Journal of Advances in Biology & Biotechnology

Volume 27, Issue 9, Page 778-787, 2024; Article no.JABB.122939
ISSN: 2394-1081

Insect Diversity and Abundance in Yellow Sticky Traps across Various Growth Stages of the Cabbage Ecosystem

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Authors' contributions

This work was carried out in collaboration among all authors. Authors SN, KARV, VM and LRCN conceptualized and designed the research work. Author CT executed field/lab experiments and collected the data. Authors CT and SN analysis of data and interpretation. Authors CT and ABR prepared the draft of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jabb/2024/v27i91351

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/122939

Original Research Article

Received: 25/06/2024
Accepted: 02/09/2024
Published: 05/09/2024

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Cite as: *T, Chethan, Sumithramma, N, Archana B. R, Kumar, A. R. V, Vidya Mulimani, and Lakshminarayana Reddy, C. N. 2024. "Insect Diversity and Abundance in Yellow Sticky Traps across Various Growth Stages of the Cabbage Ecosystem". Journal of Advances in Biology & Biotechnology 27 (9):778-87. https://doi.org/10.9734/jabb/2024/v27i91351.*

ABSTRACT

The study was conducted in a cabbage field located in Avathi village, Devanahalli Taluk, Bangalore rural district, Karnataka, India. Forty yellow sticky traps (22cm × 11cm) were strategically positioned in the field with a spacing of 10 meters between each pair of traps. Over the course of the experiment, ten traps were collected at 10-day intervals, with observations conducted at five different growth stages of the crop. A total of 19,292 insects were captured in the yellow sticky traps throughout the varying growth stages ranging from 35 to 75 Days After Planting (DAP). Notably, the peak insect count occurred at 55 DAP (4,536), followed by 45 DAP (4,446), while the lowest count was observed at 75 DAP (2,460). Similarly, the Operational Taxonomic Units (OTUs) exhibited their highest count at 35 DAP (41), closely followed by 45 DAP and 75 DAP, with the lowest OTU count occurring at 65 DAP. In terms of taxonomic categorization, the majority of insects belonged to the order Hemiptera, comprising 70% of the total catch (13,471), followed by Diptera at 17% (3,302). On the other hand, OTUs were predominantly represented by Diptera at 32%, followed by Hemiptera at 27%, Hymenoptera at 20%, Coleoptera at 12%, Lepidoptera at 5%, and Isoptera and Thysanoptera at 2% each. Diversity analysis conducted on the insects captured during different cabbage crop growth stages revealed that the Shannon and Simpson diversity indices reached their highest values at 75 DAP, with the lowest recorded at 65 DAP. Similarly, evenness and equitability were maximized at 75 DAP, contrasting with their lowest values observed at 55 DAP. Additionally, Margalef's index reached its peak at 35 DAP (4.84) and hit its lowest point at 65 DAP (3.61).

Keywords: Cabbage; evenness; Margalef's diversity index; operational taxonomic units; Shannon diversity index; Simpson's diversity index.

1. INTRODUCTION

Cabbage (*Brassica oleraceae* L.) is a highly valued winter vegetable cultivated extensively worldwide, known for its rich nutrient profile. This leafy plant is renowned for its content of vitamins, dietary fibers, and minerals, as well as its potent antioxidant and anti-inflammatory properties [1]. Cabbage has a significant presence in Indian agriculture, particularly as a cool-season crop grown in various states. According to recent reports, cabbage cultivation spans an area of approximately 4.03 lakh hectares across India, contributing to a total production of 9192 metric tons. Karnataka [2], a southern state in India, holds a notable place in cabbage production, contributing a substantial volume of 233.4 metric tons, which places it seventh among Indian states.

Despite the nutritional value and economic importance of cabbage, its cultivation is not without challenges. One of the primary concerns for farmers is the crop's susceptibility to various insect pests, which can cause significant damage and result in substantial losses [3], Major insect pests infesting cabbage include the Diamond back moth (DBM), *Plutella xylostella* Linn.; cabbage white butterfly, *Pieris brassicae* Linn.; cabbage webworm, *Hellula undalis* Fab.; cabbage aphid, *Brevicoryne brassicae* Linn.; cabbage looper, *Trichoplusia ni* Hubner; leaf webber, *Crocidolomia binotalis* Zeller; green peach aphid, *Myzus persicae* Sulzer; cabbage whitefly, *Aleyrodes proletella* Linn.; thrips, *Thrips tabaci* Lindeman; painted bug, *Bagrada cruciferarum* Burmeister; mustard sawfly, *Anthalia lugens proxima* Klug. and cabbage root fly, *Delia radicum* L. [4]. These insect pests can infest the cabbage crop at different stages of its growth, leading to heavy yield losses [5].

