Management of Melon Fruit fly, *Zeugodacus cucurbitae* (Coquillett) with Improved Protein Bait Formulation

ABSTRACT

Background: Melon fruit fly, *Zeugodacus cucurbitae* is the most destructive insect pest of cucurbits with much quarantine importance. They damage the economic produce of several vegetable crops particularly cucurbitaceous vegetables throughout the world.
Aim: Current research work was done on the management of fruit flies by focussing on attraction of both male and female fruit flies, as capturing male fruit flies only does not bring desirable reduction in infestation levels.
Methodology: An improved gel formulation of proteinex bait was formulated and evaluated in field conditions in ridge gourd for attracting both the sexes of fruit flies.
Results: In ridge gourd fields, gel proteinex bait was the most attractive to female fruit flies followed by liquid proteinex bait. Cue-lure trapped more number of male fruit flies followed by gel proteinex bait. Gel proteinex bait was significantly superior in reducing the cucurbit fruit fly incidence when compared to liquid proteinex bait and cue-lure. Improvised liquid proteinex bait *i.e.,* gel proteinex bait was significantly superior in attracting both male and female fruit flies. When compared with the cue-lure traps, in gel proteinex bait traps number of males attracted was less. However, in cue-lure, no females were attracted.
Conclusion: Gel proteinex bait traps can attract both males and females and this is the added advantage of these traps over cue-lure traps. Before oviposition itself, female fruit flies are attracted to gel proteinex bait traps for the want of proteins for egg maturation and trapping & killing them before egg laying itself is a key reason for the reduced levels of fruit fly incidence. This was clearly noticed in our study where low per cent and level of fruit fly incidences were observed in the gel proteinex bait placed cucurbit fields.

Key words: Zeugodacus cucurbitae, Gel proteinex bait, Liquid proteinex bait, Cuelure, Ridge gourd

1. INTRODUCTION

Fruit flies (Tephritidae: Diptera) are the most destructive insect pests of quarantine importance which cause severe economic losses in several cucurbitaceous vegetable crops in tropical, subtropical and temperate regions of the world. Millions of dollars are being spent on the control of fruit flies by the countries in which they are considered as the major pests and face trade fines as a result of strict pre-export treatments. Eventhough, fruit fly control treatments imposed by them are effective, bio-security issues are being created by importing the horticultural goods into pest-free areas (Dhami *et al.,* 2016).

Various insect pests infest cucurbit crops *viz.,* whitefly, mite, melon fruit fly, mealy bug, red pumpkin beetle, aphids etc., which causes tremendous yield losses. Among them, melon fruit fly, *Zeugodacus cucurbitae* Coquillett (Tephritidae: Diptera) is a major frugivorous pest causing extensive damage to several commercially cultivated fruit and vegetable crops (Kamala Jayanthi *et al.,* 2021). The most susceptible hosts of cucurbit fruit

flies are bitter gourd, ribbed gourd, bottle gourd, long melons, squash melons, snap melons and cucumber (Kapoor *et al.*, 2005).

Management of fruit flies is especially difficult since their maggots *i.e.*, the destructive stage will be inside the fruit. This limitation has led to the development of parapheromones like cue-lure and other compounds as male attractants of fruit flies. However, trapping of only male fruit flies is not sufficient to reduce the field level damage. In this context, the current studies were concentrated on the development of non sex specific fruit fly attractants, particularly female attractants for effective management of fruit flies. In the present research work, gel proteinex bait, an improvised version of liquid protein bait was evaluated for it's alluring capacity to cucurbit fruit flies in comparison with liquid proteinex bait and cue-lure in ridge gourd.

2. MATERIALS AND METHODS

Field trials *i.e.*, preliminary and confirmatory were conducted to evaluate the alluring potential of gel proteinex bait to cucurbit fruit flies in comparison with liquid proteinex bait and cue-lure. Preliminary field experiments were conducted at Kesampatti village, Melur block, Madurai district (10.138ºN, 78.284ºE) during January to April of 2023. Confirmatory trials were conducted at Sekkipatti village, Melur block, Madurai district (10.208ºN, 78.310 ºN) during April to July of 2023. For each treatment, five replications were maintained with 50 m isolation distance. The experiment was conducted in a randomized block design. Treatments included were gel proteinex bait (liquid proteinex bait + gel powder @ 0.8 g in 1 litre), liquid proteinex bait (proteinex powder + inorganic salt + preservative + sweetener in 10:10:5:2 ratio) + insecticide, Cue-lure, negative control (base materials of liquid proteinex bait except proteinex powder) and untreated control (water)

Plastic containers of one litre capacity of 10 cm diameter and 20 cm height were modified as bait traps. Four square shaped holes of 20 mm^2 were made in the middle and around the circumference of the container with a heated blade to allow the entry of attracted fruit flies. The baits were allowed to ferment for 36 hours duration and placed in the traps @ 300 ml/trap, tied at a height of 1.5 to 2 metres in pandal system. Baits were replaced once in 10 days.

