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Fruit Fly Species Complex Infesting Cucurbits in India and Their Management

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A B S T R A C T

A complex of several Dacine fruit fly species are responsible in serious crop losses in cucurbitaceous vegetables in India and in many cases make the cultivation of this high valued group of vegetables unprofitable. Zeugodacus cucurbitae, *Z tau, Z. diversus, Z. cilifera, Z. scutellaris, Bactrocera nigrofemoralis, Dacus longicornis* and *D. ciliatus* have been reported to infest cucurbits in India. Polyphagous nature, wide climatic adaptation, concealed nature of immature stages, high biotic potential and high mobility of Dacine fruit flies make them one of the major limiting factors in profitable farming of cucurbitaceous vegetables. A local area management strategy constituted of field sanitation, fruit bagging as mechanical barrier, early harvesting, use of low cost effective poison baits (e.g., over ripe banana + malathion) and para-pheromone (cue-lure) traps, spraying of neem based botanical insecticides, conservation of natural enemies, etc. should be employed in an integrated way to suppress the pest population and to minimize the damage level to the lowest extent.

Keywords: Dacine Fruit Flies, Cucurbits, Cue-Lure, Poison Bait, Management

Introduction

Among the different groups of vegetables, the cucurbits form an important group of vegetable crops cultivated extensively in India and many other countries. 58 cucurbit species are cultivated world over for various purposes (vegetable, medicinal, ornamental and utilitarian purposes) and most cucurbits possess similar characteristics like rapidly growing vines with tendrils and various bioactive compounds that make them unique, fascinating and useful family of plants (Robinson and Decker-Walters, 1999). Cucurbits harbours a number of insect pests but a few of these viz., red pumpkin beetle, fruit flies and hadda beetles are considered as of serious concern (Gupta 2004). Several species of Dacine fruit flies are associated with cucurbits in India. Polyphagous nature, wide climatic adaptation, concealed nature of immature stages, high biotic potential and high mobility make the Dacine fruit flies one of the major limiting factors in profitable farming of cucurbitaceous vegetables. However, the species composition varies from region to region depending on the variation in the climatic conditions of the regions.

Fruit damage varying from 41 to 89 per cent has been reported by various workers in cucurbits (Srinivasan, 1959; Lall and Singh, 1969; Mote, 1975; Rabindranath and Pillai, 1986, Gupta and Verma, 1992; Dhillon et al., 2005). Among the fruit flies infesting cucurbitaceous vegetables,

two species namely Zeugodacus cucurbitae (Coquillett) and Zeugodacus tau (Walker) are major pests (Gupta and Verma, 1992; Satarkar et al., 2009; Nair et al., 2017) which not only cause considerable reduction in the yield and quality but also limit the export of cucurbitaceous vegetables due to strict quarantine regulations imposed to prevent their spread in international trade. There are enough similarities in the geographic distribution, host range and damage levels of these two species (Yang et al., 1994). Beside Z cucurbitae and Z tau, some other fruitfly spp. infesting cucurbits have also been reported from some parts of the country (Patel and Patel, 1998; Kapoor, 2002; Krishna Kumar et al., 2006; Prabhakar et al., 2007; Nair et al., 2017; Singh et al., 2020). For effective formulation of management strategies against any pest thorough knowledge on its distribution, bio-ecology, host range, seasonal incidence, etc. is essential. Keeping in view the seriousness of the fruit fly menace in cultivated cucurbits, available information on all the fruit fly spp. associated with this crop in India has been reviewed here so that effective management strategies against them can be formulated which can be successfully implemented in the farmers' fields in India.

Fruit Fly Species Composition in Cucurbit Ecosystem

Dacine fruit fly spp. infesting cucurbits as recorded in India along with their host plants are given in Table 1.

Distribution and Host Range

This species is widely distributed in south-east Asia and spread to many parts of the world (Drew, 1989). It attacks mostly cucurbits but sometimes also infests other plants (Allwood et al., 1999; Kapoor and Agarwal, 1983).

