E-ISSN: 2663-1067
P-ISSN: 2663-1075
NAAS Rating (2025): 4.74
www.hortijournal.com
IJHFS 2025; 7(10): 01-05
Received: 02-09-2025
Accepted: 04-10-2025

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Comparative analysis of biorational and chemical management methods against fruit fly on citrus

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DOI: https://www.doi.org/10.33545/26631067.2025.v7.i11a.421

Abstract
Fruit flies lay eggs under the peel, inside the rind of the fruit leading to premature fruit drop and reduced marketability. This research gives a comparison among a wide range of bio rational as well as chemical methods. The data of per cent fruit infestation received after three sprays was analysed in RBD which showed that the cumulative mean of per cent fruit infestation was found in case of plots sprayed with Chlorpyriphos 50% EC + Cypermethrin 5% EC i.e. 5.39% and the coefficient of variation recorded at 6.95%.
The experiment was carried out in the cv. Nagpur mandarin (*Citrus reticulata Blanco*) at Regional Fruit Research Station, Katol during late monsoon season of the year 2024. The experiment was laid out in Randomized Block Design (RBD). The cumulative mean values with respect to per cent fruit infestation showed that Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1ml/l with 5.39 per cent fruit infestation to be the most effective treatment.

Keywords: Farmer, per cent fruit infestation, standard deviation

Introduction
Citrus fruits are grown across approximately 1.2 million hectares in India, yielding over 14 million metric tons annually (Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, 2022) [4]. Citrus fruit fly damages the crop by ovipositing just beneath the peel of the fruits in clusters of 2-36 eggs (Tara and Gupta, 2016) [17] which hatch in 2-5 days, feed on fruit pulp, causing internal decay and fruit fall; larval period lasts 5-6 days. Mature larva falls into the soil and pupate, pupal stage lasts for 7-10 days while, adult mature within 8-12 days. Total lifespan varies with climatic condition, in sub-tropical climate it completes around 4 generations while in tropical climate it completes about 10 generations per year. The common name Citrus fruit fly depicts the species *viz.*, *Bactrocera dorsalis* and *Zeugodacus cucurbitae* (previously *B.cucurbitae*) as both of these species are found to coexist (with a majority *of B. dorsalis*) in a citrus orchard. (Follet *et al.*, 2022) [7].
The FAO's area-wide management guidelines emphasize on integrated strategies like trapping, sanitation, and sterile insect techniques to suppress fruit fly populations and prevent outbreaks (FAO/IAEA, 2023) [6]. However, developing countries face major hurdles in implementing these due to limited resources, fragmented infrastructure and lack of coordinated surveillance. Fruit flies oviposit beneath the fruit peel, making early detection difficult causing foliar insecticides largely ineffective. This hidden infestation leads to premature fruit drop and internal decay. In India, damage levels vary by crop and region, with mango and guava losses ranging from 30% to over 80% in peak seasons, posing serious threats to both domestic consumption and export viability (Jakhar, 2020) [8]. The findings of this study will provide the impact of insecticides, biopesticides, natural and mineral oils on the oviposition of the fruit flies and help the citrus farmers make informed decisions about their use. Furthermore, the results of this study contribute to the development of sustainable pest management strategies that balance pest control with environmental and human health concerns.
Recent researches show that chemical insecticides can also be successfully used over the ready to eat fleshy fruits such as citrus without leaving residues for a long time. Keeping this in mind Deltamethrin 2.8% EC and Chlorpyriphos 50% EC+ Cypermethrin 5% EC is taken

for comparision. According to the EFSA report Maximum Residual Limit (MRL) for Deltamethrin 2.8% EC is 0.05 mg/kg and expected to reduce to nil by 7-14 days (EFSA, 2015) [5]. It has also been found that insecticidal resistance is easily developed in organophosphates such as Chlorpyriphos (Mansy *et al*., 2024) [12]. In some studies, on cucumber fruit fly, strong chemicals like Cypermethrin 25 EC had been found relatively less effective when compared with neem oil (Sharma *et al*., 2016) [15]. Hence, in the present research, a combination insecticide such as Chlorpyriphos 50% EC+ Cypermethrin 5% EC has been included, to validate its effects against fruit fly. Although the Chemical methods are cheap but their consumption before the reduced MRL can be life threatening. MRL for this chemical is 15 days for edible crops such as rice as per the guidelines of Raccolto (2022) [13]. Chemical methods, if taken care of their MRL, are generally cheap and can prove to be the increase the yield of the crop by decreasing the cost of input.

