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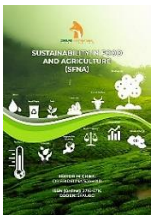

RESEARCH ARTICLE

COMPARATIVE ASSESSMENT OF DIFFERENT BAITS FOR MONITORING AND MANAGEMENT OF FRUIT FLIES *(Bactrocera* spp*)* IN RAMPUR, CHITWAN, NEPAL

Paras Regmi*, Prakash Bhattarai, Ananta Mani Bhattarai

Agriculture and Forestry University, Chitwan, Nepal
**Corresponding Author Email: regmiparas1978@gmail.com*

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ABSTRACT

Fruit flies (Diptera: Tephritidae), particularly the genus *Bactrocera*, are major pests of horticultural crops worldwide, causing significant economic losses. Effective monitoring and management of these pests are crucial for sustainable crop production. This study, conducted from March to May 2023, aimed to compare the efficacy of different baits in attracting and capturing fruit flies, specifically *Bactrocera* species, in cucumber fields at Rampur, Chitwan, Nepal. The study also aimed to identify the most effective bait for monitoring and management of these pests in the study area. Different types of baits, including commercially available lures (cue lure and methyl eugenol lure) and homemade lures (apple cider vinegar lure, banana pulp bait, local liquor lure, pumpkin lure and tulsi lure), were tested in field experiments designed in randomized complete block design with three replications. Lynfield traps baited with each lure were placed in the cucumber field and the number of trapped fruit flies was recorded. Similarly, the sex and the species of trapped fruit flies was also identified. Treatments were placed in the field two times at 15-day intervals. The effectiveness of each bait was compared based on the total number of flies captured along with the sex and species composition. At the end of the experiment, the cost of each trap was calculated. Data analysis was carried out using R Studio 4.3.0. The study revealed significant differences in the attractiveness of treatments for fruit flies. Two commercial lures, cue lure (59.33) and methyl eugenol (36.67) attracted the highest population of fruit flies, primarily males. Cue lure attracted fruit flies of the species *Bactrocera (Zeugodacus) cucurbitae, Bactrocera (Zeugodacus) scutellaris* and *Bactrocera (Zeugodacus) tau* while methyl eugenol lure attracted *Bactrocera dorsalis and Bactrocera zonata* species. Among other five different homemade baits, apple cider vinegar lure (19.33) showed the highest attraction of fruit flies followed by banana pulp bait (10.00). Similarly, the highest population of female fruit flies trapped was obtained with banana pulp bait followed by pumpkin lure. The study also identified different fruit fly species prevalent in the research area: *Bactrocera (Zeugodacus) cucurbitae, Bactrocera (Zeugodacus) scutellaris*, *Bactrocera (Zeugodacus) tau, Bactrocera dorsalis and Bactrocera zonata* with their specific preferences for certain baits. This study identified commercially available cue lure and homemade apple cider vinegar lure as promising baits for monitoring and managing fruit flies in the cucumber field in Rampur. Additionally, banana pulp demonstrated potential for attracting female flies. These findings offer alternative, potentially safer options for fruit flies control compared to traditional chemical pesticides.

KEYWORDS

Fruit fly, Lures, Monitoring, Management

1. INTRODUCTION

Cucumber (Cucumis sativus Linnaeus) is one of the widely cultivated vegetables among cucurbits which belongs to the Cucurbitaceae family (Renner et al., 2007). The cucumber is of tropical origin and is mostly cultivated in Southeast Asia, tropical America, and Africa (Staub et al., 2008). Various insect pests such as fruit fly (Bactrocera spp), red pumpkin beetle (Aulacophora foveicollis), epilachna beetle (Henosepilachna septima), cucumber moth (Diaphania indica), and others have been known to attack the cucumber at different life stages. Among them, fruit flies are of major concern. Fruit flies are one of the most devastating pests of horticultural crops in the world and they pose danger to most commercial vegetables and fruits. There are 4,000 fruit fly species in the family Tephritidae worldwide, of which 350 are economically significant (Sharma et al., 2015). Fruit flies like Bactrocera cucurbitae, Bactrocera tau, Bactrocera scutellaris attack cucurbits. Among different species of fruit flies, the Fruit fly Bactrocera cucurbitae (Coquillett) is a serious pest of cucurbit crops that reduces crop production and productivity. These insects are known as melon fly, melon fruit fly, and cucurbit fruit fly. Though they are native to India, these flies are frequently distributed in temperate, sub-tropical, and tropical regions throughout the world (Dhillon et al., 2005). They have a wide host range and the plants of the family Cucurbitaceae are their major preference. Depending on the species of cucurbit and the season, the degree of losses ranges from 30 to 100% (Dhillon et al., 2005).

