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TRAPPING OF INSECTS ON DIFFERENT COLOR STICKY TRAPS FOR MONITORING AND MANAGING KEY PESTS IN LOW TUNNEL AND WALK-IN TUNNEL VEGETABLE PRODUCTION SYSTEMS

Talha Nazir[1], Mazhar Hussain Ranjha[*2], Habib ur Rehman[3], Atif Ali[4], Ali Raza[5]

[1,*2,4,5]*Department of Entomology, University of Agriculture, Faisalabad Sub-Campus, Depalpur Okara, Pakistan*
[3]*Water Management Research Farm, Renal Khurd, Okara, Pakistan*

[*2]mazhar.ranjha@uaf.edu.pk

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Corresponding Author: *
Mazhar Hussain Ranjha

Abstract
Low and Walk-in Tunnels are mostly used for off season vegetables in Punjab, Pakistan. Effective pest monitoring and management are crucial for tunnel-based vegetable production to discourage insect pest outbreaks in a closed environment. The present research work was conducted to evaluate the insect-trapping potential of colored sticky traps in low and walk-in tunnels. Maximum pest population (8.12 average insects/trap/week) was recorded on yellow sticky traps, whereas minimum population (0.29 average insects/trap/week) was recorded on transparent traps in low vegetables tunnels. In the walk-in tunnel, the highest population (10.00 average insects/trap/week) was recorded in yellow traps, whereas the lowest (0.12 average insects/trap/week) was recorded in transparent traps. Temporal data showed the minimum number of insects on the beginning of March. These findings confirm the effectiveness of yellow sticky traps for monitoring insect pests and highlight the importance of trap color and crop season timing in optimizing pest management strategies in protected vegetable production systems.

Introduction

Protected agriculture can be described as the cultivation of crops in an environment that is extremely fertile, involving the effective use of available land and water. To ensure a consistent supply of vegetables during the off-season, farmers adopt tunnel farming (Leach and Isaacs, 2018).

Like open crop farming, proactive agriculture is not protected from pests such as insects and diseases. Insect pests such as aphids, thrips, whiteflies, hoppers, and leaf miners frequently reduce crop yield in greenhouse settings (Maleknia *et al.*, 2016). Aphids are particularly prevalent pests in greenhouse crops, lowering yields by direct phloem consumption, photosynthesis inhibition by sugary materials, and the transmission of plant viruses. Insecticides are usually used to control aphid populations, leading to insect resistance, pollinator decline, environmental pollution, and serious risks to food safety (Garibaldi *et al.*, 2018; Wyckhuys *et al.*, 2020 a,b).

Inadequate ventilation in high tunnels can lead to elevated humidity levels, which may promote the spread of diseases like leaf mold (*Fulvia fulva*) and powdery mildew (*Oidium neolycopersici*) in tomato vegetables (Frey *et al.*, 2020a). Additionally, if certain insect pests and airborne pathogens survive within high tunnels during the winter, they can lead to an initial emergence of ailments or pest infestations in the following spring (Frey *et al.*, 2020b). To effectively manage pests and diseases in high tunnel production systems, an integrated approach combining cultural, physical, and biological practices is recommended. These

strategies may include mulching, enhancing biodiversity, crop rotation, cover cropping, applying compost, splicing, soil solarization, and selecting resistant cultivars (Li *et al.*, 2021). Walk-in tunnels have two functions: they assist prolong the growing season for vegetable production and act as a physical barrier to keep out airborne diseases and non-soil-dwelling insect pests (Acharya *et al.*, 2020).

