Entomology

Exploration of attractants with different trap designs and lure mixtures for effective capturing of *Bactrocera* spp (Diptera: Tephritidae) in mango orchards of Saharanpur district of Uttar Pradesh, India

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Received 30 Nov 2023; Accepted 11 Jan 2024; Published 19 Jan 2024

Abstract

The study aimed to investigate the efficacy of various attractants, trap designs, and lure mixtures for capturing *Bactrocera* spp in mango orchards of Saharanpur district, Uttar Pradesh, India. *Bactrocera* spp, commonly known as fruit flies, pose a significant threat to mango cultivation by causing extensive damage to fruit quality and yield. This research, conducted in different mango orchards of various places viz; Behat, Nakur and Sadholi Qadeem of Saharanpur district, examined the impact of different lure mixtures in baited traps on the attraction of fruit flies, particularly *Bactrocera zonata* and *Bactrocera dorsalis*, to develop efficient and sustainable strategies for fruit fly management in these regions. The research into the fusion of various traps and lures to attract fruit flies of genus *Bactrocera* has revealed an intriguing interplay of attractants. The findings demonstrated that lure mixtures in baited traps influence the attraction of fruit flies in a species-specific manner, with different species exhibiting varying levels of attraction to different lure mixtures. Notably, the most attractive lure mixture varied among the species, underscoring the need for species-specific considerations in integrated pest management programs. A total of 3780 and 2129 flies were captured for a research period of 17 weeks during the year 2023 for *B. dorsalis* and *B. zonata* respectively. It was observed that most of the fruit flies were attracted towards the cylindrical traps possessed with methyl eugenol lure followed by a mixture of methyl eugenol and cue lure. These results shed light on the potential for optimizing bait mixtures based on the relative abundance and economic impact of different fruit fly species, offering valuable insights for local fruit fly pest control programs. Furthermore, the study highlights the importance of future research aimed at refining lure mixtures to match specific kairomone emissions and maximize attractiveness across all targeted species.

Keywords: *Bactrocera* spp, Tephritidae, attractants, trap designs, lure mixtures, mango orchards, Saharanpur district, Uttar Pradesh, India

1. Introduction

India is the largest producer of mangoes in the world, contributing to over 45% of the world's mango production. The total area under mango cultivation in India is over 2 million hectares, with an annual production of around 22 million tons [1]. The country's diverse mango varieties, totaling about 1,000, make it the home of a wide range of flavors, aromas, and tastes. This rich variety and the substantial production volumes underscore the immense significance of mangoes in India, with Uttar Pradesh standing out as a key player in this thriving industry. Uttar Pradesh's mango production volume stands at 4540.23 thousand metric tons, contributing to approximately 23% of India's mango production [2]. Additionally, the state has the highest mango productivity, with 17.1 metric tons per hectare. Mango (*Mangifera indica*) holds significant cultural, economic, and medicinal value in Saharanpur, Uttar Pradesh, India. The mango tree, a member of the flowering plant family Anacardiaceae, has been revered in Ayurvedic and indigenous medical systems for over 4000 years. This tropical fruiting tree is not only popular for its delicious fruit but also for its diverse medicinal uses. The various parts of the mango tree, including the bark, leaves, and seeds, are utilized in traditional medicinal practices to treat an array of conditions such as asthma, diarrhea, hypertension, and rheumatism. Saharanpur, located in the state of Uttar Pradesh, India, has a diverse mango cultivation belt and is renowned for its mango orchards. The region's agro-climatic conditions provide an ideal environment for mango cultivation, contributing to the production of high-quality mango varieties.

Fruit flies, particularly those belonging to the *Bactrocera* genus, pose a significant threat to fruit crops worldwide, causing substantial economic losses [3]. Among various management strategies, the utilization of methyl eugenol traps has gained prominence due to its efficacy in attracting and capturing male fruit flies [4, 5]. Methyl eugenol, a natural plant-derived compound, serves as the primary attractant for male fruit flies [6]. Its aromatic properties mimic the natural fruit odors that attract these pests. This research article explores multiple trap design and lure mixtures employed in different mango orchards of Saharanpur Uttar Pradesh India for fruit fly management using methyl eugenol, cue lure, methyl eugenol + cue lure and fruition lure. Methyl eugenol traps offer a promising method for fruit fly management, particularly in the context of male fruit fly attraction [7, 8]. The use of appropriate

materials, trap designs, and deployment methods ensures the optimal efficacy of these traps. Continuous research and field trials are crucial for refining these techniques and developing integrated pest management strategies that are effective, environmentally friendly, and economically viable in the long term. As agriculture faces the ongoing challenge of fruit fly infestations, the development and improvement of methyl eugenol traps represent a valuable contribution to sustainable pest control practices.

2. Materials and methods

This research was carried by School of Agricultural Sciences Glocal University Saharanpur Uttar Pradesh India in various mango orchards of Behat, Nakur and Sadholi Qadeem. Different trap designs were be employed, such as cylindrical traps, Dome shaped traps, yellow sticky traps and a self-made trap named "Custom" in the form an ordinary 1L mineral water bottle to maximize the capturing efficiency of different species of genus Bactrocera. Figure 1 shows different types of traps and Table 2.1 shows completely randomized block design containing every possible combination of trap design and lure employed during the research. These traps are typically made of durable materials like plastic or metal. These traps were purchased, 100 pieces 25 each type, online from Harmony Ecotech Private Limited Hyderabad Telangana. The dimensions of cylindrical traps are 11-inch (height) and 8-inch (Dia) whileas dome shaped measures 8 inch in height and 5 inch in diameter. Yellow sticky traps were measured as 8-inch square boards. Methyl eugenol dispensers or wicks were used to release the attractant slowly, ensuring a constant and enticing scent. These dispensers are often made from materials that allow controlled release over an extended period.