Z. Tau: It is present in China, India, Bangladesh, Sri Lanka, Taiwan, Indonesia, Bhutan, Brunei, Malaysia, Thailand, and Vietnam (Drew and Romig, 2013; Leblanc et al., 2014). It is a major pest of cucurbit crops in Southeast Asia (Drew and Romig, 1997). It has been recorded from 9 plant families but commonly attack fruits of plant species within the family Cucurbitaceae (Allwood et al., 1999). The species is fairly well distributed across the whole of the Indian subcontinent (Borah and Dutta, 1997; Ganie et al., 2013; Satarkar et al., 2009; Sunandita and Gupta, 2007; Nair et al., 2017).

Table I

S. No.	Fruit fly Species	Host plant recorded	Reference
1.	Zeugodacus cucurbitae	Cucumber, bitter gourd, spiny gourd, sponge gourd, ridge gourd, bottle gourd, snake gourd, ash gourd, pumpkin, pointed gourd and water melon.	Nair et al., 2017
2.	Zeugodacus tau	Cucumber, bitter gourd, spiny gourd, sponge gourd, ridge gourd, bottle gourd, snake gourd, ash gourd, pumpkin, pointed gourd and water melon.	Nair et al., 2017
3.	Z. diversus	Flowers of pumpkin, ridge gourd, ash gourd and bottle gourd.	Nair et al., 2017
4.	Z. cilifera	Flowers of spiny gourd.	Nair et al., 2017
5.	Dacus longicornis	Snake gourd and pointed gourd.	Nair et al., 2017
6.	Z. scutellaris	Cucumber, bottle gourd and pumpkin flowers	Prabhakar et al., 2007; Devi et al., 2018; Kapoor, 2002; Sunandita and Gupta, 2007, Gupta and Gupta (2007)
7.	Bactrocera nigrofemoralis	Cucumber	Devi et al., 2018; Singh et al., 2020
8.	Dacus ciliatus	bitter gourd, squash melon, pickling cucumber, little gourd, pumpkin, Citrullus lanatus, ridge gourd, sponge gourd, cucumber, Momordica charantia, Cucumis callosus, Luffa acutangula, Citrullus colocynthis, Momordica dioica Trichosanthes bracteata	Patel and Patel, 1998, Qureshi et al., 1887; Krishna Kumar et al., 2006; Chaudhary, 2012.

Z. Diversus: It is distributed in India, Bangladesh, Sri Lanka, Nepal, China, Thailand, Bhutan, Pakistan and Southern Vietnam (Drew and Romig, 2013; Leblanc et al., 2014). Flowers of many plant species in the family Cucurbitaceae including pumpkin, ash gourd, ridge gourd and bottle gourd are infested by this species (Allwood et al., 1999; Nair et al., 2017).

Z. Cilifera: It is present in Taiwan, Vietnam, Thailand, China, Laos, Malaysia, Indonesia, and Sumatra, Bangladesh and India (Drew and Romig, 2013; Leblanc et al., 2014; Nair et al., 2017). It was recorded for the first time to infest flowers of spiny gourd from India (Nair et al., 2017). Earlier it was recorded from flowers of Thladiantha hookeri (family Cucurbitaceae) (Allwood et al., 1999).

Z. Scutellaris: It is present in India, China, Myanmar, Nepal, Thailand, Bhutan, Northern Vietnam, Peninsular Malaysia (Drew and Romig, 2013) and infests flowers and fruits of species of cucurbitaceae (Allwood et al., 1999; Kapoor, 2002; Prabhakar et al., 2007; Devi et al., 2018).

Bactrocera Nigrofemoralis: It is distributed in India, Sri Lanka, Bhutan, Pakistan and Bangladesh (Drew and Romig, 2013; Leblanc et al., 2014). It is polyphagous and members of many plant families including Combretaceae, Sapotaceae, Rutaceae, Malpighiaceae, Santalaceae and Cucurbitaceae were recorded to be its host plants (Drew and Romig, 2013; Devi et al., 2018; Singh et al., 2020).

Dacus Longicornis: It is Wide spread across the region from southern Asia to Southeast Asia and recorded from host species in family Cucurbitaceae including snake gourd and pointed gourd (Drew et al., 1998; Nair et al., 2017).

