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Species Diversity and Relative Abundance of Fruit Flies (Tephritidae: Diptera) in Cucurbitaceous Vegetables

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An extensive survey was conducted in Coimbatore and Dharmapuri districts of Tamil Nadu from June, 2017 to May, 2018 to determine the species diversity and relative abundance of fruit flies in gourds *viz*., snake gourd (*Trichosanthes anguina* L.), ridge gourd (*Luffa acutangula* L.) and bitter gourd (*Momardica charantia* L.). The maximum species diversity of fruit flies was 0.15, recorded in Coimbatore in snake gourd. *Bactrocera cucurbitae* (Coquillet) (Diptera: Tephritidae) being predominant species (>95%) in both Dharmapuri and Coimbatore followed by *Dacus ciliatus* (Loew) (5%). The relative abundance of *B. cucurbitae* was high in all the three gourds at both locations. The diversity index, richness and evenness index were computed for both locations and it has concluded that fruit fly diversity was high in Coimbatore (0.06, 0.15 and 0.21, respectively) compared to Dharmapuri. Results of the present investigation may be utilized in developing a sustainable fruit fly management strategy in cucurbitaceous vegetable ecosystem.

Key words: *B. cucurbitae*, *D. ciliatus*, Methyl eugenol, Cue lure, Diversity indices, Relative abundance

Fruit flies (Diptera: Tephritidae) are important quarantine pests that may cause even up to 100 per cent yield losses in cucurbits (Dhillon *et al*., 2005). Among the fruit fly species, the melon fly, *Bactrocera cucurbitae* (Coquillet) infests over 70 hosts and it is the key insect species infesting the cucurbits *viz*., snake gourd (*Trichosanthes anguina* L.), ridge gourd (*Luffa acutangula* L.) and bitter gourd (*Momordica charantia* L.), muskmelon (*Cucumis melo* L.) and snap melon (*C. melo var. momordica* L.). This pest is widely distributed among tropical, sub-tropical and temperate regions of the world. On the other hand, the lesser pumpkin fly, *Dacus ciliatus* Loew. is becoming a silent threat in cucurbits (Krishna Kumar *et al*., 2006). Abundance of *D. ciliatus* over that of *B. cucurbitae* was also observed in some parts of India, Nepal and Pakistan (Kapoor, 2006). In India, *D. ciliatus* infests large number of melons and wild cucurbits causing serious damage in gourds ecosystem (Viraktamath *et al*., 2003).

Though the infestation pattern and damage symptoms of both species of *B. cucurbitae* and *D. ciliatus* are same but their morphology and seasonal abundance differ from each other. *B. cucurbitae* infest throughout the year and maximum number of adults are found during August whereas *D. ciliatus* is more from May to October (Krishna Kumar *et al*. 2006). In *D. ciliatus* the abdomen is petiolated, abdominal segments fused together, costal band apically expanded to form a small apical spot and a basal oblique spot present, while *B. cucurbitae* has overlapped abdominal segments and r-m cross vein are found with apical spot (David and Ramani, 2011). Though, there are many scientific reports on seasonality, host preference and degree of infestation for *B. cucurbitae* such same studies are lacking for *D. ciliatus*. Hence, thorough understanding of species composition and their abundance present in gourds ecosystem will pave way for the development of eco-friendly management practices for increased yield of cucurbits.

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Material and Methods

Survey

Survey was conducted in Coimbatore (11°14' 60.00" N; 77°18' 60.00"E) and Dharmapuri (40° 26.767' N ; 79° 58.933' W) districts of Tamil Nadu, India, during June 2017 to May 2018, to determine species diversity and relative incidence of fruit flies in cucurbit ecosystem *viz.,* snake gourd (*T. anguina*), ridge gourd (*L. acutangula*) and bitter gourd (*M. charantia*). In each district, three locations were selected randomly. Fruit flies were collected from the field daily by keeping methyl eugenol traps and cue lure traps as an attractants. Approximately 10 infested fruits from each vegetable ecosystem were collected and placed in glass cages and left undisturbed for a period of 15-20 days. The species that emerged were studied for their taxonomic identity and recorded. The species identity was confirmed by using David and Ramani (2011) taxonomical keys. If more than one species were noticed their proportion was also recorded.

The observations on number of fruit flies/trap/day and number of fruit flies /trap/week for eleven months from June 2017 to May 2018 were recorded in both the districts.

