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Population dynamics and biointensive management of mango hoppers (*Idioscopus clypealis* Leth.)

SM Pawar, SA More, GM Bansode and NR Bhalchim

Abstract
The study on the population dynamics of mango hoppers (*Idioscopus clypealis* Leth.) during flowering period and bio-intensive management of mango hoppers through sequential spraying of various BIPM packages against mango hoppers. The experiment was carried out at the College of Agriculture, Pune-5, Maharashtra. Studies on population dynamics of mango hoppers during flowering period the hoppers *I. clypealis* attended its peak population in 2nd meteorological week with 12.47 number of hoppers per panicle and at that time the average maximum and minimum temperature were noted *i.e.* 27.8 and 13 °C respectively. Later on, the population of hoppers (*I. clypealis*) declined slowly from 8th SMW to 13^{th} SMW from 10.93 to 5.48 number of hoppers per panicle.
During that period, the average range of maximum (34.00 to 38.40 °C) and minimum temperature (13.9 to 21.0 °C) was slightly increased and maximum and minimum relative humidity was observed to be decreased (89-71%) and (18 to 26%), respectively. According to the data of correlation between mango hoppers population and weather factors, it was recorded that the morning relative humidity ((0.1718**) and bright sunshine (BSS) both positively correlated with the mean hoppers population (0.6227***). This findings confirmed that the mean population of mango hoppers had a significantly favourable relationship with morning relative humidity and bright sunshine hours. The mean population of hoppers, on the other hand, had a negative correlation with minimum and maximum temperatures, precipitation and evening relative humidity.
Field experiment to study the bio-intensive management of mango hoppers (*I. clypealis*) through sequential spraying among the BIPM packages evaluated against hoppers on mango, the BIPM package of T_6 (Imida-NSE-Thia-*Ll-Ma*) consisting spray of imidacloprid 17.8% SL @ 0.30 ml/l ml per litre, later NSE 5% @ 1.00 ml per litre, followed by thiamethoxam 25% WG at 0.20 g/l ml per litre, *L. leccanii* (1×10^8 CFU/ml) @ 5.0 g per litre, followed by *M. anisopliae* (1×10^8 CFU/ml) @ 5.00 g per litre at 15 days interval found significantly superior with 4.51 mean of surviving hoppers per panicle and in reduction of hoppers population with 60.40 percent over untreated control.

Keywords: Mango hoppers, population dynamics, BIPM packages, sequential spraying

1. Introduction

Mango (*Mangifera indica* Linn.) family (Anacardiacae) is commercially most important popular fruit and it is referred as national fruit of India, also known as “king of fruits” because of its wide adaptability, sweetness, excellent flavor, delicious taste with rich source of nutrition mineral fibre, vitamin A, C and pro-vitamins. Mango word comes from Malayalam, ‘man-ka’ and in Kerala, people call mango tree as ‘Ma’ or ‘Maru’. The first mention of mango word (Manga) appeared in English in 1582 A.D. in Lichefield’s translation of lopez de casteneda’s “Discovery and Conquest of East India by the portugals” (Kumar, 2016) [14]. India is one of the leading country in world with 50% mango production, while India rank on third position in mango export. Among these, India has the largest area (Galan, 2013) [9] India is leading country with area 2339 M ha and production 20336 MT in the world. It is grown in Uttar Pradesh, Karnataka, Bihar, Gujarat, Tamil Nadu and Maharashtra. Uttar Pradesh is top producing state with total production 4807.83 MT. In Maharashtra area under cultivation of mango is about 168.15 M ha, with total production of 439.08 MT (Anonymous, 2022) [3]. It is crucial to speed up production using the available resources due to the enormous population growth and rising demands.

In India mango productivity is generally low due to ineffective orchard management, dense canopies with broader spacing and poor sunlight absorption. Mango quality and productivity have been decreasing in recent years due to a variety of factors such as changing climatic conditions, vulnerable cultivars and attack of different pests and diseases (Kumar *et al*., 2017) [13].

At the global level, 26 species of nematodes and 462 species of insects have been identified that attack on mango. Kannon and Rao (2006) [10] has reported various insect-pests *viz*., hoppers *Idioscopus clypealis* (Lethierry), *Amritodus atkinsoni* (Lethierry); mealybugs, *Drosicha mangiferae* (Green); fruit flies, *Bactrocera dorsalis* (Hendel); fruit sucking moth, *Eudocima aurantia* (Moore); thrips, *Aeolothrips itermedius* Bagnall; ants, *Oecophylla smaragdina* (Fabricius); termites, *Odontotermes* spp.; grey weevil, *Myllocerus discolour* (Boheman). The most dangerous and wide spread pest among all those previously mentioned is the hopper. Various species of mango hoppers including *A. atkinsoni*., *I. clypealis*. and *Idioscopus nitidulus* (Walker) are growing more threatening during the mango's flowering season due to climate change and favourable conditions. *I. clypealis* is the predominant and smallest size species of hopper with two spots on its scutellum without bands on wings but two spots present on its vertex. *I. nitidulus* breeds on shoots as well as inflorescence, while *I. clypealis* breed only on inflorescence (Verghese and Thangam, 2011) [32]. Due to excessive perpetuation and constant sap draining, most of the flowers dropped before fruit set, resulting in crop failure during the flowering and fruiting stages, with up to 100% losses. (Rahman and Kuldeep, 2007; Prabhakara *et al*., 2011) [24, 21]. Nymph and adult mango hoppers sucking cell sap from the phloem tissue of tender parts of twigs, inflorescence, leaves and developing fruits resulting in weakening of inflorescence, inflorescence curling and drying due to heavy puncturing and continuous sap draining, non-setting of flowers and dropping of immature fruits causing losses of up to 50 percent and thereby reducing yield. Additionally, hoppers harm the crop by excreting honey in moist weather which promotes the development of fungi such as *Capnodium mangiferae* (Cooke) and *Meliola mangiferae* (Earle), resulting in the growth of black sooty mould on the leaves, branches and fruits. The black coating of leaf surfaces interferes with the plant's normal photosynthetic activity, resulting in the failure to set flowers and the dropping of immature fruits. This is known as 'honey dew disease' (Butani, 1993) [7]. Mango hoppers were observed colonizing during both the vegetative and reproductive phases. They lay their eggs inside the trunk which cause tissue damage and damaged panicle fails to bear fruits (Babu *et al*., 2002) [4]. Under severe pest infestation, yield losses can reach 100 percent. A similar trend of continuing menace of several other insect pests of mango is noticed in terms of their development and reproduction at various stages of tree growth (Kaushik *et al.*, 2014) [12].

