EVALUATION OF DIFFERENT BIORATIONAL PEST MANAGEMENT APPROACHES FOR THE MANAGEMENT RED PUMPKIN BEETLE (*Aulacophora foveicollis* Lucas) AND FRUIT FLY (*Bactocera cucurbitae*) IN CUCUMBER CROP AND THEIR ECONOMIC ANALYSIS

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ABSTRACT

Experiment on the evaluation of different biorational pest management approaches against major insect pest of cucumber was carried out under field condition at Hazara Agriculture Research Station (HARS) Abbottabad, Khyber Pukhtunkhawa-Pakistan. The experiment comprised of 11 treatments (modules) including control. M1 (Water pepper + Bakyan + Laser), M2 (Basil oil + Neem oil + laser), M3 (Bakyan extract + Basil oil + Laser), M4 (Bakyan extracts + Neem oil + Laser), M5 (Water pepper + Neem oil + Laser), M6 (Water pepper + Basil oil + Laser), M7 (Lambda cyhalonthrin + Neem oil + laser), M8 (Lambda cyhalonthrin + Basil oil + laser), M9 (Lambda cyhalonthrin + water pepper + Laser), M10 (Lambda cyhalonthrin + Bakyan + Laser) and M11 (Control) followed Randomize Complete Block Design with three replications. Results revealed that all the tested modules were found better than control in reducing red pumpkin beetle and fruit fly infestation with increased cucumber yield. However, among the tested modules, Lambda cyhalothrin based modules were found the most effective in reducing Red pumpkin beetle population in 1st (1.14-1.44 beetle plant^{-1}) and 2nd spray application (0.72 -1.06 beetle plant^{-1}) with lowest number of infested leaves and leaf perforation by red pumpkin beetle (3.76-4.06) and (2.86- 3.20) respectively. Results further revealed that Lambda cyhalothrine based modules were recorded with lowest fruit fly infestation (8.79 – 10.04 %), with lowest fruit fly ovipositor marks (0.76- 0.86) and highest cucumber yield (7955.6 – 8622 kg ha^{-1}) and hence consequently led towards the improved quality of the cucumber. Furthermore, M5 (Water pepper + Basil oil + Laser) and M4 (Bakyan extracts + Neem oil + Laser) were found the most cost effective modules having the highest cost benefit ratio (1:26.75 and 1:25.21) respectively. It is concluded that red pumpkin beetle and fruit fly can better be managed by spraying Lamda cyhalothirn and 2nd spray of tested botanical and 3rd spray of Laser at 14 days interval is recommended for sustainable management of major insect pest of cucumber.

Keywords: Bakayan extract, Basil oil, fruitfly management, Neem oil, Red pumpkin beetle management, Water pepper extract, Lambda cyhalothrine

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INTRODUCTION

Cucumber (*Cucumis sativus*) is cultivated throughout the world due to its anti-oxidant and anti-inflammatory quality. It is a rich source of vitamins B, C, K, Magnesium, Potassium and vitamin A (Bloach, 1994). Biotic stress particularly the insect pest (red pumpkin beetles and fruit flies) significantly affect quality and production of cucumber (Sharma et al, 2016 a). Being a major pest, 30 -100% yield loss has been reported due to red pumpkin beetle, *Aulacophora foveicollis* (Lucas) (Rashid *et al.,* 2016). The adult beetles damage plant leaf by making irregular holes and also wipe out young cotyledons and flowers (Butani and Jotwani, 1984). Crop at seedling stage is most susceptible stage which rigorously affects young and tender leaves. The grubs live in the soil causes injury to the roots (Maniruzzaman, 1981).

Fruit fly *Bactocera cucurbitae*, (*Tephritidae*: Diptera) is another the major insect pest throughout Pakistan. Fruit fly alone causes damage to the extent of 70% – 80% in cucurbits. The white maggots that hatch insides the fruits cause deformity, rotting, and dropping. Flies are most active after summer rains (June) and the rainy season (July - August) (Ramjan and Kumar, 2007).

In order to manage the earlier mentioned insect pest, many control measures have been adopted but the farmers solely depend on synthetic insecticide. The indiscriminate use of synthetic insecticides causes numerous health and environmental problems (Desmarchelier, 1985; Fishwick, 1988). To find an eco friendly control methods, many plants extract such as neem oil, basil oil, bakayan extract, and water pepper extract may be used effectively against major insect pest of cucumber as they are economical, easily available and eco-friendly (Heyde and Saxena, 1984).

