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Efficacy of Home-made and Commercial Trapping Baits for the Management of Fruit Flies in Mandarin Orchards

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Abstract The current study was done to appraise the efficacy of different homemade and commercial baits in fruit fly monitoring and examine the lure that attracts fruit flies in citrus orchards at Syangja, Nepal from Feb to June 2022. The two commercial pheromones used in the experiment were Cue Lure 40 mL and Methyl Eugenol 40 mL and the other five home-based baits were Apple Cider Vinegar, Yeast fermented sugar, Mint lure, Local Brewery Liquor and Banana Lure. Lynfield traps with lures were placed in the orchard. The lures were replaced every 15 days and the traps in 50 days intervals. In this experiment, different species of fruit flies were caught; *Z. tau*, *Z. cucurbitae*, *B. dorsalis*, *B. dorsalis complex*, *B.minax*, and few counts of *Z. scutellaris* and *B. zonata*. The commercial baits used in this experiment in both trappings were able to attract the highest number of fruit flies; all of which were male. Cue lure showed the best result for *Zeugodacus* species with the highest trapping (68%) of *Zeugodacus* males while Methyl eugenol trapped a high percentage for *Bactrocera* species with *Bactrocera dorsalis* males (63%). Among the homemade baits, ACV trapping was high (16.1%) for male species of *Zeugodacus tau*, and PH (yeast lure) for *Bactrocera minax* male species (59%). Moreover, Banana lure was found effective for *Bactrocera dorsalis* male and ACV for *Bactrocera zonata* male and female species. In comparing the males and females of *Zeugodacus* species, cue lure had the better result for trapping males and methyl eugenol for females of *Zeugodacus tau sp*. Females of both *Zeugodacus* and *Bactrocera* species were less trapped in the lures in comparison.

Keywords Cue lure; Fruit fly; Mandarin; Apple cider vinegar

Citrus is the identified major horticultural commodity for mid-hill livelihood (Acharya and Adhikari, 2019). Mandarin orange (Suntala), Sweet orange (Junar), Lime (Kagati), and Hill lemon (Nibuwa) are some of the major citrus fruits grown in Nepal (Rai et al., 2022). Mandarin is grown in 62 districts of Nepal widely spreading over the mid-hill region (1000-1500 masl). Syangja is one of the major mandarins producing districts in Nepal with a productive area of 1,225 ha, production of 18,530 mt, and productivity of 15.13 mt/ha (MOALD, 2020/21).

The PMAMP project from the Government of Nepal had its coverage under the citrus zone from the fiscal year 2073/74 and upgraded it to a super zone from the fiscal year 2075/76. Mandarin is susceptible to several insect pests and pathogens among which fruit fly infestation has been seen as a major problem causing qualitative and quantitative losses.

Fruit flies are insects that belong to the class Insecta, order Diptera, and family Tephritidae. These insects lay eggs in mature fruits and vegetables via sharp ovipositors where they hatch into apodous larvae (maggots). Such immature maggots feed on the pulp and inner fruit parts which become prone to secondary infections and eventually leave them unfit for human consumption. Later on, they jump to the soil for pupation, forming barrel-shaped pupae that release adult forms at the end (Hafsi et al., 2016). These larval forms thus incur a loss in the field as well as postharvest conditions and stand as an economic insect pest of various fruits and vegetables. These insects may have some extent of host specificity, *Bactrocera dorsalis* mainly attacks Mango and tropical fruits while *B. cucurbitae* (now *Zeugodacus cucurbitae*) mainly attacks vegetables like Cucurbits (Bhowmik et al., 2014). In Nepal, seventeen species of fruit flies have been reported by Entomological Division, Nepal Agriculture Research Council namely *B. dorsalis*, *B. zonata*, *B. correcta*, *B. cucurbitae*, *B. tau*, *B. scutellaris*, *B. diversus*, *B. caudatus*, *B. minax*, *B. yashimoto*, *Dacus longicornis*, *B. nigrofemoralis*, *B. latifrons*, *B. artifacts*, *B. tuberculate*, *Dacus ciliates*, and *B.minax* (Adhikari et al., 2020).

