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Attraction of Pest Insects, Neutral Insects and Natural Enemies to Coloured Sticky Traps in Vegetable Eco-Systems

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ABSTRACT

Purpose: *Sticky traps are effective for monitoring and managing insect pests. In addition to pest insects, beneficial insects are also caught in sticky traps. Hence, it is necessary to use traps to catch pest insects selectively. The attraction of different insect groups to coloured sticky traps was studied as an attempt to suppress the insect populations selectively in the field.*

Research Method: *Sticky traps: yellow, blue, luminous green, white, and transparent (control) were set in the field for 24 hours, and the insects caught in traps were collected and identified by their ecological role: pests, beneficial and neutral insects as well as the taxonomic group in relation to the trap colour.*

Findings: *Significant variation was found among the total numbers of insects attracted to different colour traps (χ^2 =107 df=4 P<0.05). The highest number of insects was found in the luminous green trap (29.1%) followed by yellow (22.0%), white (18.8%), blue (17.9%), and transparent (12.2%). All colour traps attracted pest, beneficial and neutral insects. Data was inconsistent to specify trap colour to catch more pests and less beneficials. More dipterans (40.7%) were attracted to traps, and many of them were neutral. Blue-traps caught less number of neutral (29.1%) and beneficial insects (29.4%) compared with other coloured traps.*

Originality/ Value: *The behavioral response of different insect groups to colour was demonstrated. As sticky traps catch both beneficial and pest insects, sticky traps should be used under careful monitoring.*

Keywords: *Beneficial insects, Colour attraction, Sticky traps, Taxonomic groups*

INTRODUCTION

A wide range of vegetables are cultivated in Sri Lanka over 0.08 m ha (Weerakkody and Mawalagedara, 2020) and management of insect pests in vegetable crops is quite challenging. Sap-feeding insects are becoming more important as they function as viral disease vectors of vegetable crops. Viral diseases have become a limiting factor in vegetable production in tropical countries (Navas-Castillo *et al.,* 2011). Among the viral vectors, whiteflies, aphids, leafhoppers, and planthoppers are important. Tobacco whitefly, *Bemisia tabaci* transmit chili leaf curl virus, cucumber yellow net virus, okra yellow mosaic virus, mung bean mosaic virus (Shivanathan, 1977), horse gram yellow mosaic virus in bean (Rienzie *et al.,* 2020), and tomato yellow leaf curl virus (Cohen and Lapidot, 2007), etc. which affect significantly on local crop production. Aphids transmit cucumber mosaic virus, chili mosaic virus, cowpea mosaic virus, potato virus

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Y, etc. (Harris and Maramorosch, 1977). Hence, the management of virus vectors is an important aspect of vegetable crop production.

General insect pest management includes the application of synthetic insecticides which is the most popular among farmers (Jayasooriya and Aheeyar, 2016). However, the use of insecticides in pest management is a concern, especially due to the environmental impacts (Edwards, 1993) and human health (Bernardes *et al.,* 2015). Integrated pest management (IPM) in Sri Lanka was initiated for the rice crop in the late 1980s (Teng, 1994) and later adopted for other crops including vegetables. Adoption of IPM in vegetables is slow due to many reasons (Jayasooriya and Aheeyar, 2016). The components of IPM generally include preventive measures including the use of resistant varieties, crop rotation, management of biodiversity, parasitoid conservation, etc., and curative measures which include physical and mechanical removal of the pest stages, use of physical barriers to exclude the pests, and application of synthetic insecticides, and botanical formulations under local conditions. The use of sticky traps has been suggested to manage the populations of small flying insects such as aphids, whiteflies, thrips, and leaf and plant hoppers in protected culture as well as in open fields (Böckmann and Meyhöfer, 2017; Ramasamy and Ravishankar, 2018). Also, the sticky traps are frequently used for monitoring insect populations in open fields (Bashir *et al.,* 2014).