The biorational methods of getting rid of fruit fly such as Natural oils like Neem oil and Karanja oil, Mineral oil and Plant botanical extract have been used as a trusted solution for the management of fruit fly. These methods are proven oviposition repellents as well as they are non- harmful to the natural enemies and pollinators. *Dashparni* extract is a botanical extract made of mixture of leaf extracts used in rural India as an indigenous technique against fruit fly. It is freshly prepared and fermented for 40 days, using 10 types of leaf extracts and cow products like cow urine, cow dung as ingredients (Kasarkar, 2021) [9]. These are primarily Neem (*Azadirachta indica*), Karanja (*Pongamia pinnata*), Datura (*Datura stramonium*), Castor (*Ricinus communis*), Calotropis (*Calotropis procera*), Nerium (*Nerium oleander*), Custard apple (*Annona reticulata*), Papaya (*Carica papaya*), Guava (*Psidium guajava*) and Moonseed bean (*Tinospora cordifolia*). These plant leaves contain secondary metabolites such as azadiractin, pongamin, atropine, ricinine, cardenolides, oleandrin, squamocin, papain, quercitin which can prove effective repellent against insects. Squamocin can disrupt the mitochondrial functions in insects, Papain is a protease which can degrade insect tissues, quercetin inhibits growth, oleandrin is toxic cardiac glycoside which can disrupt insect cardiac functions, ricinine has antimicrobial properties, and atropine disrupts feeding behaviour (Aioub *et al*., 2024) [1]. Methanol and chloroform extracts from Karanja leaves show strong deterrence against pests like tea mosquito bugs. (Deka *et al*., 2013) [2]. Azadiractin disrupts molting and pupation by interfering with ecdysteroid and juvenile hormone pathways (Dhra *et al*., 2018) [3].

The results of this experiment will find out that which method is more effective among the bio rational and chemical methods described above.

Materials and Methods

The experiment was carried out in Regional Fruit Research Station (RFRS), Katol. This research station is located in the Katol taluka of Nagpur district in Maharashtra state. This experimental site is geographically located at 21ºN latitude and 78ºE latitude with an elevation of 461 m above Mean Sea Level (MSL). The climatic condition of this area is sub-tropical type. The annual average rainfall varies from 30 mm to 836.8 mm, which is mainly precipitated during June to September and from October to May the weather may exhibit a dry spell. The mean summer temperature ranges between 25 ºC to 45 ºC, while in winter it ranges from 15 ºC to 10 ºC. The Orchard of Nagpur mandarin (*Citrus reticulate Blanco*) was 16 year old with row to row and plant to plant spacing of 6 m x 6 m.

The experimental field was structured using a Randomized Block Design (RBD). The layout comprised of three replications and seven treatments randomized within each replication considering the heterogeneous nature of the field to minimize bias and account for environmental variability.

In order to compare the effectiveness of the management practices field trials were conducted in the late monsoon period of 2024 when ovipuncture marks were apparent in one fruit per tree. Three sprays were applied separately on the crop at an interval of 14 days. Treatment solutions were prepared by taking recommended quantity of treatments and mixed with water to obtain desired concentration of spray solution. Spraying was done during the morning hours using power sprayer.

The treatments supposed to be allocated were T_1-Neem oil, T_2-Karanja oil and T_4-*Dashparni* extract was prepared in the experimental site. Among the mineral oils T_3-HMO (Horticultural Mineral Oil) is a petroleum product. Among the chemical methods Pyrethroid T_5-Deltamethrin 2.8% EC and a combination insecticide T_6- Chlorpyriphos 50% EC + Cypermethrin 5% EC and T_7- Control. Information about the Manufacturer are furnished in the Table 1 and plan of Layout is shown in the Figure 1.

Dashparni extract was prepared by mixing leaf extracts ½ kg each of Neem (*Azadirachta indica*), Karanja (*Pongamia pinnata*), Datura (*Datura stramonium*), Castor (*Ricinus communis*), Calotropis (*Calotropis procera*), Nerium (*Nerium oleander*), Custard apple (*Annona reticulata*), Papaya (*Carica papaya*), Guava (*Psidium guajava*) and Moonseed bean (*Tinospora cordifolia*) leaves along with Chilli paste (250 g), garlic paste (250 g), cow dung(1 kg), cow urine (1lit) in water. The mixture was kept under shade for 40 days to ferment with occasional stirring (Zala, 2022) [18].