Observations on the number of attracted fruit flies on 5^{th} and 10th days after placement of traps (DAPT) were recorded continuously for four months. Number of trapped males and females were counted separately and male to female ratio was arrived. In each treatment, 300 fruits were observed randomly (100 fruits / replication) at ten days interval, number of healthy & infested fruits were counted and per cent fruit infestation in each

treatment was calculated. In each treatment, 60 fruits were collected randomly (20 fruits/replication), fruits were cut open and number of maggots in each fruit was noted at ten days interval. Level of incidence in each treatment was calculated by using the following formula.

$$\text{Level of incidence} = \frac{\text{Total no. of maggots observed}}{\text{No. of fruits observed}}$$

The data were subjected to statistical analysis using SPSS software (version 26) to carry out ANOVA and grouping of data by Tukey post hoc test (Tukey, 1977).

3. RESULTS AND DISCUSSION

3.1. Evaluation of gel proteinex bait in trapping melon fly, *Z.cucurbitae* in ridge gourd

3.1.1. Preliminary field experiment

3.1.1.1. Female fruit flies

Observations during early fruiting stage revealed that, at 5 days after placement of traps (DAPT), liquid proteinex bait attracted 24.70 female fruit flies (FF) / trap while this number is high in gel proteinex bait *i.e.*,36.30 FF / trap (Table 1). At 10 DAPT, highest trap catch was recorded in gel proteinex bait treatment *i.e.*, 43.80 FF / trap as against 36.60 in liquid proteinex bait treatment. As cuelure is a male attractant, no female fruit flies were observed in these traps and in untreated control also trap catch was nil.

Observations during the fruiting stage showed that, liquid proteinex bait attracted 25.04 to 39.40 FF/trap. Number of fruit flies in the traps in which gel proteinex bait was placed was more than the liquid preteinex bait traps *i.e.*, 39.00 to 47.40 FF / trap (Table 1). In cuelure traps and untreated control, no fruit flies were recorded. In negative control, 5.20 to 7.00 FF/trap were noted.

3.1.1.2. Male fruit flies

Observations on trap catches of fruit flies in early fruiting stage of the crop showed the highest catch of 73.00 and 90.70 male fruit flies (MF)/trap (Table 1) at 5 and 10 DAPT respectively. Next to this was gel proteinex bait with 31.32 to 39.72 MF/trap. Among the treatments, lowest catch was recorded in liquid proteinex bait (21.78 to 33.84 MF/trap). No fruit flies were recorded in untreated control. Negative control traps recorded 5.54 to 9.50 MF/trap.

3.1.2. Confirmatory field experiment

3.1.2.1. Female fruit flies

At 5 DAPT, comparatively gel proteinex bait attracted more number of female fruit flies *i.e.,* 79.60 and 84.60 FF/trap (Table 1) at 5 DAPT and 10 DAPT respectively. Next to this was, liquid proteinex bait which attracted 58.20 and 58.90 FF/trap at 5 DAPT and 10 DAPT respectively. In cuelure and untreated control treatments, no fruit flies were recorded. In negative control, comparatively more number of fruit flies (9.00 FF/trap) were trapped than in the preliminary trial (5.20 to 6.20 FF/trap).

At 10 DAPT, number of fruit flies per trapped were highest in gel proteinex bait traps *i.e.,* 91.80 and 98.20 FF/trap at early and fruiting stages respectively. In liquid proteinex bait traps, the number of fruit flies trapped ranged between 65.40 and 72.70 respectively. Cuelure and untreated control traps were found with no fruit flies.

3.1.2.2. Male fruit flies

Generally fruit fly catches in various traps were more in confirmatory field trial (April to July of 2023) than the preliminary trial (January to April of 2023). With regard to male fruit flies, more number was trapped in cuelure traps *i.e.,* 137.40 to 156.40 MF/trap (Table 1) during early fruiting stage and 140.70 to 158.80 MF/trap during fruiting stage. In gel proteinex bait traps, fruit fly count ranged from 67.90 to 93.20 MF/trap while in liquid proteinex bait trap, it was 53.40 to 61.00 MF/trap. Negative control traps recorded 8.20 to 9.40 MF/trap.

When total number of fruit flies *i.e.,* both male and female in various traps was probed in to, gel proteinex bait traps showed their superiority with 678.90 fruit flies (Fig 1.) followed by cuelure (593.30) and liquid proteinex bait traps (485.20). Gel proteinex bait was found to be more attractive to female fruit flies. With reference to the male fruit fly catches, it was next to the cue-lure. Putruele *et al.* (1993) reported the soybean protein hydrolysate - based bait as the most effective to attract mediterranean fruit fly. Similarly, Moreno and Mangan (1995) reported that bait formulation based on commercially available corn protein hydrolysate was highly attractive to mexican fruit fly, *A.ludens* in USA in cucurbits.