Neem, (*Azadirachta indica*), neem oil has been used against more than 500 species of insects (Koul and Wahab 2004). Neem oil significantly reduced aphids and squash bug adults, nymphs and egg masses in various cucurbits (Edelson et. al. 1998). Based on its efficacy it is one of the non-pesticidal management strategy, providing a natural substitute to conventional pesticides. Neem acts as an anti-feed ant, repellent and oviposition deterrent protecting the crop from destruction (Dube, 1989).

Essential oil of basil *(Ocimum basilicum*) have antifungal and insect-repelling qualities against aphids, cucumber beetles, squash bugs and other insect pest (Dube, 1989). *Basilicum* essential oil gave superior control by reducing 74.9% of the adults of cucumber beetles (Alvaro, 2019).

Water pepper (*Persicaria hydropiper* L.) also known as marsh-pepper smartweed, marsh-pepper knotweed, smartweed, or water pepper the entire plant can be used as pesticides (Rahmatullah *et al*., 2009). Flavonols, flavonoids and phenolic acids *P. persicaria* has anti-bacterial, anti-fungal and insecticidal activities (Hussain *et al*., 2010) and have been used to control various vegetable insect pest (Luisa *et al*. 2017).

Pakistan has a rich plant biodiversity and botanical pesticides have a great scope to use in IPM program against different insect pest. Published literature showed that neem, bakayan, basil oil and water pepper have been used against various insect pests in different crops. So the present study is an attempt to develop an IPM module by integrating the above mentioned botanicals, with insecticides in order to develop an effective and eco-friendly pest management strategy for major insect pest attacking cucumber.

MATERIALS AND METHODS

Research on evaluation of different biorational management approaches on major insect pest of cucumber was carried at Hazara Agricultural Research Station (HARS), Abbottabad, Khyber Pakhtunkhwa, Pakistan during Spring 2020. Cucumber seeds (Ever green Varity

F1) was purchased from local market and sown in pots for nursery rising and covered with polythene sheet to protect from severe cold. Healthy cucumber seedlings of uniform size were obtained from nursery raised in pots and were transplanted in well prepared field during 2nd week of April 2020. Experiment was laid out in Randomize Complete Block Design (RCBD) with three replications. Plot size was 104.52m^2. Row to row and plant to plant distance was kept 100-120 cm and 60-90 cm respectively. Uniform agronomic practices were applied to all experimental plots including control.

Extract Preparation

Leaves of Bakayan and water pepper were collected and washed with distilled water and kept for drying in shady place. After drying, the dried leaves were then grinded to powder form with the help of electric grinder. Known weight (20 gm) of the both the tested sample were soaked overnight in 1 liter of water and then sieved to get the stock solution. The stock solution was further diluted by adding 3 liter of water to get 5% field solution of both the bakayan and water pepper extract. The remaining treatments Basil oil, Neem oil, Lambda-Cyhalothrine and Laser were purchased from local market. All the treatments were applied in their assigned plots through knap sacked sprayer at morning before 9 am.

IPM Modules

Module 1 = Water pepper extract + 2nd spray of Bakayan extract @5% at 14 days interval + 3rd spray of Laser 125EC@ .025% at 14 days interval after 2nd spray

Module 2 = Basil oil + spray of neem oil @2% at 14 days interval + spray of Laser 125EC@ .025% at 14 days interval after 2nd spray

Module 3 = Bakayan extract @5%+ spray of basil oil @2% at 14 days interval + spray of Laser 125EC @ .025% at 14 days interval after 2nd spray

Module 4 = Bakayan extract @5%+ spray of neem oil @2% at 14 days interval +spray of Laser 125EC@ .025% at 14 days interval after 2nd spray

Module 5 = Water pepper + spray of neem oil @2% at 14 days interval + spray of Laser 125EC @ .025% at 14 days interval after 2nd spray

Module 6 = Water pepper + spray of basil oil at 14 days interval + spray of Laser 125EC @ .025% at 14 days interval after 2nd spray

Module 7 = Lambda-Cyhalothrine 5 EC@0.5% + spray of neem oil @2% at 14 days interval + spray of Laser 125EC @ .025% at 14 days interval after 2nd spray

Module 8 = Lambda-Cyhalothrine 5 EC@0.5% + spray of basil oil at 14 days interval + spray of Laser 125EC @ .025% at 14 days interval after 2nd spray

Module 9 = Lambda-Cyhalothrine 5 EC@0.5% + spray of water pepper at 14 days interval + spray of Laser 125EC @ .025% at 14 days interval after 2nd spray

Module 10 = Lambda-Cyhalothrine 5 EC@0.5% + spray of Laser 125EC @ .025% at 14 days interval + spray of Bakayan extracts at 14 days interval after 2nd spray.

