FARMER'S SURVEY AND MONITORING OF FRUIT FLIES (Diptera: Tephritidae) IN CITRUS ORCHARDS OF RAMECHHAP DISTRICT, NEPAL

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ABSTRACT

Fruit flies (Diptera: Tephritidae) are devastating pests in citrus orchards of Nepal causing huge losses of fruits. A farmer's survey was carried from March to December, 2021 randomly selecting 40 citrus orchard owners, and at the same time, a field monitoring of fruit flies organised in randomized complete block design with 7 times replicated 3 treatments (Cue lure and malathion in Steiner trap, Methyl eugenol and malathion in Steiner trap and protein bait in McPhail trap) were conducted in Ramechhap district of Nepal. Survey revealed that Chinese citrus fly was the most problematic insect pest of citrus orchard. However, only few farmers were practising effective control measures against this pest. Nine species of fruit flies were trapped in different lures and protein bait, when the number of fruit flies differed significantly ($p<0.05$) except *Bactrocera correcta* and *Zeugodacus cucurbitae*, which were found attracted in negligible number in Methyl eugenol and Cue lure, respectively. *Z. scutellaris, Z. tau*, *B. nigrofemoralis* were attracted to Cue lure. *B. dorsalis* and *B. zonata* were attracted to Methyl eugenol and *B. minax, B. nigrofemoralis* and *Dacus sphaeroidalis* were attracted in protein bait. The study concluded that the male lures and protein bait were useful to monitor specific fruit fly species in citrus orchards, hence their management strategies should be made accordingly.

Key words : Citrus, Chinese citrus fly, fruit fly monitoring, management

INTRODUCTION

Citrus recognized as a high-value crop in the Agriculture Perspective Plan of Nepal (APP, 1995) is cultivated in more than 60 districts in 32,188 ha productive area contributing a share of 22.94% in total fruit production (MoALD, 2022). Citrus fruits are well-known and crucial in terms of income and climatic suitability, however, citrus production has been decreasing every year due to the conventional poor crop management practices, marginal production, legal and institutional constraints, insufficient irrigation, biotic and abiotic stresses. An attack of fruit flies could be recorded as a top biotic factor in declining the citrus production in the country (Gautam *et al.*, 2020).

Fruit flies are the tree and vegetable-fruits devastating pests around the world (USDA, 2009). Most of them are polyphagous, and possess an innate capacity of a high fecundity, and quick dessimination over a wide area in a short period of time (Adhikari *et al.*, 2018). They are medium-sized, pictured-winged and highly ornamented flies those infest a wide variety of fruits, flower heads, and seeds of plants (Prabhakar *et al.*, 2012). Several citrus fruits are damaged by fruit flies quantitatively and qualitatively (Adhikari *et al.*, 2018). These pests not only causes yield losses through fruit droppings, but also limit the citrus export trade in Nepal due to phytosanitary restrictions. A total of 27 species of fruit flies has been recorded in Nepal (Adhikari *et al.*, 2022a). The most common tree fruit species are *Bactrocera dorsalis* (Hendel) and *B. zonata* (Saunders), and fruit fly species of cucurbits are *Zeugodacus tau* (Walker) and *Z. cucurbitae* (Coquillett) (Doorenweerd *et al.*, 2018; Leblanc *et al.*, 2019). Citrus fruit loss due to the Chinese citrus fly, *B. minax* (Enderlein) appeared a serious threat since 2014 in the citrus orchards of Sindhuli district, Nepal when a loss of citrus up to 97% reported (Adhikari *et al.*, 2018). This study was carried out to identify farmer's problems regarding the most severe insect pest in citrus, highlight the attraction of fruit flies in different lures and bait traps and their management practices used by farmers for the control of Chinese citrus flies in Ramechhap district of Nepal.

