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ABUNDANCE AND SPECIES RICHNESS OF FRUIT FLIES (DIPTERA: TEPHRITIDAE) IN MAJOR CUCURBIT GROWING AREAS IN ANURADHAPURA, KURUNEGALA AND KANDY DISTRICTS IN SRI LANKA AND FARMERS' PERCEPTION ON RECOMMENDED MANAGEMENT METHODS

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ABSTRACT

Fruit Flies, (*Bactrocera* spp. Diptera: Tephritidae) were collected from 25 cucurbit orchards in Anuradhapura, Kurunegala and Kandy districts using Cue Lure and Methyl Eugenol pheromone traps over a 6-month period in 2016/17 *Maha*. In addition, fruit fly infested cucurbits fruits were collected from the above sampling sites and kept in the laboratory at Horticultural Crop Research and Development Institute (HORDI), Gannoruwa under sterilized conditions to identify and count the emerging adults. Five known species of melon Fruit Flies (FF) namely, *Bactrocera cucurbitae, B. tau, B. caudata, B. trilineata, B. diversa* and unknown species under the genus *Dacus* (*Caillantra*) and a specimen of unidentified species and three species of true Fruit Flies *B. dorsalis*, *B. correcta* and *B. nigrotibialis* were collected *in* Cue-Lure pheromone traps. The collection in the Methyl Eugenol traps composed 11% melon fruit flies, *B. cucurbitae* and *B. tau,* in addition to true FF. Three species of melon FF, *B. cucurbitae* (90.9%), *B. Tau* (8.9%), and *Dacus ciliatus* (lesser pumpkin fly/cucurbit fly) (0.2%) emerged from infested pumpkin, cucumber, snake gourd, luffa and bitter gourd collected from the above sites. Farmers found to follow three different methods to control FFs: 1. Area wide Integrated Pest Management (AWIPM) introduced by the Department of Agriculture, 2. Regular application of insecticides and 3. Mixed approaches. Farmers who rely on insecticides found to apply Acephate 75% SP, Profenofos 500 g /1 EC, Abamectin 18g/1 EC and Acetamiprid 20% SP at 5 – 7 day intervals. Damage due to FF ranged from 5-40% and the lowest damage (5%) observed in farms under the AWIPM program.

Key words: Cucurbits, Cue-lure, Fruit flies, Pheromone

INTRODUCTION

The cucurbit crops, including pumpkin, bitter gourd, luffa, cucumber and snake gourd are extensively cultivated in Sri Lanka for local consumption and for export market. The estimated total annual area under different cucurbits and production are 25,978 ha and 294,866 t (AgStat, 2015). The diversity, wide adaptability to different edaphic and climatic conditions, health benefits, better return to investment and hands-on-experience in crop management have influenced farmers to invest more on cucurbit cultivation to increase their income. The tephritid fruit flies of the genus *Bactrocera,* with more than 500 species, described as important pests of fruit and vegetable crops are considered as economically important pests throughout the world (Kumar *et al.*, 2011; Bandara and Billa, 2015; Vargas *et al.*, 2015).

At present, vegetable production sector faced major problems related to safety and quality of production. Farmers are used to apply massive amount of agro-chemicals, like pesticides, herbicides, frequently even without considering pre- harvest interval and without following the recommendations of the Department of Agriculture (DOA, 2013). Furthermore, the Department of Agriculture (DOA), in order to produce pesticide residue free cucurbits with zero melon fruit fly damage for export and local market, introduced an Area Wide Integrated Fruit Fly/melon fly management (AWIPM) program in late 2014. This holistic approach included regular application of protein baits to minimize the adult populations, male annihilation through pheromones, fruit bagging, early harvesting, and orchard sanitation (Bandara *et al.*, 2006).

In order to streamline the Area Wide Fruit Fly suppression and assurance of safety and quality cucurbits develop a Good Agricultural Practices (GAP) program under the aid granted by the Asian Food and Agriculture Cooperative Initiation Secretariat, Republic of Korea (DOA, 2013). Later, group of Councillors for Agribusiness (CAB) was appointed district wise to monitor the crop management practices followed by selected farmers under Good Agricultural Practices program. The CABs are responsible for verification of the harvest meant for export from orchard to the pack-house and up to plant quarantine inspection. However, non availability of

feed-back information prevents to review the merits, demerits and farmer acceptance of the AWIPM program (Personal communication; Ms Disna Ratnasekera, Extension and Training Centre, Department of Agriculture).