Measurement of fruit fly diversity

Relative abundance of species was calculated by the formula, Relative abundance= (Number of individuals of one species / Number of individuals of all species) X 100. Species or alpha diversity of the sites was quantified using Simpson's diversity Index (SDI) (Simpson, 1949) and Shannon-Wiener index (Shanon, 1949). SDI is a measure of diversity which takes into account the number of species present, as well as the relative abundance of each species.

SDI is calculated using the formula, D = Σn (n-1)/ N(N-1) where n=total number of organisms of a particular species and N=total number of organisms of all species. Subtracting the value of Simpson's index from 1, gives Simpson's Index of Diversity (SID). The value of the index ranges from 0 to 1, the greater the value the greater the sample diversity.

Shannon-Wiener index (H') is another diversity index worked out in this study as follow as: H'= – Σ Pi ln(Pi), where Pi=S / N; S=number of individuals of one species, N=total number of all individuals in the sample, ln=logarithm to base e. The higher the value of H', the higher the diversity. Species evenness was calculated using the Pielou's Evenness Index (E1) (Pielou, 1966). Pielou's Evenness Index, E1=H'/ ln(S); H'=Shannon-Wiener diversity index, S=total number of species in the sample.

Adult emergence studies

Approximately 10 infested fruits from each vegetable ecosystem were collected and placed with and in glass cages and left undisturbed for a period of 15-20 days. The species that emerges were studied for their taxonomic identity and recorded.

Results and Discussion

The Simpson's diversity index computed for fruit flies emerged from the infested fruits varied between the crops and it was highest with 0.06 in snake gourd and ridge gourd at Coimbatore and Dharmapuri, respectively and was least in ridge gourd at Coimbatore 0.03 (Table 1).

Table 1. Diversity of fruit flies in gourds

Crop	Coimbatore			Dharmapuri		
	SDI	H'	E1	SDI	H'	E1
Snake gourd	0.06	0.15	0.21	0.05	0.13	0.18
Ridge gourd	0.03	0.09	0.12	0.06	0.14	0.20
Bitter gourd	0.04	0.10	0.14	0.04	0.11	0.15

SID- Simpson's Index of Diversity, H'- Shannon-Wiener Index, E1- Pielou's index

Similarly Shannon-Wiener Index (*H'*) is highest in snake gourd at Coimbatore (0.15) followed by ridge gourd in Dharmapuri (0.14) and was least in ridge gourd in Coimbatore (0.09). The Shannon-Wiener Index (*H'*) value revealed that the fruit fly diversity was higher in snake gourd at Coimbatore followed by ridge gourd in Dharmapuri and least in ridge gourd at Coimbatore. The even distribution of species in both locations was indicated by Pielou's value which showed that the maximum evenness pattern was seen in snake gourd at Coimbatore (0.21) followed by ridge gourd (0.20) in Dharmapuri and it was least in ridge gourd (0.12). It indicated that the diversity of fruit flies in both locations is low (0.04 to 0.06) under gourds because the value of the index ranges from 0 to 1, the greater the value the greater the sample diversity (Simpson, 1949). Since the cucurbits are infested by only two species (*B. cucurbitae* and *D. ciliatus*), resulted in low diversity index value.

Table 2. Fruit flies abundance in gourds ecosystem

Crop	Species	Relative abundance (%)	
		Coimbatore	Dharmapuri
Snake gourd	*B. cucurbitae*	96.33	96.89
	D. ciliatus	3.66	2.49
Ridge gourd	*B. cucurbitae*	98.06	96.78
	D. ciliatus	1.93	3.21
Bitter gourd	*B. cucurbitae*	97.71	97.5
	D. ciliatus	2.28	2.49

The relative incidence of fruit fly species in all the three gourds was computed to know the dominant species among *B. cucurbitae* and *D. ciliatus* in both districts. The data indicated that the B. cucurbitae is the dominant species in all the three gourds and high incidence of 98.06 per cent (Table 2) in ridge gourd and bitter gourd it was 96.33 per cent. *D. ciliatus* was less abundant with less than 5 per cent and its incidence was highest with 3.66 per cent in snake gourd and 2.28 per cent in bitter gourd at Coimbatore.

In Dharmapuri, the relative abundance of B. *cucurbitae* was highest in bitter gourd with 97.5 per cent followed by 96.89 per cent in snake gourd. The *D. Ciliatus* population was least as compared to B. *cucurbitae* which was less than 5 per cent and its

population was highest with 3.21 per cent in ridge gourd at Dharmapuri.