(a) (b) (c) (d)

Fig 2.1: Shows different types of trap design. (a) Cylindrical type. (b) Dome shaped. (c) Yellow sticky trap. (d) Custom

Traps, around 100 in number, were strategically placed within different orchards to optimize coverage of these insect pests. The research was carried in the fruity season extending for 17 standard weeks starting from week number 23 upto week number 39 covering a duration of around 5 months June-Oct of the year 2023. Placement near fruit-bearing trees, at tree canopies, or at the orchard periphery enhances the chances of capturing male fruit flies seeking mates. Regular monitoring (weekly) of traps was essential to assess fruit fly populations. Maintenance involves replenishing methyl eugenol and other lure dispensers and replacing traps as needed. Traps were inspected for captured insects, and collected specimens were transported to laboratory for identification purposes. Two species were recognized to be most dominating namely *B. dorsalis* and *B. zonata*. Statistical calculations were done by IBM software package SPSS to study the effect of different treatments on the fruit fly populations trapped during the collection period.

Table 2.1: Shows completely randomized block design for different treatments corresponding to different trap shapes and lure mixtures

Trap type/Lure Type	Methyl Eugenol (ME)	Cue lure	Methyl Eugenol (ME)+Cue Lure	Fruition lure
Cylindrical	T1	T2	T3	T4
Dome shaped	T5	T6	T7	T8
Yellow Sticky	T9	T10	T11	T12
Ordinary 1L mineral water bottle (Custom)	T13	T14	T15	T16

3. Results and discussions

A total collection of 3780 and 2129 was recorded for the two species *B. dorsalis* and *B. zonata* respectively for the 5 months duration (17 Standard weeks). Figure 3.1 shows distribution of total flies trapped against different standard weeks of year 2023. This collection was done from standard week number 23 to standard week number 39. Both the species were active throughout the fruity season but there was a maximal collection from week number 32 to week number 35. Out of the 16 total combinations represented by the CRD, treatment 'T1' was recorded with maximum flies trapped for both the species measuring numbers 367 and 229 respectively followed by treatment 'T3' numbering 349 and 213 respectively. Treatment T1 corresponds to cylindrical trap design with lure methyl eugenol as attractant. Table 3.1 shows different treatments and number of flies of species *B. dorsalis* trapped from standard week number 23 to standard week number 39.

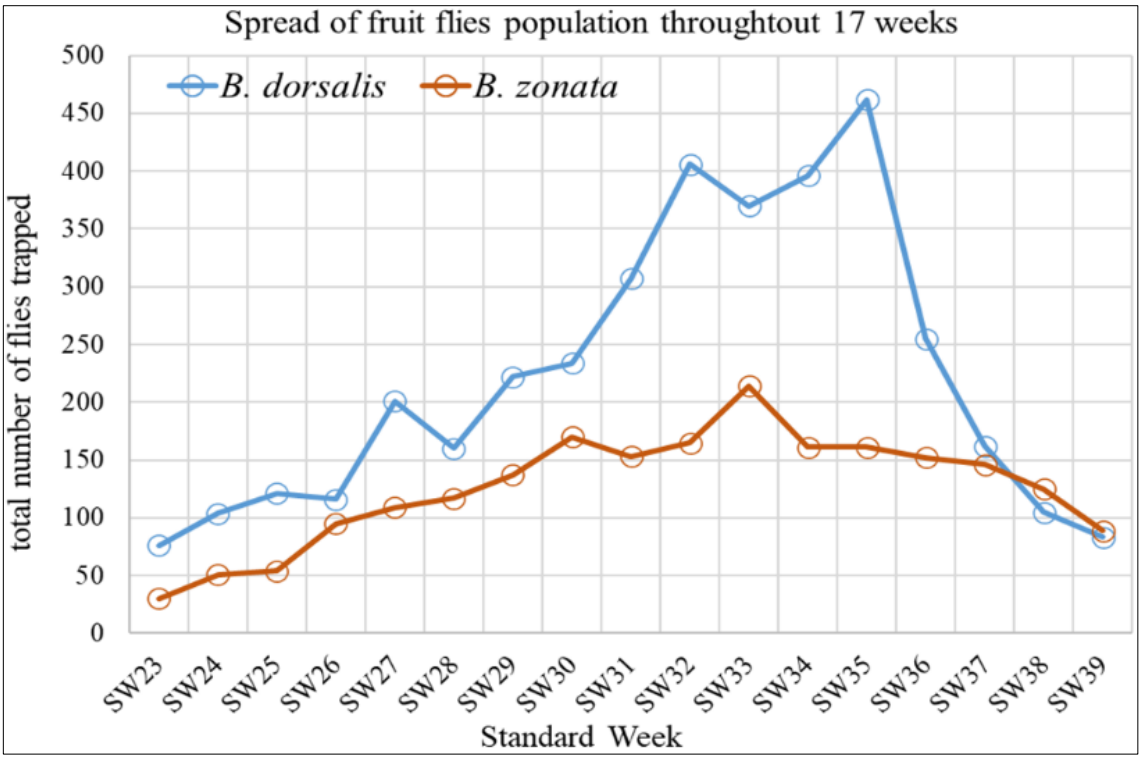

Fig 3.1: shows spread of B. dorsalis and B. zonata corresponding to different standard weeks of the year 2023