Fig 1. Total number of female and male fruit fly catches in ridge gourd

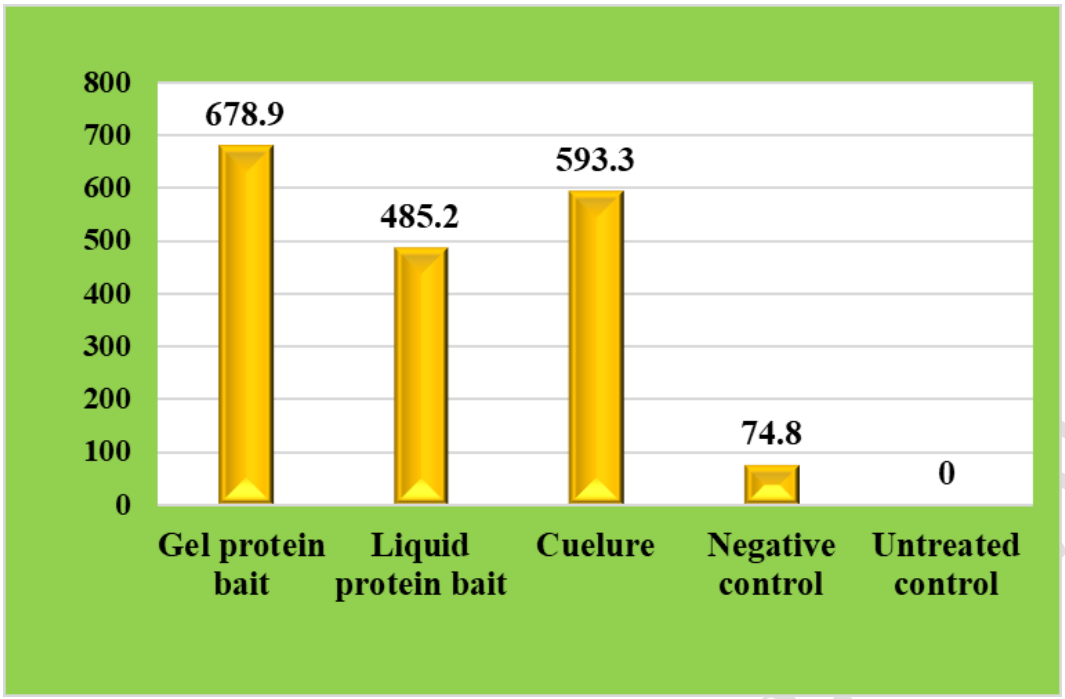


Table 1. Evaluation of trapping efficiency of gel proteinex bait to cucurbit fruit flies in Ridge gourd

Particulars	Treatment	No. of fruit flies/trap							
		Preliminary field experiment*				Confirmatory field experiment*			
		5 DAPT		10 DAPT		5 DAPT		10 DAPT	
		Early fruiting stage	Fruiting stage	Early fruiting stage	Fruiting stage	Early fruiting stage	Fruiting stage	Early fruiting stage	Fruiting stage
Female fruit flies	Gel proteinex bait	36.30 (6.07) [a]	39.00 (6.28) [a]	43.80 (6.66) [a]	47.40 (6.92) [a]	79.60 (8.95) [a]	84.60 (9.22) [a]	91.80 (9.61) [a]	98.20 (9.93) [a]
	Liquid proteinex bait	24.70 (5.02) [b]	25.04 (5.05) [b]	36.60 (6.09) [b]	39.40 (6.32) [b]	58.20 (7.66) [b]	58.90 (7.71) [b]	65.40 (8.12) [b]	72.70 (8.55) [b]
	Cue-lure	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]
	Negative control	5.20 (2.39) [c]	6.20 (2.59) [c]	7.00 (2.73) [c]	6.80 (2.69) [c]	9.00 (3.08) [c]	9.00 (3.08) [c]	9.50 (3.16) [c]	11.10 (3.40) [c]
	Untreated control	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]
	S.E(d)	0.0368	0.1570	0.0152	0.0507	0.0190	0.1652	0.0450	0.0637
	P	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Male fruit flies	Gel proteinex bait	31.32 (5.64) [b]	34.78 (5.94) [b]	37.8 (6.19) [b]	39.72 (6.34) [b]	67.90 (8.27) [b]	79.00 (8.92) [b]	84.60 (9.22) [b]	93.20 (9.68) [b]
	Liquid proteinex bait	21.78 (4.72) [c]	25.06 (5.06) [c]	33.84 (5.86) [b]	32.76 (5.77) [b]	53.40 (7.34) [c]	57.80 (7.64) [b]	57.80 (7.64) [b]	61.00 (7.84) [b]
	Cue-lure	73.00 (8.57) [a]	75.08 (8.69) [a]	90.70 (9.55) [a]	86.00 (9.30) [a]	137.40 (11.74) [a]	140.70 (11.88) [a]	156.40 (12.53) [a]	158.80 (12.62) [a]
	Negative control	5.54 (2.46) [d]	8.90 (3.07) [d]	6.64 (2.67) [c]	9.50 (3.16) [c]	8.20 (2.95) [d]	9.40 (3.46) [c]	9.20 (3.11) [c]	9.40 (3.15) [c]
	Untreated control	0.00 (0.71) [e]	0.00 (0.71) [e]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [e]	0.00 (0.71) [d]	0.00 (0.71) [d]	0.00 (0.71) [d]
	S.E(d)	0.6159	0.0254	0.0392	0.0307	0.2191	0.0457	0.0522	0.0370
	P	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