The sticky traps are non-selective insect-catching devices; hence, it is likely that the sticky traps may catch beneficial insects such as pollinators, parasitoids, and predators in addition to the target pest species (Shi *et al.,* 2021). The effectiveness of sticky traps depends on many factors (Bashir *et al.,* 2014) which include the trap colour (Idris *et al.,* 2012; Hossain *et al.,* 2020) and trap height (Atakan and Canhilal, 2004). However, the response of different insect species to colour is poorly known except for a few species (Briscoe and Chittka, 2001). It is generally known that insects are responsive to yellow colour (Saunders and Luck, 2013) and there is evidence that some species respond more to blue or brown. Thrips species particularly respond to blue colour (Tang *et al.,* 2016) while some species respond more to brown colour (Bashir *et al*., 2014). The attraction to colour has been studied with flower-visiting insects. Bee pollinated flowers are generally yellow and blue, while beetle pollinated flowers are white or dull. Fly pollinated flowers are dull red or brown (Miller *et al*. 2011). Diptera, Hymenoptera, some Lepidoptera, and Coleoptera can recognize colour, extending from near ultraviolet (UV) (320 nm) to near red (600-650 nm) wavelengths (Menzel and Backhaus, 1991). The height of the colour trap influences the efficiency of trapping the insects (Straw *et al*., 2011). The canopy level is a good height to place the traps. Most of the insects are active at the plant canopy level (Sudarjat *et al.,* 2020).

The use of sticky traps as a tool for insect management requires further understanding of their impact on beneficial insects. Parasitoids and small predatory insects play a greater role in suppression of insect pests in agroecosystems; hence, the conservation of natural enemies is very important for the natural suppression of the pest populations. Sticky traps could hinder the conservation of natural enemies. Therefore, it is important to use the sticky traps selectively on the pest species. There is a possibility to collect the insects selectively using different colour traps. The objective of this study was to identify suitable color sticky traps for the suppression of selective insect populations in relation to the attraction of insects to colours.

MATERIALS AND METHODS

Experimental Site and Time

This study was conducted in three locations: Kurunegala, Matale, and Kandy districts in Sri Lanka from January to March of 2020. The study consisted of two components: (a) Fieldworks: Installation of sticky colour traps at different vegetable fields and collection of traps (b) Laboratory study: Trap examination, removal of insects from traps, cleaning and preservation, and identification of insect specimens to possible taxonomic levels.

Selection of Experimental Sites

The vegetable fields were selected based on the type of vegetable, ecological zones, access, and growth stage of the vegetable ecosystem. Three sites were selected for the study (Table 01).

All vegetable fields were at the harvesting stage and managed under the recommendations of the Department of Agriculture, Sri Lanka, (2018) under the Good Agricultural Practices (GAP) program or a research field. The extent of vegetable fields was more than 0.5 ha in each place.

The selected vegetable field was separated into four blocks. Each block was divided into five plots and the size of the plot depends on the size of the fields. It varies from 5 - 10 m^2 among the three sites. One of the five types of traps; blue, yellow, white, luminous green and transparent colors was assigned to plots within the block randomly. In the middle of the plot, a previously prepared plastic stake was installed to hang the colored sticky trap.

The sticky traps were prepared in the laboratory by applying insect glue (commercially available; Crop Guard) evenly on both sides of the trap. The traps were in the field for 24 hours, and the traps were allocated as per the Randomized Complete Block Design with four replicates.

The colored sticky traps were made by using a boxboard (17 x 27 cm^2; 3 mm thick), covered with colored polythene (yellow, blue, white, luminous green) and enclosed within a transparent plastic sleeve. Boxboard helped to prevent the folding of the traps on the field and it gave steady stands to traps. The transparent trap was prepared in the same manner, excluding the boxboard. A thin layer of glue was applied on both sides of the polythene. Traps were installed at the canopy level of vegetable fields and left for 24 hours to catch insects. Traps were reinforced to avoid the rotation by the wind.

The insects that were trapped in the trap were removed using citronella oil and a fine paint brush (Miller *et al.,* 1993). Citronella oil dissolves the glue to a reasonable extent, allowing the removal of insects with minimum damage. The recovered insect specimens were stored temporally in citronella oil for removing the glue, followed by storing in 70% ethanol in 3ml plastic vials with a screw cap, with proper labeling. The stored specimens were examined under the microscope (1 x 5 x 20 magnification) and identified to the maximum possible taxonomic levels. Upon identification, the insects were classified as useful (natural enemies and pollinators), pest species, and neutral insects (the ecological service of the insect is not conclusive). The identifications were done using taxonomic keys based on morphological characters, compared with the published images and related literature.

Table 01: Location details of vegetable fields used in the study

Location	Agroecological zone	Vegetable types	GPS coordinates
Peradeniya, Gannoruwa	Wet zone Mid country (WM2)	Long bean, Radish, Okra, Brinjal	$7^0$16’40” N $80^0$35’27” E
Matale, Thibbatumulla	Intermediate zone Mid country (IM3)	Long bean, Bitter gourd, Cucumber, Tomato, Radish	$7^0$27’21” N $80^0$38’28” E
Kurunegala, Parabawila	Intermediate zone Low country (IL1)	Brinjal, Tomato, Luffa, Snake gourd, Bean	$7^0$23’25’’N $80^0$18’53’’E

The data were analyzed using the chi-square test and log-linear analysis in SYSTAT II software.

