Original Research Article

EFFECT OF EXPOSURE AND ASSESSMENT OF DIVERSITY, ABUNDANCE OF INSECTS IN CABBAGE CROP USING YELLOW STICKY TRAPS

ABSTRACT:

Cabbage, a leafy vegetable and cultivated worldwide for its dense heads. Many insects affecting cabbage and posing challenges to cultivation. Yellow sticky traps are adhesive sheets used in pest control to attract and capture flying insects and helping to monitor and manage infestations in gardens and greenhouses. The experiment was conducted in a cabbage field using sticky traps (22 cm X 11 cm) over a 12-day period at Avathi village, Devanahalli Taluk, Karnataka, India. As many as 60 traps were installed randomly in the field when the crop was 60 days old. Five traps were sampled daily and examined microscopically and the number of insects trapped were recorded over the 12-day study period. The number of insects caught showed an increasing trend from day 1 to day 7 and almost reached saturation by day 10. Similarly, the number of insects added to the trap decreased from 8 to 12 days after installation. These trends suggest that the 22 cm X 11 cm size sticky traps get saturated by the 10th day resulting in steadily reducing catches with further sampling. On the 10th day of exposure, the cumulative number of Operational Taxonomic Units (OTUs) was maximum. The diversity indices were also found to be maximum on the 10th day. Marginal additions of insects by numbers and OTUs after a 10-day period suggest that sticky traps of the given size are ideal for sampling insects only up to 10 days after installation in the cabbage system. Further, on the same logic, from the point of view of pest reduction, continuous exposure of sticky traps for the whole cropping period, as is currently being practiced by the farmers, is not a wise practice. Hemiptera and Hymenoptera were the major groups of insects collected in the traps.

***Keywords:** Cabbage ecosystem, Diversity indices, Operational Taxonomic Units, Yellow sticky traps.*

1. INTRODUCTION

Cabbage, *Brassica oleracea* L., is one of the most popular winter vegetables and is widely grown across the world, including India (1). It is rich in vitamin K, vitamin C, dietary fiber, potassium and manganese along with many antioxidant and anti-inflammatory properties (2). Despite its popularity and value, cabbage cultivation is fraught with challenges, particularly from insect pests. These pests pose a significant threat to cabbage crops, causing substantial yield losses if not managed effectively. On average, insect pests can result in up to 52% yield loss in cabbage fields (3). Among individual pests, severe infestation by Diamondback moth (DBM) *Plutella xylostella* (Linnaeus) has the potential to cause up to 100 per cent crop loss (4) and aphid *Brevicoryne brassicae* (Linnaeus) may cause up to 85 per cent yield loss (5-6). The estimated annual crop losses due to insect pests of cabbage in India to be 130 crores (6).

In response to these challenges, various pest management strategies have been employed by farmers to protect cabbage crops. One such method is the use of Yellow Sticky Traps (YSTs). YSTs are designed to control flying insect pests by trapping them on their sticky surface. In recent years, the use of YSTs has gained popularity among farmers in Karnataka State, who have adopted this practice throughout the entire cabbage cropping period. However, it is important to note that there is no formal recommendation for the use of YSTs specifically for the management of cabbage pests (7). Cabbage ecosystems are not only home to pests but also to a variety of natural enemies that play a crucial role in pest control (8-9). Predatory insects such as coccinellids (ladybugs), braconid wasps, minute pirate bugs, and syrphid flies are commonly found in cabbage fields and contribute to the natural regulation of pest populations (10). However, YSTs, being generalist samplers, are likely to trap these beneficial insects along with the target pests like whiteflies, aphids, and DBM (11-12). This unintended capture of natural enemies raises concerns about the ecological impact of YSTs and underscores the need for careful evaluation of their use.