Dacus Ciliatus: It is present in Africa, Egypt, Mauritius, Reunion, Iran, Pakistan, Bangladesh, India, Sri Lanka, Middle East including Oman, Saudi Arabia, UAE (Drew and Romig, 2013). It is a major pest of economic crops and infests hosts predominantly in the family Cucurbitaceae and occasionally in the families Solanaceae, Leguminosae and Mulvaceae (Drew and Romig, 2013).

Nature of Damage and Yield Loss

Irrespective of the different species of fruit flies the nature and symptoms of damage in fruits are almost same. The females make punctures with the ovipositor in the fruit skin for laying their eggs in soft tender fruit tissues. Through the ovipositional puncture watery fluid oozes out which later transforms into a brownish deposit on the fruit skin. After hatching, the maggots get entry into the fruit pulp and feed on it. Infested fruits get deformed in shape. Saprophytic microbes also get entry through the ovipositional punctures and accelerate the decomposition of fruit tissues. On the other hand, some fruit fly spp. have been reported to cause damage only on the flowers. Z diversus was reported to infest flowers of pumpkin, ridge gourd, ash gourd and bottle gourd whereas; Z cilifera was reported to infest the flowers of spiny gourd only (Nair et al., 2017). Sunandita and Gupta (2007) have reported very low infestation of Z. scutellaris in flowers of bottle gourd and pumpkin. However, Z cucurbitae and Z. tau can also infest flowers of cucurbits (Nair et al., 2017). Losses to cultivated crops may reach 100 per cent if control measures are not applied (Vayssieres and Carel, 1999). The extent of losses varies depending on the cucurbit species, variety and the season. 41 to 89% fruit damage in bitter gourd by Z. cucurbitae has been reported by various workers (Lall and Singh, 1959; Narayanan and Batra, 1960; Kushwaha et al., 1973; Gupta and Verma, 1978; Rabindranath and Pillai, 1986). Singh et al. (2000) recorded 31.27% fruit damage in bitter gourd and 28.55% in watermelon. Sisodiya and Jhala (2009) reported more than 50 per cent damage to cucurbits due to Z. cucurbitae. B. tau has been reported as a pest on a wide variety of food plants including cucurbits and in certain seasons it causes serious damage in a number of crops (Narayanan and Batra, 1960).

Crop loss in cucurbit vegetables due to fruit fly infestation is the resultant of cumulative effects of several spp. of fruit flies associated with these crops. However, only one species i.e. *Z. cucurbitae* has received more attention and has been investigated by several workers.

Behaviour and Life Cycle

The melon fruit fly remains active throughout the year on different hosts. During the severe winter months, they under go hibernation in adult stage and hide and huddle together under the leaves. During hot and dry season, the flies take shelter under humid and shady places. This species actively breeds when the temperature falls below 32.2 ºC and the relative humidity ranges between 60 to 70 per cent (Keck, 1951). Bateman (1972) reported that falling light at dusk acted as a stimulus for initiation of sexual activity in many species of Tephritidae including Z. cucurbitae. The females deposit their eggs into ripening host fruit. Apodous maggots pass through three instars before pupation which normally takes place in the ground, although in D. longicornis it occurs inside the host fruit (Nair, personal observation). Fletcher (1987) reported that mature maggots of most species left the fruit and burrowed several centimetres into the soil to pupate, and have the ability to “hop,” as a defensive mechanism against ground dwelling natural enemies. Koul and Bhagat (1994) observed that depth of pupation was greatly influenced by the soil type and moisture content.

After emergence, the adults need to feed regularly on carbohydrates and water to survive and the females require proteinaceous materials for the development of their gonads (Fletcher, 1987). Narayanan and Batra (1960) reported the adult longevity for one or two days without

food and if properly fed on the cucurbit juices, the adult longevity increases to 56 and 66 days for male and female, respectively during the monsoon months.

Narayanan and Batra (1960) observed that *Z. cucurbitae* remained active and bred throughout the year except for a short period, during the months of January and February when it was very cold. The pest produced several generations in a single year. Dacus ciliatus remained active throughout the year and upto six generations had been recorded in an equable and subtropical climate. The number of generations was less in the North where there was a clear cut winter season accompanied by a fall in temperature.