Module 11= Control

Parameters

1. **Red pumpkin beetle per plant:** Red pumpkin beetle were recorded on randomly selected 5 plant 24hrs before spray application then after 48hrs, 72hrs and 7 days intervals.
2. **Number of damaged leaves per plant by red pumpkin beetle: D**amaged leaves were counted by randomly selected five plants plot^{-1} and then the mean damaged leaves were determined.
3. **Number of leaves perforation:** Number of holes on leaves were counted by randomly selected five

plants, the mean number of leaf perforation was calculated.

4. **Number of fruits with fruit fly ovipositor marks:** Number of fruits with ovipositor marks was calculated by randomly selected 5 plants at each picking. Then mean number of fruits with fruit fly ovipositor marks was calculated.

5. **% damaged fruits by fruit fly:** After each picking, weight of cucumbers was recorded for each plot. The damaged fruits (presence of ovipositor marks) were separated from the sound fruits and were weighed. The percent damage was determined by the following formula;

$$\text{Percent damaged fruits} = \frac{\text{Weight of damaged cucumber / picking}}{\text{Weight of total cucumber / picking}} \times 100$$

6. **Yield (kg ha^{-1}):** Harvested fruit was weighed after each picking then the total yield was determined by adding yield of all picking. The yield was converted into kg ha^{-1} by using the following formula;

$$\text{Yield (kg ha}^{-1}) = \frac{\text{yield plot}^{-1}\text{ (kg)}}{\text{Plot size (m}^2)} \times 10000 \text{ m}^2$$

7. **Cost benefit ratio:** Cost benefit ratio was calculated according to the method used by Usman et al. (2015) to find out the most profitable treatment with maximum net return.

Statistics Analysis: The data on different parameters were subjected to analysis of variance by using software STATISTIX 8.1 and mean was separated by using LSD test at P=0.5% (Steel and Tori,1960).

RESULTS

Number of red pumpkin beetles plant^{-1}

Results regarding number of red pumpkin beetles recorded before and after 1st spray application are presented in Table No 1. red pumpkin beetle population recorded before spray application was non-significant ranging from 3.06 -3.86 plant^{-1}. However, post spray data shows significant variation in red pumpkin beetle population in tested IPM modules.

After 24 hours of the 1st spray application, significant reduction in red pumpkin beetle was recorded. However, red pumpkin beetle population recorded in M10 (Lambda-cyhalonthrin+bakyan extracts+laser) was lowest (1 plant-1) and not significantly different from M7 (Lambda-cyhalonthrin + Neem oil + laser (1.20 plant-1), M4 (Bakyan extracts+Neem oil+laser (1.20 plant^{-1}), M5 (Water pepper + neem oil + Laser (1.26 plant^{-1}), M1 (Water pepper + bakyan extracts + Laser) (1.40 plant $^{-1}$), M8 (Water pepper +Bakyan+ Laser) (1.40 plant^{-1}) and M9 (Lambda-cyhalonthrin + water pepper + Laser) and red pumpkin beetle population recorded in control was significantly highest (3.93 plant^{-1}) than all remaining modules.

Decreasing trend in red pumpkin beetle population was observed after 48 hours of 1st spray applications in all modules except control (4.40 plant^{-1}). Among the IPM modules, red pumpkin beetle population was significantly lowest (0.66 plant^{-1}) in M10 (Lambda-cyhalonthrin+bakyan extracts+laser) followed by M9 (Lambda-cyhalonthrin + water pepper + laser), M7 (Lambda-cyhalonthrin +Neem oil + laser), M4 (bakyan extracts + Neem oil + Laser, M3 (Bakyan extract+ basil oil + Laser) and M8 (Lambda cyhalonthrin + basil oil +

laser) with red pumpkin beetle population of 0.80 Plant^{-1}, 0.80 Plant^{-1}, 0.80 Plant^{-1}, 1.00 plant $^{-1}$ 1.00 plant^{-1} respectively. These being none significant different from each but significantly different lower than the rest of modules which bear highest red pumpkin beetle population.

Similarly after 72 Hours of 1st spray application, Lambda cyhalonthrin based modules were found the most effective modules and having significantly minimum red pumpkin beetle population ranged from (0.53 - 0.80 beetles plant^{-1}).While IPM modules which was without Lambda cyhalonthrin was found comparatively least affective and bears significantly higher beetle population ranging from (1 - 1.60 beetle plant) than modules where Lamda cyhalothrin was applied as 1st sprayed application.