MATERIALS AND METHODS

The research consisted of farmer's survey and field monitoring of fruit flies conducted from March to December, 2021 in Ramechhap, Nepal. A field survey was conducted in 5 different wards (wards 1-5) of Sunapati Rural Municipality, Ramechhap using a semi-structured questionnaire to document the farmer's knowledge, attitude and practices on fruit fly management in citrus orchard. Among the listed 400 citrus growers in the Agriculture Section of Sunapati Rural Municipality, 10% (40 citrus growers) were selected using a simple random sampling method and face-to-face interviews to record questionnaires from the respondent farmers. Secondary data concerned to this study were collected from different publications of the Prime Minister Agriculture Modernization Project, Project Implementation Unit Sindhuli and Ramechhap, and different journals and magazines.

Farmer's perceptions towards insect pests and disease problems in the citrus orchard were ranked. The scale values of 1, 0.8, 0.6, 0.4 and 0.2 were used for most severe, highly severe, moderately severe, slightly severe and least severe pest problem, respectively (Miah, 1993). Index of importance of problem was computed using the following formula.

$$I_{imp} = \sum(S_i * F_i / N) \text{ (Miah, 1993),}$$

where,

I_{imp} = Index of importance
$\sum$ = Summation
S_i = Scale value at i^{th} severity
F_i = Frequecy of i^{th} severity
N = Total number of respondents

Field Monitoring of Fruit Flies

Field monitoring was done in Sunapati Rural Municipality, Ramechhap at seven different locations using Cue lure (CL), Methyl eugenol (ME) and protein bait. McPhail trap (16 cm length, 13 cm diameter) baited with Great fruit fly bait (25% protein hydrolysate with 0.1% abamectin) for Chinese citrus fly and other fruit flies, and Steiner trap (12 cm length, 10 cm diameter) baited with Cue lure (70% w/w 4-p-hydroxy phenyl-2- butanone acetate) (Sentomole Company, UK), and Methyl eugenol (>60% w/w 4-allyl-1, 2-dimethoxy benzene) (Sentomole Company, UK) were used for other fruit fly species. The bait in Steiner trap was made lethal by means of Malathion 50% EC.

Fruit fly monitoring study was designed in Randomized Complete Block Design with 3 treatments, namely Cue lure + malathion, Methyl eugenol + malathion, and Great fruit fly bait which were replicated into 7 sites, namely Thuldhunga (R1) (27.49638^{0}N, 85.872238^{0} E), Aarukharka (R2) (27.497375^{0}N, 85.868543^{0} E), Sadi (R3) (27.50029^{0}N, 85.863541^{0} E), Kharak (R4) (27.494370^{0}N, 85.855997^{0} E), Newartol (R5) (27.498862^{0}N, 85.862149^{0} E), Dimi (R6) (27.5156^{0}N, 85.884397^{0} E), Pokhari (R7) (27.499459^{0}N, 85.893669^{0} E). Treatments were randomly selected in different locations. At least 5 m distance was maintained within treatments.

Preparation and Field Setting of Traps

Following were the treatments

1. Cue lure (1 ml) + malathion (1 ml) in Steiner trap.
2. Methyl eugenol (1 ml) + malathion (1 ml) in Steiner trap.
3. Great fruit fly bait (25% protein hydrolysate with 0.1% abamectin) (1 part mixed with 2-part water) 1 cm bottom of the McPhail trap.

One ml Cue lure cotton piece along with 1 ml malathion cotton piece was placed in Steiner trap at its top side and bottom, respectively (Bhusal *et al.*, 2020). Similarly, second treatment with Methyl eugenol in Steiner trap was made. Great fruit fly bait (1 part mixed with 2 part water) was poured in the McPhail trap maintaining its quantity at 1cm at the bottom of the trap (PQPMC, 2019). The traps were installed at 2 m above ground level each at a distance of at least 5 m from each other (Adhikari *et al.*, 2018). The protein bait solution, lure and malathion were replaced in the trap in every 15 days. (PQPMC, 2019).