In addition, a need has been arisen to identify the composition of fruit fly species damaging cucurbits in Sri Lanka and their distribution and abundance. This information would help improve the efficiency of AWIPM program and introduction of a Male Sterilization Program for their control. Availability of the species composition may also be useful in quarantine purposes. Thus, this study was undertaken to assess abundance and species richness of fruit flies in cucurbit cultivations in three districts, namely, Anuradhapura, Kurunegala and Kandy and to understand farmers' perception on the management methods available for fruit fly control.

MATERIALS AND METHODS

Diversity and abundance of Fruit Flies Infesting Cucurbits in Sri Lanka

Collection of Fruit Flies using pheromone traps

Major cucurbit growing areas, covering a total of 25 AI divisions, in three districts namely, Anuradhapura (Maradankadawala, Sharsthrawelliya, Nelubewa, Hidogama, Nachchaduwa, Madawalagama Saliyapura, Mangalagama and Ranorawa) Kurunegala (Ambanpola, Moragollagama, Rambe, Irudeniyaya and Madahapola) and Kandy (Gannoruwa, Halloluwa, Gelioya, Galagedara, Walala, Hurikaduwa, Mannikhinna (Pitawala Yaya), Nahiniwala, Pasgama, Marassana and Pahala Dambarawa) were selected for sampling (Figure 1). Two types of traps, Cue Lure (4-[p-Acetoxyphenyl]-2-butanone) and Methyl Eugenol (1,2-Dimethoxy-4-(prop-2-en-1-yl)benzene) were placed in each trap per site. Cue Lure traps were serviced in three months interval and Methyl Eugenol traps were serviced in every 2 weeks interval. Adults attracted to traps were collected monthly intervals during the cropping period and oven dried for morphological identification and counting.

Collection of Melon Fruit Flies from Infested Cucurbit Fruits

About 10-20 FF infested cucurbits (pumpkin, cucumber, snake gourd, luffa and bitter gourd) collected from the above mentioned locations in three times of cropping cycle were brought to the Entomology Laboratory at Horticultural Crops Research and Development Institute (HORDI) and kept separately on plastic trays containing 1cm layer of sterilized moistened sand in wire-mesh cages for larval development and pupation. The emerging pupae were placed in insect rearing cages containing water: sugar: Protein hydrolysate (1:1:1). The emerged adult flies were counted and identified. Information on the sampled fruit species, fruit weight, date and location were recorded. Data checked for normality and then were log transformed and analyzed using ANOVA, SAS 9.1 procedure.

Morphological Identification

Collected specimens, kept at HORDI Gannoruwa, then their identity were confirmed using standard reference keys. The key features used for the morphological identification of adult fruit flies included: Overall colour and colour pattern; wing morphology; presence, shape of thoracic vittae. The reference keys used included " The Australian handbook for the identification of fruit flies (White and Elson-Harris, 1992, Plant Health Australia, 2016), Pictorial keys for predominant *Bactrocera* and *Dacus* fruit flies (Diptera: Tephritidae) of North Western Himalaya (Prabhaka *et al.*, 2012); and Pictorial key to fruit flies of the tribe Dacini (Diptera: Tephritidae) of Sri Lanka (Tsurta *et al.*, 1999). In addition, photographs were taken from binocular microscope using a Digital Camera (Model 14.1pix.).

Method followed by Farmers to control FF in Cucurbits

A detailed survey was conducted in 2016/17 *Maha* season among 50 selected farmers in the study area using a pre-tested questionnaire with the assistance of Agriculture Instructors and CAB officers. The aim of the survey was to identify the perception of farmers on the AWIPM introduced by the DOA to control these pests.

