Journal of Food and Agricultural Technology Research
https://globalpresspk.com/
ISSN: 3007-0953 (Online)
ISSN: 3007-0945 (Print)

Leveraging Nature's Arsenal, Biopesticidal Warriors: Randomising Melon Fruit Fly (*Bacrocera Cucurbitae*) In Bitter Gourd Culture, For Sustainable Control

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Abstract: Bitter gourd cultivation in agriculture is seriously threatened by the melon fruit fly (*Bactrocera cucurbitae*), which can result in considerable financial losses and environmental issues. The adverse effects of chemical pesticides, such as environmental pollution, harm to non-target organisms, and the development of insecticide resistance, have long been significant drawbacks of conventional pest management approaches. Consequently, there has been a growing interest in exploring alternative, sustainable methods of pest control in recent years. This article focuses on using biopestidal warriors as a practical and environmentally benign method of controlling *B. cucurbitae* in the cultivation of bitter gourds. We investigated several biopestal agents, including as botanical extracts and microbial biocontrol agents, to minimize the *B. cucurbitae* infestations. The results show that treatment with Ginger (*Zingiber officinale*) and Neem (*Azadirachta indica*) extracts dramatically reduced fruit fly infection levels to 13.62% and 15.88%, respectively, compared to a 70.32% infestation rate in control plots. These findings highlight the potential of botanical extracts as efficient biopesticides in sustainable agriculture methods. We also stress the significance of integrated pest management (IPM) techniques, which combine a variety of biopesticides with cultural norms to control *B. cucurbitae* in an efficient and long-lasting manner. To mitigate melon fruit fly damage in the cultivation of bitter gourds while promoting environmental sustainability, this study emphasizes the necessity for more research and development of biopesticidal warriors.

Keywords: Microbial extracts, Botanical extracts, Biopesticides, Momordica charantia, Bitter gourd, Sustainable agriculture

Article History
Received: 10 August 2023; Revised: 27 September 2023; Accepted: 29 October 2023
Online: 7 November 2023; Published: Volume (2) Issue (2) December 2023
https://doi.org/10.69501/a3abwv70

1. Introduction

The fruit fly species *Bactrocera cucurbitae* (Diptera; Tephritidae), is also referred to as the melon fruit fly or the bitter gourd fruit fly (White *et a*l., 1992). It is a popular vegetable crop cultivated in many parts of the world due to its nutritional and medicinal properties. The fast-growing vine, which is native to the Indian subcontinent is now spread to other parts of Asia and is gaining popularity globally (Suckling *et al*., 2014). Due to its high nutritional, vitamin, and antioxidant content, bitter gourd is beneficial to human health. It is used in conventional medicine due to its possible advantages in the treatment of diabetes, enhancing digestion, and enhancing the immune system (Joseph and Jini, 2013). Bitter gourd is a warm-season vegetable that prefers humid conditions for optimal growth (CABI, 2014). The ideal humidity range for bitter gourd cultivation is around 70% to 80%. When it comes to plant height, bitter gourd is a vine that can grow quite vigorously up to 5 meters (16 feet) or even more. The vine produces long, trailing stems with tendrils that help it climb and support structures such as trellises or fences (Production Technology of Cucurbitaceous Crops, 2024). In Pakistan bitter gourd cultivation is nearly 6107 hectares and the annual yield is about 57190 tons (GOP, 2014). Bitter gourd has a great nutritional value it is low in calories and rich in nutrients. It contains vitamins C, A, and various B vitamins, as well as minerals like potassium, magnesium, and zinc (Keding and Krawinkel, 2006). It is also a good source of dietary fiber.

Plant extracts are utilized in traditional treatments as folk medicine by 80% of the world's population, according to the World Health Organization (WHO) (Sing *et al.*, 2012). Various biotic factors restrict the yield and productivity of bitter gourd, melon fruit fly (*Bactrocera cucurbitae*) being a primary concern. The melon fruit fly infests bitter gourd plants, causing damage to both leaves and fruits. The larvae feed on the fruits, leading to premature ripening, rotting, and yield losses (Singh *et al.,* 2016). The degree of losses ranges between 30 and 100% and it depends on climatic circumstances (Dhillon *et al.,* 2005; Gupta and Verma, 1992). The fly mostly affects cucurbit crops, such as pumpkins, melons, cucumbers, bitter gourd (*Momordica charantia*), and melons (Rabindranath, 1986). Averaging 6-7 millimeters in length, the adult melon fruit fly has a yellowish-brown body and black markings on its wings. Fruit rot results from the larvae of fruit flies, which hatch from the eggs laid by the female fruit fly inside the fruit and feed on the pulp (Narayanan, 1953). The poor quality and short shelf life of the

