fly is mostly depending upon the chemical insecticides along with botanicals. Though it is unsatisfactory, the lack of alternative best approaches like attractive baiting and male annihilation with lures and management with biological pesticide has not yet developed against this pest. Moreover, pest can be managed below the economic threshold through the proper insecticide schedule. Spraying of Malathion (0.05 %) during January showed better control of fruit fly (Joshi and Shinde, 1971) and fenthion found to be most effective when it was applied 3 times in a season (Patel et al., 1989).

Two application of 0.2% dichlorvos at the pea stage of the fruits and 15 days later gave the better control than the monocrotophos 0.036%, malathion 0.05% and phasalone 0.07% (Ragumoorthi and Arumugam, 1992). Dimethoate, fenthion, phosphomidon and deltamethrin were most effective and endosulfan was the least effective against *C. vesuviana* (Patel, 1990).

The syntheytic pyrethroids fenvelarate 0.005% and decamethrin 0.0015% showed consistent action against the fruit fly activity (Bagle, 1992). Diptrex at onset of fruiting showed significant reduction in larval infestation (Abbasi et al., 1994). Soil application of fenitrothion or quinalphos dust at 20 kg/ha under the canopy showed 80 to 95% reduction in adult emergence (Lakra et al., 1991). The schedule comprising 0.03% dimethoate in late October and early November and second spray after 45 days followed by 0.075% endosulfan followed 0.1% carbaryl later 0.05% malathion with 1% sugar solution at

10 days interval proved effective against this pest (Lakra et al., 1991). Insecticides schedule consist of monocrotophos 0.03%, fenthion 0.05% and carbaryl 0.01% at 15 days interval were most effective (Dashad et al., 1999). Spraying of dimethoate followed by eco-neem was showed good reduction in infestation (Singh et al., 2008) and lowest incidence of *C. vesuviana* was observed with lambda cyhalothrin 0.0025% followed by 0.0018% beta-cyfluthrin (Gyi et al., 2003). Application of fenthion 0.1% at pea stage and second spray 30 days later showed lowest fruits damage. The extract of azadiractin 1% and *Ocimum sanctum* 1% were effective up to 10 days after spraying (Rajaram and Siddeswaran, 2006). Dipterex, imidacloprid, triazophos and neem products are notable insecticides against ber fruit fly (Abbasi et al., 1992; Singh et al., 2000). The integrated management with dipterex 100g/ acre+ 5% molasses baiting and hoeing and collection of fallen fruits throughout the season proved better than single treatment applied trees (Ahmed et al., 2005). Application of neem powder and tobacco extracts significantly reduced the infestation of *C. vesuviana* and they are the potential candidates for organic cultivation of ber (Mari et al., 2013).

Post harvest management of *C. vesuviana*

Transfer of infected fruits and planting materials from the area of infested to other non infested area for domestic consumption is one mode of spread of insects pests. This can be checked through tight domestic quarantine and post harvest disinfestations of fruits or planting material. The post harvest treatment of ber fruits with 0.45 kg ethylene dibromide per 28 m^3 for 6 h with 0.25 kg for 12 h in a sealed earth ware or air tight space would be effective in causing mortality of eggs and larvae of fruit flies but because of small size it does not seem convenience method (Lakra, 2004).

Conclusion

The fruit fly *C. vesuviana* is a major pest of ber. The present management strategies are solely relies on the insecticides and organophosphates and synthetic pyrethroids are the major insecticides groups. In India, use of newer compounds, neo- nicotinoids, microbial origin compounds like spinosad are very less in fruit fly management programme. The spinosad is good alternative for malathion, which is widely used in fruit fly management programme as a poison in baits. This could be exploited, besides it is essential to develop the augmentative release technique for notified bio control agent in ber ecosystem. The pest can be suppressed below the level of economic injury with the other integrated pest management (IPM) tools like growing fruit fly resistant varieties, proper field sanitation measures with scheduled application of soft insecticides native botanicals. So far no reports on attractive compound for *Carpomyia,* like methyl euginol for *Bactrocera*. The incorporation of bait application techniques (BAT) and insect transgenic, embryo specific lethality and sterile insect release techniques in wide area management can be exploited. However the economics cost and returns should be considered before to initiate any advanced technology.

Conflict of Interests

The authors have not declared any conflict of interests

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