The results from the relative abundance revealed that *B. Cucurbitae* is the dominant species in gourds. Similarly, Kapoor *et al*. (1993) reported the incidence of *D. ciliatus* along with *B. cucurbitae* in cucurbits. Vayssieres *et al*. (2008) reported that *B. cucurbitae* and *D. ciliatus* are the major pest of cucurbit crops and the former is capable of causing heavy damage due to its longer/higher fecundity level and oviposition time compared to *D. ciliatus*.

Table 3. Emergence of *B. cucurbitae* adults from infested gourds kept in laboratory

Period	Location I-Coimbatore					
	Snake gourd		Ridge gourd		Bitter gourd	
	*Total no. of fruit flies emerged	F:M	*Total no. of fruit flies emerged	F:M	*Total no. of fruit flies emerged	F:M
Jun-17	41	0.52: 1	42	0.68: 1	29	0.53: 1
Jul-17	55	0.83: 1	51	0.59: 1	40	0.60: 1
Aug-17	77	0.83: 1	68	0.58: 1	50	0.56: 1
Sep-17	115	0.62: 1	117	0.31: 1	90	0.73: 1
Oct-17	140	0.69: 1	159	0.92: 1	132	0.59: 1
Nov-17	133	0.66: 1	141	0.53: 1	123	0.89: 1
Dec-17	73	0.83: 1	85	0.67: 1	81	0.88: 1
Jan-18	55	0.83: 1	63	0.66: 1	55	0.83: 1
Feb-18	41	0.41: 1	35	0.59: 1	36	0.71: 1
Mar-18	36	0.64: 1	25	0.92: 1	27	0.80: 1
Apr-18	28	0.65: 1	15	0.50: 1	13	0.86: 1
May-18	20	0.82:1	12	1.40:1	10	0.67:1
Total	814		813		686	
Mean±SE	67.83±11.31		67.75±13.48		57.16±11.26	

***** Count of fruit flies emerged from ten fruits

The findings of the present study clearly showed that the *B. cucurbitae* and *D. ciliatus* are the true pest species of gourds and *B. dorsalis* and *B. correcta* are not the true pest of gourds and the latter might have been attracted from neighbouring fruit crops, since the parapheromones are selective in nature and attract the insects from long distance even up to 65 km (Steiner *et al*., 1961). The female to male ratio of emerged fruit flies indicated that the proportion of males was high (0.95: 1) compared to females.

Table 4. Emergence of *B. cucurbitae* adults from infested gourds kept in laboratory

Period	Location II-Dharmapuri					
	Snake gourd		Ridge gourd		Bitter gourd	
	*Total no. of fruit flies emerged	F:M	*Total no. of fruit flies emerged	F:M	*Total no. of fruit flies emerged	F:M
Jun-17	41	0.95: 1	44	0.76: 1	48	0.41: 1
Jul-17	69	0.73: 1	66	0.69: 1	70	0.52: 1
Aug-17	136	0.66: 1	109	0.40: 1	102	0.57: 1
Sep-17	168	0.49: 1	177	0.50: 1	156	0.63: 1
Oct-17	225	0.50: 1	204	0.57: 1	203	0.80: 1
Nov-17	102	0.65: 1	101	0.91: 1	132	0.83: 1
Dec-17	62	0.82: 1	75	0.79: 1	71	0.82: 1
Jan-18	51	0.65: 1	53	0.47: 1	52	0.68: 1
Feb-18	32	0.52: 1	32	0.68: 1	31	0.55: 1
Mar-18	27	1.08: 1	21	0.31: 1	19	0.58: 1
Apr-18	13	0.44: 1	13	0.44: 1	11	0.57: 1
May-18	9	1.25: 1	7	0.40: 1	4	1: 1
Total	935		902		899	
Mean±SE	77.91±18.59		75.16±17.40		74.91±17.16	

***** Count of fruit flies emerged from ten fruits

Table 5. Emergence of *D. ciliatus* adults from infested gourds kept in laboratory