The cumulative impact of these pests can lead to significant yield reductions, sometimes as high as 52 per cent [6]. Of particular concern is the infestation by the diamondback moth (DBM), which has been known to cause up to 100% economic losses in cabbage crops, [7-8]. Additionally, the cabbage aphid, another devastating pest, can result in considerable yield losses, [8] indicating that cabbage aphids can cause up to 85% yield reduction. These pests do not only affect the quality of the produce but also the overall economic viability of cabbage farming. Thus, monitoring and controlling pest populations is critical to ensuring a successful cabbage harvest.

Various pest management strategies have been employed to mitigate the damage caused by these insect pests. Among them, the use of yellow sticky traps has gained popularity as an effective tool for monitoring and managing pest populations in cabbage fields [9]. Yellow sticky traps are an affordable and simple method used for the early detection and management of pests in both open fields and greenhouses. They typically consist of square pieces of foam or tin sheet coated with a sticky substance that attracts small insects. The color yellow is particularly effective at drawing in a wide variety of insects, including flies, aphids, thrips, and whiteflies, which are common pests in cabbage ecosystems [10]. Farmers can monitor these traps to get a sense of the pest population levels and make informed decisions about pest control interventions.

While yellow sticky traps are a well-known tool for pest management, there are no official recommendations for their use in cabbage pest monitoring or control. Despite this, farmers in Karnataka have consistently employed yellow sticky traps as part of their integrated pest management (IPM) strategies within the cabbage ecosystem [11]. These traps are used throughout the crop cycle to attract and capture pests, helping farmers manage pest populations effectively. The consistent use of yellow sticky traps by farmers, despite the absence of formal recommendations, indicates their practical utility in pest control [12]. By providing real-time data on pest presence and abundance, these traps enable farmers to take timely action, reducing the need for excessive pesticide applications and promoting more sustainable agricultural practices [13].

In Karnataka, where cabbage production is substantial, the application of yellow sticky traps has become a key component of pest monitoring efforts. Farmers deploy these traps at various growth stages of the cabbage crop to capture and monitor insect populations. The traps are typically placed at regular intervals throughout the field, starting from the early growth stages of the crop and continuing through to harvest. Farmers use the data gathered from these traps to make informed decisions about the need for pest control interventions, such as the application of insecticides or biological control agents. By monitoring pest populations closely, farmers can reduce the frequency and intensity of chemical interventions, which not only lowers production costs but also minimizes the environmental impact of cabbage farming.

This study aims to investigate the diversity and abundance of insects captured by yellow sticky traps during different growth stages of cabbage crops. The focus is on understanding how insect populations fluctuate over time and how different growth stages of cabbage attract various pests. The findings of this study will help in understanding the efficacy of yellow sticky traps as a pest monitoring tool in cabbage fields and will provide insights into the seasonal dynamics of pest populations in the cabbage ecosystem. Additionally, this research will contribute to the development of more effective pest management strategies that reduce the reliance on chemical pesticides while ensuring high cabbage yields.

2. MATERIALS AND METHODS

The experiment was conducted in a farmer's field located in Avathi village, Devanhalli Taluk, Bengaluru rural district, Karnataka, India, which lies in the Eastern dry agro-climatic zone. The field sits at an elevation of 928 meters above mean sea level with geographical coordinates of 13.2973° N latitude and 77.724262° E longitude. The cabbage variety used for this study was the F1 hybrid "Unnati," supplied by Nunhems. Yellow sticky traps were introduced into the cabbage field when the crop reached 25 days of age. A total of 40 yellow sticky traps (sized 22cm×11cm), manufactured by Gumtree Traps Pvt. Ltd. and marketed by Pest Control India Private Limited, were strategically positioned throughout the cabbage field. These traps were spaced at intervals of 10 meters and placed slightly above the crop canopy using support sticks. At intervals of 10 days, batches of 10 traps were retrieved, replaced and then gathered again after the same interval. This sequence was repeated, resulting in a total of five sets, each consisting of ten traps, being collected throughout the cabbage crop's growth cycle. The assembled traps were thoughtfully arranged within a plastic container designed to prevent trap overlap, allowing for convenient transport and safeguarding of the specimens during transit.