Likewise, decline trend in red pumpkin beetle population were observed in all the tested modules after 7 days of spray 1st application, except control. However, red pumpkin beetle population in all Lambda cyhalonthrin based modules (M7, M8, M9 and M10) were minimum (0.33 - 0.53 beetle plant^{-1}) and statistically at par with each other but significantly different from red pumpkin beetle population recorded in control (5.03 plant^{-1}) and the modules without Lamda cyhalothrin.

Mean red pumpkin beetle population shows that all the tested modules found better than control. However, after 1st spray application, red pumpkin beetle population was significantly lowest in lambda cyhalonthrin based modules (M10, M9, M7 and M10) (1.13, 1.27, 1.37 and 1.13, beetle plant^{-1}) respectively, these all were statistically at par with each other whereas modules having water pepper and basil oil as 1st spray application (M1, M2, M5 and M6) were comparatively least effective and had significantly high red pumpkin beetle population (1.25 – 1.60 beetles plant^{-1}) than former modules.

Table 1. Mean number of red pumpkin beetle recorded before and after 1st spray application at different interval in cucumber crop

	Modules	Before Spray	After 24hrs	48hrs	72hrs	7 days	Mean
M1	Water pepper + Bakyan extracts + Laser	3.86 a	1.40 bc	1.06 bc	1.00 b	0.93 b	1.65 b
M2	Basil oil + Neem oil + Laser laser	3.33 a	1.60 b	1.13 bc	1.06 b	0.86 b	1.59 b
M3	Bakyan extracts+ Basil oil + Laser	3.60 a	1.53 b	1.00 b-d	1.00 b	0.73 bc	1.57 b
M4	Bakyan extracts + Neem oil + Laser	3.26 a	1.20 bc	0.80 cd	0.60 cd	0.40 d	1.25bc
M5	Water pepper + Neem oil + Laser	3.73 a	1.26 bc	1.20 b	1.00 b	0.80 bc	1.59 b
T6	Water pepper + Basil oil + Laser	3.53 a	1.60 b	1.13 bc	0.86 bc	0.73 bc	1.60 b
M7	Lambda cyhalonthrin +Neem oil + Laser	3.86 a	1.20 bc	0.80 cd	0.53 d	0.53 cd	1.37bc
M8	Lambda cyhalonthrin + Basil oil + Laser	3.60 a	1.40 bc	1.00 b-d	0.80 b-d	0.40 d	1.44bc
M9	Lambda cyhalonthrin + water pepper + Laser	3.23 a	1.40 bc	0.80 cd	0.60 cd	0.33 d	1.27bc
M10	Lambdacyhalonthrin+Bakyan+ Laser	3.20 a	1.00 c	0.66 d	0.53 d	0.33 d	1.13c
M11	Control	3.06 a	3.93 a	4.40 a	4.73 a	5.03 a	4.23 a
$LSD_{(0.05)}$		**1.051**	**0.481**	**0.368**	**0.332**	**0.327**	**0.448**

Means in column followed by the same letters are non-significant from each other at P (0.05%) level of significance.

Result showed in Table 2 that all IPM modules were superior over applied as compared to control. After 24 hours of the 2nd spray application, significant reduction in red pumpkin beetle population was observed in all tested module except control where population of red pumpkin beetle was (3.73 beetles plant^{-1}). However, modules (M9, M1, M10, M7, M5, M4 and M2) having water pepper, bakayan extracts and neem oil used in 2nd spray application was found better and had significantly lower red pumpkin beetle population (0.80 -1.06 beetle plant^{-1}) compared to modules M3,M6 and M8 where basil oil was used in 2nd spray application.

Similar trend in red pumpkin beetle population was observed after 48 hours of the 2nd spray application. Modules (M10, M4, M1, M2, M9, M7 and M5) having water pepper, bakayan extracts and neem oil in 2nd spray application had significantly lower red pumpkin beetle population (0.73 - 0.93 beetle plant^{-1}) than basil oil based modules (M3, M6 and M8) where red pumpkin beetle population was significantly higher (1-1.06 beetles plant^{-1}) than former modules.

Similarly after 72 hours of the 2nd spray application, the data shows that Application of bakayan extracts as 2nd spray in M10 (Lambda cyhalonthrin + bakyan extracts + laser) had significantly lower red pumpkin beetle population followed by application of neem oil based Modules (M2, M4, M5 and M7) having 0.53, 0.60, 0.60 and 0.66 beetle plant^{-1}) while basil oil based modules (M3 and M6) where red pumpkin beetle population was significantly higher (1 and .86 beetles plant^{-1}) than the former modules.