Fruit Flies Identification and Data Analysis

Trapped fruit flies were collected, identified, counted and recorded at 15 days intervals. Identification was done using the important morphological characteristics including, body size, color, wing morphology, presence of thoracic vittae etc. (Prabhakar *et al.*, 2012). The data were recorded in a Microsoft Excel worksheet and analysis was subjected to Genstat® 15th edition for Analysis of Variance (ANOVA). Before performing the ANOVA, the data were square root $\sqrt{(x + 0.5)}$ transformed to reduce the variance heterogeneity. Duncan's Multiple Range Test (DMRT) at a 5% level of significance was used for mean separation (Gomez & Gomez, 1984). Abundances and composition of fruit fly species were analyzed and displayed in bar charts using Microsoft Excel.

RESULTS AND DISCUSSION

Farmer's Response to Insect Pest Problems in Citrus Orchards

Respondents (n = 40) ranked the fruit fly primarily Chinese citrus fly with an index of 0.86 followed by the citrus stink bug (0.85), citrus aphid (0.48), fruit-sucking moth (0.43) and scale insect (0.38) (Table 1). Half of the respondents (n = 20) were unknown of the vulnerable stage of fruits to *B. minax* and less than one-third (30%) of respondents remarked that the vulnerable stage was immature fruit whereas one-fifth reported that it was the mature fruit stage (Fig. 1). About 2/5th of the respondents (37.5%) said that the damage level of *B. minax* was 50-75%, whereas slightly above one-third of respondents (35%) expressed to 25-50% damage level, while very few respondents (7.5%) responded 75-100% damage level in their orchards (Fig. 2). These findings are partially similar to the findings of Khanal and Bhandari (2019) in mandarin orchards.

Table 1. Problem ranking of different insect pests in citrus orchards, Sunapati, Ramechhap district, Nepal

Insect pests	Scale of severity					Weightage	Index	Rank
	1	**0.8**	**0.6**	**0.4**	**0.2**			
Chinese citrus fly, *Bactrocera minax*	26	9	0	1	4	34.4	0.86	1
Citrus stink bug, *Rhynchocoris humeralis*	14	23	2	1	0	34.0	0.85	2
Fruit sucking moth, *Ophiusa coronata*	0	4	12	10	14	17.2	0.43	4
Citrus aphid, *Toxoptera citricida*	0	2	19	12	7	19.2	0.48	3
Citrus scale, *Aonidiella aurantii*	0	2	7	16	15	15.2	0.38	5

Farmer's perception towards insect pest problems in citrus orchard were ranked in the scale values of 1, 0.8, 0.6, 0.4 and 0.2 correspond to most severe, highly severe, moderately severe, slightly severe and the list severe, respectively. Mathematically, $I_{imp} = \sum(S_i * F_i / N)$ (Miah, 1993).

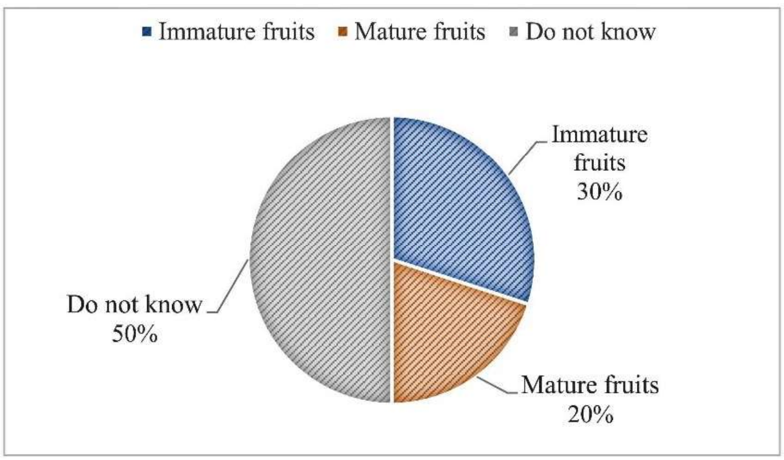

Fig. 1. Respondent's knowledge of the vulnerable stage of citrus fruits to *B. minax* in Sunapati, Ramechhap district, Nepal.