Fruit flies in Nepal mainly attack Cucurbit fruits (79%), fruits (14%), and solanaceous fruits (6%) (Adhikari et al., 2018). China has listed fruit flies as quarantine pests as per the bilateral trade protocol signed with Nepal (Sharma et al., 2015). Farmers have practiced different ways like burying the dropped fruits, composting and feeding the larvae of fruitflies to chickens, and even spraying pesticides (Acharya and Adhikari, 2019). The efforts made still seemed not enough to control the infestation. However, the fruit flies have been controlled to some extent using protein bait sprays in agricultural areas in Hawaii trapping with baited lures (Ugwu, 2019). Fruit fly management is performed through mass trapping and food-based lures in Nigeria. Mass trapping has proved to be effective in fruitfly control along with a cost-effective approach (Ugwu, 2019). Therefore, the study's objective was to evaluate the efficacies of two commercial and four homemade food baits in trapping and managing the fruitfly species in mandarin orchards in Syangja.

1 Materials and Methods

1.1 Research site

The experiment was conducted from Feb to June 2022 in three different farms at closed locations of Mandarin Farmers Group. All were located in Nepal’s mid-hill region with a subtropical climate at a latitude of 28°4'60 N, longitude of 83°52'0 E, and an elevation of 1,281 m. The average annual minimum and maximum temperature range reported during the research period were 9.6 °C-18.4 °C. The average precipitation of the study site was recorded to be 235.3 mm and the humidity of 58%.The local locations were selected due to the abundance of farmers in the area growing mandarins. Thus, the baits can be used to monitor, monitor, and manage fruit flies to assess the efficacy of different trapping lures (baits).

1.2 Research design

The experiment design followed was a Randomized Complete Block Design (RCBD). Three locations were used as three replications and eight different baits as treatments (Table 1). The treatments were aligned from east to west using a compass. The baits/lures were hung at crop height (where fruiting occurs) using iron wires. The distance between each bait from east to west was 10 m to avoid mixing intermixing of volatiles generated by such traps (Mesquita et al., 2018). Such spacing allowed the fruit flies to choose their favorite bait for feeding where they got knocked out after feeding on Malathion-poisoned baits.

Table 1 The layout of the proposed field for research (With arrangement of treatments and replication)

R1	R2	R3
T1	T5	T3
T3	T7	T5
T6	T2	T7
T2	T6	T1
T5	T4	T4
T7	T1	T2
T4	T8	T6
T8	T3	T8

1.3 Treatments

Seven treatments were prepared which comprise 2 commercial lures, Cue Lure, and Methyl Eugenol Lure (Table 2). The remaining five were prepared from home-based products and the other treatment was control. All the attractants were added with Malathion to make baits and to knock down the flies that were attracted to the food component. The detail of the treatments included for experimentation was as follows:

Table 2 Treatments selected for experimentation

Treatment number	Treatment name	Treatment composition
T1	Cue Lure (Division, 2017)	Cue Lure 40 mL, Ethyl Alcohol 60 mL, Malathion 20 mL
T2	Methyl Eugenol Lure (Division, 2017)	Methyl Eugenol 40 mL, Ethyl Alcohol 60 mL, Malathion 20 mL
T3	ACV Lure (Maung et al., 2019)	Apple Cider Vinegar 90 mL, Malathion 10 mL
T4	Protein, Hydrolysate, Bait (PH) (Lloyd et al., 2003)	Baker's Yeast 2 g, Sugar 8 g, Water 90 mL, Malathion 10 mL
T5	Mint Lure (Sumatra, 2012)	Mint Paste 50 gm, Jaggary 10 gm, Water 90 mL, Malathion 10 mL
T6	Brewery Liquor (BW) (Piñero et al., 2017)	Brewery liquor 90 mL, Malathion 10 mL
T7	Banana lure	Mashed banana pulp 100 gm, Malathion 10 mL
T8	Control	Water 90 mL, Malathion 10 mL

All treatment solutions were prepared and soaked in a cotton wick for 24 hours. Packaged mineral water bottles were used to make Lynfield Traps with 4 equidistant holes of size 6-8 mm using the hot iron rod of the same size just below the bottleneck. The cotton wick so prepared was kept inside the empty bottles and hung using threads to fit in the bottle.