Different methods have been used for the management of fruit flies like chemical (32%), mechanical (80%), indigenous (70%) (Jholmol), and in the mid hills of Nepal a combination of these (68%) methods have been used (Sapkota et al., 2010). Various management techniques including the spraying of hydrolyzed protein, para-pheromone traps, the spraying of ailanthus and cashew leaf extract, neem products, fruit bagging, field

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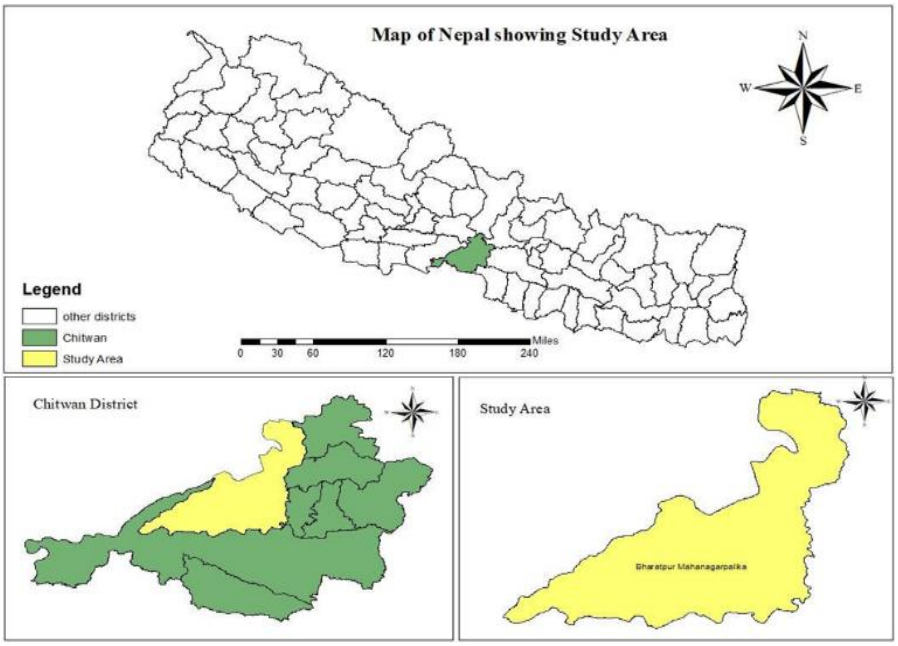
cleaning, food baits, and the spraying chemical insecticides are being used. Yet, these techniques suffer from a lack of totally reducing the insect population. To control this fly, farmers in Nepal use a variety of chemical insecticides regularly, which is extremely dangerous for producers, consumers, and the environment. Due to the growing understanding on a global scale of the harmful consequences that dangerous chemicals have, pest control techniques have been shifting from using hazardous chemicals to an eco-friendly and sustainable strategy, Integrated Pest Management (Sapkota et al., 2010).

As the three-life stage of this insect is hidden, only the adult stage is often the focus of pest control efforts. Among all the different measures, para pheromone traps were among the most effective tools for monitoring and mass trapping of fruit flies (Divya et al., 2019). Para-pheromone traps don't pollute the environment with chemicals and don't contaminate fruits with insecticide poisoning. They also provide organic vegetables and fruits. Furthermore, compared to cultural and manual approaches, they need less labor. However, growers in developing nations like Nepal cannot afford to utilize the commercially available lures and pheromones since they only attract male flies, making them a secondary method of fruit fly management. Since some males cannot be attracted and destroyed, female flies can continue to lay their eggs on fruits and vegetables that are almost ripe while still being able to reproduce. Making lures that are affordable and kill both sexes of flies using resources that are already available locally can therefore significantly support fruit fly monitoring and control initiatives at the farmer level in low-income nations like Nepal (Gupta and Regmi, 2022).

2. Materials and Methods

2.1 Experimental Site

The field trail was conducted at the Horticulture Farm of Agriculture and Forestry University in Rampur, Chitwan from the 2nd week of April 2023 to the 4th week of May 2023.The geographical classification of the research site falls in the inner terai of Bagmati Province. Geographically, it is situated at latitude 27⁰39.0110'N and longitude 84⁰ 20.8310'E with an elevation of 140.3 masl. The location was chosen because of an abundance of farmers cultivating cucurbitaceous vegetable crops such as cucumber, bottle gourd, bitter gourd, and sponge gourd, as well as the presence of tropical fruit trees such as mango. Thus, the baits may be used to trap more species of fruit flies found in Chitwan, and their efficiency and performance could be improved.

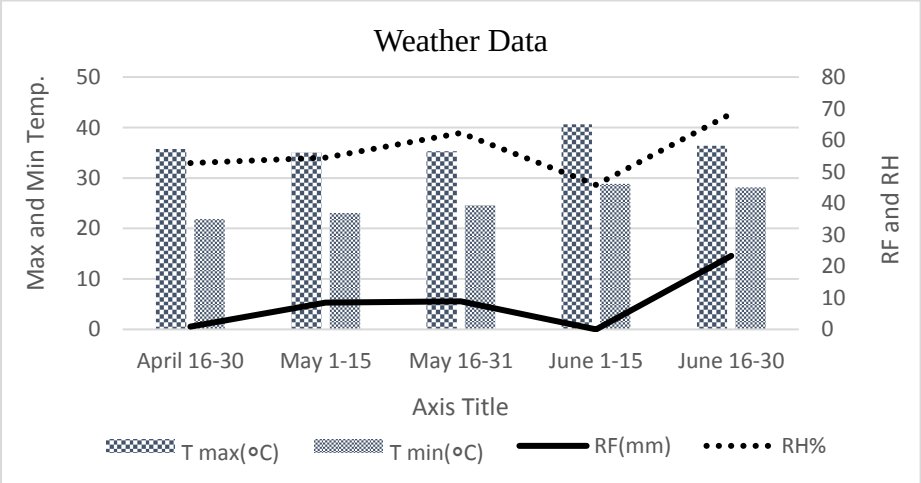


(Source : ArcGIS)