In greenhouses, biodiversity aids in the efficient management of pests by promoting the preservation and growth of natural adversaries (Dunn et al., 2020). In general, pest management is improved by increasing the diversity of natural enemies (Snyder *et al.*, 2019). Plants and increased plant diversity can boost the richness and population densities of natural enemies by offering those resources, such as alternative prey or hosts, pollen, nectar, and shelter (Zhang *et al.*, 2024). Numerous studies have demonstrated improved pest control by increasing plant diversity within or around cropping systems (Zhou *et al.*, 2024). Biocontrol is eco-friendly insect pest species management strategy (Wen *et al.*, 2023; Xiong *et al.*, 2021). *Eupeodes corollae*, a widely distributed hoverfly species, has been effectively used for the integrated management of aphids in greenhouse settings (Djellab *et al.*, 2019). Similarly, green lacewings (*Chrysoperla carnea Stephens*) are globally recognized as important biological control agents for aphids and other soft-bodied pests (Letardi *et al.*, 2020). Past research has shown successful use of C. *carnea* in controlling aphids on crops such as spinach and strawberries grown in tunnel systems (Aghdam and Nemati, 2020; Willden *et al.*, 2024). In present study we investigated the whole crop seasons of three vegetables for the potential of sticky traps of different colors in both low tunnel and walk in tunnels and the relative incidence of different insect pest's species on the three vegetables.

Materials and Methods

Experiment Site

An experiment with a Factorial Randomized Complete Block Design (RCBD) was conducted in three replications. The experiment was conducted in a Chak No. 82/6-R Sahiwal, Punjab, Pakistan. In these experiment two types of Tunnels (Low tunnel and Walk-in Tunnel) were used. For monitoring, three different-colored sticky traps (blue, red, and yellow) were used. Transparent traps made of a firm plastic sheet with glue material was used as a control. Three vegetables (Bitter gourd (*Momordica charantia*), Onion (*Allium cepa*) and Tomato (*Solanum lycopersicum*) were sown in each Tunnel. Bitter Gourd seed (Golo F-1), Onion seed (Nasarpuri), and Tomato seed (Sahel, Redrock, Anna) varieties are used in the experiment. The area covered by Walk-in tunnels is 9 acres, and the area covered by Low tunnels is 3 acres. Basal dose, i.e., 01 bag DAP, 01 Bag Urea, and 01 bag Potash per acre, was applied for cr. Gross plot size was 898.8 m^2.

Experimental Layout

Data collection

Population reduction over control for each type of insect species on different host plants (vegetables) was noted. The collected insects were brought in the Lab of Entomology, Constituent College Depalpur for specimens' diagnosis.

Statistical Analysis

Data obtained were statistically examined using ANOVAs while differences between treatment means were analyzed by using Tuckey's test at 5 % level of significance.

Results

Results showed that main effects (sticky traps and weeks) were highly significant ($P<0.01$), while the interactive effect (Sticky Traps* Weeks) was significant for average insect structure on different-colored sticky traps over one-week time intervals (Table 1).

Table 1 Analysis of Variance (ANOVA) for mean infested Vegetables plants under tunnels, planting densities.

S.O.V	DF	Low Tunnel		Walk-in Tunnel	
		F-value	P-value	F-value	P-value
Sticky Traps	3	30.82	P<0.01	32.68	P<0.01
Weeks	13	106.91	P<0.01	109.21	P<0.01
Sticky Traps* Weeks	39	2.23	P<0.05	2.31	P<0.05

Average population of insects in Low Vegetables Tunnels in March

The average population of insect's species changes during the month of March according to the results (Fig.1).In a starting the insect's population is low, with the passage of time its populations increased. The lowest mean number of insects is (0.29 insects/Trap/week) was occurring on transparent sticky traps in the initial week of March, while the highest mean number of insects (8.12 insects/Trap/week) was recorded on yellow traps in the 4th week of March. Population of insect's species on trap continuously increased with the passage of time.