infected fruits frequently render them unmarketable. However, melon fruit fly infestations have a big impact on bitter gourd farming's productivity and profitability. Conventional pest control methods mainly rely on synthetic chemical insecticides, which have been effective but raise concerns regarding their negative impacts on human health, non-target organisms, and the environment (Kumar *et al*., 2015). They not only pose risks to the environment and human health but also contribute to the development of resistance to pests (Kumar *et al.,* 2015). These pesticides' drawbacks include target selectivity, residual effects, and limited effectiveness (Pimentel *et al*., 1992). Acute poisoning, persistent illnesses, reproductive issues, and developmental difficulties are a few health hazards (Pimentel *et al*., 2000). The emergence of pest resistance is one of the major issues connected to chemical pesticides. Pests may develop defenses against the toxic effects of the chemicals over time, making pesticides useless or just partially effective. This resistance might develop as a result of genetic changes, natural selection, overuse, or misuse of insecticides. Alternative pest management strategies that are more long-term, environmentally benign, and sustainable are therefore becoming more and more necessary (Roush, 1990). Biopesticides derived from natural sources have gained significant attention as viable options for pest management in various crops, including bitter gourd. These biopesticides comprise a range of products, such as botanical extracts, microbial formulations, and biocontrol agents, which harness the power of nature to control pest populations (Rai *et al.*, 2003; Verma *et al.*, 2008). Botanical extracts from plants such as neem (*Azadirachta indica*), derris (*Derris spp*.), and pyrethrum (*Chrysanthemum cinerariifolium*) have shown insecticidal properties against a wide range of pests, including fruit flies (Ghosh *et al.,* 2005; Isman, 2006).

These extracts contain bioactive compounds that disrupt the physiological processes of pests, leading to mortality or reduced reproductive capacity. Melon fruit fly infestations have the potential to be controlled by microbial biocontrol agents such as entomopathogenic fungi and bacteria (Akhurst, 1982). *Beauveria bassiana* and *Metarhizium anisopliae*, two entomopathogenic fungi, have been investigated for their effectiveness against melon fruit flies (Shah et al., 2017). Microbial biopesticides such as *Bacillus thuringiensis* (Bt) and *Beauveria bassiana* also exhibit specific modes of action against target pests while being safe for humans and non-target organisms (Rai *et al.*, 2003).

Bacillus thuringiensis has demonstrated promise as biocontrol agent for melon fruit flies (Darwish *et al*., 2015). These bacteria create poisons that, when consumed by fruit fly larvae, are fatal. To get rid of the adult fruit flies, they can be used as foliar sprays, baits, or traps. The attraction and capture of male fruit flies using artificial or natural pheromones facilitates population monitoring and detection (Nishida *et al*., 2008). Biopesticides are inherently biodegradable, ensuring minimal persistence in the environment and reducing the risk of contaminating soil and water resources (Ghosh *et al*., 2005). They offer a more targeted approach, specifically affecting the pest species while minimizing harm to beneficial insects, pollinators, and natural enemies (Rai *et al*., 2003). Botanical extracts may interfere with an insect's nervous system, prevent reproduction, or discourage feeding (Koul *et al*., 2008).

Moreover, the incorporation of biopesticides into integrated pest management (IPM) programs promotes sustainable practices by integrating multiple control tactics, reducing reliance on synthetic chemicals, and minimizing the development of pesticide resistance (Verma *et al*., 2008). In short by harnessing nature's own arsenal, biopesticides act as warriors in the battle against pests, providing sustainable alternatives to conventional chemical insecticides. This study aims to unleash the potential of nature's biocontrol agents and explore their viability for sustainable pest management in agriculture. By assessing the performance of botanical extracts, we seek to identify effective strategies that minimize the damage caused by the melon fruit fly and promote the sustainability of bitter gourd production. Additionally, cultural practises including crop rotation, good hygiene, and the removal of fruit that is infected can aid in the decline of fruit flies. Better adoption of IPM techniques may result from educating farmers about the biology, identification, and management of the melon fruit fly. Farmers may benefit from training programs, workshops, and extension services that can teach them about monitoring strategies, cultural practices, and the appropriate application of biopesticides. Farmers' capacity to handle melon fruit fly infestations more successfully can be improved by raising knowledge of IPM among farmers.

2. Materials and Methods

2.1. Study site and experimental design

The research was conducted in a bitter gourd cultivation field with longitude (31.4790N) and latitude (74.2662E) at the Faculty of Agricultural Sciences, University of the

Punjab, Lahore, Punjab, Pakistan. A randomized complete block design (RCBD) was employed for the experimental layout having three replicates of each treatment.