In the laboratory, using a stereo-binocular microscope, a thorough examination of the traps was carried out to both quantify and identify the trapped insect species. To streamline the counting process, each trap was divided into six grids on each side, with dimensions measuring 6.6 cm x 5 cm per grid. Meticulous observations were made for each cell within the grids, accurately recording the count of ensnared insects. Every trapped insect underwent taxonomic identification to the extent possible and the various collected taxa were meticulously documented and tabulated. Subsequently, the data obtained from all grids on both sides of each trap were consolidated. Next, each morpho type underwent validation for uniformity through external morphology and was then identified up to the family level hierarchy, following the procedures outlined in Johnson and Triplehorn (4). To ensure straightforward identification and facilitate analysis, a unique numerical code was assigned to each collected taxon based on its insect morpho-type. For example, the Diamondback moth was denoted as "DBM", whiteflies as "WF", leafhoppers as "LH" and so on. Furthermore, within the same family, if morphological variations were observed, distinct codes were assigned in a sequential numerical order. For instance, the taxonomic entity "Chrysomelidae" was attributed the distinct identifier "FB", within this family, two separate morpho-types were identified and designated "FB1" and "FB2". Nevertheless, regardless of their differentiation, these taxonomic units were classified as OTU and maintained as such throughout all subsequent analyses. Using this dataset, diverse orders and families were organized into tables corresponding to different growth stages. This information was then subjected to analyses aimed at deciphering the abundance and diversity of insects captured at varying growth stages within the cabbage ecosystem using yellow sticky traps.

Diversity indices calculated are as mentioned below.

i. Shannon diversity index was calculated using the formula.

$$\mathrm{H}' = -\sum_{i=1}^{s} \mathrm{P}_i \ln \mathrm{P}_i$$

Where,

H'= Shannon Weiner index
p_i = the proportion of individuals of species i.
ln p_i = logarithm of pi

ii. Simpson's diversity Index

$$\mathrm{D} = 1 - \left(\frac{\sum n\,(n-1)}{N\,(N-1)}\right)$$

Where,

D = Simpson Index
n = the total number of organisms of a particular species
N = the total number of organisms of all species

The value of the Simpson index ranges from 0 to 1, with 1 representing infinite diversity and 0 represents no diversity.

iii. Evenness refers to how close in number each species in an environment

$$\mathrm{J}' = \frac{\mathrm{H}'}{\mathrm{H}'_{max}}$$

Where,

H' = No. derived from the Shannon diversity index
H' max = Maximum possible value of H'

The value of J' is constrained between 0 and 1. J' lower the value less evenness and higher the value more evenness.

iv. Margalef's index

$$\mathrm{D_{mg}} = \frac{\mathrm{S} - 1}{\ln \mathrm{N}}$$

Where,

D_{mg} = Margalef's diversity index
S = Number of genera recorded
N = Total number of individuals in the sample
ln = Natural logarithm.

v. Rank abundance refers to the distribution pattern of different insect species within a particular ecosystem or community. It involves ranking the abundance of species from most abundant to least abundant, which provides insights into the diversity and dominance of different species within the ecosystem.

3. RESULTS AND DISCUSSION

3.1 Diversity Index of the Insects Caught on Yellow Sticky Traps During Different Crop Growth Stages of Cabbage

The peak values for the Shannon diversity index and Simpson diversity index were recorded at 75 DAP, closely followed by the 35 DAP stage. On the other hand, the lowest diversity index was observed at the 65 DAP stage. Shannon's index, serving as an analog of diversity, is determined by the mutual entropy of species and patches, divided by the marginal entropy of individual geographic patches. This index ranges between 0 and 4.5, where higher values of H signify greater diversity. Within the scope of this study, heightened diversity was evident in the yellow sticky traps deployed during the 75 DAP stage (2.54), while a lower diversity was noted at 65 DAP (1.17). Similarly, the Simpson index ranges from 0, indicating minimal diversity to 1, indicating maximal diversity. The analysis indicates that the highest insect diversity occurred at the 75 DAP stage (0.88), which was notably greater compared to other crop growth stages. Conversely, a lower diversity of insects was observed at the 65 DAP stage (0.86). Margalef index was highest at 35 DAP (4.84) and the lowest was observed at 65 DAP (3.61). Margalef's index of richness assumes a theoretical relationship between the number of individuals and the number of species in a sample by Margalef [14].