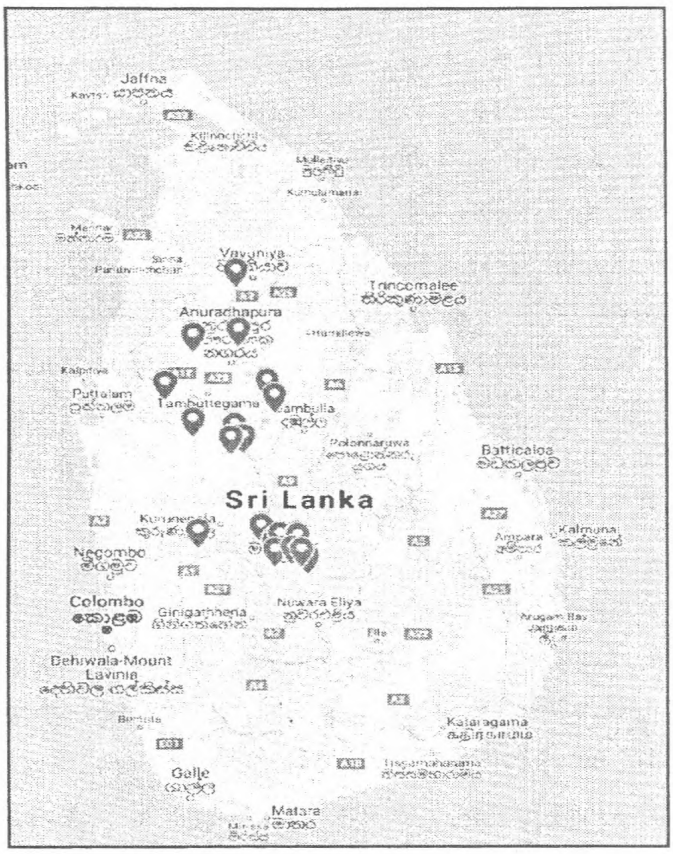


Figure 1. Locations surveyed for Fruit Fly infesting cucurbits in Anuradhapura, Kurunegala and Kandy districts of Sri Lanka.

RESULTS AND DISCUSSION

Diversity and abundance of Fruit Flies Infesting Cucurbits in Sri Lanka

Collection of adult fruit flies using pheromone traps

Six known species of Fruit Flies (FF) *B. cucurbitae, B. tau, B. caudata, B. trilineata, B. diversa, B. nigrotibialis, D. (Caillantra)* spp. (very few sample) and unidentified species (only one sample) from Anuradhapura district were collected in Cue Lure traps kept in Anuradhapura, Kurunegala and Kandy districts (Table 1 and Figures 2, 3 and 4). *B. nigrotibialis* has been recorded in *Terminalia cattappa* (Indian Almond; Kottamba in Sri Lanka) (Tsurta *et al.*, 1999). In addition two species known as true Fruit Flies (those

damage fruits) namely *B. dorsalis, B. correcta,* were also found in the trap collection. The major FFs collected in the above traps also related to the main species found in infested cucurbits collected in the above locations as indicated in Table 1. One of the cucurbit fruit flies, *D. ciliatus*, recorded in these locations did not attract to Cure Lure traps and Methyl Eugenol traps, a situation which has already been observed by Weems (2015). The FF, *B. diversa*, also known to infests fruits like guava, mango, orange, *etc.* In addition *B. diversa and B. caudata* are known to breed on flowers of some cucurbits (Phaik, 2012). *B. trilineata* has been recorded in the Dry zone earlier, but, this is the first time to record this species in the Wet zone (Kandy) (Tsurta, 1997).

Table 1. Number of Fruit Fly species / week) attracted to Cue Lure traps placed in different districts during 6 month period (Nov 2016 – May 2017) (n=25).