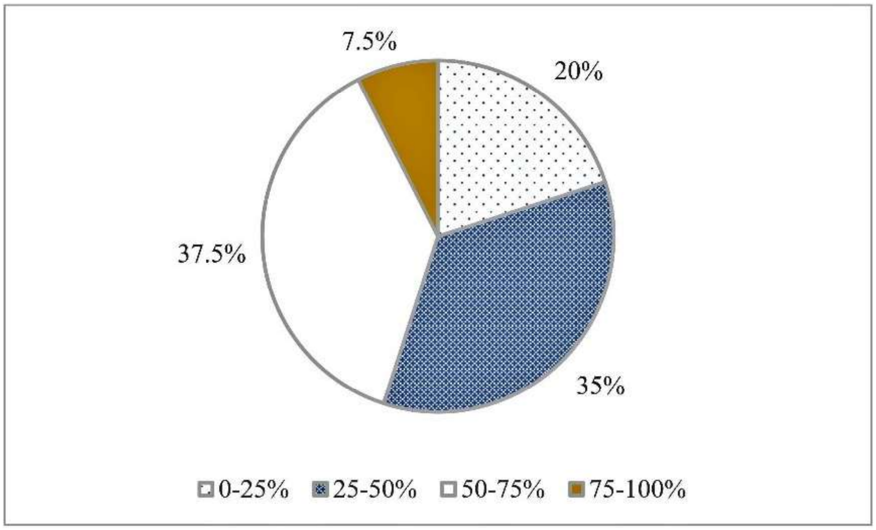

Fig. 2. Respondent's perception on the damage level of *B. minax* in Sunapati, Ramechhap district, Nepal.

Nearly 50% of respondents heard about the fruit fly in citrus gardens, while only a small proportion (12.5% and 27.5%) of farmers were able to differentiate fruit fly species and identify *B. minax*, respectively, because of the lack of technical knowledge to differentiate and identify different fruit fly species. Gautam *et al.* (2020) reported that the majority of respondents (81.7%) didn't know *B. minax.*

Farmer's Practices on Fruit Flies Management in Citrus Orchard

Nearly two-thirds of respondents used insecticides for the control of fruit flies and the rest (35%) didn't spray any insecticides. Other fruit fly management methods included biological control adopted 10% of respondents and cultural practice by 52.5% of respondents (Fig. 3). Adhikari *et al.* (2022b) reported that most of the respondents knew of chemical insecticides, orchard sanitation, cultural measures, pheromone lure/trap, botanicals, food/protein bait and exclusion measures for the control of different fruit flies. Similarly, slightly above 40% of farmers knew protein bait however, only a quarter of total farmers heard about the area-wide control programme (AWCP) initiated in their citrus orchards (Fig. 4). Similar cases were reported by Gautam *et al.* (2020) where 81.7% of farmers didn't know about protein bait for the management of *B. minax*.

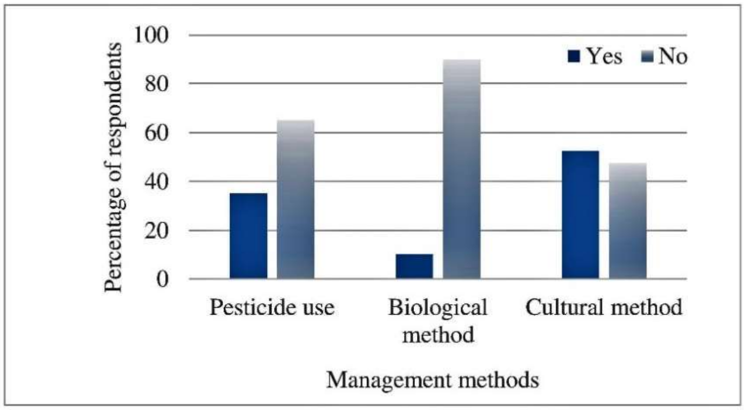

Fig. 3. Respondents practiced fruit fly management measures in Sunapati, Ramechhap district, Nepal.