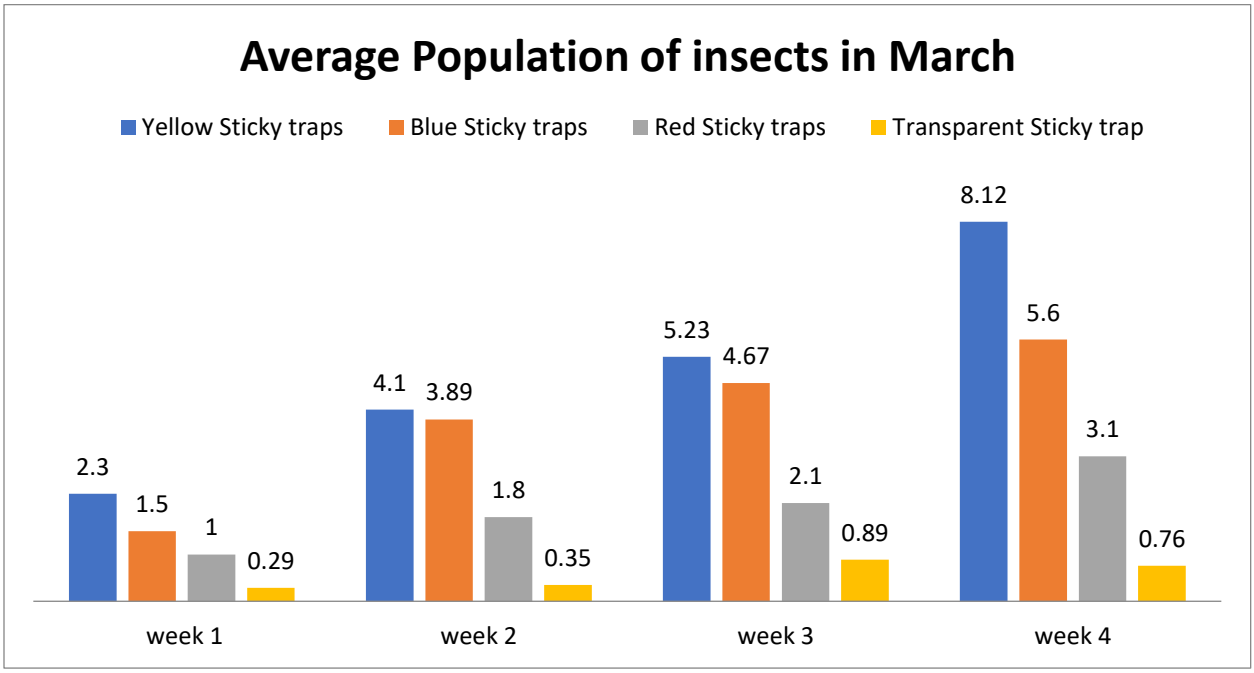


Figure 1 Mean numbers of insects on insect traps in low vegetable Tunnels at different weeks in March

Average population of insects in Low Vegetables Tunnels in April

The average population of insect's species in an April month increases as compare to march month, according to the results (Fig.2).The lowest means number of insects is (3.52 average insects/Trap/week) was occurring on Transparent sticky traps in the initial week of April, while the highest mean number of insects (7.56 insects/Trap/week) was recorded on yellow traps in the 4th week of April.