From last 15 to 20 years period, many insecticides used admirably sprayed with higher doses without following guideline which resulting in resistance and resurgence in mango hoppers. It is now exceedingly difficult to the farmers to control the attack of mango hoppers. Residues in mango fruits and created other problems like health hazards, environmental pollution, mortality of natural enemies of mango hoppers and pollinators. Pesticide residues in fresh mangoes in exports causing financial losses. Many conventional insecticides have been recommended in the past for hopper control (Rahman and Singh, 2004) [25].

Different chemical insecticides have major environmental implications and are extremely poisonous to natural enemies of mango hoppers by spraying and developing biointensive management packages which play an important role in suppressing mango hoppers and other insect pests on mango. To combat issue, different techniques and alternative methods mustbe used to control the attack of mango hoppers. It is necessary to minimize the harmful effects of chemical and synthetic pesticides and develop environmentally safer to natural enemies and non-polluting plant protection strategies by using bio-pesticides.

The use of botanical, bio-pesticides and safer insecticides in a proper bio-intensive management course of action against mango hopper with good results and that could be feasible, economical for the producer with less residue in fruits.

2. Material and Methods

2.1.1 Experimental site

The Mango trees were selected from orchard at the College of Agriculture in Pune, for recording the population dynamics of mango hoppers (*I. clypealis*) during flowering stage.

Trees of the same age, canopy and growth were selected and each tree was marked with a tag that indicated replications and treatments for those demonstrating enormous flowering.

2.1.2 Geographical location and climate

Pune is located in the tropical region of mid-western Maharashtra, on the 18 32' North latitude and 73 51'East latitude, at an elevation of 562 metre (1,840ft.) above mean sea level with warm weather conditions. According to the Agro-climatic Zone Planning Commission, this location falls within the Deccan Plateau for Semi-Arid Eco Region. It also falls under the Western Plateau and hill region (IX). The average annual rainfall is 650-750 mm and the highest temperature in summer reaches between 34 °C and 40 °C but reduces to 27 °C when the monsoon arrives. In the winter months of November to February, the minimum temperature. Ranges from 6 °C to 10 °C.

Table 1: Experimental details

1.	Location	Mango Orchard, Horticulture Farm, College of Agriculture, Pune
2.	Crop	Mango
3.	Variety	Kesar
4.	No. of trees selected for observation	5 (Five)
5.	No. of panicles/tree selected and tagged for observation	5 (Five)
6.	Date of Selection of plants	20 Nov 2021
7.	Date of tagging to panicles	28 Nov 2021
8.	Date of first record of hoppers	2 Dec 2021
9.	Date of fruit setting	20 Feb 2022

2.1.3 Selection and tagging
The present study was conducted on mango trees var. Kesar that were kept without the use of any pesticides during the research study. Two rows of plants from one side of the orchard were kept for the research and five plants were selected after shoot initiation and when hoppers activity was observed on panicle and tagged to record mango hopper population dynamics (*I. clypealis*).
Observations were conducted during the flowering period months of December 2021 to March 2022 and hoppers pre count recorded early in the morning hours from *i.e.,* 8 a.m. to 10 a.m. when hoppers are less active and easy to count the population on panicle without disturbing them. The observations of hoppers (*I. clypealis*) population were recorded from five panicles/tree at weekly interval. Selected trees were kept without application of any insecticides during the flowering period of mango and statistically analyzed with different weather parameters.

2.1.4 Correlation between mango hoppers incidence (*Idioscopus clypealis* Leth.) and weather parameters
The weekly recorded data of mean survival population *I. clypealis* was correlated with different weather parameters like temperature, relative humidity, rainfall and sunshine hours.The meteorological data reported in the Table 4. were collected from the Department of Agricultural Meteorology, College of Agriculture, Pune-5.

2.2.1 Biointensive Management of Mango Hoppers (*Idioscopus clypealis* Leth.)
The experiment "Bio-intensive management of mango hoppers (*Idioscopus clypealis* Leth.)" was conducted on mango tree in mango orchard of Horticulture Farm, College of Agriculture, Pune in Dec 2022 to march 2022.