Figure 1: Experimental site

2.2 Agrometeorological Information

The experiment site lies in the sub-tropical zone of Nepal. It is characterized by 3 distinct types of seasons namely, rainy monsoon (June-Oct), cool winter (Nov-Feb), and mild spring (Mar-May). The research was conducted from March to May. The weather pattern during the entire research period is shown in Figure.



(Source: NMRP, Rampur)

Figure 2: Weather data of experimental site at AFU Horticultural farm from April to July 2023

2.3 Experimental Design And Details

The experiment was laid out in Randomized Complete Block Design (RCBD) in the experimental field with seven treatments and three replications of each treatment.

Crop	Cucumber
Variety	Garima
Spacing between plants	0.75 m (RR) × 0.75m (PP)
Fertilizer dose	120:90:40 kg NPK/ha + Compost 20 ton/ha
Design	Randomized Complete Block Design
Treatments	7
Replications	3
Total number of plots	21
Spacing between treatments	5m
Spacing between replication	7m

2.4 Treatment Details

Seven treatments for the management of fruit flies were used. The treatments used in the experiment were Apple Cider Vinegar Lure, Banana Pulp Bait, Cue Lure, Local Liquor Lure, Methyl Eugenol Lure, Pumpkin Lure, and Tulsi Lure. Among the seven, two lures were commercially used, notably the Cue Lure and the Methyl Eugenol Lure. The former is mostly utilized for cucurbitaceous vegetable crops, whereas the latter is employed for fruit fly control in fruit orchards. The remaining five treatments were made using human-grade ingredients. All attractants used Malathion to make baits and to kill flies that were drawn to the food component.

Table 1: List of treatments used along with their composition

Treatment	Treatment Name	Composition for three treatments
T1	Apple Cider Vinegar Lure	Apple Cider Vinegar-10 ml Malathion- 2ml
T2	Banana Pulp Bait	Ripen banana pulp-50 gm Borax-1gm Molasses- 1ml Malathion- 2ml
T3	Cue Lure	Cue lure solution- 4 ml Ethyl alcohol- 6ml Malathion- 2ml
T4	Local Liquor Lure	Local Liquor- 10 ml Malathion- 2ml
T5	Methyl Eugenol Lure	Methyl Eugenol- 4ml Ethyl Alcohol- 6 ml Malathion- 2ml
T6	Pumpkin Lure	Mashed Pulp- 10gm Malathion- 2ml
T7	Tulsi Lure	Tulsi Leaves- 5gm Water- 10 ml Malathion- 2ml

2.5 Cultural Practices

The field was ploughed twice with a disc plough and disc harrow to make the soil in good tilth condition. Land leveling and removal of weeds and stubbles were done. Then, the layout was carried out the next day. Wooden pegs and rope were used for the layout of the field. The recommended dose of chemical fertilizers and FYM was spread entirely on the field and mixed well with the soil. Half of the recommended dose of Nitrogen was applied as basal dose and the remaining half dose of Nitrogen was given in two equal split doses as top dressing by ring method. Pits with dimensions of 75×75×75 cm^3 were made for transplantation of cucumber seedlings. The seedlings were transplanted on the 28th day of seed sowing. Operations like weeding, irrigation, staking, and application of remaining doses of fertilizers were carried out as per the requirements.

2.6 Preparation and Placement Of The Trap

All treatment solutions were produced and soaked in a cotton wick of ½ inch thick and 2 inches long for 24 hours. A cotton wick was soaked in 4 ml of treatment solution. Two-thirds of the cotton wick was wrapped with Aluminum foil and one-third was exposed. Then, the cotton wick was tied with wire fitted in the Lynfield trap. Lynfield traps were made locally with discarded bottled water bottles. After removing the label of a liter plastic water bottle, 4 holes of 1-inch size were made with a knife at 3 inches from the top of the bottle for the entry of fruit flies. A hole was made in the center of the lid with a needle. A thin wire of 10 inches long was taken and a knot was made at the center. Then, the wire was inserted through the hole of the lid. A loop was made for hanging the bottle and a hook was made at the other end for tying the cotton wick.

The traps were placed on the field after the initiation of the first flowering in cucumber. About 1.5 m tall bamboo pegs were taken and the G.I wire outside the lid of the bottle was tied around the bamboo peg in such a way that the height of the trap above the ground remained 1m.