The duration of life stages in fruit flies is influenced and varies with temperature and host plants (Fletcher, 1989; Yang et al, 1994). According to Bhatia and Mahto (1969) Z cucurbitae takes 36.3, 23.6, 11.2 and 12.5 days to complete its life cycle at 15, 20, 27.5, and 30 °C, respectively. Eight to ten generations may be completed in a year (White and Elson-Harris, 1994; Weems and Heppner, 2001).

In case of *Z. cucurbitae*, egg incubation period varies from 1.1 to 1.8 days (Gupta and Verma, 1995), short larval stage is completed within 3 to 6 days (Chawla, 1966; Chelliah, 1970; Doharey, 1983; Koul and Bhagat, 1994; Gupta and Verma, 1995), pupation takes place in soil at a depth of 0.5 to 15 cm depending on soil texture and moisture (Jackson et al., 1998; Pandey and Misra, 1999) and the pupal period lasts for 6 to 9 days during the rainy season while, 15 days during the winter (Narayanan and Batra, 1960). According to Koul and Bhagat (1994) females' longevity is 21.7 to 32.7 days while, the males live for 15.0 to 28.5 days.

In case of *Z. tau* pre-oviposition period and incubation period was 11.7 ± 4.49 days and 1.3 ± 0.41 days, respectively. First, second and third instars larval lasted for 1.2 ± 0.42, 1.7 ± 0.48 and 4.0 ± 0.94 days, respectively. Pupal period was 7.0 ± 0.47 days. The life cycle was completed in 14.2 ± 1.69 days (Singh et al., 2010).

Seasonal Incidence and Effect of Weather Factors

Narayanan and Batra (1960) reported heavy fruit damage during July to August in various cucurbits due to fruit flies. Gupta and Verma (1992) while studying the population fluctuations of fruit flies (B. cucurbitae and B. tau) infesting cucurbitaceous crops reported that fruit fly incidence was closely associated with weather factors and that pest status changes rapidly owing to dynamic nature of the environment. Mandal et al. (2006) observed highest fruit fly incidence during 26th SW in bitter gourd. Maharjan et al. (2015) recorded the highest number of fruit flies (167.5 male fruit flies/ 3 traps) in cue-lure trap during the first week of September with prevailing RH of 85.45 % and minimum and maximum temperature of 21.67°C and 25.04°C, respectively.

Several workers have studied seasonal incidence of *Z. cucurbitae*. Vignesh and Viraktamath (2015) recorded high incidence of fruit fly during kharif and low incidence during rabi and observed significant positive correlation of melon fruit fly incidence with minimum temperature (r= 0.388*), morning (r= 0.372*) and evening relative humidity (r= 0.427). Abhilash et al. (2017) found significant positive correlation of melon fruit fly incidence with maximum and minimum temperature but significant negative correlation with afternoon relative humidity and rainfall. Raghuvanshi et al. (2012) observed abundance of fruit flies in Cue-lure baited traps throughout the year with two peaks; in summer and *kharif* (Autumn) coincided with the 14 SW and 43 SW respectively. They also observed significant positive correlation of adult fruit fly abundance with maximum and minimum temperature. Nair and Pal (2020) recorded moderate to high population from February to October and during the cooler months i.e. from November to January the adult activity was low. The numbers of fruit flies captured in cue-lure baited traps correlated positively with temperature, relative humidity and rainfall. Maximum temperature, minimum temperature and rainfall have significant influence on Z. cucurbitae population.

According to Sawai et al., (2019) *Z. tau* had significant positive correlation with maximum relative humidity. According to Nair et al. (2020) the population of male flies of *Z. tau* showed almost similar fluctuation during the study period of two years duration in the cucurbit ecosystem of Tripura, India with two peaks in end of March to April and September-October in each year. The numbers of fruit flies captured in cue lure baited traps correlated positively with temperature, relative humidity and rainfall. Maximum temperature and minimum temperature have significant influence on *Z. tau* population. Work done on monitoring of flies infesting cucurbits, other than *B. tau* and B. cucurbitae, is very scanty.