The spectrum of evenness (J) ranges from 0, indicating absence of evenness to 1, representing complete evenness. In comparison across crop growth stages, the 75 (DAP) displayed greater evenness than other stages. In contrast, the lowest evenness was observed at 55 DAP (0.19). The parity in insect captures on yellow sticky traps demonstrated its zenith at 75 DAP (0.71), whereas the nadir occurred at 55 DAP (0.55). The other studies also highlighted a positive association between diversity and equitability, where heightened equitability signified amplified diversity and likely a healthy fauna condition [15-16]. Within the confines of this study, a conspicuously higher equitability was identified at 75 DAP (0.71), signifying elevated diversity and a robust insect population compared to other stages of crop growth (Table 1).

3.2 Rank Abundance of Insects Caught in Yellow Sticky Traps During the Growth Stages of Cabbage

At the stage of 35 days after planting (DAP), the top five positions were filled by whiteflies, aphids, gelechiid moths, blow flies and leaf hoppers. Moving to 45 DAP, the leading five ranks were held by whiteflies, aphids, leaf hoppers, gelechiid moths, and psyllids. As we progressed to 55 DAP, the first five positions were occupied by whiteflies, aphids, muscid flies, psyllids, and leaf miners. Similarly, at 65 DAP, the top five spots were taken by whiteflies, aphids, leaf hoppers, muscid flies, and gelechiid moths. Finally, at 75 DAP, the positions were claimed by whiteflies, aphids, leaf hoppers, encyrtid wasps, and thrips, in that respective order. Whiteflies and aphids consistently held the first and second positions across different growth stages of the cabbage crop, while the other positions varied with different insect species. In addition to these, insects like thrips, leaf hoppers, gelechiid moths, psyllids and leaf miners featured among the five most abundant insects during various crop growth stages of cabbage. Blow flies were recorded at 35 and 65 DAP. The encyrtid wasp caught at 75 DAP occupied the fourth position in terms of abundance. Similarly, the effectiveness of various colored sticky traps in attracting insects within cucumber crops, noting that fluorescent yellow traps outperformed other traps in capturing insect pests [16].

3.3 Number of Insects Caught on Yellow Sticky Traps in Cabbage Ecosystem

During the study period, the yellow sticky trap catches for insects belonging to different insect orders include Isoptera, Hemiptera, Thysanoptera, Lepidoptera, Diptera, Hymenoptera and Coleoptera. Among the orders mentioned, the highest number of insects were caught belonged to the order Hemiptera *i.e*., 13,471 and contributes 70 per cent of total insects caught followed by Diptera with 3,302 insects and contributes 17 per cent and the lowest was in the order Isoptera (8). Juillet [17] worked on different traps like glass barrier, malaise, rotary and sticky traps and these capture the orders of Hymenoptera, Diptera, Lepidoptera, Coleoptera and Homoptera. In the present study also yellow sticky traps captured the insects belong to the orders Hemiptera, Diptera, Coleoptera, Lepidoptera and Hymenoptera with large numbers.

In the order Hemiptera, the highest number of insects were caught belonged to the family Aleyrodidae (7,199) followed by Aphididae (3,823). The results were in accordance with [18-19] where, significantly higher (55.19 aphid trap^{-1} and 10.31 whitefly trap^{-1}) numbers of aphids and whiteflies were trapped in yellow coloured traps followed by red and green coloured plastic traps.

In the order Diptera, the highest number of insects caught belonged to the family Muscidae (1,651) followed by Agromyzidae (653) and the lowest number caught belonged Dolichopodidae (2). In the order Lepidoptera, the highest number of insects caught belonged to Gelechiidae with 967 numbres followed by Plutellidae (46). In Hymenoptera, the highest number of insects caught belonged to the family Encyrtidae with 463 numbers followed by Braconidae (145) and the lowest number was recorded in Chalcididae and Apidae (1).

In the order Thysanoptera, the family Thripidae recorded 616 numbers. In the order Coleoptera, the highest number of insects caught belonged to the family Coccinellidae (184) and the lowest were recorded in the family Staphylinidae (27). In Isoptera, the family Termitidae recorded 8 number of insects during different growth stages of cabbage (Table 2).