Districts	Species attracted	Av. No. Insects	Percentage (%)**
Anuradhapura	*B. cucurbitae*	61.5 a	45
	B. tau	39.6 abcd	29
	B. caudata	0.6 bcde	0.4
	B. trilineata	0.8 bcde	0.6
	B. diversa	0.6 bcde	0.4
	B. nigrotibialis	3.5 bcd	2.6
	Fruit fly species*	30.1 abcd	22
	D.(Caillantra) sp	(a few)	
Kurunegala	*B. cucurbitae*	134.4 a	82.2
	B.tau	0.2 cde	0.1
	B. caudata	0.9 bcde	0.5
	B. trilineata	0.5 bcde	0.3
	B.nigrotibialis	6.6 bc	4.0
	Fruit fly species*	20.8 abcd	12.9
Kandy	*B. cucurbitae*	141.7 a	64.1
	B.tau	14.7 abcd	6.6
	B. caudata	0.4 bcde	0.2
	B. trilineata	0.2 cde	0.1
	B. diversa	0.03 e	0.01
	B. nigrotibialis	13.7 abcd	6.2
	Fruit fly species*	50.4 ab	22.8
	CV	17.3	

Note: * *B. dorsalis, B. correcta;* **Means in the column (for all three districts) followed by the same letter are not significantly different at 5% DMRT.

Based on the Cue Lure trap collections, *B. cucurbitae, B. tau*, and or true fruit flies ranked as the species with highest Shannon Diversity Indices in the three districts (Hill, 1973) (Figures 1, 2 and 3). This information could be biased as the estimations are based on the insects' attraction towards the pheromone.

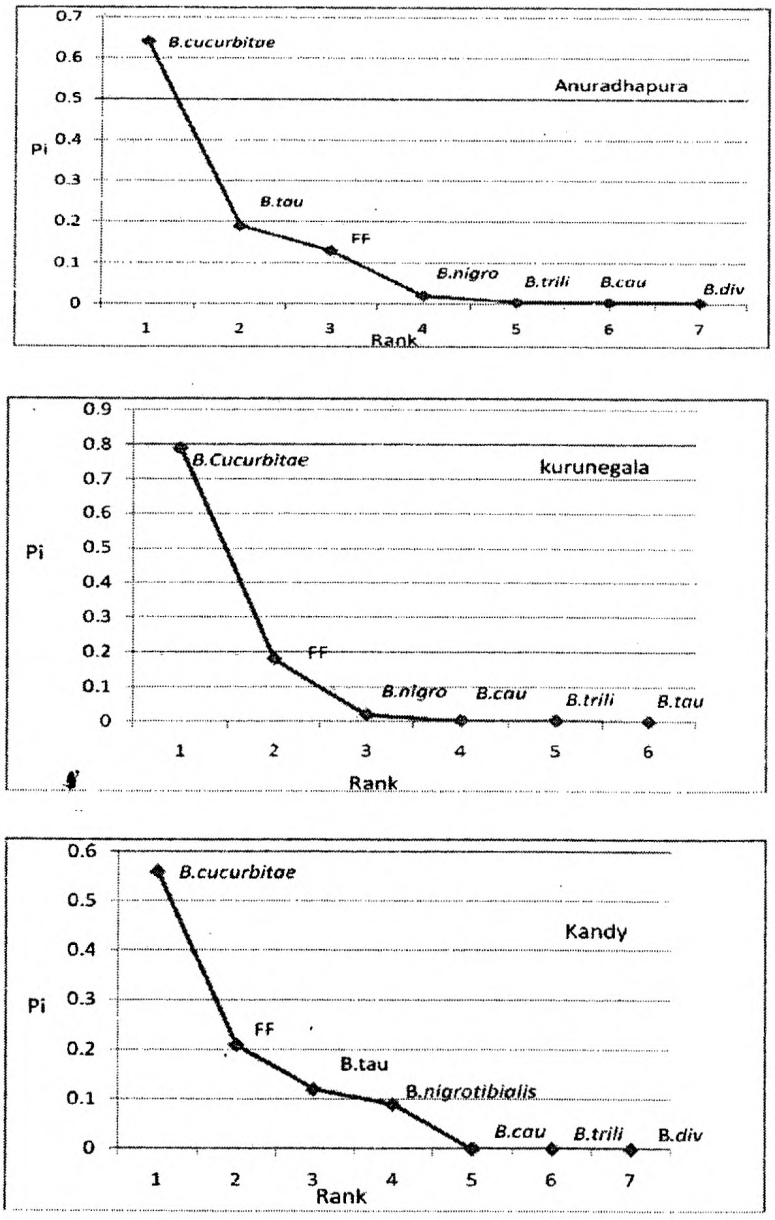


Figure 2. Shannon Diversity indices of Fruit fly species in Anuradhapura, Kurunegala and Kandy districts based on adults attracted to Cue Lure traps: Pi (proportion of the total species (Richness) made up of the i^{th} species).