Integrated Pest Management Strategies against Fruit Flies

Several efforts have been made to manage fruit flies in cucurbits, particularly targeting *Z. cucurbitae*, by using different insecticides, poison bait traps, poison bait spraying, male annihilation technique using attractant lures and combined use of bait and attractant. Some major tephritid fruit fly spp. have been successfully totally eradicated in some parts of many countries (Klassen et al., 1994). Male-sterilization of fruit flies can be successfully achieved through Chemo-sterilization or gamma irradiation (Gojrati and Keiser 1974; Odani et al., 1991). Male-sterile technique is very effective in managing fruit flies and sometimes can provide total eradication of a particular species from an isolated area. However, this technique is only effective in small areas like some islands where infiltration of untreated

male flies can be checked. Therefore, this technique is not suitable for mainland India.

Local Area Management

In mainland India, area wide eradication of fruit fly pest is quite impossible as reinvasion can not be checked. Therefore, local area management strategies for suppressing the pest are to be taken at field levels. A combination of compatible methods is to be employed to suppress the pest population.

Field Sanitation: Removal of the infested fruits and burying them into deep pits can reduce population increase. Burying damaged fruits 0.46 m deep in the soil prevents adult fly eclosion and reduces population increase (Klungness et al., 2005). Vijaysegaran (1985) reported that orchard sanitation by collecting and destructing all unwanted fruits from the trees and the ground significantly reduced the fruit fly population. Schmid and Dos-Santos (1998) recommended elimination of fruit fly infested fruits as cultural method of control. Makhmoor and Singh (1999) reported that pupal mortality of fruit flies was increased with an increase in the irrigation and hoeing frequency.

Bagging of Fruit: Bagging of fruits on the tree (3 to 4 cm long) with 2 layers of paper bags at 2 to 3 day intervals prevent adult flies laying eggs and thereby 40 to 58% increased net returns were reported (Fang, 1989; Jaiswal et al., 1997). According to Akhtaruzzaman et al. (1999) if cucumber fruits are bagged at 3 days after anthesis and the bags are retained for next 5 days, effective control of fruit flies can be achieved.

Use of Parapheromone (Cue-Lure Traps) against Male Flies

Among the fruit fly spp. associated with cucurbits, *Z. cucurbitae, Z. tau, Z. cilifera*, Dacus longicornis, Bactrocera nigrofemoralis and Z. scutellaris are attracted to cue-lure [4-(p-acetoxyphenyl)-2-butanone] traps (Drew and Romig, 2013; Nair et al., 2017; Nair et al., 2018; Prabhakar et al., 2007; Gupta and Gupta, 2007) while Z. diversus is weakly attracted to Methyl eugenol (4-allyl-1,2-dimethoxy benzene-carboxylate) (Nair et al., 2017) and D. ciliatus is neither attracted to cue lure nor in Methyl eugenol (Drew and Romig, 2013). With the use of cue lure traps male can be eliminated and in absence of the males the laying of fertilized eggs by females will be prevented. This technique is known as Male Annihilation Technique (MAT). Cue-lure traps can be successfully used for monitoring as well as mass trapping of fruit fly adults in cucurbit ecosystem. A number of cue-lure based attractants in various trade names are available in the Indian market.

Rameash et al. (2009) evaluated the efficacy of seven dispenser blocks of cue-lure against the Z. cucurbitae in bitter gourd and according to his observations, on the basis of mean fly catch per week, the average ranking of dispensers was in the order of plywood block (10.93) > acacia wood block (6.57) > strawboard block (8.20) > cotton wad block (6.63)> rubber block (2.40) > sponge block (2.50) > soft board block (1.73). While standardizing the optimum dose of cue-lure to suppress population of Z. cucurbitae in cucurbit crops, Chaudhary and Patel (2012) observed that 0.25 ml dose remained active for 32 weeks while, the remaining doses (0.05, 0.10, 0.15, 0.20) attracted male flies only upto 30 weeks.