2.2.2 Experimental details
Location: Mango Orchard, Horticulture Farm, College of Agriculture, Pune
Variety: Kesar
Design: Randomized Block Design
No. of Treatment: 07(seven)
No. of Replication: 03(Three)
No. of tree/treatment: 03(two)
No. of sprays: 05(five)
No. of plant tagged: 03(three)

Treatment/replication
No. of panicle tagged:05 (five)

/treatment/replication
Date of first spraying: 1st Jan, 2022
Date of second spraying: 16th Jan, 2022
Date of third spraying: 1st Feb, 2022
Date of fourth spraying: 17th Feb, 2022
Date of fifth spraying: 3rd March, 2022

Observation
Pre-treatment observation: 24 hour before application of first spray
Post-treatment observation: 7, 10, 14 DAS
Sprayer used: Knapsack sprayer
Requirement of water: 10 litre/for each treatment

The 21 number of trees and panicles were selected and tagged before application of first spray. This experiment was conducted with seven treatments and three replications with Randomized Block Design when the hopper population seen on panicles.

Table 2: Details of bio-pesticides, botanical and chemical insecticides used for spraying during the research trial

Sr. No.	Insecticide	Dose (g or ml/litre)	Trade name	Name of Manufacturer
1.	*Metarhizium anisopliae* (1×108 CFU/ml)	5.00	Phule Metarhizium 1.15%WP	Biocontrol Laboratory, Agril. Entomology Section, College of Agriculture, Pune
2.	*Lecanicillium lecanii* (1×108 CFU/ml)	5.00	Phule bugicide 1.15%WP	
3.	*Beauveria bassiana* (1×108 CFU/ml)	5.00	Phule Beauveria 1.15% WP	
4.	Azadirachtin 10000 ppm	3.00	Neemazal-T/S (10000 ppm 0.15%)	E. I. D. Parry India Limited.
5.	Neem seed extract (5%)	1.00	-	-
6.	Imidacloprid 17.8% SL	0.30	Confidor	Bayer crop science limited.
7.	Thiamethoxam 25 % WG	0.20	Actara	Syngenta Group Co., Ltd.
8.	Deltamethrin 2.8% EC	0.90	Decis	Bayer crop science limited.
9.	L. Cyhalothrin 5% EC	0.60	Xylo-5	Atul limited, Dist. Valsad, Gujarat.

2.2.3 Experimental Material
i. Insecticides and bio-pesticides
The insecticides, botanicals and bio-pesticides required for the experiment were obtained from the Department of Agricultural Entomology Bio-control Laboratory, College of Agriculture, Pune and from local market.

ii. Equipments
The material such as power sprayer, measuring cylinder, weighing balance, labels, threat, plastic bucket and hand gloves etc.

2.2.4 Preparation of spray formulation
For each treatment, 10 litre of water used and required quantity of bio-pesticides, botanical insecticides and chemical insecticides measured with weighing balance and applied at morning hours as per the doses. The spray formulation was prepared and sprayed on the tree as per the treatment. Every time, sprayer was cleaned properly to avoid the contamination. The pesticides mixed properly before application and sticker @1g added for better results.

2.2.5 Application of insecticides
The spraying of treatment wise insecticides was carried out early in the morning 8.00 to 10.00 a.m. The mango tree were sprayed with respective treatment and spraying was done on flowers, leaves and stem of mango trees and care was taken to spray complete tree canopy every time. The sprayer was cleaned with clean water every time. The first spray was applied during bud sprouting and the population of hoppers

was found to be above ETL (12 hoppers/panicle), with subsequent sprays applied at 15 day intervals. The treatment consisting sprays of microbial pesticides viz., *M. anisopliae, B. bassiana, L. leccanii* and botanical pesticides like Azadirachtin and NSE along with chemical insecticides like imidacloprid, thiamethoxam, deltamethrin and lambda cyhalothrin were given as per the schedule 15 days interval in different sequences of bio-intensive pest management packages. Spraying was carried out in the morning, for the application of biopesticides and botanical pesticides for spraying knapsack spray pump was used from 1st to last spray. While separate knapsack sprayer used for application of chemical treatments during the research trial.

Table 3: Details of treatment of BIPM packages and chemical insecticides

Tr. No.	Treatments (BIPM packages)	Time of application
T1	*Ma-Ll*-Bb-Aza-NSE	15 days interval
T2	*Ma*-Aza-*Ma*-Aza-Bb	15 days interval
T3	NSE-*Ma-Ll*-NSE-Bb	15 days interval
T4	Delta-NSE-Aza-*Ma-Ll*	15 days interval
T5	Delta-Lamb-Aza-Ma-*Ll*	15 days interval
T6	Imida-NSE-Thia-*Ll-Ma*	15 days interval
T7	Untreated control	-

The observation of mean survival population of hopper (*I. clypealis*) were recorded from five tagged panicle and five no. of trees as per the treatment of 7,10 and 14 days after each spray. The data was analyzed statistically in Randamized Block Design (RBD) and used for interpretation and results and discussion.

2.2.6 Method of analysis of data

The data of hopper population correlated with weather parameters by using statistical method of correlation coefficient (r). The data of surviving population of nymph and adult of hoppers before and after treatment were transformed into square root transformation ($\sqrt{X+0.5}$) and subjected to statistical analysis by using randomized block design. Where (x=count of surviving population of hoppers). The analysis of pooled data of year 2022 was carried out to ascertain the relative effect of insecticide, bio-pesticide and botanical treatment against mango hoppers. Appropriate statistical methods were employed to work out standard error (SE) and critical difference (CD) for deciding the significance of treatment. (Gomez and Gomez, 1984).