The Methyl Eugenol traps, in addition to attracting true fruit flies, namely (*B. dorsalis, B. kandiensis, B. correcta, B, zonnata,* and a few specimens of *B. versicolor* also attracted melon fruit fly *B. cucurbitae* (Table 2). Male annihilation through pheromone trapping is one of the recommended techniques to reduce the insect population in Melon Fruit Fly control programmes. Most of the farmers were aware about Methyl Euginol pheromone traps than Cue-Lure traps. The melon Fruit Fly (*B. cucurbitae*) counts in Cue-Lue traps were significantly higher than those collected in Methyl Euginol traps. Therefore, farmer awareness about pheromones is considered important in melon fly control programs.

Table 2. Average Number of Melon Fruit Fly species / week) attracted to Methyl Euginol traps placed in different districts during 6 month period (Nov 2016 – May 2017) (n=25).

Districts	Species attracted	No. Insects/w (%)	Percentage
Anuradhapura	*B. cucurbitae*	18.3 c	5.7
	Fruit fly species**	301.3 a	94.3
Kurunegala	*B. cucurbitae*	36.7 c	25.9
	Fruit fly species**	104.7 b	74.1
Kandy	*B. cucurbitae*	1.1 d	0.8
	B. tau	0.1 e	0.2
	Fruit fly species**	126.2 b	99.0
CV%		13.9	

Note: *Means followed by the same letter are not significantly different at 5% DMRT

** *B. dorsalis, B. kandiensis, B. correcta, B, zonnata, B. versicolor* (very few)

Fruit Flies emerged from Infested Cucurbit Fruits

Three species of FF, *B. cucurbitae* (melon fruit fly) *B. tau,* and *D. ciliatus* (lesser pumpkin fly/cucurbit fly) emerged from the cucurbit fruits (namely pumpkin, cucumber, snake gourd, luffa and bitter gourd) collected from Anuradhapura, Kurunegala and Kandy districts (Table 3). Among these three species, *B. cucurbitae* was the most predominant species (>86%) followed by *B. tau* identified from Kurunegala , Kandy and Anuradhapura districts. It is a primary pest of fruits and vegetables of the family Cucurbitaceae throughout South and Southeast Asian regions (Sangvorn *et al.*, 2011).

Apart from the above two species a few specimens (0.2%) of *D. ciliatus* was observed from infested snake gourd collected from Sharsthrawelliya, Pawakkulama (in Anuradhapura district) and Hurikaduwa (in Kandy district). *D. cilliatus* was first reported in India in 1914 and found to occur in Eastern, Southern and Central Africa, Mauritious and Reunion Island, Arabian Peninsula, Pakistan, India, Bangladesh and Sri Lanka. Cucurbits are known hosts of *D. cilliatus* with several other crops such as passion flower, citrus, tomato (Weems, 2015). In addition to *B. cucurbitae* and *B.tau*, *B. diversa* emerged from infested pumpkin flowers from Kandy district.