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The effectiveness of YSTs in pest management is influenced by several factors, including the duration of trap exposure, the color and shade of the traps, the area and shape of the traps, the number of traps per unit area, and weather conditions (13-14). Additionally, the economic viability and impact on pest populations, as well as the diversity and type of insects captured, are critical considerations (15). Given these complexities, a comprehensive evaluation of YSTs is necessary to determine their utility and optimize their use in cabbage pest management. As a preliminary step towards understanding the role of YSTs in cabbage pest management, we conducted a study to evaluate the effect of exposure duration on the diversity of insects attracted to YSTs over a 12-day period. This study aims to provide insights into the efficacy of YSTs and their potential impact on both pest and beneficial insect populations, thereby contributing to the development of more effective and sustainable pest management practices in cabbage cultivation.

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2. MATERIAL AND METHODS

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The experiment was conducted in a farmer's field at Avathi village, Devanhalli Taluk, Bengaluru rural district, Karnataka State, India, under the eastern dry zone of the state (13.2973° N; 77.724262° E; 928 m above MSL). The cabbage grown was an F1 hybrid "Unnati", from Nunhems India Pvt. Ltd. and YSTs (22 cm×11 cm) manufactured by Gumtree Traps Pvt. Ltd. and marketed by Pest Control India Pvt. Ltd. were installed in the cabbage field in March 2021 when the crop was 60 days old. A total of 60 yellow sticky traps, were numbered serially and installed randomly in the cabbage field (0.4 ha) at just above canopy level on a wooden stick, maintaining a 10 m distance between any two traps. Five traps were collected sequentially every day up to 12 days from 15/03/2021 to 26/03/2021. The traps were placed in plastic boxes avoiding their overlap and transferred to the laboratory for observation. The traps were examined under a stereo-binocular microscope to count and identify the species of insects trapped. For easy counting, traps were divided into six grids of 7.33 cm x 3.66 cm on each side and the number of insects trapped was counted and recorded. Trapped insects were identified to the nearest taxon and the data were tabulated. Data collected from all the grids from both sides were pooled for each trap. Each morpho-type was then verified for uniformity based on the external morphology and identified up to the family level hierarchy (16). Each taxon collected was given a unique number based on the morpho-type of the insect for easy identification and analysis. For example, the Diamondback moth was coded as DBM, whiteflies as WF, leafhoppers as LH and so on and the taxa that are morphologically different in the same family were further divided and coded separately in a numerical order. For example, Chrysomelidae had the unique ID of flea beetles (FB) and had two different morpho-types that were named FB1 and FB2 separately. Each such taxonomic unit was considered as an Operational Taxonomic Unit (OTU) as a proxy for species and these were used as such for all the analyses. The data were tabulated according to different orders, families and functional groups of insects that were trapped in YSTs and subjected to analyses to find out the abundance and diversity of insects that were caught on 12 consecutive days in the cabbage ecosystem.

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The species accumulation curve or collector's curve of a population gives the expected number of observed species or distinct classes as a function of sampling effort. However, in order to simplify this aspect and to verify the possibility of a near asymptotic accumulation curve, logistic equations were fitted following DeSapio (1978), for both the numbers of insects collected and the numbers of OTUs collected over the 12 day period. The number of OTUs observed on each day of the sample period were different as the samples were randomly collected from different traps. Therefore, to overcome this constraint, the OTUs collected on the 12 day sampling period were pooled by the corresponding days of sampling and the logistic equations were fitted to check for the potential asymptotic nature of the curve. Standard regression analyses on MS Excel were used to check the goodness of fit of the equations by working out the relation between the observed and the expected values. The equations were in the form of,

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$$N_t = \frac{K}{1 + C^{e-rt}}$$

Where,

N_t = the number of insects /OTUs trapped

K= maximum potential numbers of insects/OTUs likely to occur in the ecosystem

C= constant of proportionality (approximately equal to (K-N)/N)

r = slope of the regression equation that indicates the relative growth rate per sample

t = the dates of sampling

Diversity indices were calculated using the Shannon-Weiner Index, Simpson Index, Evenness index and Margalef's diversity index.