Red pumpkin beetle population after 7 days of the 2nd spray application shows that application of Bakayan extracts, as 2nd spray in M10 (Lambda cyhalonthrin + bakyan extracts+ laser), neem oil in M2 (Basil oil + Neem oil + laser) and M7 (Lambda-cyhalonthrin + Neem oil + laser) had significantly lower red pumpkin beetle population (0.06, 0.20 and 0.26 beetles plant$^{-1)}$ respectively than remaining modules including control.

Mean Column in Table 2 shows that red pumpkin beetle population was significantly lower in all the tested modules as compared to control where red pumpkin beetle population was significantly high (3.26 beetles plant^{-1}). However, after 2nd spray application, red pumpkin beetle population was significantly lowest in modules where bakayan extracts, neem oil and water pepper were used as 2nd spray application (M10, M1, M9, M2, M8, M4 and M5) with population of (0.72, 0.90, 0.91, 0.93,0.95 and 1.01 beetle plant^{-1}) respectively, these all were non significantly different from each other whereas modules having basil oil as 2nd spray application (M3, M6 and M8) were comparatively least effective and had significantly high red pumpkin beetle population (1.06 – 1.25 beetles plant^{-1}) than non-basil oil based modules.

Table 2. Red pumpkin beetle recorded before and after 2nd spray application at different interval in cucumber crop

	Modules	Before Spray	After 24hrs	48hrs	72hrs	7 days	Mean
M1	Water pepper + Bakyan extracts + Laser	2.14 b	0.86 cd	0.73 bc	0.46 e	0.33 c-e	0 .90cd
M2	Basil oil + Neem oil + Laser	2.00 b	1.06 cd	0.80 bc	0.53 de	0.20 ef	0.91cd
M3	Bakyan extracts + Basil oil + Laser	2.26 b	1.53 b	1.06 b	0.86 bc	0.53 bc	1.24b
M4	Bakyan extracts + Neem oil + Laser	2.00 b	1.00 cd	0.73 bc	0.60 de	0.46 b-d	0.95b-d
M5	Water pepper +Neem oil +Laser	2.00 b	1.00 cd	0.93 bc	0.60 de	0.53 bc	1.01b-d
M6	Water pepper + Basil oil+ Laser	2.13 b	1.46 b	1.06 b	1.00 b	0.60 b	1.25b
M7	Lambda cyhalonthrin + Neem oil + Laser	1.66 b	1.20 bc	1.00 b	0.66 c-e	0.26 d-f	0.93cd
M8	Lambda cyhalonthrin + Basil oil + Laser	2.00 b	1.00 cd	0.93 bc	0.73 cd	0.40 b-e	1.06bc
M9	Lambda cyhalonthrin + water pepper + Laser	2.00 b	0.80 d	0.86 bc	0.53 de	0.40 b-e	0.91cd
M10	Lambda cyhalonthrin+Bakyan extracts+ Laser	1.80 b	1.00 cd	0.60 c	0.20 f	0.06 f	0.72d
M11	Control	3.66 a	3.73 a	3.66 a	3.13 a	2.13 a	3.26a
	LSD (0.05)	**0.603**	**0.368**	**0.350**	**0.221**	**0.221**	**0.311**

Means in column followed by the same letters are non-significant from each other at P (0.05%) level of significance.

Infested leaves plant^{-1} and number of leaf perforation

Results showed the effect of different modules on cucumber leaf infestation by red pumpkin beetle presented in Table 3. As compared to control and leaf infestation was minimum (3.43) in M8 (Lambda cyhalonthrin+Basil oil+laser) followed by 3.80 infested leaves in M 9 (Lambda cyhalonthrin+ water pepper+ laser) and 3.76 infested leaves recorded in M 10 (Lambda cyhalonthrin+Bakyan+laser).

Leaf infestation recorded in these modules was statistically at par with each other. Similarly modules without Lamda cyhalothrin, M1-M6 were found comparatively least effective having leaf infestation ranging from (4.40 - 4.73 leaves plant^{-1}) but having significantly lower number of infested leaves than control (5.33 infested leaves plant^{-1}).