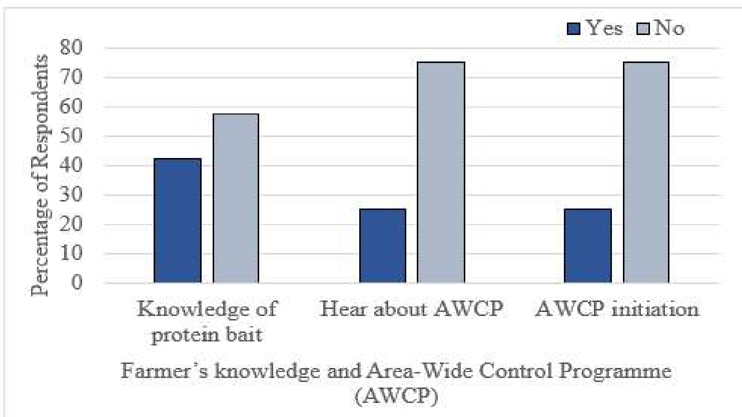

Fig. 4. Use of protein bait and area-wide-control-program initiation in Sunapati, Ramechhap district, Nepal.

Abundance and Diversity of Fruit Flies

A total of 8143 fruit flies of 9 different fruit fly species were recorded during the study period of March to September 2021 from 7 different locations (Table 2 and Fig. 5). Among the seven locations, a maximum number of fruit flies, 2666, was trapped in Sadi and a minimum number, 505, in Pokhari (Table 2). The mean number of fruit flies over time in ME was higher as compared to CL and protein bait traps. Difference in the abundance of fruit flies in different locations might be due to differences in the availability of food sources (Bhusal *et al.*, 2020). The highest number of fruit flies in Sadi might be due to suitable environmental conditions and host availability for fruit flies. Pashi *et al.* (2021) found the infestation rate was affected by altitudes. These findings found to be in line with the results of Leblanc *et al.* (2019), where *B. dorsalis, Z. cucurbitae, B. nigrofacia, B. zonata* and *Z. tau* is abundant at places of lower and mid altitudes than higher altitudes.

Table 2. Abundance of fruit fly species at different locations, Sunapati, Ramechhap district, Nepal (March to September, 2021)

Orchard site	Number of fruit fly species									Total
	Zeugodacus tau	*Zeugodacus cucurbitae*	*Bactrocera dorsalis*	*Zeugodacus scutellaris*	*Bactrocera minax*	*Dacus sphairoidalis*	*Bactrocera nigrofemoralis*	*Bactrocera zonata*	*Bactrocera correcta*	
Thuldhunga	77	-	559	69	10	2	7	16	2	742
Aarukharka	142	2	1060	64	4	1	21	10	-	1304
Sadi	605	15	1746	270	5	2	10	6	-	2666
Kharak	168	7	972	152	7	5	6	5	-	1322
Newartol	79	-	793	71	5	3	5	21	-	977
Dimi	131	1	395	86	5	-	3	6	-	627
Pokhari	99	-	259	130	6	2	4	5	-	505
Total	1308	25	5784	842	42	15	56	69	2	8143

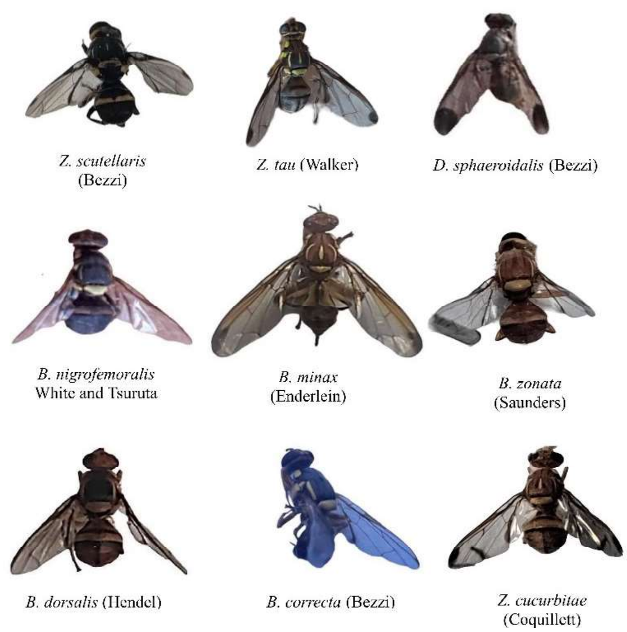

Fig. 5. Photos of different species of fruit flies trapped in CL, ME, and protein bait traps in Sunapati, Ramechhap district, Nepal.