Effect of different trap design with different lure types was studied by plotting number of fruit flies trapped corresponding to various week numbers. Figure 3.2 shows spread of *B. dorsalis* for 17 weeks taking into consideration different trap designs with one lure type taken at a time. From the figure we observe that cylindrical trap was most effective in capturing the fruit flies of both the types corresponding to methyl eugenol followed by dome shaped and others. Also, we studied the effect of different lure types by considering one trap design at a time. Figure 3.3 shows the spread of *B. dorsalis* population trapped during 17 weeks. From the figure we can observe that methyl eugenol in association with cylindrical trap design is seen to be most effective in capturing the fruit flies in the mango orchards. Methyl eugenol was followed by a mixture of methyl eugenol and cue lure and others.

Table 3.1: Shows number of flies of species *B. dorsalis* captured during 17 standard weeks corresponding to various treatments

S. No.	SW	Date and Month	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	Total
1	23	Jun 6 - Jun 12	10	6	6	5	8	6	5	4	5	10	6	4	5	7	11	7	105
2	24	Jun 13 - Jun 19	7	10	11	6	8	6	8	5	9	5	3	8	6	4	4	5	105
3	25	Jun 20 - Jun 26	4	8	4	5	10	6	11	7	9	6	9	5	9	11	9	11	124
4	26	Jun 27 - Jul 3	10	11	6	9	9	10	11	5	5	9	9	11	5	11	7	3	131
5	27	Jul 4 - Jul 10	12	11	15	23	17	23	13	12	13	16	12	12	15	17	15	15	241
6	28	Jul 11 - Jul 17	18	16	17	15	22	22	12	21	20	11	22	16	18	16	22	19	287
7	29	Jul 18 - Jul 24	16	11	23	21	11	11	16	23	22	23	11	12	17	17	11	14	259
8	30	Jul 25 - Jul 31	20	12	16	16	20	22	18	16	12	17	20	21	17	16	14	15	272
9	31	Aug 1 - Aug 7	28	31	25	28	32	23	32	33	23	21	20	19	19	33	33	32	432
10	32	Aug 8 - Aug 14	21	32	31	27	31	32	25	26	29	21	19	29	32	27	33	26	441
11	33	Aug 15 - Aug 21	20	24	32	27	23	29	29	27	22	27	30	26	31	19	25	24	415
12	34	Aug 22 - Aug 28	26	32	21	20	20	31	20	23	23	30	25	30	19	20	26	24	390
13	35	Aug 29 - Sep 4	23	25	26	29	21	33	29	27	19	19	29	26	23	31	19	21	400
14	36	Sep 5 - Sep 11	11	16	11	13	19	14	14	16	16	15	14	13	17	11	18	19	237
15	37	Sep 12 - Sep 18	17	19	17	11	11	19	16	14	18	13	14	13	14	18	18	13	245
16	38	Sep 19 - Sep 25	13	17	11	17	18	19	11	17	13	12	15	16	11	19	17	13	239
17	39	Sep 26 - Oct 2	12	16	19	13	12	14	18	17	17	12	12	13	14	18	11	11	229
		Total	268	297	291	285	292	320	288	293	275	267	270	274	272	295	293	272	4552