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Shannon Index is a popular diversity index in the ecological literature, where it is also known as Shannon's diversity index, Shannon–Wiener index. It 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

Simpson's Diversity Index is a measure of diversity that takes into account the number of species present, as well as the relative abundance of each species. It was calculated using the formula.

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

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. Species richness represents a measure of the variety of species based simply on a count of the number of species in a particular sample, although it can be expressed more usefully as species richness per unit area, ranging from alpha (referring to a certain site) to gamma (for an entire study area) level.

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.

Margalef's index was one of the first attempts to compensate for the effects of sample size by dividing the number of species in a sample by the natural log of the number of organisms collected, calculated using the formula.

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

Where,

Dmg = Margalef's diversity index

S = Number of genera recorded

N = Total number of individuals in the sample

ln = Natural logarithm.

3. RESULTS AND DISCUSSION

3.1 Cumulative and the additional number of insects caught in yellow sticky traps

The total cumulative number of insects from day one to twelve was ranges from 730 to 5,735 (Table 1). A total of 43,618 insects were caught and from the second day of exposure the additional

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$$\mathrm{N}_t = \left(\frac{5800}{1 + 2.82^{e-0.613t}}\right)$$

The goodness of fit was verified by regressing the observed values against the expected values and found to match (n=12; r = 0.819; p<0.05). Clearly this indicates that the sticky traps used are not useful in catching additional insects. Such a situation can arise either due to lack of space for the additional insects to get trapped on the YSTs. As the first option is unlikely, it can be safely concluded that the sticky traps of the size used get saturated by the 10th day. Logistic equation fitted clearly suggests a saturation of space rather than the availability of insects as such.

The studies on cumulative and the additional number of insects caught in YSTs in cabbage ecosystem clearly indicates that the sticky traps used are not useful in catching additional insects as shown in Fig. 1 and it can be safely concluded that the sticky traps of the size used get saturated by the 10th day. Similar study to address the trap catch pattern by Pavan *et al.* (17) suggested the saturation time for sticky traps. However, considering that the logistic equation could give a very good fit for the present data set suggests the optimal time would be half the number expected to be caught in the trap as the most ideal for the best trap catch efficiency. As a result, it is ideal to anticipate that time taken to reach 50 per cent of the maximum expected (*i.e.*, K value in the present context) catches would be the most ideal time to replace the traps if maximum catching efficiency is the expected outcome. In the present study this would be approximately 5*th* or 6*th* day of trapping considering the type of YSTs used. Corresponding to that expectation, the maximum additional catches also matched on the sixth day with an aberration on the eighth day. Given this and the fact that further increase was observed to be marginal beyond the eighth day, it can be safely suggested that a maximum of eight day period of trapping would be ideal to run these sticky traps in cabbage fields if yield per day is the criteria of trapping. In essence, unlike the farmers practice it is desirable to replace the traps regularly at eight day intervals for better management of the pests, if that is the primary aim.

3.2 Total and cumulative number of OTUs caught in yellow sticky traps in cabbage ecosystem

Twelve consecutive days of trap exposure in the cabbage ecosystem shows that the number of total OTUs ranges from 16-30 and the cumulative number of OTUs were 12- 42 (Table. 1). The cumulative numbers of OTUs caught from day one to twelve were found highest on 10th day (42 OTUs) and there was no further addition of OTUs (Fig. 1). Therefore, an attempt was made to verify the potential saturation of taxa in the sticky traps by fitting a logistic equation as outlined earlier. The attempt yielded the equation

$$\mathrm{N}_t = \frac{43}{(1 + 0.878^{e-0.410t}}$$

The goodness of fit was verified by A test of correlation of the observed values against the expected values as a measure of goodness of fit indicated a strong relationship (n=12; r = 0.987; p<0.05). Clearly this suggests that, by the 10th day, cumulative number of OTUs were highest and further additions are not expected. Hence, a sampling strategy using the current YSTs can sample most of the trappable taxa by the 10th day and exposures beyond are unlikely to help sample additional taxa.