3. Result and discussion

3.1 Population Dynamics of Mango Hoppers (*Idioscopus clypealis* Leth.) During Flowering Period

The average weekly weather parameters and nymph and adult population of mango hoppers during the flowering period of mango and presented in Table 4. The population of nymph and adult stages of *I. clypealis* species of hopper (5.12 number of hoppers per panicle) appeared on mango in 48th SMW when the temperature ranged between 15.6 to 28.0 °C and relative humidity ranged from 58 to 93 percent and immediately after shoot initiation stage for the first time. Later on, it was gradually increased with 6.00, 6.80, 7.40, 7.80 and 11.92 number of hoppers per panicle in 49th SMW, 50th SMW, 51st SMW, 52nd SMW and 1st SMW, respectively and during that period the maximum temperature range was in between 26.5 to 29 °C and minimum temperature range was 52 to 21.6 °C with maximum and minimum humidity 93 to 98 and 38 to 60 percent, respectively. It was ascertained from the study that mango hopper population emergence was coincided with the emergence of inflorescence. The hoppers *I. clypealis* attended its peak population in 2nd SMW with 12.47 number of hoppers per panicle and at that time the average maximum and minimum temperature was 27.8 and 13 °C, respectively. Hoppers per panicle was remain at peak level from 3rd SMW to 6th SMW with 12.34, 11.80, 11.52 and 11.02 hoppers population per panicle in 3rd, 4th, 5th and 6th SMW, respectively. But in 7th SMW it was increased slightly and was 11.84 number of hoppers per panicle. During this period, the peak population may be due to suitable climatic conditions and maximum flowering.

Table 4: Meteorological data with mean hopper population

SMW	Temp (°C)		Relative Humidity (%)		WS km/hr	RAIN (mm)	Epan (mm)	BSS (hr)	Population of hoppers No./panicle
	Max.	Min.	I	II					
48	28.5	15.6	93	58	1.8	76.4	2.8	5.3	5.12
49	26.5	16.5	96	60	0.8	8.9	1.5	4.2	6.00
50	28.8	15.0	96	48	1.1	0.0	2.3	6.4	6.80
51	28.7	12.3	98	38	0.8	0.0	2.5	7.7	7.40
52	29.7	13.4	96	42	1.2	0.0	2.4	7.6	7.80
1	29.0	14.2	98	42	1.1	0.0	2.6	6.9	11.92
2	27.8	13.4	96	42	1.6	0.0	3.0	7.1	12.47
3	28.5	12.6	96	40	1.3	0.0	3.1	7.8	12.34
4	27.6	11.1	89	40	2.9	0.0	3.6	8.6	11.80
5	30.9	10.2	96	25	1.8	0.0	3.8	9.6	11.52
6	30.7	12.1	95	30	2.1	0.0	4.3	9.1	11.02
7	30.7	12.8	90	26	2.0	0.0	4.5	9.8	11.84
8	34.0	13.9	89	24	1.4	0.0	5.2	9.7	10.93
9	34.4	15.0	79	27	1.1	0.0	5.2	8.9	10.32
10	34.0	17.5	77	27	1.4	0.0	4.7	7.4	10.12
11	36.0	16.0	76	18	1.5	1.2	5.9	9.3	9.98
12	37.7	21.0	71	18	2.5	0.0	6.4	6.7	7.20
13	38.4	18.7	76	15	2.6	0.0	6.4	7.9	5.48

Later on, the population of hoppers *I. clypealis* declined slowly from 8th SMW to 13th SMW from 10.93 to 5.48 numbers of hoppers per panicle. During that period, the average range of maximum (34.00 to 38.40 °C) and minimum temperature (13.9 to 21.0 °C) was slightly increased and maximum and minimum relative humidity was observed to be decreased (71-89%) and (18 to 26%), respectively. Talpur *et al*., (2002) [29] recorded mango hoppers appearance during the month of December. Zagade and Chavan (2013) [33] recorded the peak incidence of mango hoppers during 2nd SMW. Patel *et al.* (2015) [20] reported that the mango hoppers were active from 40th meteorological week till May. The peak hoppers population (5.50 hoppers/panicle) was reported during 19th meteorological week. Chaudhari *et al.* (2017) [8] recorded the incidence of hoppers from 4th standard week of January (with peak, 80 hoppers/20 panicles) to 4th week of February following with 8th standard week and declined from 2nd standard week of March which disappeared during 2nd week of May. Bhut *et al.* (2017) [6] studied the activity of the incidence of mango hoppers was found enormously during the month of December to March. The finding reported by all these authors agreement with the current investigation.

3.1.2 Correlation between incidence of mango hoppers (*Idioscopus clypealis* Leth.) and weather parameters

According to the data of correlation between mango hoppers (*I.clypealis)* population and weather parameters like morning relative humidity (RH I) and bright sunshine (BSS) had a considerably favourable interaction with each other which showed in Table 4.2. However, no statistically significant relationship was discovered between maximum temperature (Tmax), minimum temperature (Tmin), evening relative humidity (RH II) and rainfall. The maximum temperature (Tmax) and minimum temperature (Tmin) had a significant negative relationship with the average hopper's population per panicle with r values of (-0.1569) and (-0.5903), respectively. Evening relative humidity and rainfall both had a negative association with r value for the hopper's population (-0.2488 and -0.4622).

Additionally, it was recorded that the morning relative humidity ((0.1718**) and bright sunshine (BSS) both positively correlated with the mean hoppers population (0.6227***). The results showed that morning relative humidity and bright daylight hours have a substantial positive correlation with the mean population of mango hoppers. The average number of hoppers, in contrast, showed a negative relationship with the minimum and maximum temperature. The results of present findings are collaborative with the earlier results.