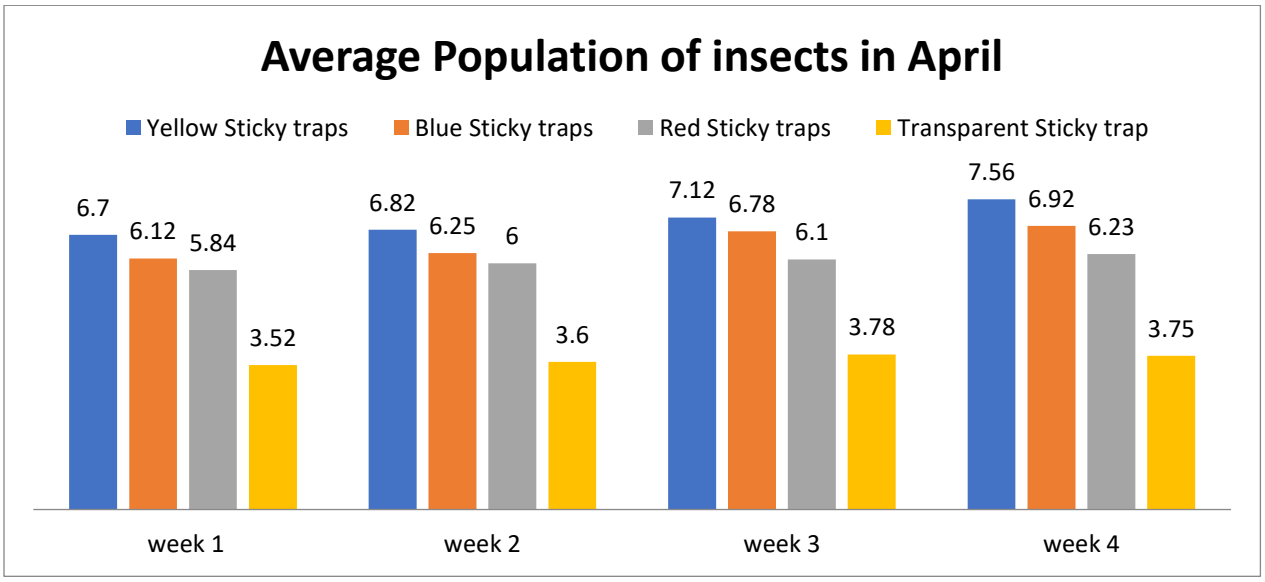


Figure 2 Mean numbers of insects on insect traps in low vegetable Tunnels at different weeks in April.

Average population of insects in Low Vegetables Tunnels in May

Average population of insects fluctuated during the month of May, according to the findings (Fig. 3). During the 4th week, there was the lowest mean number of insects on traps, followed by the 1st week average number of insects have highest, while the fourth week's lowest mean number of insects was observed on all sticky traps.

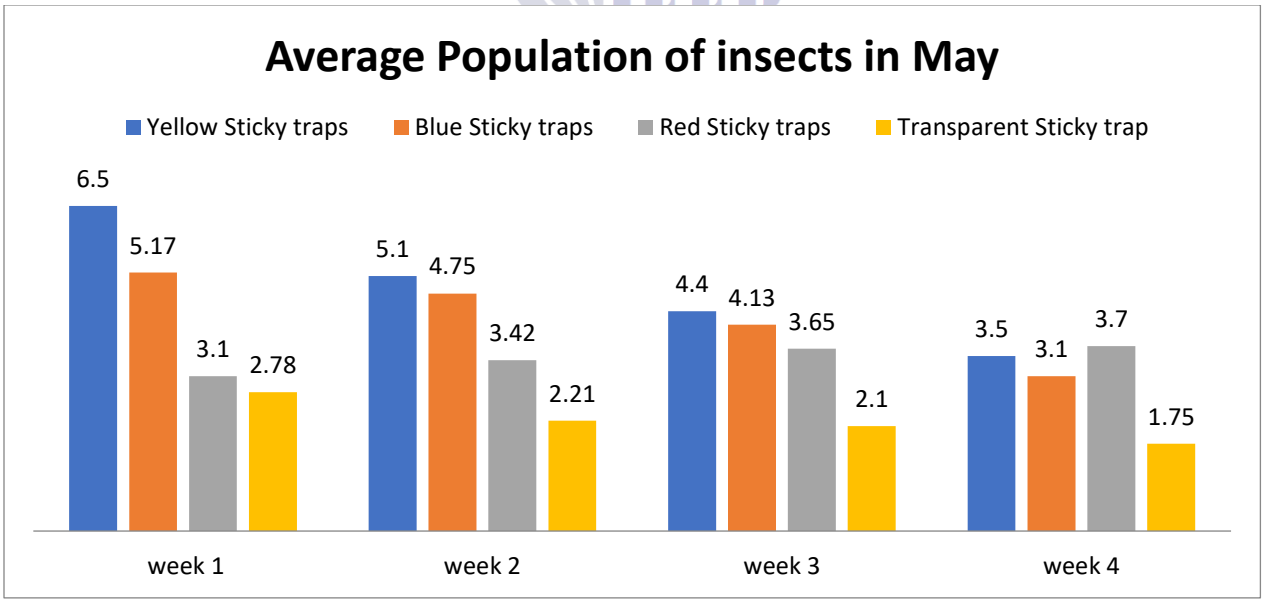


Figure 3 Mean numbers of insects on insect traps in low vegetable Tunnels at different weeks in May

Average population of insects in Low Vegetables Tunnels in a June

Average population of insects varied during the month of June, according to the findings (Fig. 4). During the 4th week, there was the lowest average number of insects on traps, followed by the 3rd week, while the maximum insect population was observed on yellow sticky traps during 1stweek.