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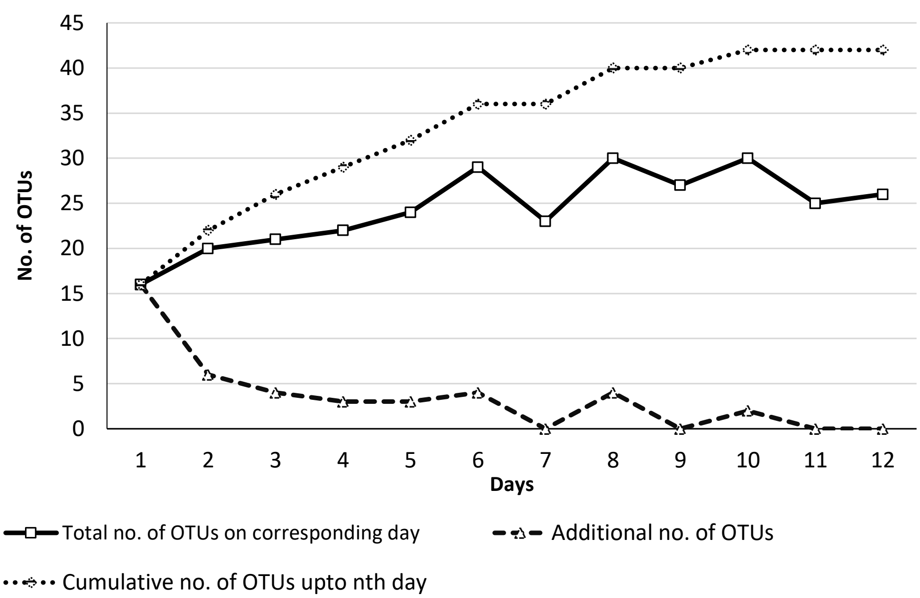

Figure 1. Total, cumulative and additional number of OTUs caught in yellow sticky traps in cabbage ecosystem

3.3. Diversity indices of the insects caught on yellow sticky traps

The Simpson, Simpson and Margalef's diversity index was found highest on the 10th day *i.e.*, 0.75, 1.72 and 3.36 and the lowest diversity index was seen at the first day 0.52, 1.17 and 2.27. Evenness (J) or Shannon evenness index of the insect caught on the yellow sticky traps in cabbage ecosystem were generally low on all days of trapping. The highest 'J' value was observed on the second day (0.21) followed by first day (0.20) and the lowest was for the 8th day (0.11) of the trap exposure. An average 'J' value of 0.174 also indicated the high variance for the insects caught in the YSTs (Table 1).

Table 1. Number of insects, OTUs and diversity indices of insects caught on yellow sticky traps in cabbage ecosystem.

Day	Total insects caught	Additional insects caught	No. of OTUs caught	Additional no. of OTUs caught	Cumulative no. of OTUs caught	Simpson diversity index	Shannon diversity index	Evenness index	Margalef's index
1	730	730	16	16	16	0.52	1.17	0.20	2.27
2	1341	611	20	6	22	0.62	1.45	0.21	2.63

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3	2329	988	21	4	26	0.58	1.35	0.18	2.58
4	2460	131	22	3	29	0.59	1.40	0.18	2.69
5	2606	146	24	3	32	0.55	1.31	0.15	2.92
6	3686	1080	29	4	36	0.59	1.41	0.14	3.41
7	3474	212	23	0	36	0.57	1.35	0.16	2.69
8	4615	1141	30	4	40	0.51	1.21	0.11	3.43
9	5268	653	27	0	40	0.71	1.60	0.18	3.03
10	5595	327	30	2	42	0.75	1.72	0.18	3.36
11	5778	183	25	0	42	0.70	1.54	0.18	2.77
12	5736	42	26	0	42	0.70	1.52	0.17	2.88