Number of leaf perforation varied significantly in different modules (Table 3). Lambda cyhalonthrin based modules were found the most effective resulting in significantly lower number of leaf perforation ranging from 2.66-3.20 leaf perforation followed by M 2 (Basil oil +Neem oil + Laser) and M 4 (Bakyan extracts + neem oil + Laser) and M6 (Water pepper+ basil oil+ laser) where leaf perforation was 3.13, 3.33 and 3.40 leaf perforation respectively. While the highest leaf perforation was recorded in control (5.73 leaf perforation).

Table 3. Effect of different IPM modules on cucumber leaf infestation by red pumpkin beetle.

	Modules	No. of infested leaves	No of leaf perforation
M1	Water pepper + Bakyan extracts + Laser	4.33 bc	3.63 bc
M2	Basil oil +Neem oil + Laser	4.73 ab	3.13 b-d
M3	Bakyan extracts+ Basil oil+ Laser	4.26 bc	3.66 bc
M4	Bakyan extracts + Neem oil + Laser	4.00 bc	3.33 b-d
M5	Water pepper+Neem oil +Laser	4.40 bc	3.83 b
M6	Water pepper+ Basil oil+ Laser	4.40 bc	3.40 b-d
M7	Lambdacyhalonthrin+Neem oil + Laser	4.06 b-d	3.20 b-d
M8	Lambdacyhalonthrin+Basil oil+laser	3.43 d	2.96 cd
M9	Lambdacyhalonthrin+water pepper+Laser	3.80 cd	2.66 d
M10	Lambdacyhalonthrin+Bakyan extracts+laser	3.76 cd	2.86 d
M11	Control	5.33 a	5.73 a
	$LSD_{(0.05)}$	**0.775**	**0.764**

Means in column followed by the same letters are non-significant from each other at P (0.05%) level of significance

Fruits with fruit fly ovipositor marks:

As presented in Table 4 all modules were significantly superior in reducing number of fruits with ovipositior marks over control. M8 (Lambda cyhalonthrin + basil oil + Laser), (M7 (Lambdacyhalonthrin + Neem oil +Laser), M9 (Lambdacyhalonthrin + water pepper +Laser), M10 (Lambdacyhalonthrin + Bakyan extracts + Laser) and M5 (Water pepper + Neem oil + Laser) were equally effective resulting in lowest number fruits with fruit fly ovipositor marks (0.76 - 0.86) as compared to control (1.40). Similarly number of fruits with fruit fly ovipositor marks recorded in M 2 (Basil oil +Neem oil + laser), M3 (Bakyan extract+ Basil oil+ Laser), M1 (Water pepper + Bakyan extracts + laser) and M4 (Bakyan extracts + Neem oil + Laser) were 1.06, 1.10, 1.13, and 1.16 respectively, These modules were not significantly different from each other but significantly higher number of infested fruit than earlier modules.

Percent damage fruits by fruit fly:

Results in Table 4 show the damaging level in cucumber by fruit fly. Results revealed that all the tested modules were found superior over control in reducing damage by fruit fly. However, lowest fruit damage was recorded in Lambda cyhalothrin based modules M9 (lambda cyhalonthrin + water pepper + laser) (8.79%) followed by M 7 (lambda-cyhalonthrin + neem oil+ laser) (9.40%) and M 10 (lambda cyhalonthrin + bakyan extacts + laser) (9.56%), these were non-significantly different from each other but significantly lower than all other tested modules including control where fruit damage was (30.57%). Similarly the fruit damage recorded in M3 (Bakyan extracts + basil oil + laser) M4 (Bakyan extracts+ neem oil + laser), M1 (water pepper+ bakyan extracts + laser) and M2 (Basil oil

+ Neem oil + Laser) was 14.88, 15.81%, 16.13 % and 17.69% respectively, These were not significantly different from each other but significantly lower than control.

Marketable Yield (kg ha^{-1}):

Results presented in Table 5 revealed that cucumber yield was significantly affected by different IPM modules as compared to control (df=10), (F value=5.98), (P value=0.0003). Higher yield of cucumber was recorded when lambda cyhalonthrin was used in combination with other tested plant extracted and laser. However, M8 (Lambda cyhalonthrin + Basil oil + Laser) gave maximum yield (8822 kg ha^{-1}) followed M9 (8622 kg ha^{-1}), M10 (7955 kg ha^{-1}), M7 (7177 kg ha^{-1}) and M6 (7066.7 kg ha^{-1}). These were statistically at par with each other. While modules without Lambda cyhalonthrin gave significantly lower yield ranging from (5355.6-7066.7 kg ha^{-1}) compared to the modules where lambda cyhalonthrin was used in combination with botanicals and laser.