Zagade and Chaudhari (2010) [34] recorded a substantial negative association between the mean population of mango hoppers including maximum temperature (r =-0.525*), minimum temperature (r = -0.561**) and afternoon relative humidity (r = -0.556*) and then gradually declined until the 9th SMW. Patel *et al.* (2016) explained how the weather parameter was positively influenced by the maximum temperature, sunshine and evaporation (r = 0.594), while, the weather parameter was negatively influenced by the evening relative humidity, wind speed and rainfall (r = -0.594). Likewise, Zagade and Chavan (2013) [34] reported the significant negative correlation with maximum temperature, minimum temperature and relative humidity.

Zala (2018) [35]. observed that the population of hoppers displayed a significant positive relation with the number of hours per day of bright sunshine (r = 0.325). In contrast, it demonstrated a weak negative correlation with morning and evening relative humidity, which peaked at 24.75 hoppers/panicle or inflorescence during 12th SMW.

Anant *et al*. (2019) [2] identified a non-significant link between hoppers population and weather parameters, *i.e.* non-significant correlation with temperature and rainfall. Therefore, the findings of the current analysis supported by these earlier investigators' observations.

However, there was a clear contrast in the hoppers population and correlation with weather parameters, which may have been caused by site-specific factors including the age of tree, management practices, orchard canopy, presence of natural enemies, season and variety.

Table 5: Correlation of incidence of mango hoppers (*Idioscopus clypealis* Leth.) during flowering period with weather parameters

Weather parameter	Tmax (℃)	Tmin (℃)	RH I (%)	RH II (%)	RAIN (mm)	EPAN (mm)	BSS (hr)
Hoppers population (*I.clypealis*)	-0.1569	-0.5903	0.1718**	-0.2488	-0.4622	0.0689	0.6276***

** Significant at 5 percent level.
***Significant at 1 percent level.

3.2 Biointensive Management of Mango Hoppers (*Idioscopus clypealis* Leth.)

Five BIPM packages which includes bio-pesticides, botanicals and chemical insecticides were tested in this study by application of sprays for five times at 15 days interval in varied combinations against mango hopper *I. clypealis* and survival population of hoppers per panicle per tree were recorded after each sprays and finally pooled mean data used to calculate percent reduction over control after fifth spray which is revealed that the population of mango hoppers *I. clypealis* was moderate to high during the flowering stage of crop and presented in Table 5.

Among the biointensive packages tested against the mango hopper *I. clypealis* the treatment T6 which includes first spray of imidacloprid 17.8% SL @ 0.30 ml per liter of water followed by second spray of botanical NSE @ 5% followed by third spray of thiamethoxam 25 WG @ 0.20 gm per liter of water followed by fourth spray *L. leccani* (1 x 108 CFU/ml) @ 5.00 gm per liter of water and fifth spray of *M. anisoplae* (1 x 108 CFU/ml) @ 5.00 gm per liter of water in sequence and at 15 days interval (two sprays of chemical insecticides viz., imidacloprid 17.8% SL @ 0.20 ml per liter of water and thiamethoxam 25 WG @ 0.20 gm per liter of water, two sprays of entomopathogens *i.e*. *L. leccani* (1 x 108 CFU/ml) @ 5.00 gm per liter of water and *M. anisoplae* (1 x 108 CFU/ml) @ 5.00 gm per liter of water and single spray of botanical NSE @ 5 percent was found significantly superior in suppressing the population of mango hopper *I. clypealis.* The overall mean survival population of mango hoppers after fifth in T6 treatment was 4.51 numbers of hoppers per panicle with 60.40 percent reduction in hoppers population over control. It was statistically at par with the treatment T5 with 4.77 number of mean survival hoppers per panicle.

The treatment T5 consist of five number of sprays at 15 days interval and in sequence of first spray of deltamethrin 2.80% EC @ 0.90 ml per liter of water followed by second spray of lambda cyhalothrin 5% EC @ 0.60 ml per liter of water, followed by third spray of azadirachtin 10000 ppm @ 3.00 ml per liter of water, followed by fourth spray of *M. anisoplae* ((1 x 108 CFU/ml) @ 5.00 gm per liter of water and fifth spray of *L. leccani* (1 x 108 CFU/ml) @ 5.00 gm per liter of water (two sprays of chemical insecticides viz., deltamethrin 2.80% EC @ 0.90 ml per liter of water and lambda cyhalothrin 5% EC @ 0.60 ml per liter of water, two sprays of entomopathogens *i.e*. *L. leccani* ((1 x 108 CFU/ml) @ 5.00 gm per liter of water and *M. anisoplae* ((1 x 108 CFU/ml) @ 5.00 gm per liter of water and single spray of botanical azadirachtin 10000 ppm @ 5 percent and recorded 58.12 percent reduction in hoppers population.

The next significant treatment is T4 *i.e*. first spray of deltamethrin 2.80% EC @ 0.90 ml per liter of water followed by second spray of NSE @ 5%, followed by third spray of azadirachtin 10000 ppm @ 3.00 ml per liter of water, followed by fourth spray of *M. anisoplae* (1 x 108 CFU/ml) @ 5.00 gm per liter of water and fifth spray of *L. leccani* ((1 x 108 CFU/ml) @ 5.00 gm per liter of water and 6.19 number of hoppers per panicle were recorded in it and was at par with treatment T1 and T2 with 41.26 and 31.95 percent reduction in hoppers population, respectively. The treatment T1, T2 and T3 includes three sprays of entomopathogens *viz*., *M. anisoplae* ((1 x 108 CFU/ml), *L. leccanii* ((1 x 108 CFU/ml) and *B. Bassiana* ((1 x 108 CFU/ml) @ 5.00 gm per liter of water and two botanical *i.e*. azadirachtin 10000 ppm and NSE 5% but in different sequence.