The CL traps attracted 5 fruit fly species with the highest proportion of *Z. tau* (55.5%) followed by *Z. scutellaris* (40.8%), while the proportion of *B. dorsalis, Z. cucurbitae* and *B. nigrofemoralis* ranged from 0.9% to 1.6%. Likewise, 5 fruit fly species were attracted to ME with the highest percentage of *B. dorsalis* (98.7%) followed by *B. zonata, B. nigrofemoralis, Z. scutellaris* and *B. correcta* (Fig. 6). However, Noman *et al.* (2021) found *B. zonata* (60%), in most abundant followed by *B.*

dorsalis (22%), *B. cucurbitae* (16%), and *B. correcta* (2%) in Methyl eugenol. Similarly, in protein bait traps, 8 species, namely *Z. tau, B. minax, B. dorsalis, B. nigrofemoralis, Z. scutellaris, D. sphaeroidalis B. zonata* and *Z. cucurbitae* were found attracted to the tune of 47.3%, 18.8%, 9.8%, 9.4%, 8.9%, 4.5%, 0.9% and 0.4%, respectively (Fig. 6). The percentages of fruit flies trapped in different lures were found different from the previous study by Adhikari *et al.* (2018). This variation in the number of species attracted to lures may be due to differences in lure concentrations and agro-ecological conditions. Small numbers of *B. dorsalis* were also found trapped in CL traps. It might be due to more abundance of *B. dorsalis* in certain months, lures contamination during handling of different lures at the same time and placement of traps at a nearer distance of 5 m. Maximum number of fruit fly species were found attracted to protein bait traps (Fig. 6), that might be the protein bait remained common source of protein essential to healthy oviposition and maintenance of life for each and every kind of fruit flies. However, protein bait traps are less sensitive as compared to para-pheromone lures (IAEA, 2003).

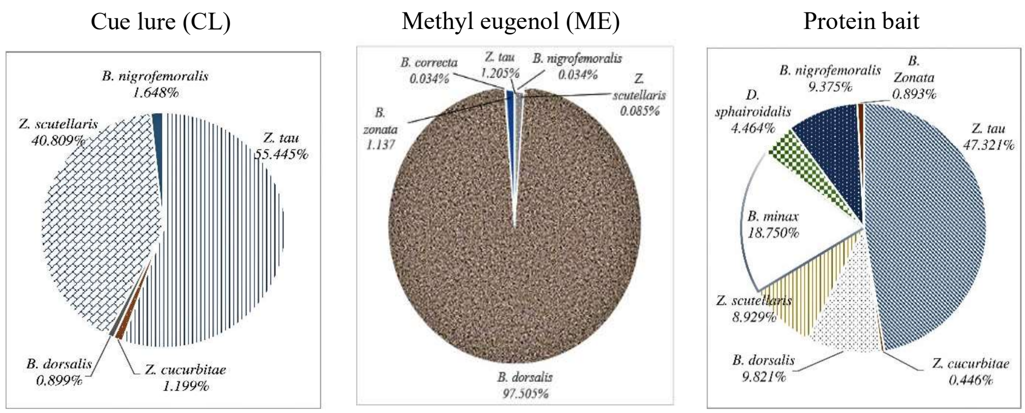

Fig. 6. Fruit fly species composition attracted to CL, ME, and protein baits from March to September in Sunapati, Ramechhap district, Nepal.