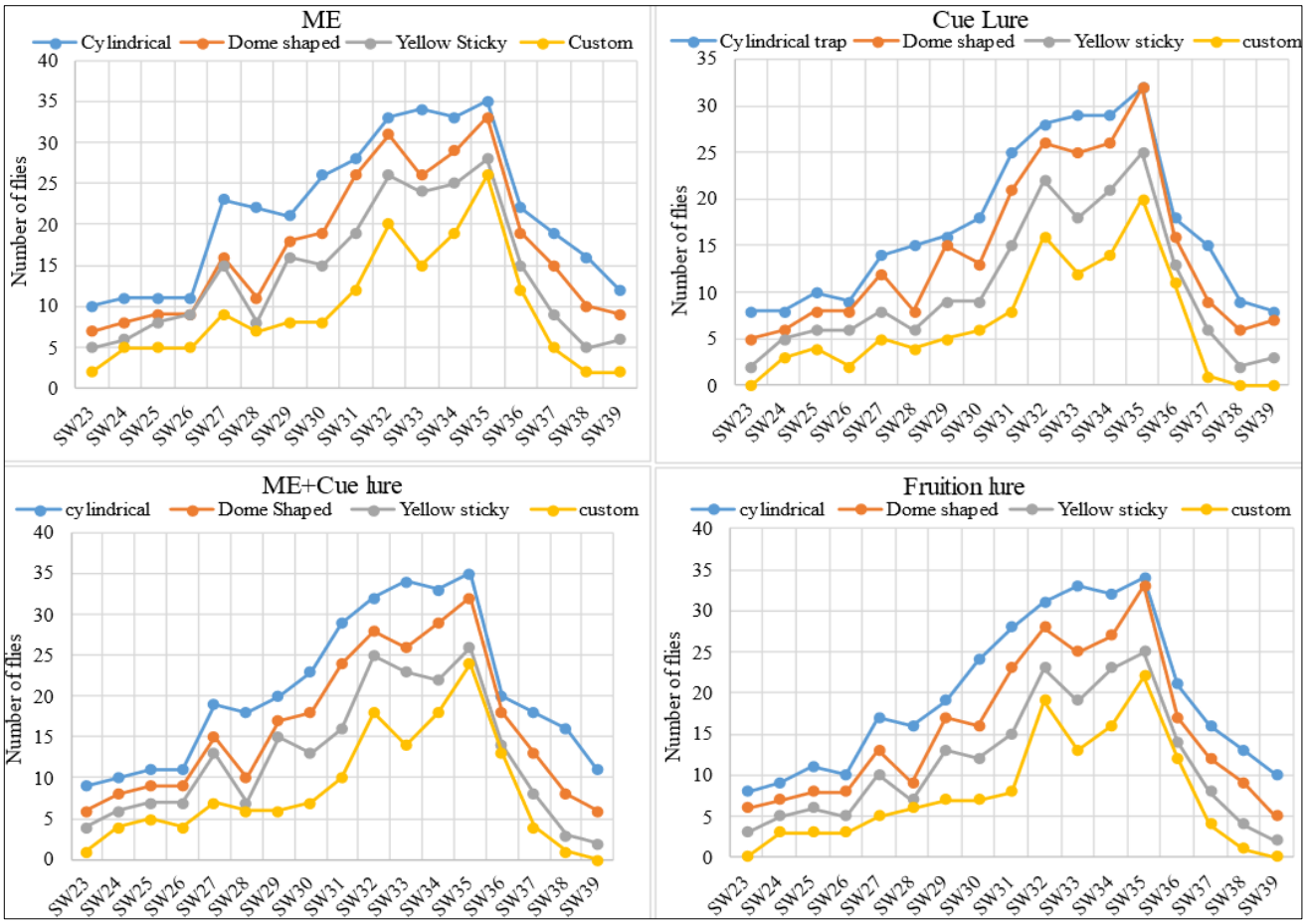

Fig 3.2: Shows spread of *B. dorsalis* taking into consideration effect of different types of trap design with different lure types taken one at a time