The experiment was laid out in Randomized Block Design (RBD). Six trees in each treatment (2 trees/ replication) were selected for analysis of experiment. The marketed fruits were harvested separately in each treatment at 14 days after spraying. The ripe fruits after plucking were observed for the presence of oviposition marks on the external. The fruits were also checked for the presence of actively pulp feeding maggots by the cutting with a sharp knife and such fruits were counted as observations and all the other type of damaged fruits were rejected.

The observations before spray were recorded one day before application of treatments. They were calculated by randomly selecting 30 fruits per treatment and observed for the presence of oviposition marks. The per cent fruit infestation was calculated on the basis of number of fruits damaged by fruit fly out of the total number of fruits damaged. The arcsine transformed values of the data obtained were used for data analysis using MS Excel. The per cent fruit infestation was worked out by using the following formula:

$$\% \text{ Fruit infestation} = \frac{\text{No. of fruits damaged by fruit fly}}{\text{Total number of damaged fruits}} \text{ X } 100$$

Table 1: Details of treatments in the experiment

Treatment No.	Treatments	Trade Name	Manufacturer's Name and Address	Dosage (ml/lit)
T_1	Neem Oil	Neemasol	DG Agronutrients Pvt. Ltd., Nashik, Maharashtra- 422011	10
T_2	Karanja Oil	Pure Karanja oil	Deve herbes Pvt. Ltd., Janak Puri, New Delhi, 110058	10
T_3	Horticultural Mineral Oil (HMO)	All Weather Horticultural and Dormant spray	Green Dragon Home Solutions, Sector- 3, Rohini, Delhi-110085	20
T_4	*Dashparni* extract	--	On farm preparation	50
T_5	Deltamethrin 2.8%EC	Decis	Bayer Bioscience Pvt. Ltd. Thane, Maharashtra- 400607	0.5
T_6	Chlorpyriphos 50%EC + Cypermethrin 5%EC	Yalban	Yawalkar Pesticides Pvt. Ltd., Nagpur, Maharashtra- 440026	1
T_7	Control	--	--	--

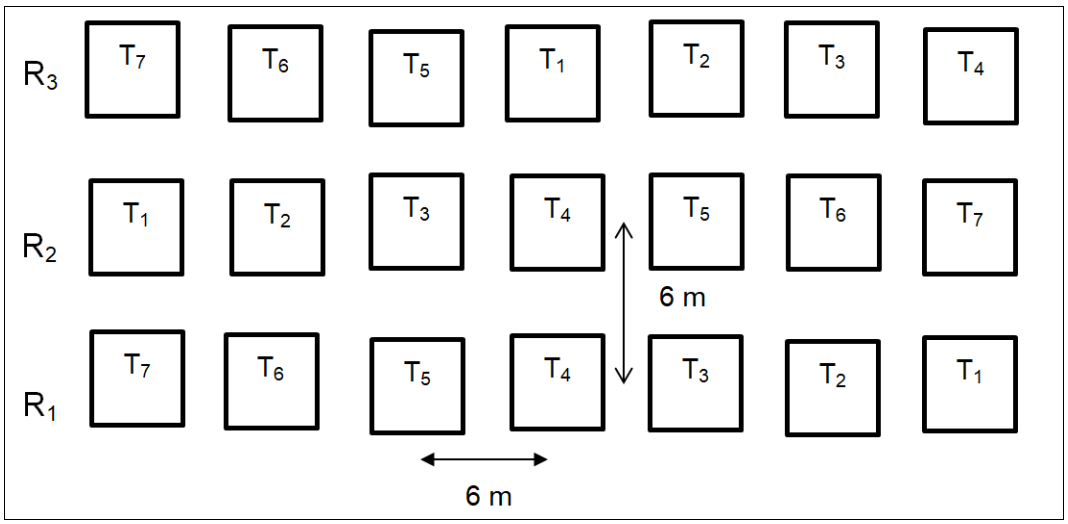

Fig 1: Plan of Layout for evaluation of efficacy of different treatments against citrus fruit fly