RESULTS AND DISCUSSION

In this study, a total of 1571 insects were caught in all sticky traps with five different color and the insects were grouped as pest insects (36.5%), natural enemies (29.2%), and neutral insects (34.3%). The total number of insects per site significantly varied with the sites (χ^2 =146 df=2 P<0.05) and that was 779, 406, and 386 for Peradeniya, Kurunegala, and Matale respectively. Further, the total number of insects per trap, across all sites, significantly varied with the trap colour (χ^2 =121 df=4 P<0.05). The totals: 346 (22%), 282 (17.9%), 295 (18.8%), 457 (29.1%) and 191 (12.2%) were collected in yellow, blue, white, luminous green and transparent traps respectively.

Pest, beneficial, and neutral insect groups all respond differently to trap color (Figure 01). There was a significant variation of the catch per colour in pests (χ^2 =45.4 df=4 P<0.05), in beneficial insects (χ^2 =41.6.4 df=4 P<0.05), and neutral insects (χ^2 =33.4 df=4 P<0.05). A significant difference in trap catches with colour was found in each insect group of pests, beneficial and neutral insects in each sampling location.

Trap Performance in Vegetable Field at Kurunegala

A total of 406 insects were collected at the Kurunegala site and the number of insects collected was significantly different among trap colors (χ^2 =68.7 df=4 P<0.05). The least number of insects was caught in a yellow trap (13.75±4.7 per trap) and it was not significantly different from blue, white, and transparent traps. The highest number was caught in the green trap (36.75±6.4 per trap).

The numbers of pests, neutral insects, and beneficial insects, caught on traps were significantly different in luminous green (χ^2 =11.1 df=2 P<0.05) catching more neutral insects, and transparent traps (χ^2 =7.1 df=2 P<0.05) catching less number of pest insects. No significant difference was found among insect groups (pest, neutral and beneficial) in yellow, blue and white colored traps (Table 02).

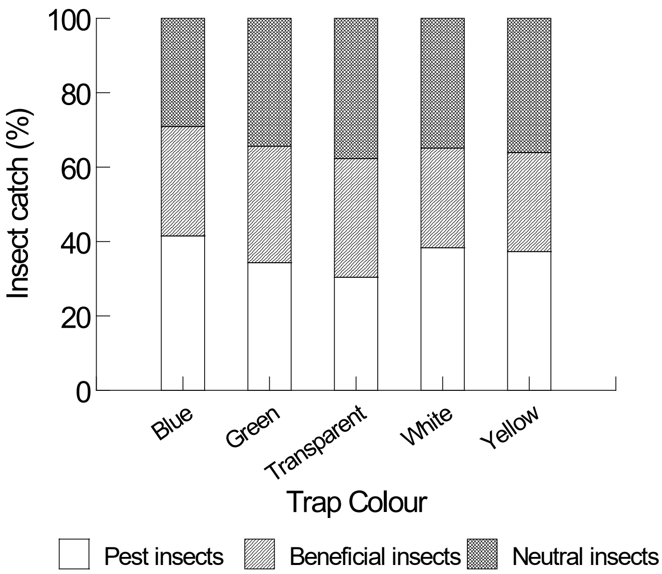

Figure 01: Response of pest, beneficial, and neutral insects to different colors as the percent caught in colored sticky traps in vegetable ecosystems in three locations.

Table 02: The relative proportion of pests, natural enemies, and neutral insects caught in different colour traps over 24 hours at Kurunegala, Matale, and Peradeniya sites.