Obtained results correspondace with outcome seized by Adnan *et al*. (2014) [1] who used imidacloprid (0.3%), endosulfan (0.5%), cypermethrin (0.4%) and natural neem oil (3%), in an experiment to control the mango hoppers, *I. clypealis.* All treatments significantly performed better the control at controlling mango hoppers. In the event of the second spray, imidacloprid was most effective for percentage reduction in hoppers population (92.50). It also showed the biggest overall reduction in hoppers population (88.59) and reduced toxicity to the mango hoppers' natural enemies such as lacewing. Neem oil based on azadirachtin was discovered to be an effective bio-pesticides against mango hoppers with reductions of 48.35, 60.15 and 56.54 percent after 24, 72 and 168 hours of spraying, respectively. Natural enemies also increased after the first and second spraying of neem oil. Following the use of chemical insecticides, planned applications of various bio-pesticides and botanical products used to build BIPM packages in sequential spraying in the current experiment demonstrated variable relative performance in reducing the number of mango hoppers. The BIPM packages T6 (Imida-NSEThia-*Ll-Ma*) were found to be the most efficient, producing a minimum of 4.51 pooled mean per panicle with a 60.40 percent reduction over control. The BIPM packages T5 (Delta-lambdaAza-*Ma-LI)* found better treatment, however, produced a 4.77 pooled mean population of hoppers per panicle with a 58.12% reduction over control.

According to Sarode and Mohite (2016) [27] imidacloprid was nearly effective as thiamethoxam and lambda cyhalothrin in controlling mango hoppers. The bio-pesticides *M. anisopliae, V. leccanii, B. bassiana* and NSKE were found effective for reducing the mango hoppers that survived, and there was no discernible difference between them. Further, Chaudhari *et al.* (2017) [8] evaluated that management of mango hoppers with newer chemical pesticides, entomopathogens and botanical was carried out under pot culture and field conditions. The experiment's findings showed that imidacloprid 17.8% SL at 0.007 percent was superior to all other pesticide treatments with the highest hoppers mortality occurring 1, 3, 7 and 14 days after spraying both in I and II sprays and with mean mortality of 95.35 and 94.06 percent, respectively and on par with thiomethoxam 25% WG at 0.0025%, which demonstrated the next best efficacy with mean mortality of 93.99 and 88.56 percent. Despite being effective, malathion 0.075% was the least effective insecticide tested. Neem oil and two botanical were shown to be equally effective at 1 percent and superior to NSE 5 percent with mean mortality range from 79.71 to 66.40 percent in the first and second rounds of spraying. In field conditions, the entomopathogen *L. leccanii* 1.15% WP was found to be more effective at suppressing the mango hoppers with mean mortality rates of 86.04 and 71.99 percent reported in the first and second spray treatments, respectively.

On the same way, Kadavkar *et al.* (2018) [11] investigated the potency of newer insecticides against mango hoppers during a field experiment. The treatments included imidacloprid 17.8SL, emamectin benzoate 5% SG, buprofezin 25% SC, beta-cyfluthrin 8.49% + imidacloprid 48 19.81% 25EC, spinosad 45 SC, thiamethoxam 25 WG, flonicamid 50 WG, azadirachtin 1000 ppm, thiamethoxam 0.27% + chlorantraniliprole 25%, deltamethrin 0.72% + buprofezin 5.65% EC, *M. anisopliae* 1.15 WP and untreated control, respectively.

All insecticidal treatments for mango hoppers management were found to be superior to the untreated control. The most effective treatment for mango hoppers was determined to be imidacloprid 17.8 SL, whereas the efficiancy of more recent pesticides was as follows. Deltamethrin 0.72% + buprofezin 5.65% EC, buprofezin 25% SC, azadirachtin 1000 Beta-cyfluthrin 8.49% + imidacloprid 19.81%, flonicamid 50 WG, thiamethoxam 0.27% + chlorantraniliprole 25%, emamectin benzoate 5% SG. and *M. anisopliae*, respectively.

The most effective BIPM packages was T6 (Imida-NSE-Thia-*Ll-Ma*) with a minimum of 4.80 mean per panicle with a 60.40 percent reduction over control. The findings presented here are in agreement with Poornima *et al*. (2018) investigation into the efficacy of a number of pesticides against mango hoppers. After 14 days of the third spray, the results concluded that thiamethoxam 25WG at 0.3 g per litre was significantly effective in reducing the hoppers population (1.15 /inflorescence). In addition, thiamethoxam recorded the highest yield (111.43 q/ha), followed by lambda cyhalothrin and imidacloprid. Morever, lambda cyhalothrin 5 EC at 0.5 ml/l and imidacloprid 17.6 SL at 0.25 ml/l were found to be significant in suppressing hoppers population (4.75 and 5.58 /inflorescence), respectively.