Results and Discussion

The per cent fruit infestation by citrus fruit fly ranged from 45.8% to 48.91% before the spray was carried out (Table 2). After the first spray, all the treatments were found to be more effective than the control. Lowest mean per cent of fruit infestation was recorded in plots sprayed with Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1ml/l with 8% fruit infestation followed by Deltamethrin 2.8% EC @ 0.5ml/l with 8.6%. In the second spray, again Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1 ml/l with 5.5% showed the lowest mean per cent fruit infestation, followed by Deltamethrin 2.8%EC @ 0.5ml/l with 6.5%. In the third spray Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1ml/l with 2.8% was the most effective treatment followed by Deltamethrin 2.8% EC @ 0.5ml/l with 3.45%. The mean per cent fruit infestation after all the three sprays revealed that Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1ml/l and Deltamethrin 2.8% EC @ 0.5ml/l were found to be at par with each other followed by Karanja oil 1% @ 10ml/l. The lowest fruit infestation in case of these treatments can be attributed to their properties of feeding deterrence and repellence. Maximum per cent reduction in per cent fruit infestation after all the three sprays was recorded in treatment Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1ml/l followed by Deltamethrin 2.8% EC @ 0.5 ml/l.

Analysis of Variance (ANOVA) revealed significant differences among the treatments with respect to per cent fruit infestation. The calculated Critical Difference (CD) at 5% was 1.225, indicating that any two treatments differing by ≥1.225% are statistically significant. For instance, T6 (5.39%) and T_1 (11.04%) differ by 5.65% which exceeds the CD threshold, confirming a statistically significant difference. Similarly, T_7 (39.44%) showed the highest infestation and was significantly different from all other treatments. The coefficient of variation (CV) was recorded at 6.95%, indicating a high level of experimental precision and minimal variability among the replications.

The results are in conformity with the findings of Saji *et al.* (2023) [14] reported lowest fruit infestation with Deltamethrin and among the bio rational methods, Neem oil was considered superior with 17% fruit infestation and HMO was inferior as compared to the chemical insecticides was also found effective in reducing fruit infestation. Similarly, Leong *et al.* (2021) [11] suggested that, HMO and Imidachloprid were the most effective management methods for preventing adult females from landing on flushes. The results of his study showed that HMO appeared to have less impact on both primary parasitoids than synthetic insecticides on Citrus psylla. Khanna *et al.* (2023) [10] observed that while *Dashparni ark* produced very little damage reduction, but at higher concentration it boosted the viability. For Neem oil, their investigation revealed that, 1.5 mg/ml foliar application has a maximum beneficial boosting effect on the viability of cell, but it was found toxic at dosage of 2 mg/ml. Shinde *et al.* (2021) [16] recorded the highest ovipositional deterrence of Neem oil 90% and 88% against *B. tau* and *B. cucurbtiae* in the study of plant extracts as oviposition deterrents against fruit flies in vegetable.

Table 2: Cumulative mean of per cent fruit infestation of fruit fly on citrus across the three sprays of *Kharif* season (*Ambia bahar*) 2024

Tr. No.	Treatment details	Per cent fruit infestation				Mean	Reduction over control (%)
		Before Spray	1st Spray	2nd Spray	3rd Spray		
T_1	Neem oil	48.91 (44.12)	12.00 (20.47)	11.20 (20.00)	10.30 (18.81)	11.04 (19.77)	27.29
T_2	Karanja oil	48.67 (43.41)	9.65 (18.43)	9.50 (18.43)	7.60 (16.09)	9.12 (17.68)	36.38
T_3	(HMO) Horticultural Mineral Oil	45.80 (43.05)	14.10 (22.37)	12.90 (21.46)	16.50 (18.71)	12.55 (20.89)	26.08
T_4	*Dashparni* extract	46.95 (43.23)	21.5 (28.30)	19.00 (27.16)	16.50 (23.83)	19.11 (26.48)	14.77
T_5	Deltamethrin 2.8 EC	48.13 (43.89)	8.60 (17.35)	6.50 (14.88)	3.45 (10.43)	6.14 (14.48)	62.45
T_6	Chlorpyriphos 50% EC + Cypermethrin 5% EC	47.59 (43.54)	8.00 (16.53)	5.50 (13.66)	2.80 (9.43)	5.39 (13.50)	64.24
T_7	Control	41.00 (42.37)	36.00 (40.20)	42.50 (37.26)	41.31 (40.01)	39.44 (39.16)	--
	F Test	--	P<0.05	P<0.05	P<0.05	P<0.05	--
	SEm (±)	--	0.450	0.253	0.397	0.866	--
	CD @ 5%	--	1.389	0.779	1.224	1.225	--
	CV%	--	3.310	2.011	3.515	6.952	--