Table 1: Treatment Specification

Sr. No.	Treatment	Group/ Family	Active ingredient
T1	*Capsicum frutescens*	Insect Repellent	Capasaicin
T2	*Allium cepa*	Insect Repellent	Acetogenin
T3	*Zingiber officinale*	Insect Repellent	Rhizome volatiles
T4	*Azadirachta indica*	Neonicotinoids	Limonoid
T5	*Piper nigrum*	Insect Repellent	Piperine
T6	Clay	Insect Repellent	Kaolin
T7	*B. bassiana*	Entomopathogen	Strain GHA
T0	Control	-	-

2.1. Biopesticides and treatments

A range of biopesticides were selected for evaluation in this study.

2.2. Experimental plot preparation

The bitter gourd field was prepared by eliminating weeds and other detritus. The bitter gourd seeds were purchased from the vegetable seed market of Lahore and, it was drenched with water, overnight. The seedlings were cultivated in meticulously prepared patches after 24. Each plot included four trenches with one plant in each. Every horticultural procedure required for the plants' healthy growth and development was carried out to minimize any potential cross-contamination or interference.

2.3.Biopesticide application

Botanicals like Onion (*Allium cepa*), Green Chili (*Capsicum frutescens*), Ginger (*Zingiber officinale*), Neem (*Azadirachta indica*), Black pepper (*Piper nigrum*), Clay and *B.bassiana* were collected from the market. Fruits, seeds, and leaves were collected and then cleaned under running tap water. One litre of water was used to dissolve 100 grammes of ground-cut fruits, seeds, and leaves, which were then boiled for 30 minutes to create a 10% extract. After cooling down, the solutions were filtered through muslin fabric. The produced aqueous extract was stored at room temperature in plastic bottles. The fruit setting process was

initiated after the spray was applied. Spraying was performed using a handheld sprayer, ensuring uniform coverage of the plants. Care was taken to apply the treatments during appropriate weather conditions, such as calm winds and no rainfall, to maximize efficacy.

2.4. Pest monitoring

Pest monitoring was conducted regularly to assess the population dynamics of the melon fruit fly. Yellow sticky traps were placed in the field at a standardized height and spacing to attract and capture adult fruit flies. The traps were inspected and replaced at regular intervals to record the number of trapped flies.

2.5. Data collection

Data was collected average on pest infestation. These included the number of fruit fly eggs, larvae, and pupae present on the bitter gourd plants, as well as the percentage of infested fruits. The mean population was calculated before and after application. The following formula was used to compute the percentage (%) of cucumber fruits that were infested:

$$\text{Infested Fruits (\%)} = \frac{\text{Number of damaged fruits}}{\text{Total number of harvested fruits}} \times 100$$

2.6. Statistical analysis

Data was collected before and 1, 2, 3, 7, and 10 days following treatment application. Fruits were harvested 10 DATs after every spray. The percentages of afflicted fruit above control were used to assess the effectiveness of the proposed bio-pesticides. The gathered data were submitted to proper statistical analysis (ANOVA) tool to find significant differences between treatments. Post-hoc tests, like Tukey's honestly significant difference (HSD) test, were performed to identify specific treatment effects. The significance level was set at $p < 0.05$.

3. Results and discussion

The study aimed to evaluate the effectiveness of different biopesticides in controlling the melon fruit fly (*Bactrocera cucurbitae*) in bitter gourd cultivation. Botanicals break down rapidly into harmless metabolites and appear less likely to build up genetic resistance to targeted species. They are also less harmful to mammals and other beneficial organisms (Rahman, 2009). The following results were obtained from field trials and statistical analysis:

When compared to the control, it is discovered that every treatment trialled for the chosen pesticides greatly decreased the percentage of infested fruit. ($P<0.05$, Table 1). However, the types and concentrations of