(Source: Paras, 2023)

Figure 3: Lynfield trap installed in the field

(Source: Paras, 2023)

Figure 4: Changing cotton-soaked lure wrapped with Aluminum foil after 15 days

2.7 Observation And Data Recording

Regular monitoring was carried out after the traps were placed on the field after the first flowering. The trapped flies were counted at 3-day intervals in each trap. Thus, collected fruit flies in the trap were counted, categorized, and classified according to population, sex, and species.

The sexes of the trapped fruit flies were distinguished based on the presence or absence of sharp ovipositors. The observed insect species were distinguished by morphological features based on identification guidelines provided by:

- Field Guide for Identification of Fruit Fly Species of Genus Bactrocera Prevalent in and around Mango Orchards (Choudhary et al., 2014)
- Identification of Cucurbit Fruit Flies and Their Relative Attractiveness to Different Cues and Releasers (Chiluwal et al., 2022)
- Occurrences and field identities of fruit flies in sweet orange (Citrus sinensis) orchards in Sindhuli, Nepal (Adhikari and Joshi, 2018)
- The Australian Handbook for The Identification of Fruit Flies Version 3.1 (Plant Health Australia, 2018)

Ath the end, the cost of the ingredients and materials to prepare the individual traps are considered to find the cost of the trap.

2.8 Tabulation and Analysis of Data

The data obtained from the experimental field were statistically analyzed to find out the significance of treatments according to the principles of experimental design. The obtained data was tabulated in Microsoft Excel and further analyzed by R-STUDIO 4.3.0. Duncan's Multiple Range Test (DMRT) was employed to find out the significant differences between the mean values at a 5% level of significance. The significance was determined using the format of the ANOVA table. The coefficient of variance, grand mean, and standard error of mean were calculated using R-STUDIO 4.3.0.

3. RESULTS

3.1 Average population of fruit flies

3.1.1 First Trapping

The result shows that the average number of fruit flies trapped per trap was found to be highly influenced by the application of treatments on all days after trap placement. The highest population of fruit flies trapped was found on Cue lure (15.67) after 6 days of trap placement while lowest population of fruit flies were attracted by Banana Pulp Bait and Local Liquor Lure, 0.67 each. The population of fruit flies was recorded the most 6 days after trap placement.

Table 2: Average population of fruit flies trapped on different days during first trapping in Rampur Chitwan, 2023

Treatments	3DATP	6DATP	9DATP	12DATP	15DATP
Apple Cider Vinegar Lure	3.67^{c} (2.02)	5.33^{c} (2.39)	5.00^{b} (2.32)	1.67^{c} (1.46)	1.00^{c} (1.23)
Banana Pulp Bait	1.33^{c} (1.34)	1.67^{d} (1.46)	2.67^{c} (1.76)	2.33^{b} (1.64)	0.67^{c} (0.99)
Cue Lure	12.33^{a} (3.57)	15.67^{a} (4.02)	10.00^{a} (3.23)	11.33^{a} (3.43)	10.00^{a} (3.23)
Local Liquor Lure	1.00^{c} (1.17)	1.33^{d} (1.34)	2.00^{c} (1.56)	1.33^{c} (1.28)	0.67^{c} (1.05)
Methyl Eugenol Lure	8.00^{b} (2.90)	8.33^{b} (2.97)	7.67^{ab} (2.84)	7.33^{b} (2.78)	5.33^{b} (2.40)
Pumpkin Lure	1.00^{c} (1.17)	1.33^{d} (1.34)	2.33^{c} (1.67)	1.67^{c} (1.44)	1.00^{c} (1.17)
Tulsi Lure	1.67^{c} (1.46)	2.00^{cd} (1.56)	1.33^{c} (1.34)	1.33^{c} (1.34)	1.00^{c} (1.22)
Grand mean	1.95	2.15	2.11	1.91	1.62
F value	20.98***	34.63***	16.31***	18.45***	23.49***
P value	<0.001	<0.001	<0.001	<0.001	<0.001
SEm(+/-)	0.025	0.025	0.025	0.028	0.25
LSD (0.05)	0.64	0.54	0.54	0.60	0.55
CV (%)	18.34	14.03	14.49	17.77	19.01

CV: Coefficient of Variance; DATP: Days After Trap Placement; *, **, and *** represent significance at 5%, 1%, and 0.1% level of significance respectively; SEm: Standard error of mean; LSD (0.05): Least Significant Difference at 5% level of significance; same letters in the superscript indicates the similar effect according to DMRT at 0.05 level of significance: Figures inside parentheses indicate $\sqrt{(x+0.5)}$ transformation values.

3.1.2 Second Trapping

During second trapping, similar results are obtained as in first trapping. However, highest population of fruit flies trapped was in Cue lure (12.33) at 3DATP while equal lowest population of fruit flies attracted was found in Banana Pulp Bait Local Liquor Lure, and pumpkin lure at 15 DATP.