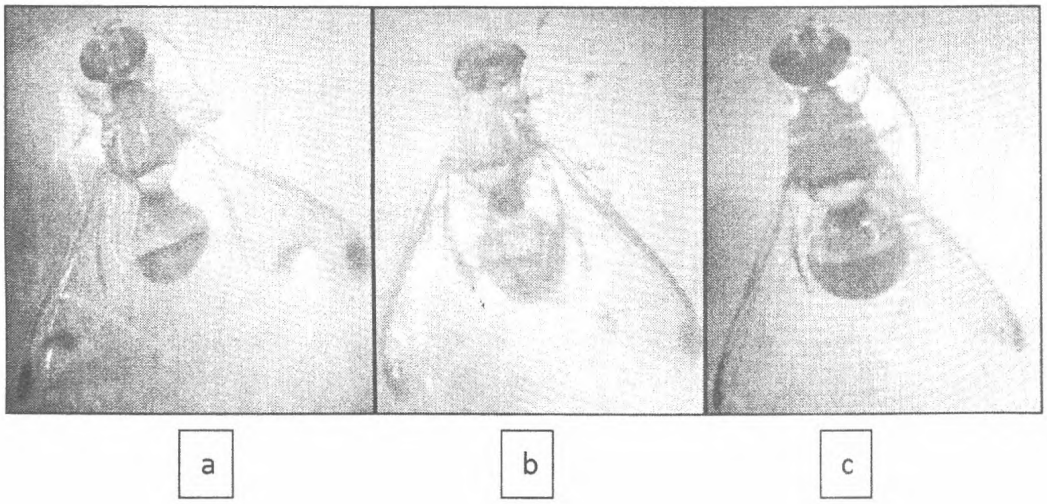
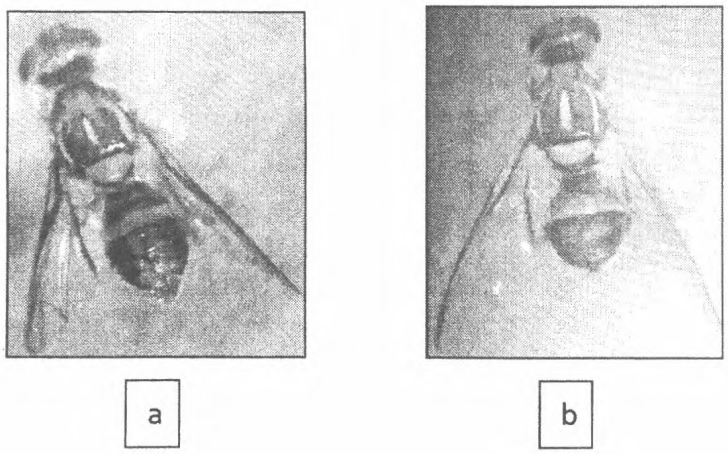


Figure 3. Photographs of *(a) Bactrocera cucurbitae, (b) Bactrocera tau and (c) Dacus ciliates* (10x20x1.4).



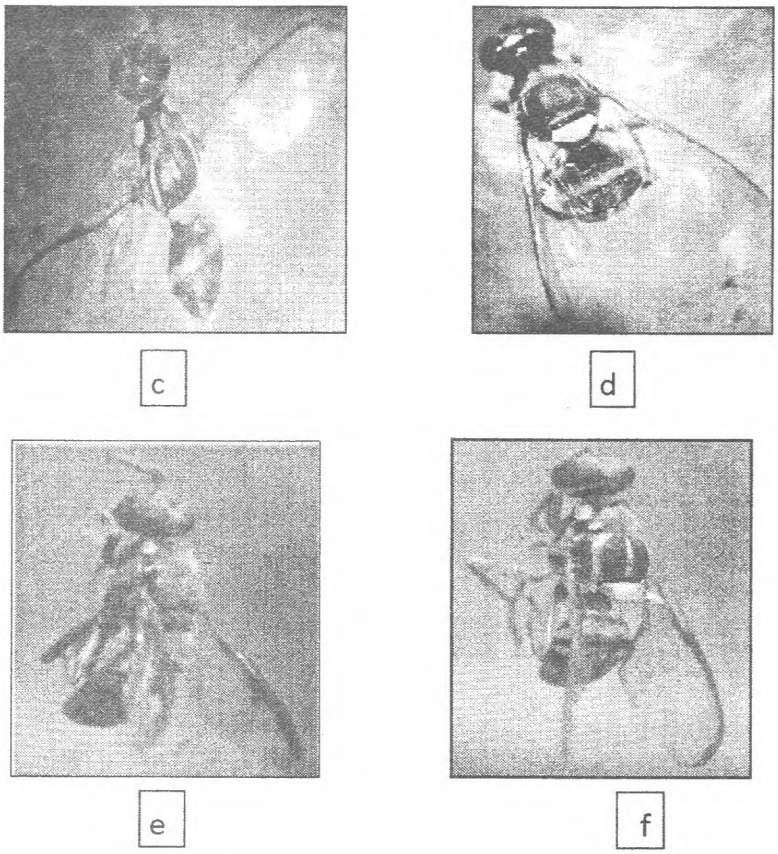
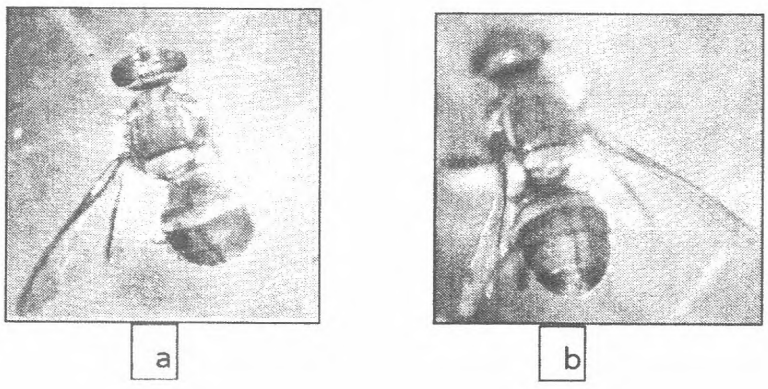