Tumbada *et al.* (2018) [31] assessed the effectiveness of *M. anisopliae* (1x109 CFU/ml), *M. anisopliae* (1x107 CFU/ml), *B. bassiana* (1x109 CFU/ml), *B. bassiana* (1x107CFU/ml), *L. leccanii* (1x109CFU/ml), *L. leccanii* (1x107CFU/ml), Thiamethoxam 25WG application was observed to statistically lower the hoppers population (1.14 hoppers /panicle) better than other treatments. Azadirachtin 10,000 ppm (2.85 hoppers/panicle), *M. anisopliae* at 1 x 109 CFU/ml (3.27 hoppers/panicle) and *L. leccanii* (1 x 109 CFU/ml) were the following effective treatments.

The *B. bassiana* (1x107CFU/ml) treatment was shown to be the less effective against the hoppers. Same way, Kumar *et al.* (2020) [15] assessed the chemical and biological pesticides were tested in the field to manage the mango hoppers, *A. atkinsoni*. These were treated with different methods like NSKE at 5% > neem oil at 1500 PPM > thiamethoxam 50 WG at 0.01% > dinutefuran 50% > imidacloprid 17.8 SL at 0.005% > dimethoate 30 EC at 0.005% > *M. anisopliae* 1x108 cfu/ml > *B. bassiana* 1.0X108 cfu/ml. With a mortality rate of only 4.59%, dinutefuran was statistically superior to all other treatments including the untreated control. Second, imidacloprid was equally successful in suppressing *A. atkinsoni*. Agreed with equivalent results accomplished by Shanmugam *et al.* (2021) [28] by spraying *M. anisopliae* (1x109 cfu/ml) at 2 ml/l (M1), azadirachtin 1500 ppm at 4 ml/l (M2) and application of imidacloprid at 0.5 ml/l (or other pesticides) (FP) were the studied management modules that were evaluated by on-farm trials in farmers' fields. After the initial application of *M. anisopliae* (M1), azadirachtin 1500 ppm (M2) and farmers' practices (FP), the mean hoppers population/panicle was measured as 16.43,17.90 and 8.95, respectively. After second spray, the average hoppers population per panicle was 14.36,16.12, 7.07 and 26.57 in the *M. anisopliae* (M1), azadirachtin 1500 ppm (M2), farmers practice (FP) and control respectively. the percentage reduction over control in farmers practice was 73.39 percent which was superior than the other management modules. The application of *M. anisopliae* (M1), azadirachtin 1500 ppm (M2) recorded 45.95 and 39.33 percent reduction of hoppers population than the control. The application of *M. anisopliae* (M1) and azadirachtin 1500 ppm (M2) recorded 53.8 q/ha and 52.6 q/ha with a benefit cost ratio of 1.51 and 1.37, respectively. Based on benefit cost ratio the order of efficacy of different management modules were imidacloprid 17.8 SL (FP) > *M. anisopliae* (M1) > azadirachtin 1500 ppm(M2). The percentage reduction over control in farmers practice was 73.39 percent which was superior than the other management modules. The application of *M. anisopliae* (M1), azadirachtin 1500 ppm (M2) recorded 45.95 and 39.33 percent reduction of hoppers population than the control. The application of *M. anisopliae* (M1) and azadirachtin 1500 ppm (M2) recorded 53.8 q/ha and 52.6 q/ha with a benefit cost ratio of 1.51 and 1.37, respectively. Based on benefit cost ratio the order of efficacy of different management modules were imidacloprid 17.8SL (FP) > *M. anisopliae* (M1) > azadirachtin 1500 ppm (M2). Among the entomopathogens, *L. leccanii* showed higher mean mortality of 86.04 percent which was on par with imidacloprid and thiamethoxam on 1,3 and 14 DAS. *B. bassiana* was also on par with *L. leccanii* after 3, 7 14 DAS with mean percent mortality of 77.92. The result obtained was well supported by Singh (2008) reported that the sole application of *L. leccanii* at the dose of 5g /l had lower hoppers population of 1.7 per panicle.

Thus, the prior study workers' reports on the effects of bio-pesticidess like *L. leccanii*, *M.anisopliae*, *B. bassiana* and botanical like NSE and azadirachtin on mango hoppers may give support to the present finding in this regard.

Table 6: Effect of different BIPM packages on mango hoppers population (*Idioscopus clypealis* Leth.)

Tr. No.	Name of Treatment	Pre count	Mean survival population of hopper *Idioscopus clypealis* Leth/panicle after spray						% reduction over control
			I	II	III	IV	V	Pooled Mean	
T1	*Ma-Ll-Bb*-Aza-NSE	11.10 (3.41)	9.95 (3.23)	8.14 (2.94)	6.06 (2.56)	4.85 (2.31)	4.46 (2.23)	6.69 (2.68)	41.26
T2	*Ma*-Aza-*Ma*-Aza-*Bb*	11.48 (3.46)	9.93 (3.23)	8.08 (2.93)	7.29 (2.79)	7.09 (2.75)	6.37 (2.62)	7.75 (2.87)	31.95
T3	NSE-*Ma-Ll*-NSE-*Bb*	11.80 (3.51)	10.66 (3.34)	8.81 (3.05)	7.69 (2.86)	7.56 (2.84)	6.67 (2.68)	8.28 (2.96)	27.30
T4	Delta-NSE-Aza-*Ma-Ll*	11.42 (3.45)	9.17 (3.11)	6.11 (2.57)	5.42 (2.43)	5.25 (2.40)	5.00 (2.35)	6.19 (2.59)	45.65
T5	Delta-lambda-Aza-*Ma-Ll*	11.01 (3.39)	8.30 (2.97)	4.95 (2.34)	4.19 (2.17)	3.78 (2.07)	2.65 (1.77)	4.77 (2.30)	58.12
T6	Imida-NSE-Thia-*Ll-Ma*	13.44 (3.73)	8.67 (3.03)	5.46 (2.44)	3.77 (2.07)	2.79 (1.81)	1.86 (1.53)	4.51 (2.24)	60.40
T7	Untreated control	12.35 (3.58)	12.07 (3.55)	12.12 (3.55)	11.99 (3.53)	10.35 (3.29)	10.43 (3.31)	11.39 (3.45)	–
	SE±	0.09	0.12	0.10	0.08	0.04	0.11	0.09	
	CD at 5%	0.27	0.37	0.31	0.25	0.13	0.33	0.27	
	CV (%)	4.11	3.58	7.23	5.46	8.74	7.94	-	