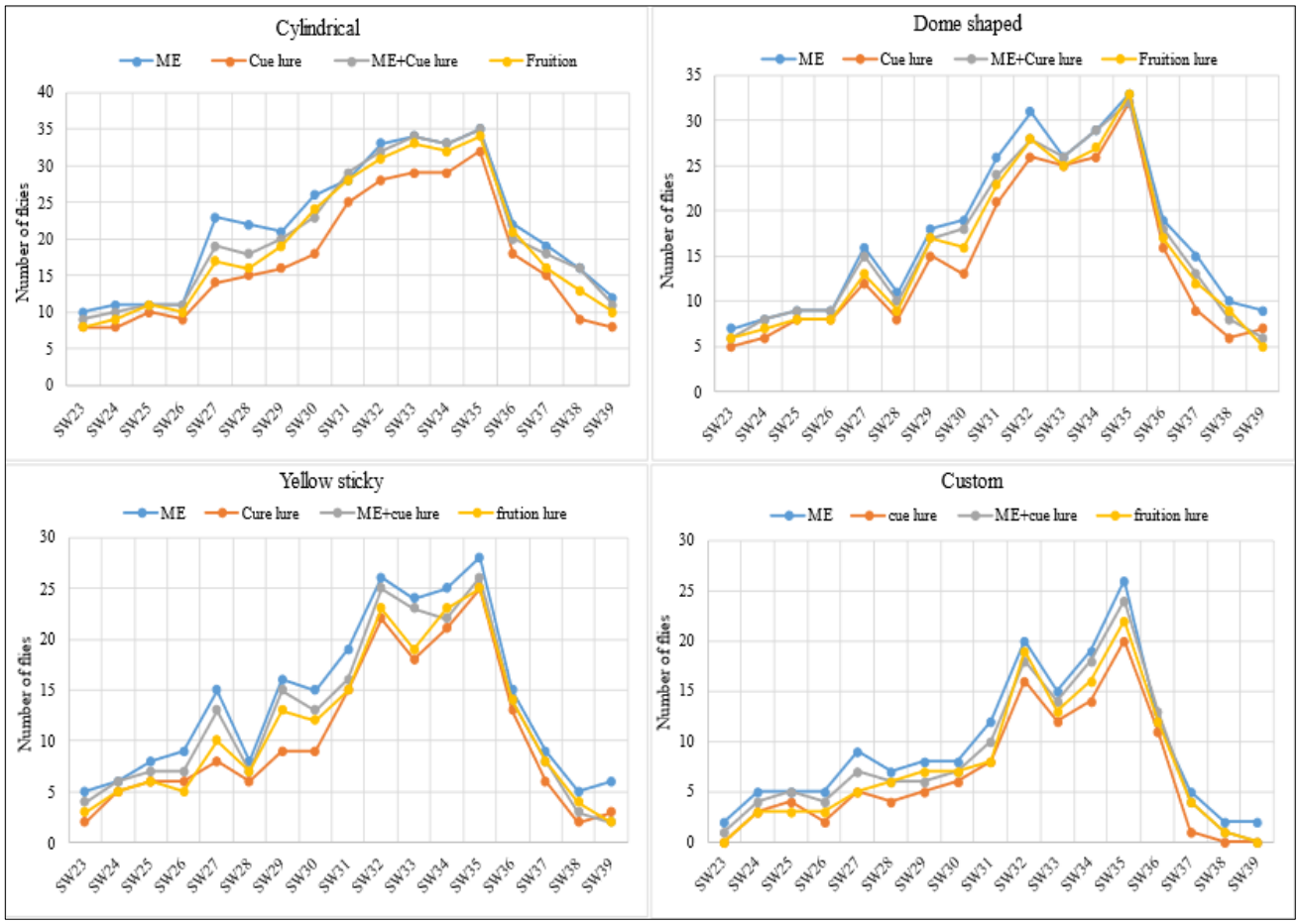

Fig 3.3: Shows spread of B. dorsalis by taking into consideration effect of different types of lures with trap different trap designs taken one at a time

Table 3.2: Shows multifactor analysis of variation (ANOVA) of population of *B. dorsalis* done by IBM SPSS software

Analysis of variation (*B. dorsalis*)					
Dependent Variable: Number of flies					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	21216.522[a]	31	684.404	191.756	<.001
Intercept	52530.882	1	52530.882	14718.044	<.001
SW	15603.993	16	975.250	273.244	<.001
Treatment	5612.529	15	374.169	104.834	<.001
Error	856.596	240	3.569		
Total	74604.000	272			
Corrected Total	22073.118	271			
a. R Squared = .961 (Adjusted R Squared = .956)					

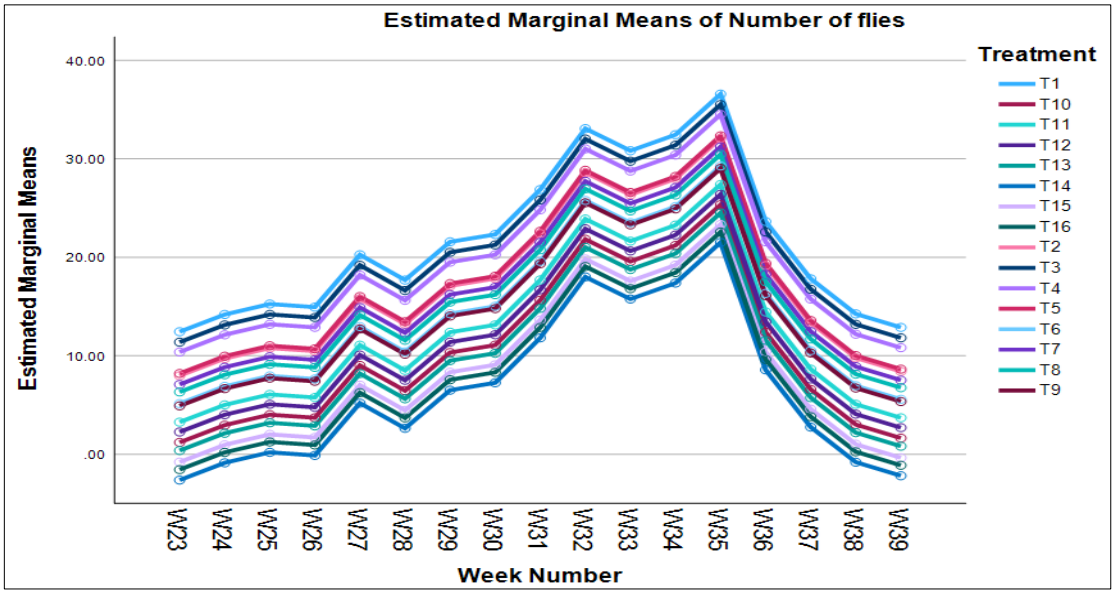

Fig 3.4: Shows the variation of means of different standard weeks corresponding to different treatments

Similar results were observed for species *B. zonata*. Table 3.3 shows the number of flies of species *B. zonata* captured throughout the 17 standard weeks in collaboration with different treatments. Most of the flies were captured during the mid-season i.e., from week 32 to week 35. Figure 3.5 shows spread of species *B. zonata* considering different trap designs and lure types. Again, cylindrical trap design associated with methyl eugenol is found to be most effective process in capturing maximum number of fruit fly species. It was followed by dome shaped trap design lured with methyl eugenol and others. Figure 3.6 shows the effect of lure type with trap design taken one at a time. Lure methyl eugenol in association with cylindrical trap design is recorded to be the most effective method in eradicating a large number of fruit flies from the mango fields.