1.4 Data collection and observation

The fruit flies collected in the Lynfield trap were counted and categorized according to species and sexes at a fortnight interval of trap placement (PPD, 2013). The specimens were preserved by dry preservation techniques in the insect collection box. The sexes were distinguished based on the presence or absence of sharp ovipositor. The distinction between species was made according to identification guidelines and the identification chart provided by:

- Occurrences and field identities of fruit flies in sweet orange (*Citrus sinensis*) orchards in Sinduli, Nepal (Adhikari and Joshi, 2018)
- Field Guide for Identification of Fruit Fly Species of Genus *Bactrocera* Prevalent in and around Mango Orchards (Choudhary et al., 2014)
- PQPMC, NPPO, Nepal guidelines in insect collection and identification (PQPMC, 2014)
- THE AUSTRALIAN HANDBOOK FOR IDENTIFICATION OF FRUIT FLIES, Version 3.1 (Schutze et al, 2018).

1.5 Staistical analysis

The obtained data were systematically arranged, entered, and processed for analysis using Ms. Excel program. The collected data will be subjected to the Analysis of Variance (ANOVA). Duncan's multiple range test (DMRT) was used to compare means which were separated by (LSD) at a 5% level of significance (Gomez and Gomez, 1984).

2 Results

2.1 Trapped fruit fly species

The fruit fly species trapped in the lures were collected, observed and counted as per the protocol provided by Plant Protection Directorate (PPD, 2013). The identification of fruit flies was carried in accordance with their taxonomical characteristics and differentiation among the traps was found in related to species (PQPMC, 2014).

Of all the collected fruit fly specimens, two different genera, *Zeugodacus* and *Bactrocera* were observed having different species. The genus *Zeugodacus* observed in the traps includes, *Zeugodacus tau* (ZT), *Zeugodacus scutellaris* (ZS), *Zeugodacus cucurbitae* (ZC). Also, the genus *Bactrocera* includes, *Bacterocera dorsalis* (BD), *Bacterocera dorsalis complex* (BDC), *Bacterocera zonata* (BZ), *Bacterocera minax* (BM).

2.2 Respective performance of lures on different fruit fly species

2.2.1 Response of Zeugodacus species of fruitfly to different traps

Comparing the efficiency of attractants (Table 3) at a 5% level of significance, cue lure showed more effect on males of *Zeugodacus tau* (215.33) followed by ACV (51.33) and protein hydrolysate treatment (49.66). Methyl eugenol, mint lure, BWS, and banana lure did not affect capturing them. In contrast, methyl eugenol had a pronounced effect on females of *Zeugodacus tau* (50) species of fruitflies while cue lure had zero effect. Other treatments had a less significant effect.

Similarly, traps baited with cue lure had a significant effect on *Zeugodacus scutellaris* sp. (60.67) while others didn't record any of them. Cue lure also reported more population of male. *Zeugodacus cucurbitae* sp. (23.33) and ACV attracted 8 fruitflies of *cucurbitae* sp. No species of *cucurbitae* were observed in other lures. The less significant population of females of *Zeugodacus cucurbitae* was observed in either lure or traps (Table 3).