Average number of fruit fly species trapped in three different types of lures and bait (CL, ME, and protein bait) were significantly different ($P<0.05$ and 0.01) except for *B. correcta* and *Z. cucurbitae* (Table 3). Three species of fruit flies, *Z. tau, Z. scutellaris*, and *B. nigrofemoralis* were significantly attracted to CL traps. Likewise, *B. dorsalis* and *B. zonata* were attracted to ME traps. Similarly, protein bait trap was found significantly attractive to *B. minax, B. nigrofemoralis* and *Dacus sphaeroidalis.* But, it was less attractive to *Z. cucurbitae* and *B. correcta* and did not significantly differ from the fruit flies counts in lure and protein bait traps. *B. minax* and *D. sphaeroidalis* were only attracted to protein bait traps, and *B. zonata* was only attracted to ME traps. The maximum mean number of fruit flies recorded in CL, ME, and protein bait were *Z. tau* (130.4), *B. dorsalis* (757.9) and *Z. tau* (4.1), respectively (Table 3). Bhusal *et al.* (2020) reported that the population of *Z. cucurbitae, Z. tau* and *Z. scutellaris* were influenced by CL, and *B. dorsalis, B. zonata* and *B. tuberculata* were attracted to ME. Likewise, Khursheed and Raj (2019) also found the population of *B. dorsalis* and *B. zonata* in ME and the population of *Z. tau, Z. scutellaris and Z. cucurbitae* in CL. Vargas *et al.* (2000) reported that the traps of ME and CL were highly attractive lures to *B. dorsalis* and *B. cucurbitae*, respectively.

Table 3. Average number of fruit fly species trapped in different lures/bait traps in citrus orchards of Sunapati, Ramechhap district, Nepal (March to September, 2021)

Treatment	Number of fruit fly species								
	Zeugodacus tau	*Zeugodacus cucurbitae*	*Bactrocera dorsalis*	*Zeugodacus scutellaris*	*Bactrocera minax*	*Dacus sphairoidalis*	*Bactrocera nigrofemoralis*	*Bactrocera zonata*	*Bactrocera correcta*
CL	130.42 (11.42)[a]	2.50 (1.58)	2.19 (1.50)[b]	108.99 (10.44)[a]	0.50 (0.71)[b]	0.50 (0.71)[b]	4.97 (2.23)[a]	0.50 (0.71)[b]	0.50 (0.71)
ME	9.30 (3.05)[b]	0.50 (0.71)	757.90 (27.5)[a]	1.00 (0.99)[b]	0.50 (0.71)[b]	0.50 (0.71)[b]	0.69 (0.83)[b]	9.36 (3.06)[a]	0.69 (0.83)
PB	17.14 (4.14)[b]	0.61 (0.78)	2.92 (1.70)[b]	2.99 (1.73)[b]	6.40 (2.53)[a]	2.43 (1.56)[a]	2.69 (1.64)[a]	0.74 (0.86)[b]	0.50 (0.71)
SEM(±)	1.29	0.29	1.76	0.71	0.81	0.11	0.23	0.19	0.07
$LSD_{0.05}$	3.98	ns	5.42	2.17	0.25	0.34	0.71	0.60	ns
CV%	55	75	45.4	42.5	16.2	29.7	38.9	33.2	25.5
G-mean	6.2	1.02	10.2	4.39	1.31	0.99	1.57	1.54	0.75
F value	0.001 (***)	0.1 (ns)	<0.001 (***)	<0.001 (***)	<0.001 (***)	<0.001 (***)	0.004 (**)	<0.001 (***)	0.397 (ns)

CV = Coefficient of variation, Means followed by the same letter in a column are not significantly different by DMRT at 5%, ** significant at 1% level of significance, *** significant at 0.1% level of significance, [ns] Non-significant. Figures in parenthesis indicate data transformed to $\sqrt{(x+0.5)}$, SEM = Standard error of mean, $LSD_{0.05}$ = Least significant difference at 5% level of significance

CONCLUSIONS

The majority of farmers consider the Chinese citrus fly as the most problematic pest in citrus orchards. Different fruit fly species are attracted to specific lures and traps such as *Z. tau, Z. scutellaris* and *B. nigrofemoralis* in Cue lure, *B. dorsalis* and *B. zonata* in Methyl eugenol and *B. minax, B. nigrofemoralis* and *D. sphaeroidalis* in protein bait. Hence, management of fruit flies should be done by using their respective lures and bait with an understanding of their diversity in a citrus orchard.

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