Table 3.3: Shows distribution of species B. zonata trapped during 5 months (June-October) of collection period corresponding to different treatments

S. No.	SW	Date and Month	T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	T14	T15	T16	Total
1	23	Jun 6 - Jun 12	5	0	5	3	1	5	2	2	1	0	3	2	3	4	0	1	37
2	24	Jun 13 - Jun 19	0	5	5	4	5	4	1	4	5	1	3	2	2	4	1	1	47
3	25	Jun 20 - Jun 26	4	2	2	3	1	3	5	1	2	4	1	1	0	3	4	4	40
4	26	Jun 27 - Jul 3	0	4	5	1	3	2	1	1	3	5	5	4	3	2	5	4	48
5	27	Jul 4 - Jul 10	4	12	11	5	4	12	11	7	10	5	11	10	10	12	5	5	134
6	28	Jul 11 - Jul 17	9	8	5	11	10	4	5	9	9	8	10	8	12	8	7	11	134
7	29	Jul 18 - Jul 24	6	12	6	8	10	11	6	5	12	11	7	6	11	7	12	9	139
8	30	Jul 25 - Jul 31	6	12	4	9	5	5	6	11	12	6	12	11	12	10	12	12	145
9	31	Aug 1 - Aug 7	18	15	12	13	12	14	15	11	16	18	12	15	11	15	11	11	219
10	32	Aug 8 - Aug 14	15	14	14	16	18	17	17	16	17	13	16	12	13	14	17	16	245
11	33	Aug 15 - Aug 21	16	15	16	16	17	18	15	12	18	18	17	17	13	17	18	12	255
12	34	Aug 22 - Aug 28	14	18	11	13	15	15	17	14	15	11	17	11	14	13	18	12	228
13	35	Aug 29 - Sep 4	15	17	12	12	14	14	15	12	17	16	11	14	13	18	14	13	227
14	36	Sep 5 - Sep 11	7	6	10	6	7	7	11	8	11	13	6	12	7	12	8	13	144
15	37	Sep 12 - Sep 18	10	9	9	12	6	11	7	13	11	8	13	11	7	10	6	11	154
16	38	Sep 19 - Sep 25	8	8	13	9	8	10	8	12	13	10	11	7	11	6	13	6	153
17	39	Sep 26 - Oct 2	6	7	6	13	6	11	6	13	12	13	6	9	11	8	10	11	148
			143	164	146	154	142	163	148	151	184	160	161	152	153	163	161	152	2497

Our results are in agreement with the experiments of Verghese, Abraham, *et al*. 2002) [9]. They have reported species *B. dorsalis* as major insect pests of different mango varieties in Bangalore. Dil Mahjoora Majeed *et al* (2024) [10, 11,12,13,14] studied the population of different species of genus *Bactrocera* in Guava orchards of Saharanpur Uttar Pradesh and have reported *B. dorsalis* and *B. zonata* as most abundant fruit fly species infesting these orchards. M Khosravi *et al*. (2018) [15] reported two species *B. dorsalis* and *B. zonata* as the major pests of mango fruit in Iran and reported methyl eugenol as most effective control of these species. Bilal Rasool, *et al*. (2023) [16] also reported *B. dorsalis* and *B. zonata* as most harmful pests effecting mango cultivation. J K Bana *et al* (2018) [17] have also reported *B. dorsalis* and *B. zonata* as most prevalent fruit fly species of genus *Bactrocera* infesting mango orchards of south regions of Gujarat, India. A. Mariadoss *et al* (2020) [18] have reported two species *B. dorsalis* and *B. zonata* as major harmful pests of mango in Ranga Reddy district of Telangana, India.