Table 3 Number of *Zeugodacus* species in the lures as influenced by the use of different lures in the Mandarin Orchard of Syangja, Nepal 2022

Treatments	*Zeugodacus* sp.					
	ZT (Male)	ZT (Female)	ZS (Male)	ZS (Female)	ZC (Male)	ZC (Female)
Cue lure	215.33^{a}	0.00^{e}	60.67^{a}	0.00^{a}	23.33^{a}	0.00^{b}
ME	0.00^{c}	50.00^{a}	0.00^{b}	0.00^{a}	0.00^{c}	0.00^{b}
ACV	51.33^{b}	13.67^{bc}	0.00^{b}	0.00^{a}	8.00^{b}	2.66^{a}
PH	49.66^{b}	14.67^{b}	0.00^{b}	0.00^{a}	1.00^{c}	0.00^{b}
Mint Lure	0.00^{c}	1.33^{e}	0.00^{b}	0.00^{a}	0.00^{c}	0.00^{b}
BWS	0.00^{c}	3.33^{de}	0.00^{b}	0.00^{a}	0.00^{c}	0.00^{b}
Banana lure	0.00^{c}	8.0^{cd}	0.00^{b}	0.00^{a}	0.00^{c}	0.00^{b}
Control	1.00^{c}	0.00^{e}	0.00^{b}	0.00^{a}	0.00^{c}	0.00^{b}
LSD (0.05)	44.1	6.13	16.57	-	3.53	1.42
S.E(m) ±	44.53	2.02	5.46	-	1.16	0.47
F probability	>0.001	>0.001	>0.001	-	>0.001	>0.05
CV%	23.47	10.82	12.7	-	19.95	24.94
Grand mean	39.67	11.4	7.59	-	4.04	0.34

Note: Difference letter means in column with the same superscript are not significantly different by DMRT at 0.05 level, LSD: Least Significant Difference, ns: non-significant, CV: Coefficient of variation, SEM: Standard error of the mean, ♂: male, ♀: female

The results showed that (Figure 1) population density of males of *Zeugodacus tau* was seen higher in Cue lure among commercial baits while was higher in ACV within home-based baits. Likewise, females of *Zeugodacus tau* were reported in Methyl eugenol trap among all in comparison.

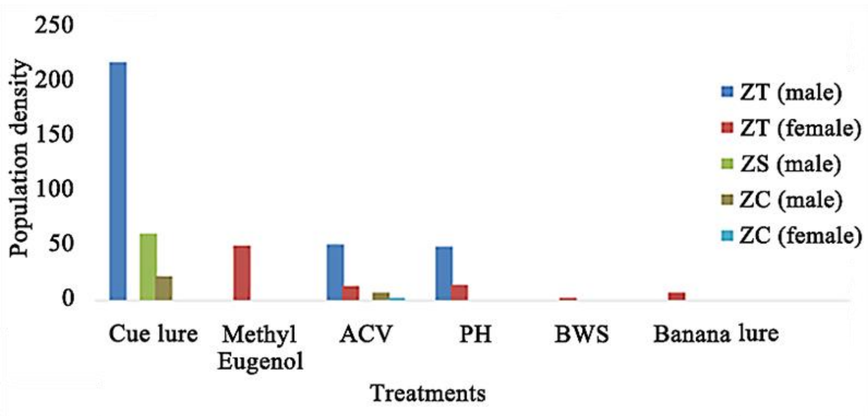

Figure 1 Population density of male and female *Zeugodacus* sp. trapped at the study sites

2.2.2 Response of *Bactrocera* species of fruitfly to different traps

Results presented the significant effect of methyl eugenol (158.34) on males of *Bacteria dorsalis,* followed by banana lure (32.33) and BWS (29) at a 5% level of significance (Table 4). In the evaluation of trap to other species, only *Bactrocera dorsalis complex* was reported in methyl eugenol but other lures didn't attract significant mass. Only 9 females of *Bactrocera zonata* were observed in ACV lure and 59 males of *Bactrocera minax* in PH. Also, a significant population of females (20.33) of *Bactrocera minax* were trapped in PH baited trap. No species of *Bactrocera minax* were observed in other remaining traps similar to those above.