Table 3: Average population of fruit flies trapped on different days during second trapping in Rampur Chitwan, 2023

Treatments	3DATP	6DATP	9DATP	12DATP	15DATP
Apple Cider Vinegar Lure	5.00^{c} (2.34)	4.67^{b} (2.27)	5.00^{bc} (2.32)	3.00^{b} (1.86)	1.67^{c} (1.46)
Banana Pulp Bait	2.33^{d} (1.66)	3.00^{c} (1.86)	2.67^{cd} (1.76)	1.33^{b} (1.27)	0.67^{c} (1.05)
Cue Lure	12.33^{a} (3.57)	12.00^{a} (3.53)	11.00^{a} (3.36)	10.33^{a} (13.29)	9.00^{a} (3.54)
Local Liquor Lure	1.67^{d} (1.46)	1.33^{d} (1.34)	2.00^{d} (1.56)	1.33^{b} (1.34)	0.67^{c} (1.05)
Methyl Eugenol Lure	8.67^{b} (3.57)	9.67^{a} (3.18)	7.67^{ab} (2.84)	7.33^{a} (2.78)	5.33^{b} (2.41)
Pumpkin Lure	1.67^{d} (1.46)	2.00^{cd} (1.56)	2.33^{d} (1.68)	1.33^{b} (1.34)	0.67^{c} (1.05)
Tulsi Lure	1.67^{d} (1.46)	1.67^{cd} (1.44)	1.33^{d} (1.34)	3.00^{b} (1.56)	1.67^{c} (1.46)
Grand mean	2.14	2.17	2.14	1.19	1.72
F value	28.52***	45.26***	14.39***	15.01***	19.77***
P value	<0.001	<0.001	<0.001	<0.001	<0.001
SEm(+/-)	0.023	0.018	0.028	0.029	0.30
LSD (0.05)	0.49	0.40	0.61	0.64	0.65
CV (%)	13.095	10.37	16.07	18.61	21.22

CV: Coefficient of Variance; DATP: Days After Trap Placement; *, **, and *** represent significance at 5%, 1%, and 0.1% level of significance respectively; SEm: Standard error of mean; LSD (0.05): Least Significant Difference at 5% level of significance; same letters in the superscript indicates the similar effect according to DMRT at 0.05 level of significance: Figures inside parentheses indicate $\sqrt{(x+0.5)}$ transformation values.

3.2 Population Of Males And Females On Different Trapping

3.2.1 First Trapping

During first trapping, cue lure, methyl eugenol lure, and tulsi lure attracted male fruit flies only while apple cider vinegar lure, banana pulp bait, local liquor lure, and pumpkin lure attracted both male and female fruit flies.

Cue lure (59.33) attracted the highest number of male fruit flies followed by methyl eugenol lure (36.67). The lowest number of male fruit flies were found in pumpkin lure (3.33) which was statistically at par with banana pulp bait (3.67), local liquor lure (4.00), and tulsi lure (7.33). The lowest population of female fruit flies was 0.00 in three different treatments viz. cue lure, methyl eugenol lure, and tulsi lure. The highest number of fruit flies were tapped in banana pulp bait (5.00) which was statistically at par with pumpkin lure (4.00).

3.2.2 Second Trapping

Also, during the second trapping, female and male fruit flies were attracted to apple cider vinegar lure, banana pulp bait, local liquor lure, and pumpkin lure while cue lure, methyl eugenol lure, and tulsi lure attracted male fruit flies only. The highest number of female fruit flies were attracted to banana pulp bait followed by pumpkin lure, which was statistically at par with apple cider vinegar lure. Local liquor lure (2.00) also attracted female fruit flies which was higher than that of cue lure (0.00), methyl eugenol lure (0.00), and tulsi lure (0.00). The lowest number of male fruit flies were found in pumpkin lure (1.67) and banana pulp bait (1.67). Cue lure (58.00) attracted the highest number of male fruit flies followed by methyl eugenol lure (38.67).

Table 4: Average population of male and female fruit flies trapped during first and second trapping in Rampur Chitwan, 2023

	First	trapping		Second	trapping	
Treatments	Male	Female	Total	Male	Female	Total
Apple Cider Vinegar Lure	13.00^{c} (3.72)	3.67^{ab} (2.14)	16.67^{c} (4.17)	14.00^{c} (3.81)	5.33^{b} (2.40)	19.33^{c} (4.45)
Banana Pulp Bait	3.67^{e} (2.09)	5.00^{a} (2.44)	8.67^{d} (3.07)	1.67^{f} (1.46)	8.33^{a} (2.96)	10.00^{d} (3.22)
Cue Lure	59.33^{a} (7.76)	0.00^{c} (1.00)	59.33^{a} (7.76)	58.00^{a} (7.65)	0.00^{d} (0.71)	58.33^{a} (7.65)
Local Liquor Lure	4.00^{e} (2.23)	2.33^{b} (1.82)	6.33^{d} (2.69)	5.00^{e} (2.34)	2.00^{c} (1.52)	7.00^{d} (2.73)
Methyl Eugenol Lure	36.67^{b} (6.13)	0.00^{c} (1.00)	36.67^{b} (6.13)	38.67^{b} (6.26)	0.00^{d} (0.71)	38.67^{b} (6.26)
Pumpkin Lure	3.33^{e} (2.06)	4.00^{a} (2.23)	7.33^{d} (2.88)	1.67^{f} (1.46)	6.33^{ab} (2.60)	8.00^{d} (2.91)
Tulsi Lure	7.33^{d} (2.88)	0.00^{c} (1.00)	7.33^{d} (2.88)	8.33^{d} (2.96)	0.00^{d} (0.71)	8.33^{d} (2.96)
Grand mean	3.84	1.66	4.23	3.71	1.66	4.31
F value	138.91***	34.29***	95.91***	363.29***	37.83***	166.52***
P value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
SEm(+-)	0.027	0.016	0.028	0.018	0.023	0.021
LSD (0.05)	0.59	0.34	0.62	0.39	0.495	0.046
CV (%)	8.61	11.49	8.27	5.88	16.79	6.01