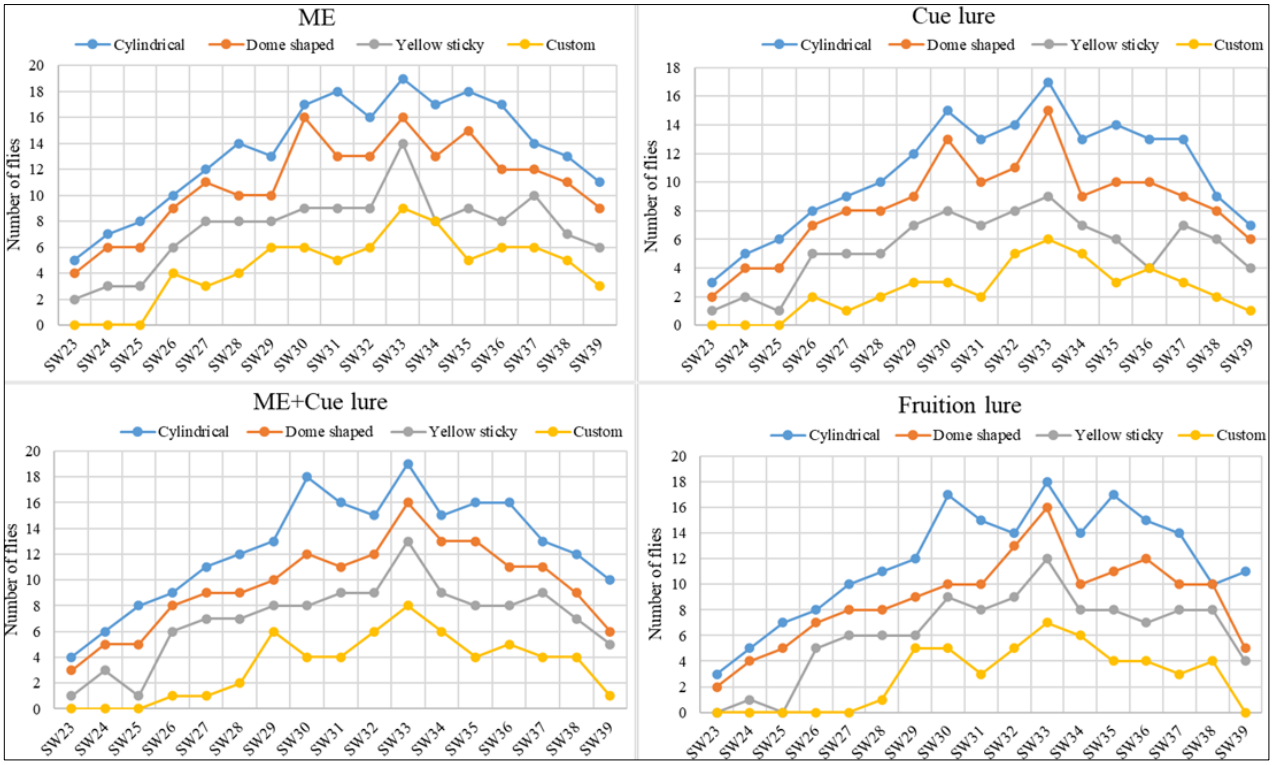

Fig 3.5: Shows spread of species *B. zonata* over 17 standard weeks studying effect of trap design by taking one lure type at a time

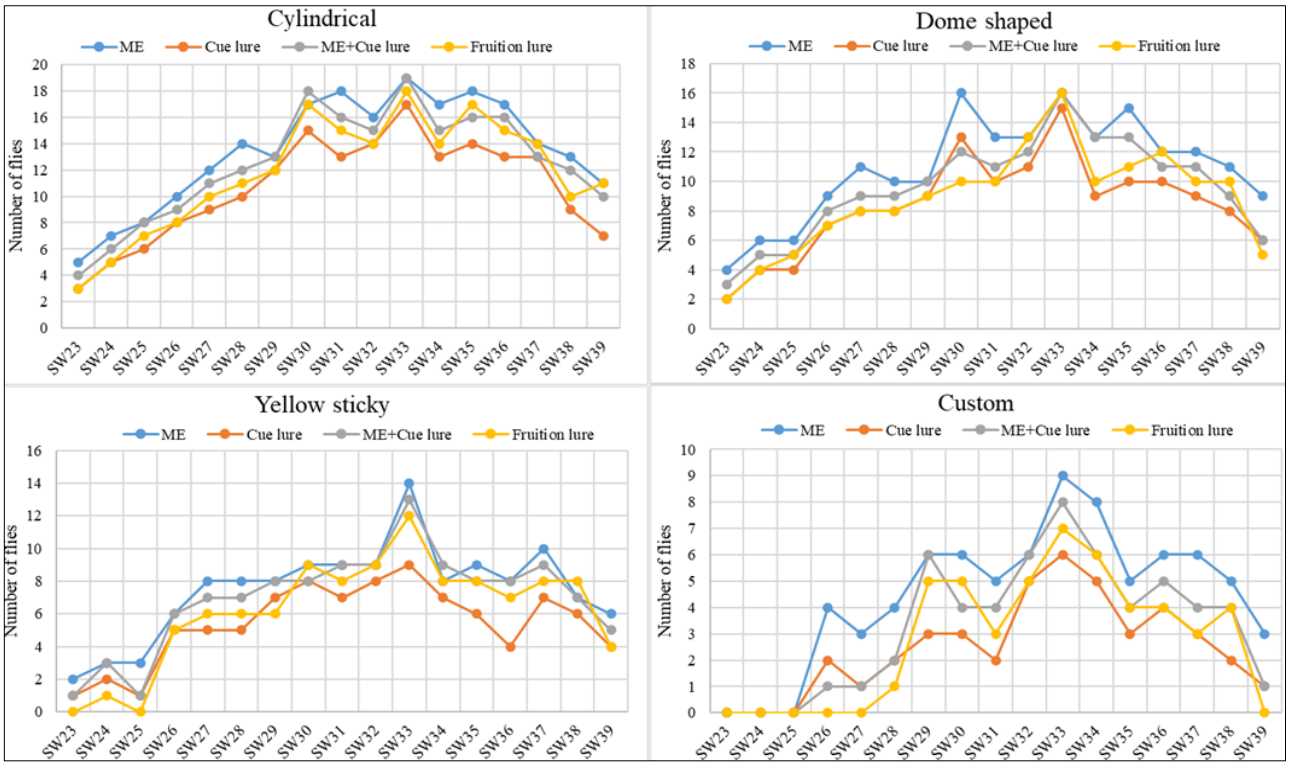

Fig 3.6: Shows spread of species *B. zonata* over 17 standard weeks studying effect of different lure types by considering one trap design at a time

Kavita Bajaj *et al* (2021) [19] have studied effect of trap design on trapping fruit flies and have reported triangular design and PAU design associated with methyl eugenol as most effective control method in eradicating *B. dorsalis* and *B. zonata* from Kinnow Mandarin orchards.