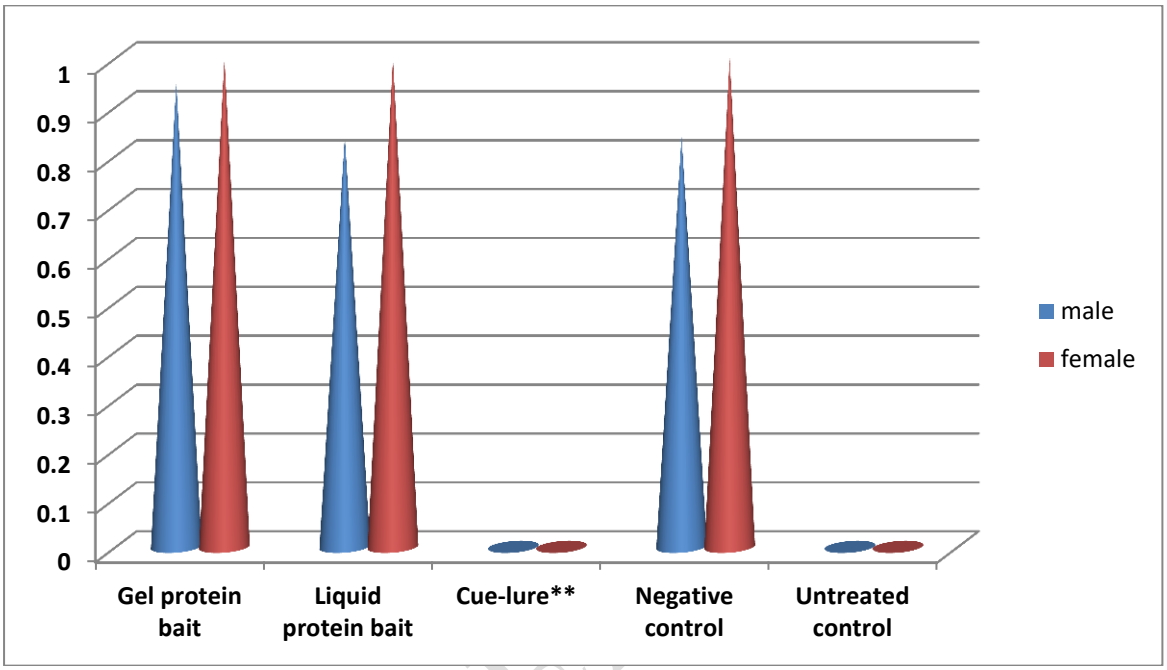
* Mean of 5 replications DAPT – Days after placement of traps Figures in parentheses are square root transformed values

Means followed by the same letter in a column are not significantly different by Tukey's HSD test. (P=**0.05**)

3.1.3. Male to female ratio of cucurbit fruit flies in various traps

Male to female ratio was more in gel proteinex bait (0.95:1) followed by liquid proteinex bait and negative control (0.84:1) (Fig 2.). As in cuelure traps, no males were trapped, ratio was not arrived. Negative control attracted more female fruit flies than the males.

Fig 2. Male to female ratio of *Z. cucurbitae* in various traps in ridge gourd



When male and female catches of gel proteinex bait were compared, number of males trapped was slightly lesser than that of females. This observation showed less protein requirement of male fruit flies when compared to females and this was also supported by the statements of Shelly *et al.,* 2004 (*Z.cucurbitae*), Shelly *et al.,* 2005 (*B.dorsalis*) and Perez-Staples *et al.,* 2007 (*B. tryoni*).

3.1.4. Evaluation of gel proteinex bait in reducing the cucurbit fruit fly incidence

3.1.4. 1. Early fruiting stage

In the preliminary field experiment, in ridge gourd fields in which gel proteinex bait was installed, incidence of cucurbit fruit fly was low (30.93%) when compared to liquid proteinex bait (43.25%) and cue-lure (58.43%). Among the different treatments, highest fruit fly incidence of 82.27% was recorded in untreated control (Table 2).

In the confirmatory field experiment, gel proteinex bait was found to be the effective treatment with 23.99 per cent fruit fly incidence. Liquid proteinex bait traps placed fields recorded the fruit fly incidence ranging from 33.60% (II obs.) to 36.80% (VI obs.) with a mean per cent incidence of 35.21% followed by cue-lure (50.45%). Untreated and negative

control plots recorded 78.00% and 73.23% mean incidences respectively. When overall mean per cent incidences were looked in to, superiority of gel proteinex bait in reducing the cucurbit fruit fly incidence was apparent (27.46%) than the liquid proteinex bait (39.23%) and cue-lure (54.44%).