CV: Coefficient of Variance; DATP: Days After Trap Placement; *, **, and *** represent significance at 5%, 1%, and 0.1% level of significance respectively; SEm: Standard error of mean; LSD (0.05): Least Significant Difference at 5% level of significance; same letters in the superscript indicates the similar effect according to DMRT at 0.05 level of significance: Figures inside parentheses indicate $\sqrt{(x+0.5)}$ transformation values.

3.3 Species Of The Trapped Fruit Flies

3.3.1 First Trapping

Among Zeugodacus cucurbitae, cue lure attracted the highest number of fruit flies (27.67), while tulsi lure had the lowest capture rate (0.00). For Zeugodacus scutellaris, cue lure was the most effective bait (14.33), with local liquor lure and banana pulp bait capturing the fewest flies (0.67). Zeugodacus tau showed a preference for cue lure (17.33) over other baits, with tulsi lure failing to attract any flies (0.00). In the case of Bactrocera dorsalis, methyl eugenol lure was the most successful (16.00), while cue lure and pumpkin lure did not capture any individuals. Lastly, Bactrocera zonata was most attracted to methyl eugenol lure (13.00), with banana pulp bait having the lowest capture rate (0.33).

Table 5: Average population of different species of fruit flies trapped during first trapping in Rampur Chitwan, 2023

Treatments	Z. cucurbitae	Z. scutellaris	Z.tau	B. dorsalis	B. zonata
Apple Cider Vinegar Lure	4.00^{b} (2.11)	3.67^{b} (2.02)	3.67^{bc} (2.04)	3.00^{bc} (1.82)	2.67^{b} (1.74)
Banana Pulp Bait	5.00^{b} (2.33)	0.67^{cd} (0.99)	1.00^{d} (1.23)	1.67^{c} (1.46)	0.33^{cd} (0.88)
Cue Lure	27.67^{a} (5.30)	14.33^{a} (3.84)	17.33^{a} (4.20)	0.00^{d} (0.71)	0.00^{d} (0.71)
Local Liquor Lure	2.00^{c} (1.56)	0.67^{cd} (1.05)	1.00^{d} (1.23)	1.67^{c} (1.39)	1.00^{c} (1.25)
Methyl Eugenol Lure	4.00^{b} (2.11)	1.33^{c} (1.34)	2.33^{c} (1.68)	16.00^{a} (4.06)	13.00^{a} (3.660
Pumpkin Lure	1.67^{c} (1.46)	1.00^{cd} (1.22)	4.67^{b} (2.26)	0.00^{d} (0.71)	0.00^{d} (0.71)
Tulsi Lure	0.00^{d} (0.71)	0.00^{c} (0.71)	0.00^{e} (0.71)	4.667^{b} (2.27)	2.67^{b} (1.77)
Grand mean	2.23	1.59	1.91	1.77	1.53
F-test	106.21***	40.84***	76.00***	37.57***	59.58***
P value	<0.001	<0.001	<0.001	<0.001	<0.001
SEm(+-)	0.02	0.24	0.019	0.71	0.019
LSD (0.05)	0.44	0.52	0.42	0.58	0.42
CV (%)	11.05	18.15	12.43	18.40	15.31

CV: Coefficient of Variance; DATP: Days After Trap Placement; *, **, and *** represent significance at 5%, 1%, and 0.1% level of significance respectively; SEm: Standard error of mean; LSD (0.05): Least Significant Difference at 5% level of significance; same letters in the superscript indicates the similar effect according to DMRT at 0.05 level of significance: Figures inside parentheses indicate √ (x+0.5) transformation values.

3.3.2 Second Trapping

The results of the second trapping trapping showed that cue lure mostly attracted Zeugodacus cucurbitae (28.00), Zeugodacus scutellaris (13.00), and Zeugodacus tau (17.00) species. Apple cider vinegar lure was the second most effective bait for Zeugodacus cucurbitae (5.33) and Zeugodacus scutellaris (4.67) species. Local liquor lure was the least effective bait for Zeugodacus cucurbitae (0.67) and Zeugodacus scutellaris (0.67), while pumpkin lure was the least effective bait for Zeugodacus tau (1.00). Methyl Eugenol Lure attracted Bactrocera dorsalis (18.33) and Bactrocera zonata (16.33) species. Tulsi lure was the second most effective bait for Bactrocera dorsalis (5.00) and Bactrocera zonata (3.33) species. Apple cider vinegar lure was effective in attracting both Bactrocera dorsalis (3.33) and Bactrocera zonata (2.67) species. Cue lure and pumpkin lure did not attract any Bactrocera dorsalis, while methyl eugenol lure and pumpkin lure did not attract any Bactrocera zonata species.