Trap color	Total catch	Percentage of catch (%)			Level of Significance
		Pest	Natural enemies	Neutral insects	
Kurunegala					
Yellow	55	34.5	30.9	34.6	0.930^{ns}
Blue	72	30.5	43.0	26.5	0.197^{ns}
Green	147	26.5	27.2	46.3	0.004**
White	69	33.3	39.1	27.6	0.449^{ns}
Transparent	63	17.4	41.3	41.3	0.028*
Matale					
Yellow	74	17.6	18.9	63.5	0.001**
Blue	80	42.5	17.5	40.0	0.011**
Green	111	34.2	27.0	38.7	0.313^{ns}
White	69	31.9	24.6	43.5	0.154^{ns}
Transparent	52	38.5	25.0	36.5	0.437^{ns}
Peradeniya					
Yellow	217	44.7	28.1	27.2	0.002**
Blue	130	46.9	29.2	23.9	0.003**
Green	199	40.2	36.7	23.1	0.008**
White	157	43.3	22.3	34.4	0.005**
Transparent	76	35.5	29.0	35.5	0.720^{ns}

Note: * significant; ** highly significant; ^{ns} not significant

Trap Performance in Vegetable Field at Matale

A total of 386 insects were collected at the Matale site and the number of insects collected in traps was significantly different with trap colour (χ^2 =24.12 df=4 P<0.05). The least number of insects was caught in a transparent trap (13.0±2.4 per trap) while the highest number was caught in a green trap (27.75±5.1 per trap). The numbers of pests, neutral insects, and beneficial insects, caught on traps were significantly different in yellow traps (χ^2 =30.3 df=2 P<0.05) and blue traps (χ^2 =9.1 df=2 P<0.05) (Table 02) but not in green, white and transparent traps.

Trap Performance in Vegetable Field at Peradeniya

A total of 779 insects were collected at the Peradeniya site, and the number of insects collected was significantly different among traps (χ^2 =81.17 df=4 P<0.05). The least number of insects was caught in a transparent trap (19.0±2.5 per trap) while the highest number was caught in a yellow trap (54.25±7.03 per trap). The numbers of pests, neutral insects and beneficial insects, caught on traps were significantly different in green traps (χ^2 =9.7 df=2 P<0.05), yellow traps (χ^2 =12.6 df=2 P<0.05), blue trap (χ^2 =11.4 df=2 P<0.05) and white trap (χ^2 =10.5 df=2 P<0.05) but not in transparent traps (Table 02).

Response of Insects in Different Taxa to Different Trap Colors

During the study, of the total collection of 1571 insects, 1545 insects were identified into orders Diptera (40.7%), Hemiptera (21.0%), Hymenoptera (18.4%), Coleoptera (8.3%), and Thysanoptera (11.6%). A few insects (26) were identified in the orders Lepidoptera, Neuropterans and Odonata. A few specimens of spiders (Order Araneae) were also found in the collection.

Dipteran Insects: The dipteran insects caught on the traps belong to the families: Tipulidae, Culicidae, Chironomidae, Agromyzidae, Muscidae and Tephritidae. As per the difficulty of removing the insects from sticky traps the identification of insects to lower taxonomic levels became difficult.

The log-linear analysis of dipterans showed that the number collected significantly varied with the location (χ^2=17.7 df=2 P<0.05) as well as the colour of the trap (χ^2=53.3 df=4 P<0.05). In addition, the interaction between color and location is also significant (χ^2=20.2 df=8 P<0.05).

In Peradeniya site, the number of dipterans caught in traps (253) was significantly varied with the trap colour (χ^2=26.0 df=4 P<0.05). The yellow trap attracted the highest (28.9%), while the blue trap attracted the least percent (13.0%) (Table 03) of dipteran insects. In the Kurunegala site, the number of dipterans caught in traps (213) was significantly varied with the trap colour (χ^2=40.5 df=4 P<0.05). The green trap attracted the highest (37.1%) while the white trap attracted the least percent (13.1%) (Table 03). In the Matale site, the number of dipterans caught in traps (163) significantly varied with the trap colour (χ^2=14.8 df=4 P<0.05). The yellow trap attracted the highest (26.4%) while the white trap attracted the least percentage (9.8%) (Table 03). Considering the results, in two locations, most of the dipteran insects were attracted to the yellow colour. Most of the dipteran insects were neutral insects, so using yellow colour traps could harm neutral dipteran insects.

Table 03: Response of insects for different trap colours in three locations: Kurunegala, Matale and Peradeniya over a 24 hr period