3.1.4. 2. Fruiting stage

In the preliminary field experiment, lowest cucurbit fruit fly incidence noted was 31.91% in gel proteinex bait traps placed plots as against the highest incidence (78.91%) observed in untreated control (Table 2). In the confirmatory field experiment also gel proteinex bait treatment successfully controlled the cucurbit fruit fly and recorded 23.93% incidence. Liquid proteinex bait and cue-lure treatments were placed next with 35.63% and 48.92% incidences respectively. Overall results of both the trials revealed the superiority of gel proteinex bait in reducing the cucurbit fruit fly incidence (27.92%) when compared to liquid proteinex bait (39.39%) and cue-lure (52.72%).

This reduction in fruit fly incidence can be attributed to the highest number of male and female fruit flies trapped in gel proteinex bait traps i.e., 678.90 (Fig 1). Even though cue-lure traps attracted 593.30 fruit flies, they all were males only. As female fruit flies play a vital role in the population build up in field conditions, alluring capacity of gel proteinex bait to female fruit flies along with males significantly reduced the fruit fly damage in ridge gourd During this study, improvised version of the liquid proteinex bait *i.e.*, gel proteinex bait was found to be significantly superior than the liquid proteinex bait in it's attraction to melon fruit flies. It attracted more female and male fruit flies than the liquid proteinex bait. When compared to cue-lure trap, gel proteinex bait traps attracted less number of males. However, in cue-lure, female attraction was nil and gel proteinex bait traps can attract both males and females.

Alluring potential of gel proteinex bait traps to female fruit flies is a very positive factor in reducing the fruit fly incidence levels in the field as females are the major reason for the population build up. Moreover, females are attracted to these traps before oviposition itself as they require proteins for egg maturation. Drew and Yuval (1999) suggested that both male and female fruit flies require proteinaceous food baits for their survival and reproduction and the females have a stronger preference for protein sources than males. So, trapping of females before egg laying itself is a key reason for the reduced levels of fruit fly incidence.

This is apparent in the present study where low per cent and level of fruit fly incidences were observed in the gel proteinex bait placed cucurbit fields. Manrakhan and Lux

(2006) stressed the importance of proteinaceous substrates for the sexual maturation and ovary development of tephritid male and female fruit fly adults. Shelly and Nishimoto, (2017) also confirmed that protein deprivation led to decreased mating success in fruit flies.

As the fruit fly maggots are present inside the fruits, trapping the adult fruit flies is the only effective alternative for the management of fruit flies in field conditions. In the light of this point, outcome of the present study in which gel proteinex bait was found to be alluring to both male and female fruit flies will fit in the integrated fruit fly management.

Table 2. Evaluation of various traps in reducing the percent incidences of cucurbit fruit flies