Table 4 Number of *Bactrocera* Species in the Lures as Influenced by the use of different lures in the Mandarin Orchard of Syangja, Nepal 2022

Treatments	*Bactrocera* species							
	BD (Male)	BD (Female)	BDC (Male)	BDC (Female)	BZ (Male)	BZ (Female)	BM (Male)	BM (Female)
Cue lure	0.00^{d}	0.00^{a}	0.00^{d}	0.00^{a}	0.00^{d}	0.00^{b}	0.00^{b}	0.00^{b}
ME	158.34^{a}	0.00^{a}	21.33^{a}	0.00^{a}	0.00^{c}	0.00^{b}	0.00^{b}	0.00^{b}
ACV	24.00^{bc}	0.00^{a}	0.00^{b}	0.00^{a}	8.00^{a}	9.0^{a}	0.00^{b}	0.00^{b}
PH	0.00^{d}	0.00^{a}	0.00^{b}	0.00^{a}	1.00^{c}	0.00^{b}	59.0^{a}	20.33^{a}
Mint lure	7.34^{cd}	0.00^{a}	1.67^{cd}	0.00^{a}	0.00^{c}	0.00^{b}	0.00^{b}	0.00^{b}
BWS	29.00^{b}	0.00^{a}	3.00^{d}	0.00^{a}	0.00^{c}	0.00^{b}	0.00^{b}	0.00^{b}
Banana lure	32.33^{b}	0.00^{a}	6.33^{b}	0.00^{a}	0.00^{c}	0.00^{b}	0.00^{b}	0.00^{b}
Control	0.00^{d}	0.00^{a}	0.00^{d}	0.00^{a}	0.00^{c}	0.00^{b}	0.00^{b}	0.00^{b}
LSD (0.05)	17.30	-	2.82	-	6.91	4.32	16.27	2.17
Sem	5.70	-	0.93	-	2.27	0.47	5.36	0.71
F probability	>0.001	-	>0.001	-	>0.001	>0.05	>0.001	>0.001
CV%	11.48	-	23.9	-	34.68	33.99	26.01	18.85
Grand mean	31.37	-	4.04	-	11.37	1.91	7.37	2.54

Note: Different letter means in column with the same superscript are not significantly different by DMRT at 0.05 level, LSD: Least Significant Difference, ns: non-significant, CV: Coefficient of variation, SEM: Standard error of the mean

The results of overall population of *B. dorsalis* trapped (Figure 2) reported that higher in Methyl eugenol in which all were males. Also, the density of males of *B. minax* was higher in PH among all lures. For homemade baits, Banana lure, followed by BWS and ACV showed trapped *B. dorsalis* male. The females observed were only of *B. minax* in PH.

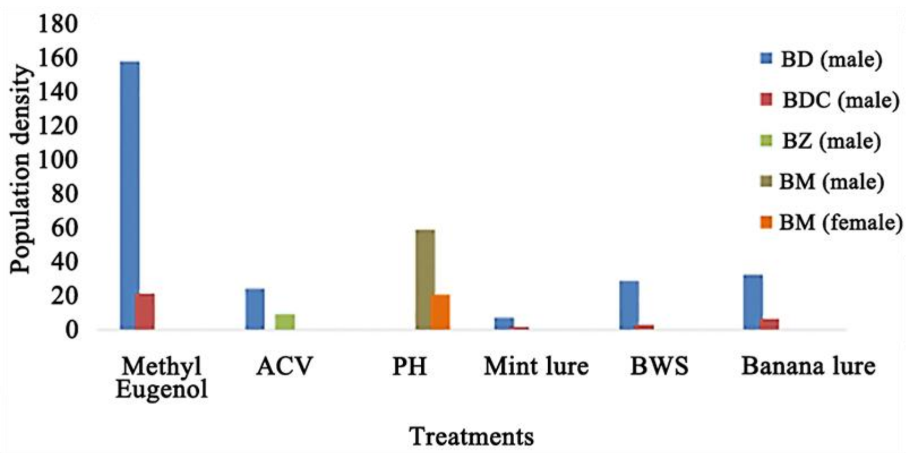

Figure 2 Population density of male and female *Bactrocera* sp. trapped at the studysites