Table 3.4: Shows multifactor analysis of variation (ANOVA) of species *B. zonata* done by IBM SPSS software

Analysis of Variance (*B. zonata*)					
Dependent Variable: Number of Flies					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	5582.901[a]	31	180.094	122.799	<.001
Intercept	16664.121	1	16664.121	11362.613	<.001
SW	2393.316	16	149.582	101.994	<.001
Treatment	3189.585	15	212.639	144.990	<.001
Error	351.978	240	1.467		
Total	22599.000	272			
Corrected Total	5934.879	271			
a. R Squared = .941 (Adjusted R Squared = .933)					

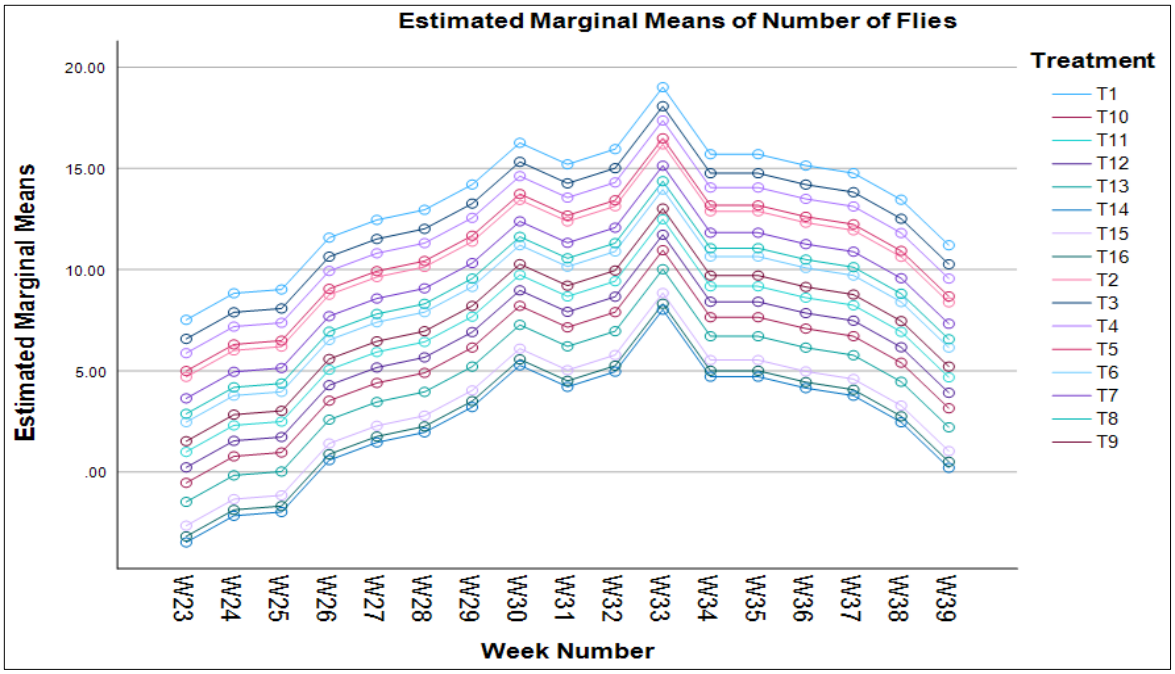

Fig 3.7: Shows variation of weekly means against different standard weeks of species *B. zonata* corresponding to different treatments

The data collected during the 17 standard weeks starting from week number 23 ending at week number 39 was analyzed for statistical fluctuations via IBM software SPSS. Multi factor analysis of variation (ANOVA) was carried at a significance level of 5% to study the weekly mean populations under the cumulative effect of both trap design and lure type. Table 3.2 and Table 3.4 shows the ANOVA results for mean population of *B. dorsalis* and *B. zonata* respectively. From the results we observe that both standard week and treatment type are significant in effecting the population of these flies. Figure 3.4 and Figure 3.7 show variation of estimated weekly means under the effect of different treatments. From these figures we can see that treatment T1, which is cylindrical trap design associated with methyl eugenol, is the most effective treatment in controlling the fruit fly populations in the mano orchards. T1 is followed by T3 which comprises of cylindrical trap design lured with methyl eugenol + cue lure and others. Treatment T16 that consists of self-made fruit fly trap named as custom lured with cue lure was observed to be trapping least number of flies hence not recommended for effective control of pest management in these fields.

4. Conclusion

The research findings reveal the intricate interplay of trap shape and size, lure mixtures, and peak season in trapping fruit flies, emphasizing the necessity of species-specific considerations and the optimization of attractant-related variables for effective pest management strategies. The influence of trap shape and lure type revealed that cylindrical traps associated with methyl eugenol was most effective method in controlling maximal portion of the trapped flies. These findings illuminate the need for optimizing various factors, including attractant type and trap design, to enhance fruit fly trapping efficiency. The diverse range of traps, lure combinations and standard weeks in various studies reflect the intricate nature of fruit fly attraction and the influence of lure mixtures. Key findings include the species-specific responses to different lure mixtures, with variations in attractiveness among species. *B. dorsalis* were more attracted followed *B. zonata*.

5. Authors contribution

All the authors have equally participated in the write up process

of this article. Dil Mahjoora Majeed has solely collected the species and with the help of Dr Mohd Majid Jamali identified the species in the laboratory. Dr Aijaz Majeed has carried the statistical calculations and the whole research was supervised by Dr Mohd Majid Jamali.

6. Conflict of interest statement

The authors declare no conflict of interest.

7. Acknowledgement

The authors would like to thank School of Agricultural Sciences, Glocal University, Saharanpur, Uttar Pradesh, India for availing permissions to carry our research process in mango orchards of different places. The authors also thank the owners of these mango orchards for allowing us to carry our collection smoothly and hustle free.

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