Figures in paranthesis are (√x+0.5) transformation.

3. Conclusion

1. The hoppers *I. clypealis* attended its peak population in 2nd SMW with 12.47 number of hoppers per panicle and at that time the average maximum and minimum temperature were 27.8 and 13 °C, respectively. The population of hoppers per panicle was remain at peak level from 3rd SMW to 6th SMW with 12.34, 11.80, 11.52 and 11.02 hoppers population per panicle in 3rd, 4th, 5th and 6th SMW, respectively. But in 7th SMW it was increased slightly and was 11.84 numbers of hoppers per panicle. During this period, the peak population due to suitable climatic conditions and maximum flowering.
2. The correlation between the hopper population and meteorological variables showed that the highest (Tmax), minimum (Tmin) and morning relative humidity (RH-II) temperatures had negative relationship with the hopper population. However, there was a notable positive relationship between the hopper population and both Bright sunshine (BSS) and Relative humidity (RH-I).
3. Among the BIPM packages evaluated against hoppers on mango, the BIPM package of T_6 (Imida-NSE-Thia-*Ll-Ma)* consisting spray of imidacloprid 17.8% SL @ 0.30 ml/l ml per litre, later NSE 5% @ 1.00 ml per litre, followed by thiamethoxam 25% WG @ 0.20 g/l ml per litre, *L. leccanii*

@ 5.00 g per litre, followed by *M. anisopliae* 5.00 g per litre @ 15 days interval found significantly superior with mean of surviving hoppers per panicle was 4.51 and in reduction of hoppers population with 60.40 percent over untreated control.

4. The next best BIPM package was T_5 (delta-lambda-Aza-*Ma-Ll)* consisting of spray of deltamethrin 2.8% EC at 0.90 ml per litre, followed lambda cyhalothrin 5% EC @ 0.60 ml per litre, followed by azadirachtin 10000 ppm at 3ml per litre, *M. anisopliae* @ 5g per litre afterwards *L. leccanii* @ 5.00 g per litre at 15 days interval showed mean of surviving hoppers per panicle was 4.77 and reduction over control of hoppers population was about 58.12 percent.
5. Among the BIPM packages following sequential spray evaluated against hoppers on mango, the BIPM package of T_4(Delta-NSE-Aza-*Ma-Ll*) consisting spray of deltamethrin 2.8% EC @ 0.90 ml per litre followed NSE 5% @ 1.00 ml per litre, azadirachtin 10000 ppm @ 3 ml per litre. followed by *M. anisopliae* (1×10^8 CFU/ml) @ 5.00 g per litre, followed by *L. leccanii* **(**1×10^8 CFU/ml) @ 5.00 g per litre found good in reduction of hoppers population with 45.65 percent over untreated control with mean of surviving hoppers per panicle was 6.19.
6. Among the BIPM packages following T_1 (*Ma-Ll-Bb*-Aza-NSE) sequential spray evaluated against hoppers on mango including *M. anisopliae* (1×10^8 CFU/ml) at 5.00 g per litre. followed by *L. leccanii* (1×10^8 CFU/ml) @ 5.00 g per litre, *B. bassiana* (1×10^8 CFU/ml) with dose 5.00 g per litre, followed by azadirachtin 10000 ppm @ 3 ml per litre, followed by NSE 5% @ 1.00 ml per litre recorded percent reduction in hoppers population over control was 41.26 and mean of surviving hopper population of *I. clypealis* was 6.69 per panicle.
7. Among the BIPM packages following T_2 (*Ma-Aza-Ma*-Aza-*Bb)* sequential spray against mango hopper with spray 5.00 g per litre, followed by azadirachtin 10000 ppm @ 3 ml per litre, *M. anisopliae* (1×10^8 CFU/ml) at 5.00 g per litre, azadirachtin 10000 ppm @ 3 ml per litre after that treatment *B. bassiana* with dose 5.00 g per litre with percent reduction over control 31.95 with mean of *I. clypealis* was 7.75 per panicle.
8. Among the BIPM packages following T_3 (NSE-*Ma-Ll*-NSE-*Bb*) containing sequential spray against mango hopper was NSE 5 percent @ 1.00 ml per litre, followed by *M. anisopliae* (1×10^8 CFU/ml) @ 5.00 g per litre, *L. leccanii* (1×10^8 CFU/ml) @ 5.00 g per litre, followed by NSE 5 percent @ 1.00 ml per litre after that *B. bassiana* (1×10^8 CFU/ml) with dose 5.00 g per litre which was observed inferior treatment over all treatment and percent reduction over control was 27.30 with mean of survival population of *I. clypealis* was 8.28 per panicle.

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