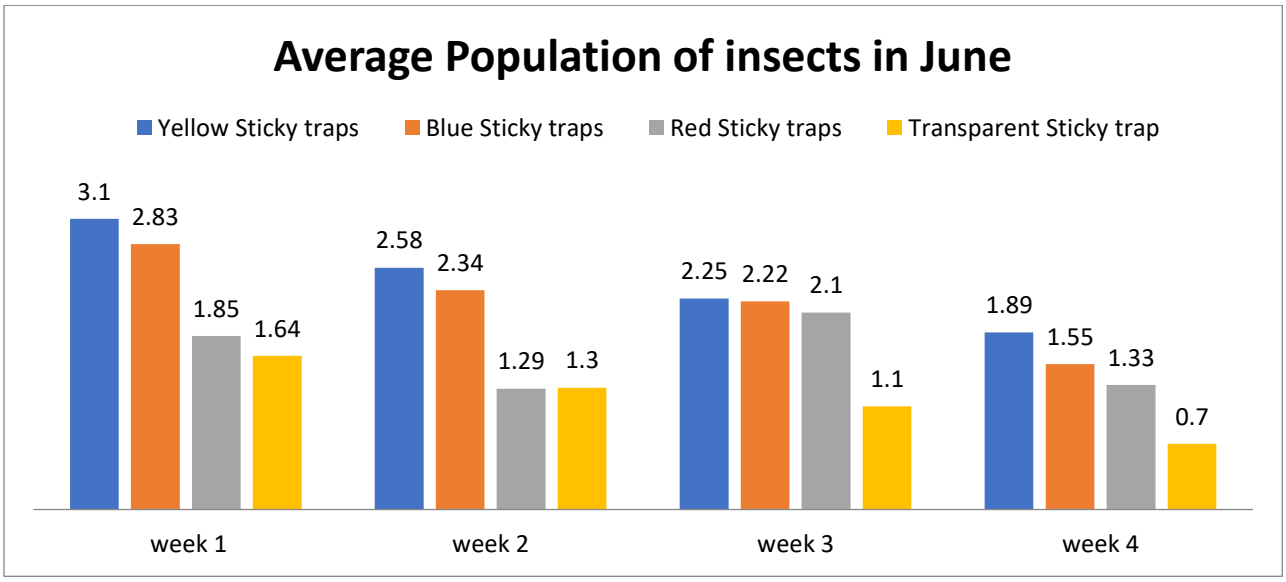
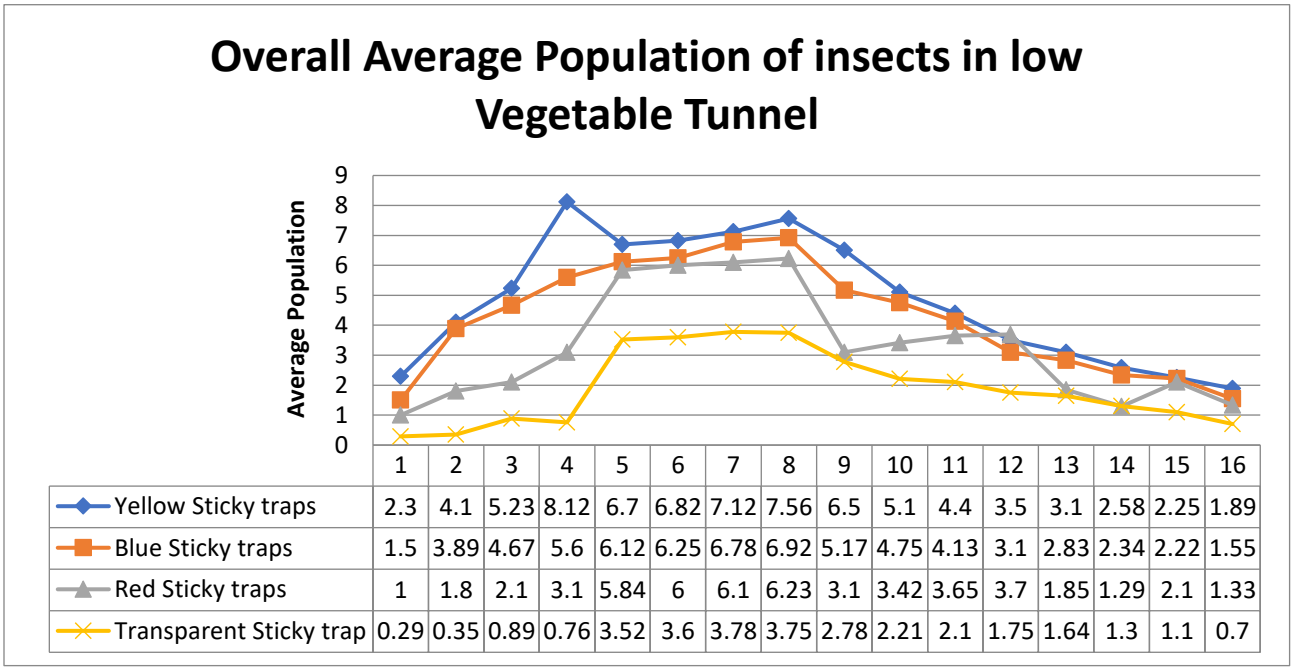