Location	Total no. of insects	Percentage of insects caught in coloured traps				
		Yellow	Blue	Green	White	Transparent
Order: Diptera						
Peradeniya	253	28.9	13.0	24.9	20.6	12.6
Kurunegala	213	18.3	16.9	37.1	13.1	14.6
Matale	163	26.4	17.8	25.8	20.2	9.8
Order: Hemiptera						
Peradeniya	184	37.0	8.7	28.8	16.3	9.2
Kurunegala	86	22.1	14.0	34.9	20.9	8.1
Matale	55	14.5	16.4	40.0	12.7	16.4
Order: Hymenoptera						
Peradeniya	146	21.2	19.3	34.2	13.7	11.6
Kurunegala	65	16.9	21.6	24.6	20.0	16.9
Matale	73	15.1	24.7	31.5	15.0	13.7
Order: Coleoptera						
Peradeniya	79	35.4	12.7	21.5	20.3	10.1
Kurunegala	23	17.4	13.0	47.8	4.4	17.4
Matale	26	30.8	19.2	19.2	15.4	15.4
Order: Thysanoptera						
Peradeniya	91	14.3	34.1	13.2	38.4	0.0
Kurunegala	23	0.0	21.8	39.1	26.1	13.0
Matale	65	1.5	35.4	24.6	20.0	18.5

Hemipteran Insects: The hemipteran insects caught on the traps belonged to the families: Cicadellidae, Delphacidae, Aleyrodidae, Aphidae, Psyllidae, Miridae and Coreidae. Some insects have been damaged during recovery; hence, beyond the identification to the family level.

The log-linear analysis of hemipterans showed that the number of collected insects significantly varied with the location (χ^2=53.7 df=2 P<0.05) as well as the colour of the trap (χ^2=47.0 df=4 P<0.05). In addition, the interaction between colour and location was also significant (χ^2=18.4 df=8 P<0.05). In Peradeniya site, the number of hemipterans caught in traps (184) significantly varied with the trap colour (χ^2=57.3 df=4 P<0.05). The yellow trap attracted the highest (37%) while the transparent trap attracted the least percent (9.2%) (Table 03). In the Kurunegala site, the number of hemipterans caught in traps (86) significantly varied with the trap colour (χ^2=17.3 df=4 P<0.05). The green trap attracted the highest (34.8%) while the transparent trap attracted the least percent (8.1%). In the Matale site, the number of hemipterans caught in traps (55) significantly varied with the trap color (χ^2=14.0 df=4 P<0.05). The green trap attracted the highest (40%) while the white trap attracted the least percent (12.3%) (Table 03).

Hymenopteran Insects: The hymenopteran insects caught on the traps belonged to the families: Braconidae, Ichneumonidae, Trichogrammatidae, Mymaridae, Chalcidae, Eucolidae and Apidae. As the hymenopterans are very fragile, some insects caught on traps are beyond the identification to family level.

The log-linear analysis of hymenopterans showed that the number collected significantly varied with the location (χ^2=31.6 df=2 P<0.05) as well as the colour of the trap (χ^2=18.4 df=4 P<0.05). However, the interaction between colour and location was not significant.

In the Peradeniya site, the number of hymenopterans caught in traps (146) significantly varied with the trap colour (χ^2=22.9 df=4 P<0.05). The yellow trap attracted the highest (21.2%) while the transparent trap attracted the least percentage (13.7%) (Table 03). In the Kurunegala site, the number of hymenopterans caught in traps (65) did not significantly vary with the trap colour. The mean number caught per trap was 13. In Matale site, the number of hymenopterans caught in traps (73) did not significantly vary with the trap colour. The mean number caught per trap was 14.6 (Table 03).

The most important beneficial insects such as parasitoids and pollinators were belonging to the order Hymenoptera. Considering the results, most of the hymenopterans were attracted to luminous green-colored traps. Therefore, luminous green traps are not a viable option for sticky traps as they harm more on beneficial insects.

Coleopteran Insects: The coleopteran insects caught on the traps belonged to the families: Chrysomelidae, Coccinellidae, Scolytidae and Curculionidae.

The log-linear analysis of coleopteran showed that the number collected significantly varied with the location (χ^2=37.2 df=2 P<0.05) as well as the colour of the trap (χ^2=10.2 df=4 P<0.05). However, the interaction between color and location was not significant.

In Peradeniya site, the number of coleopterans caught in traps (79) significantly varied with the trap colour (χ^2=15.5 df=4 P<0.05). The yellow trap attracted the highest (35.4%) while the transparent trap attracted the least percentage (10.1%). In Kurunegala site, the number of coleopterans caught in traps (23) significantly varied with the trap colour (χ^2=12.4 df=4 P<0.05). The green trap attracted the highest (47.8%) while the white trap attracted the least percent (4.3%). In the Matale site, the number of coleopterans caught in traps (26) did not significantly vary with the trap colour. The mean number of insects caught per trap was 5.2 (Table 03).