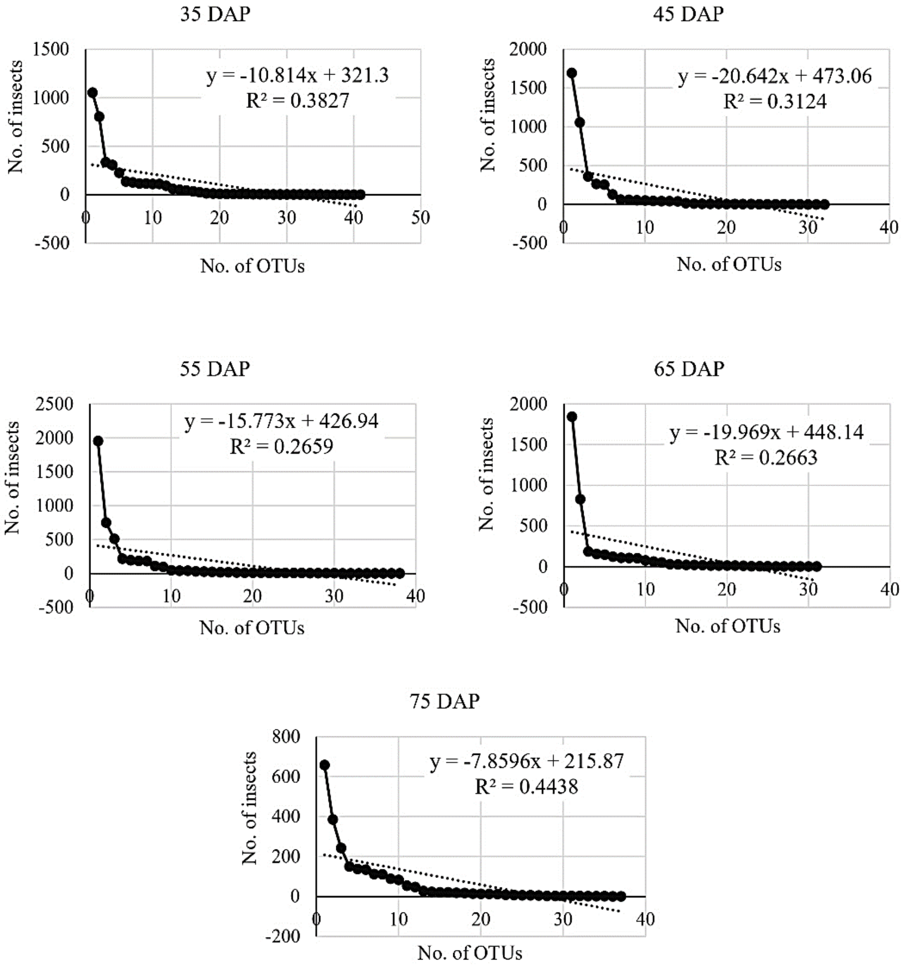

Fig. 1. Rank abundance of the insects caught in yellow sticky traps at different growth stages of the crop

Table 1. Diversity analysis of insects caught in yellow sticky traps in a cabbage ecosystem at different growth stages

Diversity indices	35 DAP*	45 DAP	55 DAP	65 DAP	75 DAP
OTUs	41	32	38	31	36
Individuals	3,862	4,446	4,536	3,988	2,460
Simpson diversity index	0.86	0.78	0.77	0.73	0.88
Shannon diversity index	2.43	2.047	2.025	1.947	2.564
Evenness	0.277	0.242	0.199	0.226	0.360
Margalef's diversity index	4.843	3.691	4.394	3.618	4.483
Equitability	0.654	0.590	0.556	0.566	0.715