Period	Location I-Coimbatore					
	Snake gourd		Ridge gourd		Bitter gourd	
	*Total no. of fruit flies emerged	F:M	*Total no. of fruit flies emerged	F:M	*Total no. of fruit flies emerged	F:M
Jun-17	0	0	0	0	2	1: 1
Jul-17	7	1.33: 1	2	1: 1	3	0.50: 1
Aug-17	11	0.83: 1	3	0.50: 1	3	0.50: 1
Sep-17	7	1.33: 1	6	1: 1	4	1: 1
Oct-17	6	1: 1	4	0.33: 1	3	2: 1
Nov-17	-	-	-	-	-	-
Dec-17	-	-	-	-	-	-
Jan-18	-	-	-	-	-	-
Feb-18	-	-	-	-	-	-
Mar-18	-	-	-	-	-	-
Apr-18	-	-	-	-	-	-
May-18	-	-	-	-	-	-
Total	31		16		16	
Mean±SE	2.5 ± 1.10		1.33 ± 0.56		1.33 ± 0.44	

* Count of fruit flies emerged from ten fruits

Two species of fruit flies *viz*., B. *Cucurbitae* and D. *Ciliatus* emerged from the infested fruits. The fly emergence indicated that the B. *Cucurbitae* is the dominant species infesting cucurbits throughout the year and high infestation shown during cooler months (October) in ridge gourd, snake gourd and bitter gourd which was 159/ten fruits, 140/ ten fruits and 132 / ten fruits respectively at Coimbatore (Table 3). The emergence of fruit flies showed that in Dharmapuri also the B. *Cucurbitae* was the dominant species in

Table 6. Emergence of *D. ciliatus* adults from infested gourds kept in laboratory

Period	Location II-Dharmapuri					
	Snake gourd		Ridge gourd		Bitter gourd	
	*Total no. of fruit flies emerged	F:M	*Total no. of fruit flies emerged	F:M	*Total no. of fruit flies emerged	F:M
Jun-17	4	3: 1	4	1: 1	4	3: 1
Jul-17	5	0.67: 1	6	0.50: 1	3	0.50: 1
Aug-17	7	1.33: 1	8	1.67: 1	5	1.50: 1
Sep-17	6	1: 1	4	0.33: 1	6	2: 1
Oct-17	5	0.67: 1	6	1: 1	4	1: 1
Nov-17	2	1: 1	2	1: 1	1	0:1
Dec-17	-	-	-	-	-	-
Jan-18	-	-	-	-	-	-
Feb-18	-	-	-	-	-	-
Mar-18	-	-	-	-	-	-
Apr-18	-	-	-	-	-	-
May-18	-	-	-	-	-	-
Total	29		30		23	
Mean±SE	2.41 ± 0.76		2.56 ± 0.82		1.91 ± 0.63	

* Count of fruit flies emerged from ten fruits

gourds where more number of flies emerged during cooler months (October) in snake gourd, ridge gourd and bitter gourd which was 225/ ten fruits (Table 4), 204 /ten fruits and 203 /ten fruits, respectively. The D. ciliatus showed emergence only from June to October in Coimbatore and it is extended up to November in

Dharmapuri. The highest emergence of D. ciliatus was recorded during August (11/ ten fruits) (Table 5) in snake gourd in Coimbatore and 8/ ten fruits (Table 6) in ridge gourd in Dharmapuri.

Fruit fly composition emerged from infested fruits were mostly *B. cucurbitae* along with a population of *D. ciliatus*. Less proportion (4.5%) of *D. ciliatus* in cucurbit ecosystem was also represented by Kumar *et al.* (2006). Studies by Mwatawala *et al.* (2010) revealed that besides *B. cucurbitae*, indigenous species *viz.*, *D. bivittatus* (Bigot), *D. ciliatus*, *D. punctatifrons (*Karsch) and *D. frontalis* (Becker) have been attracted to the traps kept in cucurbit ecosystem. The results further showed that *B. cucurbitae* and *D. ciliatus* were the species attracted in gourds and also the parapheromones used in gourds are not suitable for trapping *D. ciliatus*. These findings are supported by White and Elson- Harris (1992) who also reported that the *D. ciliatus* is not attracted to parapheromone lures.

Conclusion

The present study revealed that the fruit fly species diversity in gourds was high in Coimbatore compared to Dharmapuri. The *B. cucurbitae* and *D. ciliatus* are the true pests of gourds. *B. cucurbitae* was the dominant species over *D. ciliatus* in both locations. The *B. cucurbitae* emerged high in gourds during cooler months (June to October) and *D. ciliatus* incidence was high during June to November. Therefore, management of fruit flies in gourds ecosystem can be adopted during these periods will reduce the incidence and increase the yield of cucurbits. Results of the present investigation may be utilized in developing a sustainable fruit fly management strategy in the cucurbitaceous vegetable ecosystem.

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