Thysanopteran Insects: The log-linear analysis of thysanopterans showed that the number collected significantly varied with the locations

(χ^2=7.6 df=2 P<0.05) as well as the colour of the trap (χ^2=52.2 df=4 P<0.05). Further, the interaction between the colour and location was also significant (χ^2=46 df=8 P<0.05).

In the Peradeniya site, the number of Thysanopterans caught in traps (91) significantly varied with the trap colour (χ^2=11.1 df=4 P=0.03). The white trap attracted the highest (38.5%) while the transparent trap attracted the least percentage (0%). In the Kurunegala site, the number of Thysanopterans caught in traps (23) did not significantly vary with the trap colour and the average insect number per trap was 4.6. In the Matale site, the number of Thysanopterans caught in traps (65) significantly varied with the trap colour (χ^2=19.5 df=4 P=0.03). The blue trap attracted the highest (35.4%) while the yellow trap attracted the least percent (1.5%) (Table 03).

Any agricultural ecosystem contains a wide range of species which include insects and other arthropods. This has been demonstrated in this study as well. The richness of insect species and species abundance are related to resource availability and resource concentration (Haddad *et al.,* 2001). Plant texture (foliage, flower, stem) and nectar resources are more strongly related to species richness and abundance (Marques *et al.,* 2000). The sampling sites of this study had different crops and even in different stages of the crop phenology, producing a variation in resources for insects, resulted in variation in insect abundance. Peradeniya, Kurunegala, and Matale sites had 50, 26, and 24% of the total insect catch, respectively, which explained the variability of abundance among the sites. The insects caught in traps included pests as well as beneficial and neutral insects. The role of neutral insects in the agroecosystem is not evident. But, it is important that the beneficial insects and neutral insect components should not be disturbed when implementing pest management strategies.

The insects caught on the trap could be due to attraction to the trap colour or caught on the trap due to random movement. The total number of insects caught per trap included the insects caught through both mechanisms. It is difficult to separate the proportion of insects caught randomly as the insect vision is not fully comprehended to date. It can be assumed that the catch on transparent trap could be the result of random movement of insects, 12.2% of the total catch of this study, but there is no scientific evidence to prove this argument. In this experiment, the number of total insects caught in transparent traps was 15.5% in Kurunegala, 13.4% in Matale, and 9.7% in Peradeniya sites.

Data show the tendency for significant increases when the insect number caught in traps was high (>75 insects/trap) (Table 02). This might be due to the dissociation of the randomly caught component from the caught component due to attraction to the colors. However, the data in this study do not show any clear attractions of pest, beneficial or neutral insects to any particular colors (Figure 01). Hence, the use of sticky traps as a tool in pest management should be done with extreme care as they catch beneficial insects and neutral insects in addition to the pest.

A lack of clear attraction to particular color could be associated with species-specific attraction. Different insect species attracted to different colors. As an example, the parasitoids, *Aphelinus mali, Encarsia* spp., and some predators such as lacewings are attracted to yellow colour (Shaw and Wallis, 2008), while Castillo and Rojas (2020) showed the variation of colour attraction of the parasitoids: *Cephalonomia stephanoderis, Prorops nasuta,* and *Phymastichus coffea.* The variation of colour attraction of phytophagous insects is also well documented. Thrips are more attracted to blue than white and yellow (Pobozniak *et al.,* 2020). Aphids are attracted to yellow and bright green (De Barro, 1991). Whiteflies are attracted to yellow (Webb *et al*., 1985). A similar variation was found among many taxonomic groups (Disney *et al*., 1982). Hymenopterans are also differently attracted to yellow, blue, white, fluorescent blue, and fluorescent yellow (Buffington *et al*., 2020). A hemipteran predator, *Macrolophus pygmaeus* is attracted blue and yellow (Böckmann and Meyhofer, 2017). Hence, it is clear that an inconsistent pattern of colour attraction could be due to the variability of species in three locations. This suggests that the colour trap recommendation should be crop specific considering the associated insect community as well as crop phenology specific to ensure the least harm to beneficial and neutral insects.

Having considered the overall results of this study, the use of sticky traps for the purpose of mass trapping of pest species should be done with extreme care, especially in the traps set in open fields. A study of attraction to colour by species may be useful to make a conclusion on which colour sticky traps should be used for which crop at which stage.

CONCLUSIONS

None of the traps caught more than 50% of pest insects, so it is in doubt whether sticky traps could be used without affecting the non-target insects like beneficial insects and neutral insects.

Declaration of interest statement

The authors declare no conflicts of interest.

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