3.4. Abundance and richness by taxa of insects caught on yellow sticky traps

The insects caught on the trap were classified up to order level and family level. The insects belonging to seven orders *viz*., Thysanoptera, Hemiptera, Isoptera, Lepidoptera, Diptera, Coleoptera and Hymenoptera were caught on yellow sticky traps in cabbage ecosystem. Among these Hemipteran insects caught maximum in numbers followed by Hymenoptera and least number found in Isoptera (Fig. 2; Table.2). The highest richness of the taxa was found in the order Hemiptera followed by Diptera and least found in the order Isoptera and Thysanoptera (Table. 2). Many research studies suggest that yellow sticky traps catch different insects and are best suited for monitoring of whiteflies, aphids, thrips, psyllids and a few other smaller insects. Yellow sticky traps used to monitor the populations of the seven different species of thrips infesting cotton, sunflower, groundnut and soybean (18), whitefly *Bemesia tabaci* Genn. (Hemiptera; Aleyrodidae) in cotton (19), flea beetle *Chaetocnema pulicaria* F. E. Melsheimer (Coleoptera; Chrysomelidae) (20), citrus psyllid *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae) in citrus. Juillet (21) worked on different traps like glass barrier, malaise, rotary and sticky traps and insects captured belong to orders Hymenoptera, Diptera, Lepidoptera, Coleoptera and Homoptera. In the present study also YSTs captured the insects belonging to the orders Hemiptera, Hymenoptera, Lepidoptera, Diptera, Thysanoptera and Coleoptera in large numbers. In line with these studies, the current study clearly demonstrated the whiteflies to be the major insect species to be trapped in YSTs. Other smaller insects and serious pests of cabbage such as aphids and DBM were also found trapped in reasonably good numbers in the YSTs (Table. 3).

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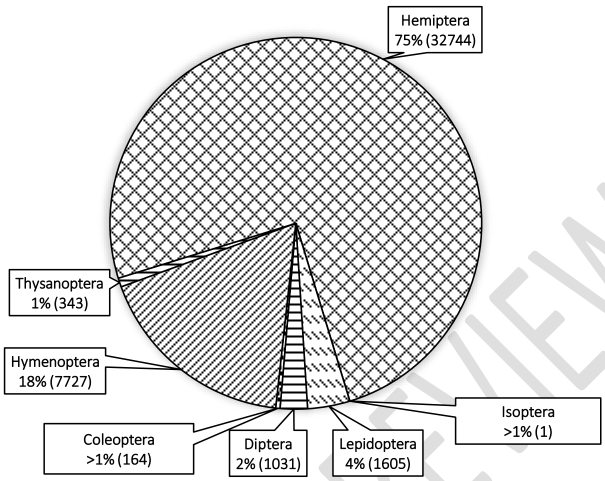

Figure 2. Percentage and number of insects belonging to different orders caught in yellow sticky taps in cabbage ecosystem.

Table 2. Abundance and species richness of the insects with respect to insect orders trapped in yellow sticky traps in cabbage ecosystem.

Order	Family	Richness	Abundance
Thysanoptera	Thripidae	1	343
Total		1	343
Hemiptera	Aleyrodidae	1	22240
	Cicadellidae	4	1903
	Aphididae	1	8026
	Psyllidae	1	354
	Pentatomidae	1	1
	Delphacidae	1	11
	Lygaeidae	1	120
	Geocoridae	1	28
	Miridae	1	41
	Anthocoridae	1	20
Total		13	32744
Isoptera	Termitidae	1	1
Total		1	1
Lepidoptera	Plutellidae	1	1582

	Gelechiidae	1	23
Total		2	1605
Diptera	Anthomyiidae	1	159
	Tephritidae	1	15
	Cecidomyiidae	1	1
	Agromyzidae	1	541
	Syrphidae	1	4
	Culicidae	1	27
	Muscidae	2	177
	Chloropidae	1	61
	Ulidiidae	1	42
	Calliphoridae	1	1
	Sepsidae	1	3
Total		12	1031
Coleoptera	Chrysomelidae	2	21
	Coccinellidae	2	139
	Staphylinidae	1	4
Total		5	164
Hymenoptera	Braconidae	2	7085
	Encyrtidae	2	611
	Chalcididae	1	1
	Bethylidae	1	1
	Formicidae	1	29
Total			7727