DAP – Days After Planting

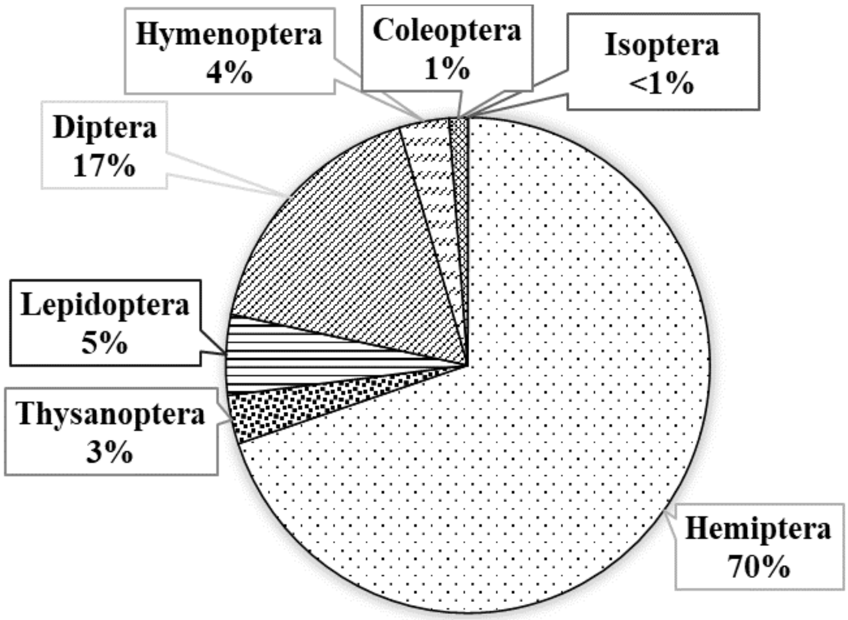

Fig. 2. Percentage distribution of total number of insects of different orders caught in yellow sticky traps in a cabbage ecosystem

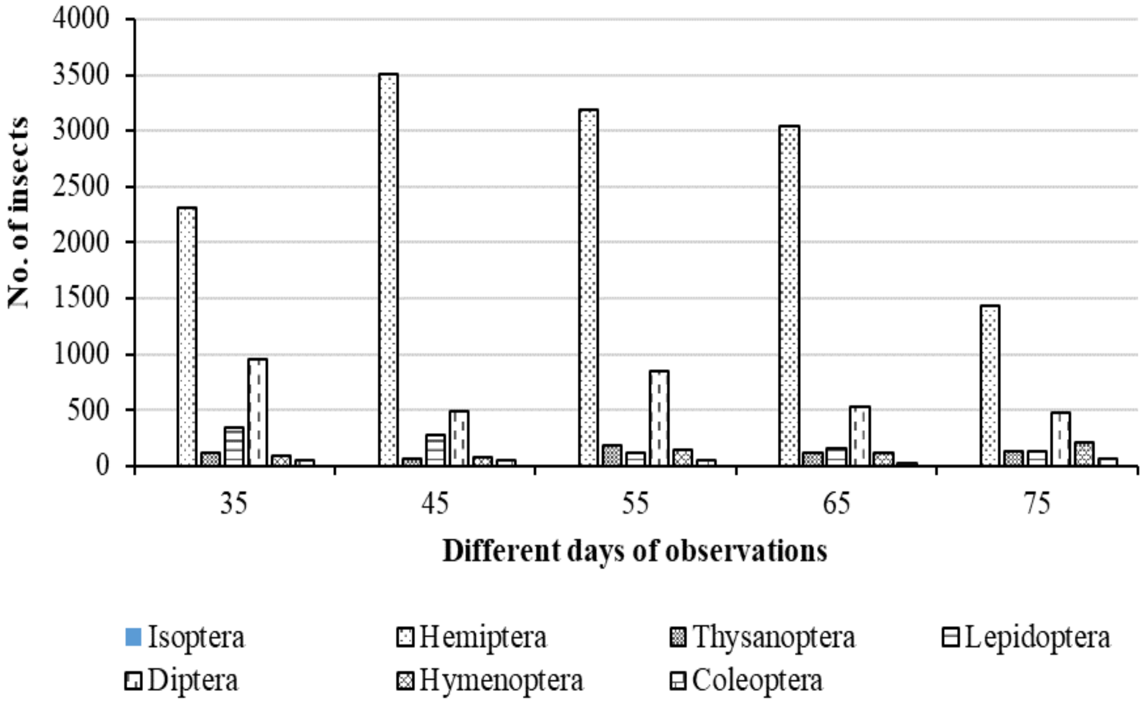

Fig. 3. Total number of insects of different orders caught in yellow sticky traps in a cabbage ecosystem

Table 2. Abundance and taxonomic affiliations of insects caught on yellow sticky traps