Table 4. Cucumber fruit infestation by fruit fly affected by different IPM modules

	Modules	Mean No. of fruits with fruit fly ovipositor marks	% damage Fruits
M1	Water pepper + Bakyan extracts + Laser	1.13 bc	16.13 b
M2	Basil oil + Neem oil + Laser	1.06 bc	17.69 b
M3	Bakyan extracts + Basil oil + Laser	1.10 bc	14.88 bc
M4	Bakyan extracts + Neem oil + Laser	1.16 b	15.81 b
M5	Water pepper + Neem oil +Laser	0.86 de	11.47 cd
M6	Water pepper + Basil oil + Laser	0.96 cd	10.04 d
M7	Lambdacyhalonthrin + Neem oil +Laser	0.76 e	9.40 d
M8	Lambdacyhalonthrin + Basil oil + Laser	0.76 e	9.71 d
M9	Lambdacyhalonthrin + water pepper +Laser	0.86 de	8.79 d
M10	Lambdacyhalonthrin + Bakyan extracts + Laser	0.86 de	9.56 d
M11	Control	1.40 a	30.57a
	LSD (0.05)	**0.184**	**4.317**

Means in column followed by the same letters are non-significant from each other at P (0.05%) level of significance

Table 5. Marketable yield of cucumber recorded in different IPM modules

	Modules	Marketable Yield (kg ha^{-1})
M1	Water pepper + Bakyan extracts + Laser	6155 de
M2	Basil oil + Neem oil + Laser	5355 ef
M3	Bakyan extracst + Basil oil + Laser	6511c-e
M4	Bakyan extracts + Neem oil + Laser	6755 c-e
M5	Water pepper + Neem oil +Laser	6600 c-e
M6	Water pepper + Basil oil + Laser	7066 b-d
M7	Lambdacyhalonthrin + Neem oil +Laser	7177 a-d
M8	Lambdacyhalonthrin + Basil oil + Laser	8822 a
M9	Lambdacyhalonthrin + water pepper +Laser	8622 ab
M10	Lambdacyhalonthrin + Bakyan extracts + Laser	7955 a-c
M11	Control	4000 f
	LSD $_{(0.05)}$	**1661**

Means in column followed by the same letters are non-significant from each other at P (0.05%) level of significance

Economic analysis of different IPM modules

Results regarding economic analysis of different IPM modules used against major insect pest of cucumber are presented in Table 6. It was found that all the tested modules were found profitable having CBR value > 1. However, M5 (water pepper + Neem oil + Laser) bearing the highest CBR (1: 26.57) was the most profitable Modules. M 4 (Bakyan extracts + Neem oil + Laser) was the next most profitable module (1: 25.21) followed by M 9 (Lambda-cyhalonthrin + water pepper + Laser) and M10 (Lambdacyhalonthrin + Bakyan extracts + Laser) with CBR value of 24.68 and 20.14 respectively. While M2 (Basil oil+Neem oil+ laser) was least profitable having the lowest CBR value (1: 10.36).

Table 6. Economic analysis of IPM modules against major insect pest of Cucumber crop

Modules	Marketable yield (kg ha^{-1}) A	Gross income (Rs.) B	cost of control ha^{-1} (Rs.) C	Return over control (Rs.ha^{-1}) D	Net increase over control (Rs.ha^{-1}) E=(D-C)	C : B ratio F=(D/C)
M1	4910	147327	4970	74211	69241	13.93
M2	4152	124580	10970	124580	113610	10.36
M3	5266	157985	9970	157985	148015	14.85
M4	5215	156478	5970	156478	150508	25.21
M5	5485	164577	5970	164577	158607	26.57
M6	6042	181281	9970	181281	171311	17.18
M7	6188	185660	9845	185660	175815	17.86
M8	7780	233409	13845	233409	219564	15.86
M9	7571	227135	8845	227135	218290	24.68
M10	6938	208165	9845	208165	198320	20.14
M11	2437	73116				

Average price of cucumber = Rs.30/- kg^{-1}

DISCUSSION

Cucumber is the cultivated throughout the world and is attacked by different insect pest. In the present different IPM modules were evaluated against two major insect pests of cucumber Red pumpkin beetle (*A. foveicollis*) and fruit fly (*B. cucurbitae)*. It was found that red pumpkin beetle arrived when the cucumber crop was in early growth stage. Fruit fly infestation started at the time of flower and fruit setting stage respectively. Similar finding was also reported by Diver, (2008) red pumpkin beetle attacked at earlier cropping stage.