3 Discussion

The commercial baits used in this experiment in both trappings were able to attract the highest number of fruit flies; all of which were male. The Cue Lure attracted male counterparts of *Z. tau and Z. cucurbitae* (Table 3) while Methyl Eugenol Lure attracted male counterparts of *B. dorsalis and B. zonata* (Table 4). Among home-based baits, banana, and brewery liquor lure also attracted male flies similar to that in Methyl Eugenol Lure but the numbers were amongst the least (Table 4). The Apple Cider Vinegar (ACV) and yeast lure attracted both male and female flies. As per (Table 3; Table 4), the protein bait attracted adult fruit flies both male and female of *Zeugodacus tau and Bactrocera minax* species evident in this experiment while the banana lure attracted only male flies of genus *Bactrocera* species. For attracting female flies, yeast lure was found superior along with being cost-effective.

Traps baited with attractant and insecticide can be a direct tool for pest control (Sarango et al., 2009). The commercial lures were able to attract only male fruit flies as also reported by (Adhikari et al, 2018). *Bactrocera dorsalis* were highly trapped in Methyl eugenol lure (Adhikari et al., 2018). Among home-based lures, Apple Cider Vinegar and Protein Hydrolysate performed better by attracting a diverse genre of flies that infest both fruits and vegetables (Division, 2017). The findings (Sumatra, 2012) also validated that the Brewery Waste solution and Tulsi lure attracted flies similar to that of the Methyl Eugenol lure but the numbers were least. Local-sourced banana baits or jaggery had equivalent effectiveness as protein hydrolysate bait (Mumford, 2006). Chinese fruit flies (*Bactrocera minax*) were more attributed to being trapped through hydrolyzed protein bait, which is in line with the results of (Sharma and Dahal, 2020). The baits made from apple cider vinegar, yeast lure and pumpkin were able to attract female fruit flies which was also depicted in the research by (Mumford, 2006). ACV captured both male and female species of *Zeugodacus tau* as per results from (Gupta and Regmi, 2022). The study of (Becher et al., 2012) also explained a similar conclusion that different volatile compounds were identified from the yeast fermentation of minimal media which are preferred by fruitflies. Similarly, results from (Kleiber, 2013) presented that Dipterans of the *Drosophilidae* family were found attracted to Apple Cider Vinegar while in the experiment at Maranthana, Pyuthan, Nepal; Dipterans of the Tephritidae family were also found attracted to it. The fruit fly management using male sex pheromone lures stands as an indirect method of fruit fly management. As a management approach rather than a control approach; it doesn't kill all the male flies and hence the females still can mate and oviposit in the cucurbitaceous fruits and vegetables. The females have also shown some extent of interspecific mating. The findings were supported by (Schutze et al., 2018). Concerning the total number of insects trapped, a similar conclusion was derived by (Ekman, 2015), where the number of adult fruit flies trapped in the commercially used lures was relatively higher than others. A significant difference was noted between the adult fruit flies caught by different lures (Bharathi et al., 2004).

4 Conclusion

The use of homemade and commercial lure-baited lynfield traps significantly captures fruitfly species and reduces the production cost and negative impact of pesticide residue. Furthermore, cue lure, and methyl eugenol along with lures based on Apple Cider Vinegar, Protein Hydrolysate, Brewery liquor, and Banana lure poisoned with malathion can be suggested for fruit fly management within the IPM as more a cost-effective approach. So, including this method in fruit fly management has been effective in minimizing fruitfly infestation in the studied mandarin farm areas of the Syangja district.

Author's contributions

PA was involved in framing the research idea and designing the experiments.PA along with NA, KB, BL, RP, and SP was involved in conducting the research, data analysis and interpretation, and drafting of the manuscript. ML was involved in the supervision of the research and JS in the review process and figured final shape of the manuscript. All authors read and approved the final manuscript.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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