Figure 4. Photographs of *(a)B. Diversa, (b) B. Caudate* and *(c)B. Trilineata*, *(d)B. Nigrotibialis*, (e) *D. (Caillantra)* sp.1 and (f) unidentified species (only one specimen) (10x20x1.4).



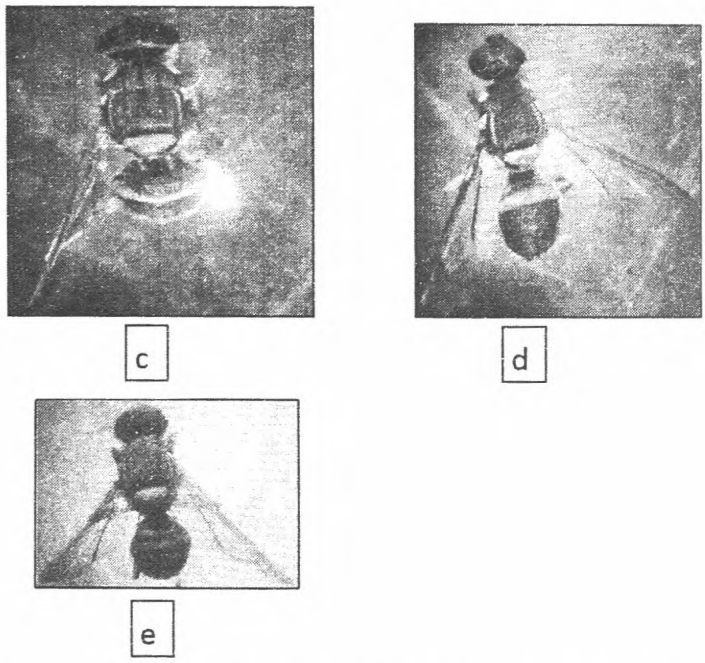


Figure 5. Photographs of *(a)B. Dorsalis, (b)B. Kandiensis, (c)B. Zonata, (d), B. Correcta and (e) B. Versicolor* (10x20x1.4)

Farmers' Perception and Management Methods Followed in Managing Fruit Flies

The farmer survey revealed those farmers followed three different methods for FF suppression: 1. those introduced by AWIPM program, 2. regular application of insecticides, 3. other approaches (Table 4). Farmers who rely insecticides found to have applied Acephate 75% SC, Profenofos 500 g /1 EC, Abamectin 18g/1 EC and Acetamiprid 20% SP regularly at 5 – 7 day intervals. Farmers who follow mixed practices have used homemade pheromone (pieces of pineapple/cucumber + Methyl Euginol + Insecticide), covering of fruits with polythene, sanitation and irregular application of insecticides. Damage due to FF ranged from 5% to 40%. The lowest damage was observed in farms under the AWIPM program.