Particulars	Treatment	Fruit fly incidence (%)														
		Preliminary field experiment*							Confirmatory field experiment*							Overall Mean
		I obs.	II obs.	III obs.	IV obs.	V obs.	VI obs.	Mean	I obs.	II obs.	III obs.	IV obs.	V obs.	VI obs.	Mean	
Early fruiting stage	Gel protein bait	35.00 (36.29) [a]	33.90 (35.63) [a]	27.00 (31.32) [a]	28.60 (32.35) [a]	30.00 (33.23) [a]	31.12 (33.92) [a]	30.93 (33.79) [a]	21.60 (27.71) [a]	22.80 (28.54) [a]	23.70 (29.15) [a]	24.24 (29.51) [a]	24.60 (29.75) [a]	27.00 (31.32) [a]	23.99 (29.34) [a]	27.46 (31.64) [a]
	Liquid protein bait	40.00 (39.25) [b]	45.90 (42.67) [b]	44.80 (42.04) [b]	43.60 (41.34) [b]	40.80 (39.72) [b]	44.40 (41.81) [b]	43.25 (41.14) [b]	35.20 (36.41) [b]	33.60 (35.44) [b]	34.00 (35.69) [b]	35.20 (36.41) [b]	36.50 (37.19) [b]	36.80 (37.19) [b]	35.21 (36.41) [b]	39.23 (38.78) [b]
	Cue-lure**	64.40 (53.40) [c]	56.80 (48.93) [c]	55.20 (48.01) [c]	58.20 (49.74) [c]	58.60 (49.98) [c]	57.40 (49.28) [c]	58.43 (49.92) [c]	54.80 (47.78) [c]	55.60 (48.24) [c]	49.00 (44.45) [c]	40.84 (39.74) [c]	52.10 (46.23) [c]	50.40 (48.47) [c]	50.45 (45.28) [c]	54.44 (47.72) [c]
	Negative control	78.60 (62.48) [d]	79.50 (63.11) [d]	77.20 (61.51) [d]	78.90 (62.69) [d]	80.00 (63.47) [d]	79.00 (62.76) [d]	78.86 (62.69) [d]	72.40 (58.34) [d]	70.40 (57.07) [d]	78.40 (62.34) [d]	74.70 (59.83) [d]	71.50 (57.76) [d]	72.00 (57.62) [d]	73.23 (58.85) [d]	76.04 (60.83) [d]
	Untreated control	81.72 (64.72) [e]	83.00 (65.68) [e]	80.20 (63.61) [e]	82.90 (65.61) [e]	85.00 (67.25) [e]	80.80 (64.04) [d]	82.27 (65.14) [e]	76.40 (60.97) [e]	76.40 (60.97) [e]	80.60 (63.90) [e]	80.40 (63.75) [e]	75.40 (60.30) [e]	78.80 (60.16) [d]	78.00 (62.06) [e]	80.13 (63.54) [e]
	S.E(d)	**0.62128**	**0.8348**	**0.8966**	**0.0351**	**0.3081**	**0.6981**	**0.2627**	**1.1847**	**1.1469**	**0.7534**	**0.6332**	**1.7074**	**1.8506**	**0.2256**	**0.2443**
	P	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Fruiting stage	Gel protein bait	31.00 (33.85) [a]	30.20 (33.35) [a]	33.80 (35.57) [a]	29.50 (32.91) [a]	32.40 (34.71) [a]	34.60 (36.05) [a]	31.91 (34.41) [a]	22.60 (28.40) [a]	27.60 (31.71) [a]	25.20 (30.15) [a]	23.40 (28.94) [a]	21.30 (27.50) [a]	23.50 (29.01) [a]	23.93 (29.28) [a]	27.92 (31.91) [a]
	Liquid protein bait	45.00 (42.15) [b]	44.80 (42.04) [b]	43.60 (41.34) [b]	40.00 (39.25) [b]	43.40 (41.23) [b]	42.20 (40.53) [b]	43.16 (41.05) [b]	36.80 (37.37) [b]	40.00 (39.25) [b]	33.10 (35.14) [b]	36.20 (37.01) [b]	33.20 (35.20) [b]	34.50 (35.99) [b]	35.63 (36.65) [b]	39.39 (38.90) [b]
	Cue-lure**	51.80 (46.05) [c]	60.60 (51.15) [c]	54.20 (47.43) [c]	55.60 (48.24) [c]	59.98 (50.78) [c]	57.00 (49.05) [c]	56.53 (48.76) [c]	50.40 (45.25) [c]	51.00 (45.60) [c]	42.70 (40.82) [c]	54.80 (47.48) [c]	48.22 (44.00) [c]	46.40 (42.96) [c]	48.92 (44.39) [c]	52.72 (46.70) [c]
	Negative control	74.80 (59.90) [d]	73.00 (58.72) [d]	76.60 (61.10) [d]	70.80 (57.32) [d]	75.40 (60.30) [d]	78.20 (62.20) [d]	74.80 (59.90) [d]	72.00 (58.08) [d]	69.20 (56.32) [d]	67.20 (55.09) [d]	68.30 (55.76) [d]	67.50 (55.27) [d]	72.30 (58.27) [d]	69.41 (56.44) [d]	72.10 (58.16) [d]
	Untreated control	79.60 (63.18) [e]	76.80 (61.24) [e]	80.60 (63.90) [e]	73.68 (59.16) [e]	82.80 (65.53) [e]	80.00 (63.47) [e]	78.91 (62.69) [e]	78.80 (62.62) [e]	74.70 (59.83) [e]	72.50 (58.40) [e]	72.40 (58.34) [e]	70.60 (57.19) [e]	76.30 (60.90) [e]	74.21 (59.50) [e]	76.56 (61.03) [e]
	S.E(d)	**1.0021**	**0.8289**	**0.7911**	**0.6723**	**1.0364**	**0.8690**	**0.5622**	**1.7267**	**1.0338**	**1.0424**	**0.8175**	**0.4193**	**1.4578**	**0.7279**	**1.5538**
	P	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**

* Mean of five replications
obs. – observation

DAPT – Days after placement of traps
Figures in parentheses are arcsine transformed values

Means followed by the same letter in a column are not significantly different by Tukey's HSD test. (P=0.05)

3.1.5. Evaluation of gel proteinex bait in reducing the level of incidence of cucurbit fruit fly

3.1.5.1. Early fruiting stage

In the preliminary field experiment, in gel protein bait, comparatively less LoI (2.99) of fruit fly was recorded. Among the six observation periods, range of LoI in these effective treatments was from 2.80 (III obs.) to 3.24 (VI obs.). This treatment was followed by liquid protein bait and cue-lure with 5.65 and 7.47 LoI respectively. Highest LoI of 23.71 was recorded in untreated control (Table 3).

In the confirmatory field experiment also, LoI was lowest (2.34) in gel protein bait while it was 22.75 in untreated control. Negative control recorded LoI of 18.33. In liquid protein bait and cue-lure placed fields level of incidence of cucurbit fruit fly was comparatively more i.e., 5.00 and 6.92 respectively than in the gel protein bait placed fields. Overall mean values of level of incidence of preliminary and confirmatory field trials clearly showed the promising role of gel protein bait treatment in reducing the level of incidence of cucurbit fruit fly (2.66) than the other treatments.

3.1.5.2. Fruiting stage

In the preliminary field experiment, the lowest LoI recorded in gel protein bait, liquid protein bait and cue-lure installed plots were 4.12 (I obs.), 6.06 (I obs.) and 8.32 (III obs.) respectively. In untreated and negative controls, LoIs were very high *i.e.*, 27.46 and 23.94 respectively (Table 3).