For dispensing para-pheromones (methyl eugenol / cue lure), many type of traps have been developed. Madhura and Viraktamath (2003) evaluated the efficacy of different type of traps viz., Steiner trap, sticky trap, Delta trap, IIHR trap, Morocco trap, Jackson trap, open pan trap in capturing the fruit flies. Disposable plastic water bottles (1L) trap with four windows (1 sq inch) cut open just below the shoulder of the bottle as recommended by the Indian Institute of Horticultural Research, Bangalore (Verghese et al., 2006) can be used effectively for trapping through both Male Annihilation Technique (MAT) and Bait Application Technique (BAT). According to Jiji et al., (2009) the recommended height of the trap placement to obtain highest catch of melon flies in cucumber is 30 cm from ground level. In bitter gourd the optimum height (1.36m) for maximum catch was below the height of the pandal and vegetation (Jiji et al., 2005). It would be ideal to standardize the height of trap placement for a crop and geographic location to exert maximum control, depending on crop canopy and other ecological factors (Jiji et al., 2009).

Use of Poison Baits against Female Flies

Poison baits can be used by bait spraying or in bait traps. Bait applications increase control effectiveness up to four times as compared to insecticides alone (Stainer et al., 1958).

Effectiveness of different baits for attracting and suppressing fruit flies in cucurbits has been tested by various workers. Chowdhury et al. (1993) captured 2.36 to 4.57 flies/ trap/ day in poison bait traps containing trichlorfon in bitter gourd. According to Saikia and Dutta (1997) fenvalerate at 0.02 % with 1% molasses was the best among fifteen treatments tested against *Z. tau* on ridge gourd. Sood and Nath (1999) found that yellow traps smeared with attractant solution containing jaggery and 0.1 % dichlorvos attracted greatest number of *Z. tau* flies in tomato fields. Akhtaruzzaman et al., (2000) recorded effective control of melon fly with the application of molasses + malathion + water @ 1: 0.1: 100. According to Satpathy and Rai (2002) bait containing pulp of over ripe banana (1 kg) + carbofuron (10 g) + citric acid (1 g) was the best combination in luring *Z. cucurbitae*. According to Bharati et al. (2004) banana and soybean hydrolysate were 85-95 per cent more attractive to *Z. cucurbitae* adult than fishmeal, beef extract, bread

and dog biscuit. Among different traps tested, Pandey et al. (2010) recorded significant superiority of banana based poison bait trap containing banana (1 kg) + carbofuron (10 g) + yeast (10 g) + citric acid (5 g) in terms of higher catches of fruit fly throughout the cropping season.

Protein bait acts as a food attractant as the immature female fruit flies need a protein meal for eggs development (Allwood, 1997). According to Vargas et al. (2003) the type of protein influences attraction of flies to the baits. Dale and Nair (1966) recommended a coarse spray of a liquid bait containing 1 per cent yeast protein and 0.1 per cent malathion in Kerala to control fruitflies of economic importance. Fabre et al. (2003) reported that Solbait (protein hydrolysate) was the most effective in capturing females of melon fly. According to Ravikumar and Viraktamath (2007) among different protein food baits, proteinex and 5 per cent ammonium acetate attracted significantly more females of *B. correcta, B. dorsalis, B. cucurbitae* and total fruit flies (16.84 fruit flies/ trap/ week) in guava. Gupta and Verma (1978) reported that fenthion (0.025%) in combination with protein hydrolysate (0.25%) reduced the damage to the extent of 8.7% as against 43.3 % damage in untreated control. Gupta and Verma (1982) reported that spraying with fenitrothion (0.025%) + protein hydrolysate (0.25%) or molasses (0.5%) resulted in lowest rate of infestation by *Z. cucurbitae* and this combination was significantly superior over bait spray of malathion (0.25%) + gur (0.5%).

Verghese et al. (2005) studied the comparative attractiveness of three indigenous lures/baits with three established attractants in fruit flies and reported that methyl eugenol attracted highest number of flies (18.25 flies/ day/ trap) followed by cuelure (13.5 flies/day/trap) and tulsi (5.88 flies/ day/ trap) whereas, flies attracted to banana, jaggery and protein hydrolysate were negligible.

While cue-lure attracts only male flies, poison baited traps attract female flies and thus are not comparable with each other for their effectiveness in attracting fruit flies, both should be used simultaneously for getting effective suppression of fruit fly populations. Kiran Rana and Kanwar (2014) reported that combined treatment of cue-lure baited traps and poison bait spray was most effective in management of fruit fly spp. in bitter gourd as compared to control rather than their separate applications.