3.5. Abundance of functional groups of insects caught on yellow sticky traps

The total number of insects caught in the Yellow Sticky Traps was 43,618 and they were classified into 5 classes based on the ecological function (feeding habit) namely, Herbivores, Predators, Parasitoids, Scavengers and Pollinators and Medically and Veterinary important insects. The insects grouped under herbivores were highest in number followed by parasitoids and lowest number found in the group of predators (Table. 3). High numbers of whiteflies and aphids that are herbivores of cabbage are obviously abundant in the system and there was a relatively high catch of Hymenoptera. However, braconid parasites being in abundance in the traps is a matter of concern and need to be further evaluated to understand their host species and their impact on the pests of cabbage wherever the YSTs are used. The YSTs appear to mostly capture the phytophagous groups that are pestiferous on cabbage. Clearly the present study indicates a generalist sampler like the YST may help census a good part of the diversity of insects characteristic of the system where sampling is made. Results are inline with the study by Pinto-Zevallos and Vänninen (22)

In conclusion, the study indicated that YSTs can be good generalist sampler of insects accounting for many orders. For the given size of 22 X11 cm, the ideal period of exposure of YSTs in the cabbage field would be about eight days and any further deployment may not be beneficial. Thus the current method of deploying these traps for the entire cropping period , as is being practiced by the farmers of Karnataka, needs to be revised and periodical replacement is in order for purposes of pest management. While this can be a tentative suggestion, it is also necessary to explore the possibility of removal of

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braconids and other beneficial Hymenoptera from the system due to YST trappings in cabbage ecosystem. Generally, technology should be based on sound science, but in the case of YSTs, it appears that the technology has preceded science and more detailed studies are in order to comprehensively understand the impact of YSTs on various functional groups and the consequent utility in terms of pest management in cabbage and other cropping systems.

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Table 3. Abundance of functional groups caught on yellow sticky traps

Sl. No.	Taxa	Order	Family	Abundance
1	Herbivores	Thysanoptera	Thripidae	343
		Hemiptera	Aleyrodidae	22240
			Cicadellidae	1903
			Aphididae	8026
			Psyllidae	354
			Pentatomidae	1
			Delphacidae	11
			Lygaeidae	120
		Lepidoptera	Plutellidae	1582
			Gelechiidae	23
		Coleoptera	Chrysomelidae	21
		Diptera	Anthomyiidae	159
			Tephritidae	15
			Cecidomidae	1
			Agromizidae	541
		Total		**35340**
2	Predators	Coleoptera	Coccinellidae	139
			Staphylinidae	4
		Hemiptera	Geocoridae	28
			Miridae	41
			Anthocoridae	20
		Diptera	Syrpidae	4
		Hymenoptera	Formicidae	29
		Total		**265**
3	Parasitoids	Hymenoptera	Braconidae	7085
			Encyrtidae	611
			Chalcididae	1
			Bethylidae	1
		Total		**7698**
4	Medical & Veterinary pests	Diptera	Culicidae	27
			Muscidae	17
		Total		**44**
5	Scavengers	Diptera	Chloropidae	61
			Muscidae	160
			Ulidiidae	42
			Calliphoridae	1
			Sepsidae	3
		Isoptera	Termitidae	1
		Total		**268**

4. CONCLUSION

The study demonstrates that yellow sticky traps (YSTs) are effective generalist samplers for monitoring insect diversity in cabbage ecosystems, particularly capturing herbivorous pests like whiteflies and aphids. However, the traps also capture beneficial insects, such as parasitoid braconids, raising concerns about their broader ecological impact. The optimal exposure time for YSTs is eight days, beyond which their efficacy diminishes. The findings suggest that current practices, such as continuous deployment, should be revised to enhance pest management while minimizing unintended effects on non-target insect populations. Further research is needed to fully understand the ecological consequences of YST use.

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