Table 6: Average population of different species of fruit flies trapped during second trapping in Rampur Chitwan, 2023.

Treatments	Z. cucurbitae	Z. scutellaris	Z.tau	B. dorsalis	B. zonata
Apple Cider Vinegar Lure	5.33^{b} (2.41)	4.67^{b} (2.27)	3.33^{b} (1.19)	3.33^{c} (1.95)	2.67^{b} (1.77)
Banana Pulp Bait	3.00^{c} (1.86)	1.33^{c} (1.34)	1.00^{cd} (1.27)	3.33^{c} (1.95)	1.00^{c} (1.22)
Cue Lure	28.00^{a} (5.34)	13.00^{a} (3.67)	17.00^{a} (4.18)	0.00^{d} (0.71)	0.00^{d} (0.71)
Local Liquor Lure	0.67^{d} (1.05)	0.67^{cd} (0.99)	1.33^{c} (1.34)	3.00^{c} (1.87)	1.33^{c} (1.34)
Methyl Eugenol Lure	3.33^{c} (1.93)	0.33^{cd} (0.88)	0.33^{cd} (0.88)	18.33^{a} (4.34)	16.33^{a} (4.09)
Pumpkin Lure	2.00^{d} (1.56)	1.33^{c} (1.34)	4.67^{b} (2.27)	0.00^{d} (0.71)	0.00^{d} (0.71)
Tulsi Lure	0.00^{d} (0.71)	0.00^{d} (0.71)	0.00^{d} (0.71)	5.00^{b} (2.34)	3.33^{b} (1.95)
Grand mean	2.12	1.60	1.79	1.98	1.69
F-test	99.41***	49.30***	39.71***	229.33***	138.61***
P value	<0.001	<0.001	<0.001	<0.001	<0.001
SEm(+-)	0.021	0.021	0.027	0.012	0.014
LSD (0.05)	0.47	0.46	0.58	0.25	0.31
CV (%)	12.49	16.09	18.13	7.05	10.15

CV: Coefficient of Variance; DATP: Days After Trap Placement; *, **, and *** represent significance at 5%, 1%, and 0.1% level of significance respectively; SEm: Standard error of mean; LSD (0.05): Least Significant Difference at 5% level of significance; same letters in the superscript indicates the similar effect according to DMRT at 0.05 level of significance: Figures inside parentheses indicate √ (x+0.5) transformation values.

3.4 Cost Of The Trap

The cost of the ingredients and materials is used to determine the cost of the traps prepared. The most expensive trap were Cue lure and Methyl Eugenol lure, which cost NRs.160.12 each. The cheapest trap was the one with pumpkin lure, which cost NRs.26.06. The other four homemade lures with traps were also in the range of NRs. 26.62- NRs. 27.842.

Table 7: Cost of preparation of different traps

Trap name	Ingredients and materials (For 3 traps)	Cost (NRs) of three traps	Cost of a trap (NRs)
Apple Cider Vinegar Lure	Apple Cider Vinegar-10 ml Malathion- 2ml Plastic bottle-3 GI wire- 1.5m	0.423×10+ 1.18×2+ 20×3+ 1.5×10= 81.59	27.197
Banana Pulp Bait	Ripen banana pulp-50gm Borax- 1gm Molasses- 1ml Malathion- 2ml Plastic bottle-3 GI wire- 1.5m	0.12×50+ 0.14×1+ 0.026×1+ 1.18×2+ 20×3+ 1.5×10= 83.526	27.842
Cue Lure	Cue lure solution- 4 ml Ethyl alcohol- 6ml Malathion- 2ml Plastic bottle-3 GI wire- 1.5m	100×4+ 0.5×6+ 1.18×2+ 20×3+ 1.5×10= 480.36	160.12
Local Liquor Lure	Local Liquor- 10 ml Malathion- 2ml Plastic bottle-3 GI wire- 1.5m	0.2×10+ 1.18×2+ 20×3+ 1.5×10= 79.36	26.453

Table 7(cont.): Cost of preparation of different traps			
Methyl Eugenol Lure	Methyl Eugenol- 4ml Ethyl Alcohol- 6 ml Malathion- 2ml Plastic bottle-3 GI wire- 1.5m	100×4+ 0.5×6+ 1.18×2+ 20×3+ 1.5×10= 480.36	160.12
Pumpkin Lure	Mashed Pulp- 10gm Malathion- 2ml Plastic bottle-3 GI wire- 1.5m	0.07×10+ 1.18×2+ 20×3+ 1.5×10= 78.06	26.02
Tulsi Lure	Tulsi Leaves- 5gm Water- 10 ml Malathion- 2ml Plastic bottle-3 GI wire- 1.5m	0.5×5+ 1.18×2+ 20×3+ 1.5×10= 79.86	26.62