Use of Botanicals against Fruit Flies

Ranganath et al. (1997) reported that the neem oil at 1.2 per cent was the most effective treatment in reducing damage in cucumber, while neem cake at 4.0 per cent and dichlorvos at 0.2 per cent were the most effective against the pest in ridge gourd. Tomar and Singh (2001) and More (2007) observed that NSKE 5 per cent was most effective against *B. cucurbitae* Babu et al. (2002) reported that neemazal (@ 3 and 5 ml/ l) provided significant control against B. cucurbitae and recorded a reduction of 70.5 per cent damage. Reduced fruit fly infestation with neem oil at 1, 1.5 and 2 per cent and neem seed water extract at 1, 2 and 3 per cent concentration was recorded by Khattak et al. (2009). Sharma et al. (2011) found 1.0% drek seed kernels extract + diet to be effective against B. tau on tomato under field conditions. Sharma et al. (2016) stated that under organic conditions four sprays of neem oil formulation @ 5 ml/ l coinciding with infestation at 10 day interval can be effectively used to manage fruit flies.

Use of Combination of Treatments

An integration of different management options is always necessary for effective suppression of any pest. According to Jaiswal et al. (1997) use of cuelure along with field sanitation is very effective in controlling melon fly. Rajapakse (2000) reported that the use of neem based products along with predatory ants, Oecophylla smaragdina gave an excellent control of *Z. cucurbitae*. According to Nath et al. (2007) subsequent application of NSKE @ 5 per cent, bait spray (Malathion 50 g + molasses 500 g + 50 l water) and cypermethrin resulted in minimum fruit fly damage as compared to untreated plot of bottle gourd crop. Pandey et al. (2008) found NSKE + banana based poison bait as the most effective in reducing bitter gourd fruit damage by fruit flies. Ranganath et al. (2015) reported that bait spray treatment (jaggery @ 15 g per litre mixed with deltamethrin @ 1 ml per litre) coupled with sanitation (collection and destruction of melon fly infested fruits) and cuelure traps (@ 15/ acre) provided effective management of melon fly on bitter gourd with the lowest fruit damage (14.38%). Praveen et al. (2012) reported that field sanitation, Male Annihilation Technique (MAT) using cue-lure, Bait Application Technique (BAT) successfully reduced the infestation level of *Z. cucurbitae* in gherkin. Nair et al. (2021) tested four traps and seven attractants alone and in combinations for their efficacies in trapping fruit flies in bitter gourd and reported that McPhail trap, Cuelure, Banana slurry and yellow sticky traps provided satisfactory results. Ammonium acetate, citronella oil and fish meal attracted significantly lesser number of flies. However, Ammonium acetate in combination with banana slurry or molasses had shown synergistic effect in trapping flies. Cuelure and banana slurry were the best attractants and if used together can effectively reduce the population of both male and female flies.

Conclusion

From the available literatures it is understandable that though several species of fruit flies are associated with cucurbits in India, only one species i.e., *Z. cucurbitae* was mostly investigated by majority of researchers. Therefore,

some more investigations on other important spp., especially *Z. tau*, *D. longicornis* and *D. ciliatus* are also needed. As in some areas of India a complex of fruit fly species are involved in causing damage to the cucurbitaceous crops, investigation on species composition is necessary in other parts of the country too. Regarding management of the fruit fly pest, it can be concluded that several methods are available, each of which has its own advantages in reducing fruit fly population at least to some extent and if used in an integrated manner, can effectively suppress the pest. Therefore, a combination of compatible methods such as field sanitation, fruit bagging as mechanical barrier (as and when feasible), harvesting as early as possible, installation of low cost but effective poison baits (e.g., over ripe banana + malathion) and attractant (particularly cue-lure) in low cost traps (e.g., plastic mineral water bottles) at proper places, spraying of neem based botanical insecticides, conservation of natural enemies present in the field, etc. are to be employed to suppress the pest population so that the damage caused by this group of devastating pests can be minimized to the lowest extent and the Indian farmers can be encouraged to grow pesticide residue free vegetables for the consumers as well as for their own families .

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