In the confirmatory field experiment also, results of gel protein bait treatment were encouraging as it recorded the lowest LoI (2.36) when compared to liquid protein bait (5.03) and cue-lure (7.61). In untreated control, LoI was 26.08. Overall mean level of incidences was investigated and found the lowest value (3.52) with the gel protein bait treatment followed by liquid protein bait (5.78) and cue-lure (8.35).

Table 3. Evaluation of various traps in reducing the level of incidences of cucurbit fruit flies in ridge gourd

Particulars	Treatment	Level of incidence														
		Preliminary field experiment*							Confirmatory field experiment*							Over all Mean
		I obs.	II obs.	III obs.	IV obs.	V obs.	VI obs.	Mean	I obs.	II obs.	III obs.	IV obs.	V obs.	VI obs.	Mean	
Early fruiting stage	Gel protein bait	2.90 (1.84) [a]	3.06 (1.89) [a]	2.80 (1.81) [a]	2.82 (1.82) [a]	3.16 (1.91) [a]	3.24 (1.93) [a]	2.99 (1.87) [a]	1.92 (1.55) [a]	2.20 (1.64) [a]	2.13 (1.62) [a]	2.14 (1.62) [a]	2.68 (1.78) [a]	3.00 (1.87) [a]	2.34 (1.68) [a]	2.66 (1.77) [a]
	Liquid protein bait	5.42 (2.43) [b]	5.22 (2.39) [b]	5.36 (2.42) [b]	6.50 (2.64) [b]	5.00 (2.34) [b]	6.40 (2.63) [b]	5.65 (2.48) [b]	5.12 (2.37) [b]	5.62 (2.47) [b]	5.27 (2.40) [a]	3.98 (2.12) [b]	5.02 (2.35) [b]	5.04 (2.35) [b]	5.00 (2.35) [b]	5.32 (2.41) [b]
	Cue-lure**	6.82 (2.71) [c]	7.04 (2.75) [c]	7.36 (2.80) [c]	7.60 (2.84) [c]	8.60 (3.02) [c]	7.40 (2.81) [b]	7.47 (2.82) [c]	6.18 (2.58) [c]	6.98 (2.73) [c]	5.96 (2.54) [b]	7.64 (2.85) [c]	7.82 (2.88) [c]	6.98 (2.73) [c]	6.92 (2.72) [c]	7.19 (2.77) [c]
	Negative control	15.12 (3.95) [d]	17.80 (4.28) [d]	20.80 (4.61) [d]	20.80 (4.61) [d]	24.40 (4.99) [d]	21.80 (4.72) [c]	20.12 (4.54) [d]	17.00 (4.17) [d]	14.80 (3.91) [d]	19.00 (4.41) [b]	20.60 (4.59) [d]	21.62 (4.70) [d]	17.00 (4.18) [d]	18.33 (4.34) [d]	19.22 (4.44) [d]
	Untreated control	17.30 (4.22) [e]	23.40 (4.89) [e]	24.20 (4.97) [e]	24.60 (5.01) [e]	27.80 (5.32) [e]	25.00 (5.05) [d]	23.71 (4.92) [e]	19.80 (4.50) [e]	17.60 (4.25) [e]	23.50 (4.88) [c]	25.40 (5.09) [e]	26.40 (5.18) [e]	23.80 (4.93) [e]	22.75 (4.82) [e]	23.23 (4.88) [e]
	S.E(d)	**0.0591**	**0.0550**	**0.0665**	**0.0703**	**0.1050**	**0.0918**	**0.0431**	**0.0964**	**0.0858**	**0.1477**	**0.0649**	**0.0706**	**0.0741**	**0.0635**	**0.0647**
	P	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
Fruiting stage	Gel protein bait	4.12 (2.15) [a]	5.00 (2.34) [a]	4.74 (2.28) [a]	4.80 (2.30) [a]	4.80 (2.30) [a]	4.66 (2.27) [a]	4.68 (2.28) [a]	1.96 (1.57) [a]	2.50 (1.73) [a]	2.13 (1.62) [a]	3.04 (1.88) [a]	2.10 (1.61) [a]	2.44 (1.71) [a]	2.36 (1.68) [a]	3.52 (2.00) [a]
	Liquid protein bait	6.06 (2.56) [b]	6.12 (2.57) [b]	7.02 (2.74) [b]	6.44 (2.63) [b]	6.80 (2.69) [b]	6.80 (2.69) [b]	6.54 (2.65) [b]	3.66 (2.04) [b]	5.80 (2.51) [b]	4.93 (2.33) [b]	4.94 (2.33) [b]	5.24 (2.39) [b]	5.66 (2.48) [b]	5.03 (2.35) [b]	5.78 (2.50) [b]
	Cue-lure**	9.20 (3.11) [c]	9.34 (3.14) [c]	8.32 (2.97) [c]	8.98 (3.08) [c]	8.78 (3.05) [c]	10.02 (3.24) [c]	9.10 (3.10) [c]	7.30 (2.79) [c]	7.24 (2.78) [c]	8.20 (2.97) [c]	8.04 (2.92) [c]	7.16 (2.77) [c]	7.76 (2.87) [c]	7.61 (2.84) [c]	8.35 (2.98) [c]
	Negative control	23.04 (4.85) [d]	25.00 (5.04) [d]	24.20 (4.97) [d]	22.80 (4.82) [d]	23.20 (4.86) [d]	25.40 (5.09) [d]	23.94 (4.94) [d]	21.40 (4.68) [d]	20.40 (4.57) [d]	27.40 (5.27) [d]	22.30 (4.77) [d]	21.96 (4.74) [d]	23.00 (4.85) [d]	22.74 (4.80) [d]	23.34 (4.88) [d]
	Untreated control	24.80 (5.02) [e]	30.00 (5.50) [e]	25.20 (5.06) [e]	25.60 (5.10) [e]	28.80 (5.41) [e]	30.40 (5.55) [e]	27.46 (5.29) [e]	25.00 (5.05) [e]	22.60 (4.81) [e]	28.30 (5.37) [e]	25.10 (5.05) [e]	29.80 (5.50) [e]	25.70 (5.12) [e]	26.08 (5.16) [e]	26.77 (5.22) [e]
	S.E(d)	**0.0967**	**0.1918**	**0.1426**	**0.1221**	**0.0991**	**0.0930**	**0.0647**	**0.0595**	**0.0696**	**0.1243**	**0.0851**	**0.0566**	**0.0685**	**0.0964**	**0.0624**
	P	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**