Figure 4 Mean numbers of insects on insect traps in low vegetable Tunnels at different weeks in June



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Yellow Sticky traps	2.3	4.1	5.23	8.12	6.7	6.82	7.12	7.56	6.5	5.1	4.4	3.5	3.1	2.58	2.25	1.89
Blue Sticky traps	1.5	3.89	4.67	5.6	6.12	6.25	6.78	6.92	5.17	4.75	4.13	3.1	2.83	2.34	2.22	1.55
Red Sticky traps	1	1.8	2.1	3.1	5.84	6	6.1	6.23	3.1	3.42	3.65	3.7	1.85	1.29	2.1	1.33
Transparent Sticky trap	0.29	0.35	0.89	0.76	3.52	3.6	3.78	3.75	2.78	2.21	2.1	1.75	1.64	1.3	1.1	0.7

Figure 5 Comparison of average number of insects captured on different colored sticky traps over different weeks in low tunnel during the study period

Average population of insects in Walk-in Vegetables Tunnels in March

The average population of insect's species changing during the month of March according to the results (Fig.6).In a starting the insect's population is low, with the passage of time its populations increased. The lowest mean number of insects is (0.3 insects/Trap/week) was occurring on transparent sticky traps in the initial week of March, while the highest mean number of insects (6.65 insects/Trap/week) was recorded on yellow traps in the 4th week of March. Population of insect's species on trap continuously increased with the passage of time.