In the present study, all the tested modules found better than control in managing the major insect pest of cucumber. Significant reduction in red pumpkin beetle was recorded after 24 hours 48, 72 and 7 days of spray application in Lambda cyhalothrin based modules as compared to the rest of modules. The effectiveness of Lambda cyhalothrin might be due to its toxicity by rapid contact and ingestion activity which is unusual for a botanical product.

In 2nd spray all the tested botanical basil oil, neem oil, bakayan extract and water pepper were found better than control against red pumpkin beetle. However, Basil oil was found least effective in reducing red pumpkin beetle population as compared to other tested botanicals. The least effectiveness of Basil oil in open field condition might be due to its mode of action. (Kim and Lee, 2014) reported Basil oil as fumigants and effective for managing coleopteran pests of stored products, which occur in enclosed places.

Neem oil and Bakayan extract were found effective against red pumpkin beetle. The effectiveness of neem oil and Bakayan extract might be due to their multiple modes of action in insects (antifeedant, oviposition deterrent, repellant and growth regulator against wide range of insect (Gahukar, 2016).

Number of infected leaves and leaves perforation was significantly affected by spray application. Minimum infested leaves and minimum leaf perforation was recorded in Lambda cyhalothrin based modules. Leaf infestation and leaf perforation are the

result of RBP infestation. Modules with low red pumpkin beetle infestation had the lowest number of infested leaf. The present findings are in agreement with the work of Iqbal *et al.,* (2017) they compared different botanicals and insecticide and found lowest red pumpkin beetle population plant^{-1} and minimum infected leaves in insecticide Lufron treated plot.

Significant variation in fruit fly infestation was observed all modules. However, less number of fruit with fruit fly ovipositor marks and less fruit infestation was recorded in modules having Labmada cyhalothirn as 1st spray application followed by 2nd spray of neem oil, bakayan, water pepper oil and 3rd spray of laser. The present results were in close with the findings of Thakur and Gupta (2013) who reported that *Azadiracta indica* plant extract was more effective and also reported its effectiveness on reduction in egg hatchability over other botanicals. Similarly, Singh and Srivastava (1985), Khattak *et al.,* (2009) also recorded deterrence of oviposition by *B. cucurbitae* on neem seed oil treated bitter gourd fruit. Ragumoorthi *et al.,* (1998) low infestion and ovipostion marks might be due to ovipositional deterrence and anti feedant property of neem based products. Singh (1998) evaluated neem extract at 1.25-20% and pure azadirachtin at 1.25-10 ppm as oviposition deterrents to *B. cucurbitae* on pumpkin and they reported that neem seed kernal extract deterred oviposition by *B. cucurbitae* at all the concentration. (Farmanullah *et al.* 2012; Qambrani *et al.* 2020) revealed that Laser and lambda cyhalothrin proved to be the best toxicant for fruit fly. Oke, (2008) reported that the effectiveness of Lambda cyhalothrine that Lamda-cyhalothrine was found to be better that improve increase the quality of harvested cucumber fruits in relation to infestation of fruits with ovipositor marks.

The ultimate aim of the farmers is to get maximum return from crops As mentioned in Table 8, economic analysis of different modules shows that all the tested modules were profitable had positive CBR. Modules M5 (Water pepper + Neem oil +Laser) had highest CBR value (26.57) followed by M4 (Bakayan extract + Neem oil +Laser) which stand 2nd having CBR value (25.21). The high CBR in these modules was due to low cost of control. Water pepper and bakayan are the most common botanicals and available free of cost. Our findings cannot be strictly compared with findings of earlier researchers as modules used in the present study have never been report. Furthermore, the cost of control and value of commodity show discrepancy and varies from region to region.

Conclusion and Recommendations

All the tested modules were found better than control in managing major insect pests of cucumber. However, Lamda cyhalothrin based modules was found the most effective had lowest red pumpkin beetle and fruit fly infestation with enhanced cucumbers yield. Modules other than Lambda cyhalothrin based modules were not as effective as Lambda cyhalorhtin based modules. M5 (Water pepper + Neem oil + Laser) and M4 (Bakyan extracts + Neem oil + Laser) were not the most effective against major insect pest of cucumber but found the most cost effective with high CBR value (26.57 and 25.21) respectively. All the tested botanicals and synthetic insecticide have the potential to manage major insect pests of cucumber. Therefore it is recommended to integrate the tested botanicals and insecticides and their timely application to combat the Red pumpkin beetle and fruit fly in cucumber crop.

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