Table 3. Fruit Fly species emerged from the field collected infested cucurbits (cucumber, pumpkin, snake gourd, bitter gourd and luffa) (n=100) (2016/17)

Districts	Species Emerged	Percentage (%)
Anuradhapura	*B. cucurbitae*	98.2 a
	B. tau	1.6 c
	D. ciliatus	0.2 c
Kurunegala	*B. cucurbitae*	88 a
	B.tau	12 b
Kandy	*B. cucurbitae*	86.6 a
	B. tau	13.3 b
	D. cilliatus	0.1c
	CV	13.7

Note: *Means with the same letter(s) are not significantly different at 5% DMRT

There were six reasons mentioned by the surveyed farmers for non-adoption of AWIPM program. Among them the highest percentages of the farmers have idea of fast action of insecticides / willingness to rely on insecticides and different time of planting of cucurbits in *Yaya* (Table5). Non awareness, trust worthiness and higher infestation of FF were showed in lower percentage of the farmers. It was also observed that most farmers who cultivate cucurbits in isolated and smaller areas (<0.2ha) preferred to follow AWIPM methods than those who cultivated in larger areas (Table 6).

Table 4. Fruit Fly Control Methods adopted by the farmers under cucurbit cultivation in Anuradhapura, Kurunegala and Kandy districts and the observed fruit damage (n=50)

Method of control	Percentage of farmers	Damage due to FF %
1. Cue-lure Pheromone traps.+ protein bait+ sanitation (IPM)	44 a	>5
2. Application of Insecticides	42 a	10-40
3. Other	14 b	10-40
CV%	27.1	

Table 5. Reasons for non-adoption of AWIPM program mentioned by the surveyed farmers in Anuradhapura, Kurunegala and Kandy districts (n=50)

Reasons for non-adoption	Percentage of farmers
1. Non awareness	5
2. Unavailability of continues supply of protein bait	12
3. No Trust on AWIPM package	10
4. Fast action of insecticides	38
5. Different time of planting of cucurbits in *Yaya*	24
6. Higher infestation of FF	11
CV%	23.2

Table 6. Adoption rate of IPM practices for Fruit Fly control under cucurbit cultivation in Anuradhapura, Kurunegala and Kandy districts according to the type of field (n=50).

Type of field	Percentage (%)
1.Cucurbit growing in Isolated field	76
2.Cucurbit growing in Yaya	24

CONCLUSION

The Cue-Lure traps found to attract five known species of melon Fruit Flies *B. cucurbitae, B. tau, B. caudata, B. trilineata, B. diversa* from all districts studied and a few sample of *D. caillantra* spp. and one unidentified specimen from Anuradhapura. In addition, three species known as true Fruit Flies, namely, *B. dorsalis, B. correcta* and *B. nigrotibialis,* were also found to attract to Cue-Lure traps. Three species of melon Fruit Flies, namely, *B. cucurbitae* (> 86%), *B. tau,* and *D. ciliatus* (lesser pumpkin fly/cucurbit fly) were collected from infested pumpkin, cucumber, snake gourd, luffa and bitter gourd from Anuradhapura, Kurunegala and Kandy districts. *D. ciliatus* was not attracted to Cue-Lure or Methyl Eugenol pheromone traps. Methyl Eugenol, in addition to Fruit Flies, also attracted a few Melon Fruit Fly *B. cucurbitae*.

Farmers in the above districts found to follow three different methods for Fruit Fly control in cucurbit cultivations. Six reasons mentioned for non-adoption of AWIPM program were non awareness, unavailability of continues

supply of protein bait, Trust worthiness of AWIPM package, fast action of insecticides/ willingness to rely on insecticides, different time of planting of cucurbits in *Yaya (*non co-operation among farmers in a same area), and higher infestation of FFs. Therefore, conducting more awareness programme among farmers is an urgent need to improve FF control methods adopted by the farmers in three aforesaid districts. Moreover, the fruit fly damage in farmers' fields who adopted the recommended IPM practices were lower (<5%) than that of those followed pesticides based management methods (> 40%). Farmers who cultivated cucurbits in isolated fields found to prefer IPM practices than those in intensively cultivated areas.

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