Sl No.	Order	Family	Days after planting					Total no. of insects	Total no. of OTUs
			35	**45**	**55**	**65**	**75**		
1	Isoptera	Termitidae	1	0	3	0	4	8	1
	Total							**8**	**1**
2	Hemiptera	Pentatomidae	1	0	0	0	0	1	1
		Membracidae	1	0	0	0	0	1	1
		Anthocoridae	0	0	0	0	0	0	1
		Delphacidae	2	8	1	12	1	24	1
		Miridae	8	46	40	13	7	114	1
		Psyllidae	111	255	216	104	113	799	1
		Geocoridae	2	0	1	0	0	3	1
		Lygaeidae	10	39	17	1	3	70	1
		Aphididae	805	1055	749	828	386	3823	1
		Cicadellidae	319	405	212	237	264	1437	4
		Aleyrodidae	1052	1693	1953	1843	658	7199	1
	Total							**13471**	**14**
3	Thysanoptera	Thripidae	116	60	180	122	138	616	1
	Total							**616**	**1**
4	Lepidoptera	Plutellidae	8	9	10	5	14	46	1
		Gelechiidae	335	263	110	147	112	967	1
	Total							**1013**	**2**
5	Diptera	Anthomyiidae	8	0	0	0	0	8	1
		Tephritidae	5	3	2	0	0	10	1
		Culicidae	0	2	4	9	9	24	1
		Chloropidae	127	17	10	75	24	253	1
		Muscidae	287	258	584	284	238	1651	3
		Agromyzidae	136	128	193	106	90	653	1
		Ulididae	12	6	18	19	21	76	1
		Calliphoridae	307	6	6	0	6	325	1
		Dolichopodidae	1	1	0	0	0	2	1
		Sepsidae	45	63	31	30	55	224	1
		Cecidomyiidae	3	0	0	5	18	26	1
		Tipulidae	26	0	1	0	2	29	1
		Drosophilidae	0	0	6	0	15	21	1
	Total							**3302**	**15**
6	Hymenoptera	Vespidae	0	2	0	0	2	4	1
		Apidae	0	0	0	1	0	1	1
		Ichneumonidae	0	1	3	0	1	5	2
		Bethylidae	5	0	0	0	3	8	1
		Chalcididae	1	0	0	0	0	1	1
		Encyrtidae	64	64	103	73	159	463	2
		Formicidae	2	3	7	3	0	15	1
		Braconidae	14	8	28	46	49	145	3
	Total							**642**	**12**
7	Coleoptera	Coccinellidae	35	41	40	20	48	184	2
		Chrysomelidae	6	4	7	5	7	29	2
		Staphylinidae	7	6	1	0	13	27	1
	Total							**240**	**5**

3.4 Number of Insects OTUs Caught on Yellow Sticky Traps in Cabbage Ecosystem

At different growth stages of cabbage crop, the highest OTU were caught during 35 DAP followed by 55 DAP and the lowest number was found in 65 DAP (Table 1). During the total growth stages of the cabbage crop, trap catches include many OTUs that belong to different insect orders. Among the different insect orders, Diptera includes the highest number of OTUs compared to others with OTUs number of 15 contributing to 31 per cent of the total number of

OTUs followed by the order Hemiptera with 14 OTUs and contributing to 27 per cent, the order Hymenoptera includes 12 OTUs with 24 per cent , the order Coleoptera includes 5 OTUs with 10 per cent, the order Lepidoptera includes 2 OTUs with 4 per cent and the orders Isoptera and Thysanoptera with single OTUs contributes 2 per cent of the total number of OTUs trapped on yellow sticky traps (Table 2).

The yellow sticky traps are a common method for monitoring many pests, but it has not been shown whether they could be used as a control method [19-20]. The main reasons for the insect number fluctuations in cabbage ecosystem may be due to two reasons, the first reason is, that the studies were undertaken right in the farmers field and the farmer grew the crop with regular interventions of pest management along with other practices. The second reason is after 60 DAP the crop moves towards the senescing stage where the populations of insects tend to reduce.

4. CONCLUSION

This study underscores the importance of deploying sticky traps at optimal growth stages, particularly during the middle to late stages of cabbage growth, for effective pest monitoring. While the traps are valuable for tracking pest populations, their direct use as a pest control method remains inconclusive. Overall, yellow sticky traps provide an efficient, low-cost tool for monitoring diverse insect populations in agricultural ecosystems, aiding in timely pest management interventions

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

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

ACKNOWLEDGEMENT

The authors thank College of Agriculture, UAS, GKVK, Bangalore, for his guidance during the course of investigation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
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