NRs : Nepalese Rupees

4. Discussion

The results obtained from the experiment for the management of fruit flies in the field condition of Rampur, Chitwan showed that the two lures (cue lure and methyl eugenol lure) gave highly significant attraction of fruit flies in both first and second trapping for fifteen days. The results suggest that the number of fruit flies attracted to each lure increases from 3 days after trap placement to 6 days after trap placement and 9 days after trap placement and then decreases gradually. The maximum population of fruit flies were trapped in cue lure (15.67) 6 days after trap placement on first trapping. Methyl eugenol lure was found to be the next effective treatment after cue lure with a maximum population (9.67) obtained after six days of trap placement in second trapping. This analysis also reported cue lure (45%) highly effective with the highest population trapped followed by methyl eugenol lure (23%) in their study (Chiluwal et al., 2022). Among five homemade baits (apple cider vinegar lure, banana pulp bait, local liquor lure, pumpkin lure, and tulsi lure), local liquor lure was least effective compared to other baits. The reported that local liquor lure was able to attract only a few populations of fruit flies prevalent in the field (Piñero et al., 2017). The population of attracted flies decreased at 12 days after trap placement and 15 days after trap placement because of the volatile nature of treatments and the effectiveness of treatment decreased as time elapsed.

The results showed that cue lure, methyl eugenol lure, and tulsi lure attracted male fruit flies only while apple cider vinegar lure, banana pulp bait, local liquor lure, and pumpkin lure attracted both male and female fruit flies. Banana pulp bait was the most effective treatment followed by pumpkin lure in attracting the female fruit fly populations. The results above for the attraction of male fruit flies in cue lure and methyl eugenol lure are in accordance with the findings of who reported that these lures attracted male fruit flies only in the field experiment (Adhikari and Joshi, 2018). Similarly, tulsi lure also attracted male fruit flies only because of the presence of the low amount of methyl eugenol on tulsi (Gupta and Regmi, 2022). Cue lure and pumpkin lure attracted Z cucurbitae, Z scutellaris, and Z tau only. Methyl eugenol can also attract a few populations of these three species. The attraction of Zeugodacus fruit flies towards cue lure is also explained by (Chiluwal et al., 2022). B dorsalis and B zonata can be attracted with apple cider vinegar, banana pulp bait, local liquor lure, methyl eugenol lure, and tulsi lure. Among them, methyl eugenol lure attracted the maximum population of B dorsalis, and B zonata followed by tulsi lure. The results above for species of the trapped fruit flies are in accordance with the findings of where apple cider vinegar lure and local liquor lure were able to attract all species of fruit flies prevalent in the field respectively (Gupta and Regmi, 2022; Piñero et al., 2017).

The traps with commercial lures cost more than traps with homemade lures. The cost of cue lure and methyl eugenol lure with trap was 5.75-6.15 times higher than the other homemade lures with traps.

5. Conclusions

Chemical pesticides are frequently used to control or suppress the fruit fly population, but it has a harmful impact on human health, soil health, ecology, and the environment, as well as create the possibility of the development of resistance in insects against insecticides. Along with the toxic chemical pesticides, recently innovative measures like trapping and baiting are available for the control and management of fruit flies. These function as a major tool in the eco-friendly management of insect pests.

The current findings show that two commercial lures, Cue lure and Methyl Eugenol lure are effective for the control and management of fruit flies. Among five different homemade baits, apple cider vinegar lure is the most effective for attracting fruit flies while local liquor lure attracts the least population of fruit flies prevalent around the fields. Cue lure, methyl eugenol lure, and tulsi lure attract the male fruit flies only. Apple cider vinegar lure, banana pulp bait, local liquor lure, and pumpkin bait attract both male and female fruit flies. Apple cider vinegar lure was able to attract both male and female fruit fly populations of all five species prevalent in the research area Z. cucurbitae, Z. scutellaris, Z.tau, B. dorsalis, and B. zonata. Banana pulp bait and pumpkin lure also attracted both male and female fruit fly populations but lower than apple cider vinegar lure and higher than local liquor lure. Controlling fruit flies that infest the Cucurbitaceae family like Z. cucurbitae, Z. scutellaris, and Z. tau cue lure showed higher trapping ability. Those fruit flies that infest fruits like mango, guava, peach, etc like B. dorsalis, B. zonata, and B. correcta methyl eugenol showed higher trapping ability. Apple cider vinegar lure and banana pulp bait were the only treatments that attracted all the fruit fly species prevalent around the experimental site.Among all the treatments, three treatments, apple cider vinegar lure, banana pulp bait, and local liquor lure attracted all species of fruit flies. Among five homemade baits, the Apple cider vinegar lure was superior in attracting the fruit fly population, attracting both sexes and all species of fruit flies. For controlling fruit flies like Z. cucurbitae, Z. scutellaris, and Z.tau cue lure is effective, while for fruit flies like B. dorsalis and B. zonata methyl eugenol is effective in the case of commercial baits.

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