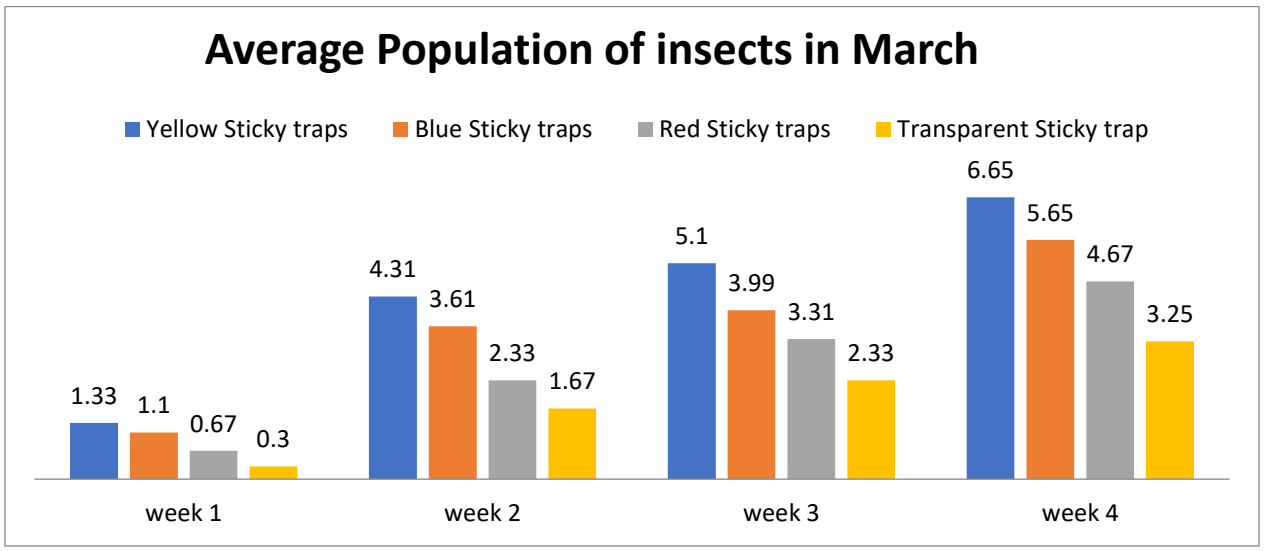


Figure 6 Mean numbers of insects on insect traps in Walk-in vegetable Tunnels at different weeks in March

Average population of insects in Walk-in Vegetables Tunnels in an April

In Walk-in tunnel showed that maximum population (10 Avg. insects/trap/week) were recorded in case of yellow sticky traps while the lowest (4.31 Avg. insects/trap/week) were captured on transparent traps. Blue sticky traps were the next more effective for insect attraction as compared to the red color sticky traps. On Transparent sticky traps lowest populations of insects recorded in (Fig. 7).

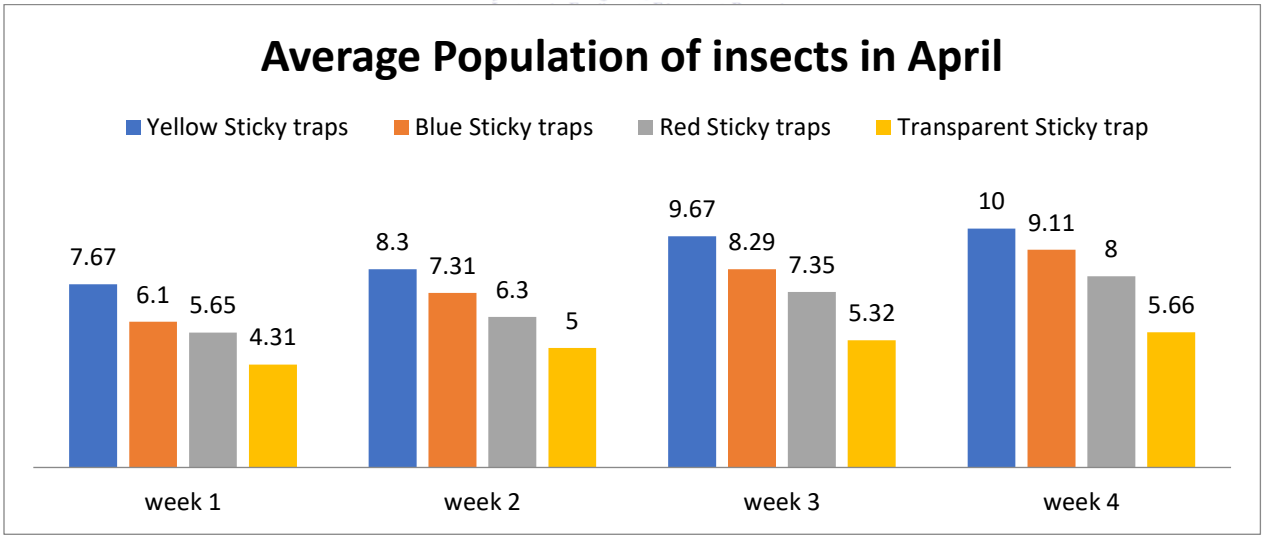


Figure 7 Mean numbers of insects on insect traps in Walk-in vegetable Tunnels at different weeks in April