the pesticides tested had an impact on how effective they were. The largest fruit fly infestation was seen in the control (70.32%) after the foliar application of biopesticides (Table 1). All test treatments were shown to be superior to the control. If left untreated, fruit infection levels shown a sharp and continuing rise in bitter gourd. However, when the chosen biopesticides were applied to the plants, the degree of infection rose gradually. *Piper nigrum* and Clay had the largest percentage of fruits (38.63, 33.68%) affected by cucurbit fruit flies. The modest cucurbit fruit fly infestation (30.71,20.51%) was found in *Capsicum frutescens* and *Allium cepa*. The lowest percentage of infested fruits (13.62, 15.88%) was found in *Zingiber officinale* and *Azadirachta indica*. These treatments kept superior than control in terms of performance. Agrawal and Dev (2013) found that 66.3% of melon fruit fly (*Bactrocera cucurbitae*) pupae died when exposed to 5% aqueous neem seed kernel extract. In south Andaman, India, neem cake (4.0%) was shown to be beneficial against pest assault on ridge gourd, while neem oil (1.2%) was found to be most effective against melon fruit fly infestation on cucumber (Ranganath *et al*., 1997). The current findings are consistent with these observations. While they were statistically better than the untreated control, Sood and Sharma (2004) found substantially reduced fruit infection in summer squash by *B. cucurbitae* when synthetic neem derivatives were used. Our results also coordinated with Sultana et al., 2020, in this study, fewer cucurbit fruit flies attacked cucumber fruits that were treated with ginger. Merely 7.06% of the fruits under this treatment had cucurbit fruit fly infestations. When compared to the control, the ginger treatment decreased fruit fly infestation by 14.17 times. Neem oil (2%), garlic extract (5%), newspaper bagging, and trichlorfon (metallic) at 80% SP were the five treatments included in the investigation. Experimental control revealed that, in comparison to the control, paper bagging and botanical extracts (garlic and neem oil) decreased *B. cucurbitae* infestation and enhanced bitter gourd crop quality and production.

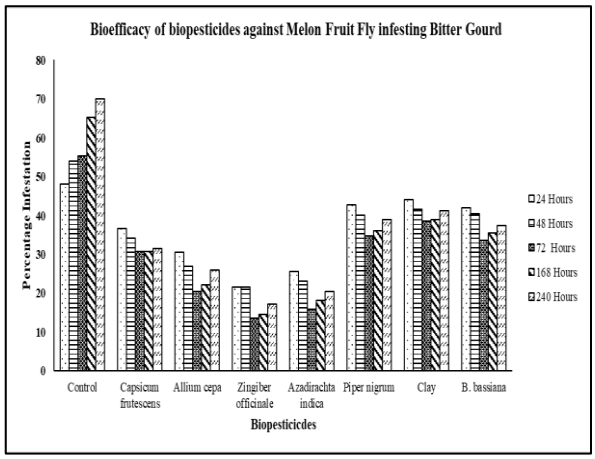

Figure 1. Bioefficacy of biopesticides against Melon Fruit Fly infesting Bitter Gourd

These methods are advised for the environmentally friendly control of *B. cucurbitae* (Ali *et al*., 2023).

The findings of this research will contribute to the development of integrated pest management strategies that prioritize environmental stewardship, reduce chemical inputs, and enhance the overall resilience of bitter gourd cultivation systems (Pawar *et al*., 2021). By leveraging the power of biopesticides, we can foster a harmonious relationship between agriculture and the environment, promoting sustainable and ecologically responsible pest control practices. Despite management improvements for the melon fruit fly, more studies are required to improve IPM tactics. IPM eliminates dependency on chemical pesticides, prevents resistance development, and fosters long-term pest management by using a comprehensive and sustainable strategy (Kumar *et al.*, 2020*).* Future research may focus on improving the biopesticides' application timing and dosage, assessing the effects of various cultural practices on fruit fly populations, and creating novel methods for protecting natural enemies. Through targeted teaching and training programs, efforts should also be made to increase the adoption and application of IPM practices among farmers. The significance of using integrated pest management techniques and the need for additional study to improve the use of biopesticides, assess cultural practices, and improve farmer uptake and education (Martinez *et al.*, 2023).

4. **Conclusion**

In conclusion, this study emphasizes the significance of using sustainable and eco-friendly methods to manage the melon fruit fly (*B. cucurbitae)* in the cultivation of bitter gourds. by investigating the possibility of biopestidal warriors such as microbial biocontrol agents, plant extracts, and entomopathogens. In an experimental bitter gourd field, a treatment with ginger (*Zingiber officinale*) had the greatest effectiveness (14.62%) for controlling cucurbit fruit fly infestation. The neem leaf (*Azadirachta indica*) treatment has a low fruit fly infestation (18.25%). The greatest amount of bitter gourd was likewise generated by this procedure. Therefore, to manage the cucurbit fruit fly infestation in the field in an environmentally benign manner, neem leaves and ginger extracts can be employed as bio-pesticides in place of hazardous pesticides. The clay treatment was shown to be somewhat effective, but because it is easier to apply and extremely finer than coarse spray, it has an impact on the quality of the fruit. Considering the issues related to the environment and human health, biopesticides

can be employed in conjunction with other potent insecticides.

Author Contributions

Romana Naveed and Gul Shafae contributed equally to the conception and design of the study. RN conducted the experiments and data collection. GS contributed to the analysis and interpretation of the data. Both authors participated in drafting and revising the manuscript critically for important intellectual content. All authors have read and approved the final version of the manuscript.

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