* Mean of five replications
obs. – observation
DAPT – Days after placement of traps

Figures in parentheses are square root transformed values
Means followed by the same letter in a column are not significantly different by Tukey's HSD test. (P=**0.05**)

4. Conclusion

In ridge gourd fields, the most attractive to female fruit flies was gel proteinex bait followed by liquid proteinex bait. With regard to male fruit flies, cue-lure trapped more number of male fruit flies followed by gel proteinex bait. Placement of gel proteinex bait traps significantly reduced the cucurbit fruit fly incidence when compared to liquid proteinex bait and cue-lure. Improvised liquid proteinex bait i.e., gel proteinex bait significantly attracted both male and female melon fruit flies than the liquid proteinex bait. For the want of proteins for sexual maturation, before egg laying, female fruit flies are attracted to gel proteinex bait and hence, trapping before oviposition is an apt reason that can be attributed to the reduced levels of fruit fly incidence. This point was manifested in our study where low levels of fruit fly incidences were observed in the gel protein bait placed cucurbit fields.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

Dhami, M., Gunawardana, D., Voice, D. & L. Kumarasinghe. (2016). A real-time PCR tool box for accurate identification of invasive fruit fly species. *Journal of Applied Entomology*, 140 (7): 536-552.

Drew, R.A.I. & Yuval, B. (1999). The evolution of fruit fly feeding behaviour in fruit flies (Tephritidae). CRC Press, pp. 731–749.

Kamala Jayanthi, P.D., Saravan Kumar, P. & Vyas, M. (2021). Odour cues from fruit arils of *Artocarpus heterophyllus* attract both sexes of oriental fruit flies. *Journal of Chemical Ecology*, 47: 552-563.

Kapoor, V.C. (2005). Taxonomy and biology of economically important fruit flies of India. *Israel Journal of Entomology*, 35(36), 459-475.

Mangan, R.L. & Thomas, D.B. (2014). Comparison of torula yeast and various grape juice products as attractants for Mexican fruit fly (Diptera: Tephritidae). *Journal of Economic Entomology*, 107(2): 591-600.

Manrakhan, A. & Lux, S.A. (2006). Contribution of natural food sources to reproductive behaviour, fecundity and longevity of *Ceratitis cosyra*, *C.fasciventris* and *C.capitata* (Diptera: Tephritidae). *Bulletin of Entomological Research*, 96 (3): 259-268.

Perez-staples, D.I.A.N.A., Prabhu, V. & Taylor, P.W. (2007). Post-teneral protein feeding enhances sexual performance of Queensland fruit flies. *Physiological Entomology*, 32(3): 225-232.

Putruele, G., Abbiati, N.N. & Vaccaro, N.C. (1993). Soyabean protein hydrolysate bait for medfly control. In Fruit Flies. Springer New York pp. 369-374.

Shelly, T.E., Pahio, E. and Edu, J. (2004). Synergistic and inhibitory interactions between methyl eugenol and cue lure influence trap catch of male fruit flies, *Bactrocera dorsalis* (Hendel) and *B.cucurbitae* (Diptera: Tephritidae). *Florida Entomologist*, 87: 480-486.

Shelly, T.E., Edu, J. & Pahio, E. (2005). Lack of an irradiation effect on the mating performance of mass-reared males of the Mediterranean fruit fly. *Florida Entomologist*, 88(4): 547-548.

Shelly, T., Kurashima, R., Nishimoto, J. & Andress, E. (2017). Capture of *Zeugodacus cucurbitae* (Diptera:Tephritidae) in traps baited with torula yeast solution versus cucumber volatile plugs. *Florida Entomologist*, 100(1): 15-20.