*values in the parentheses are arsine transformed

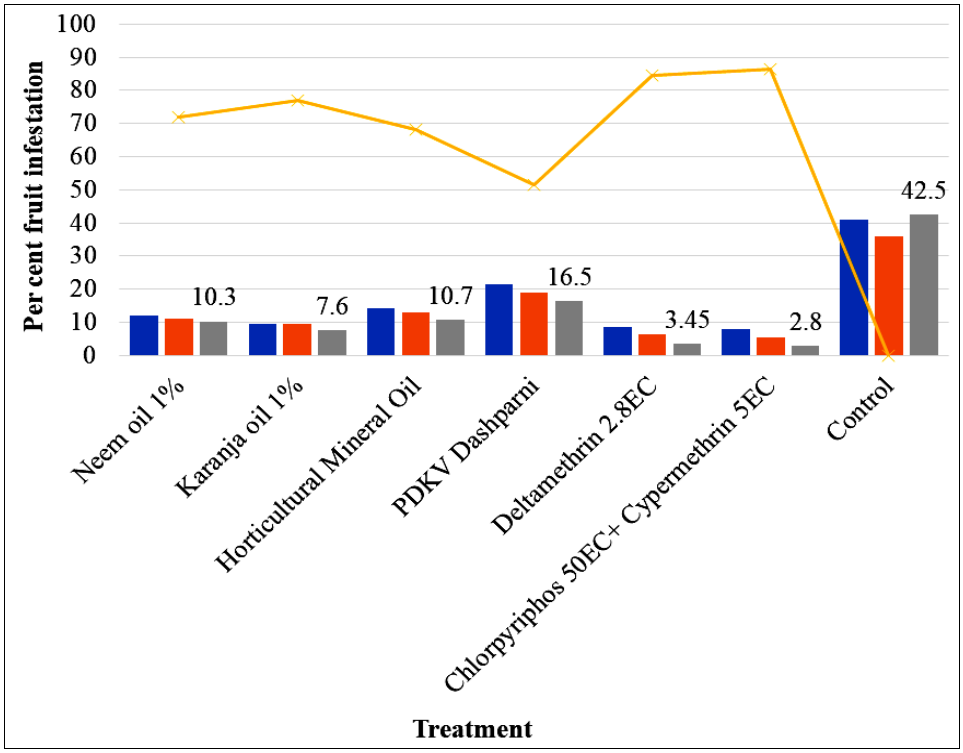

Fig 2: Cumulative Efficacy of treatments against citrus fruit fly across three sprays: per cent fruit infestation

Summary and Conclusion

Among the various treatments Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1ml/l proved to be the most effective management of citrus fruit fly followed by Deltamethrin 2.8% EC @ 0.5ml/l, Karanja oil @ 10ml/l, Neem oil @ 10ml/l, HMO @ 20ml/l and *Dashparni extract* @ 20ml/l. Although *Dashparni extract @ 50ml/l* was found to be the least effective but significantly superior over the control. The treatment Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1ml/l recorded per cent fruit infestation of 5.39%. It was also observed that among the various treatments *Dashparni extract @ 50ml/l* was found to be the safest treatments as it does not cause any harm to the pollinators and natural enemies whereas, Chlorpyriphos 50% EC + Cypermethrin 5% EC @ 1ml/l was found to be most toxic to the pollinators and natural enemies. The ANOVA revealed significant differences among treatments, supported by a low CV value of 6.95%, which is well within the acceptable threshold for field experiments.

This research concludes that chemical treatments performed better than the biorational treatments and advice the strict adherence to the prescribed concentration for safe use. The research has observed that some treatments show effective reduction in per cent fruit infestation while others fail to deliver such results in the citrus orchard mainly due to shortcomings in formulation technology. The conventional methods such as Natural oils and botanical extract offer environmentally friendly alternatives but require significant improvements in the commercial formulation and application techniques. Future research should focus on developing cohesive formulations of the natural products to reduce reliability on synthetic chemicals.

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