Average population of insects in Walk-in Vegetables Tunnels in a May

Average population of insects changed during the month of May, according to the results (Fig. 8). The highest mean number of insects was observed on control traps in the starting week of April, while the lowest mean number of insects was recorded on blue traps in the fourth week. Insect's population continuously decreased.

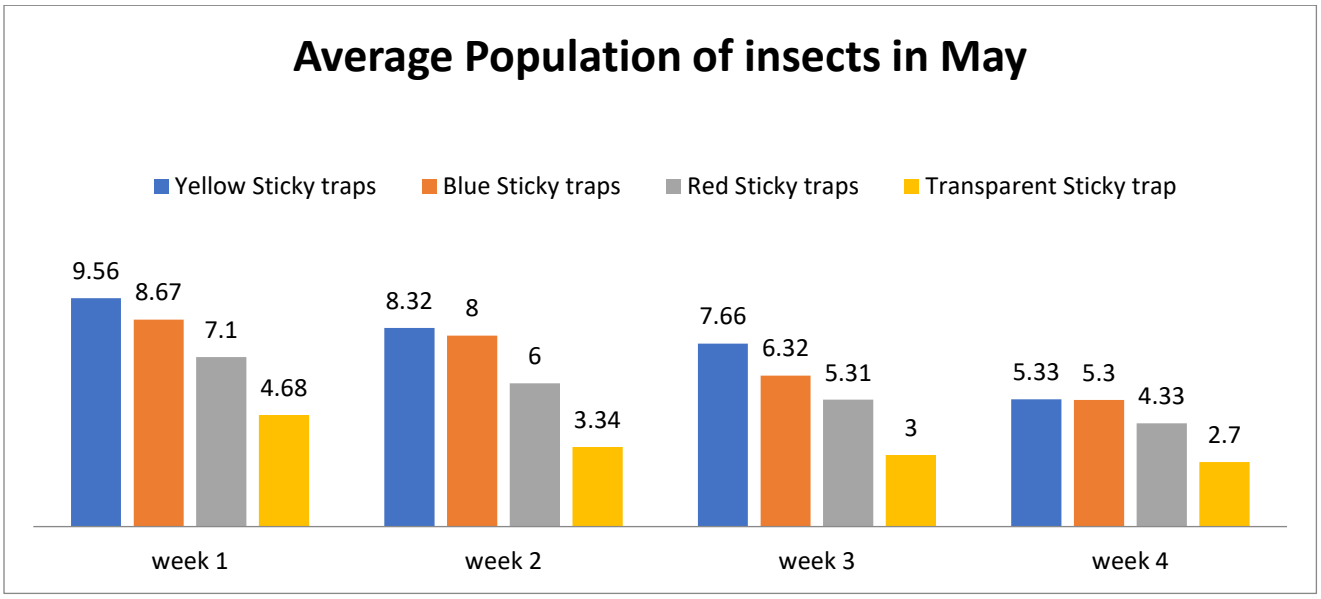


Figure 8 Mean numbers of insects on insect traps in Walk-in vegetable Tunnels at different weeks in May

Average population of insects in Walk-in Vegetables Tunnels in a June

Average population of insects fluctuated during the month of June, as shown in (Fig. 9). On Yellow sticky traps, the average number of insect was observed as maximum (4.67) in the 1st week, trailed by average population in the 3rd week (2. 8 insect/week), on transparent sticky traps, the average number was minimum in the fourth week (0.12 average insect/trap/week) on transparent sticky trap.

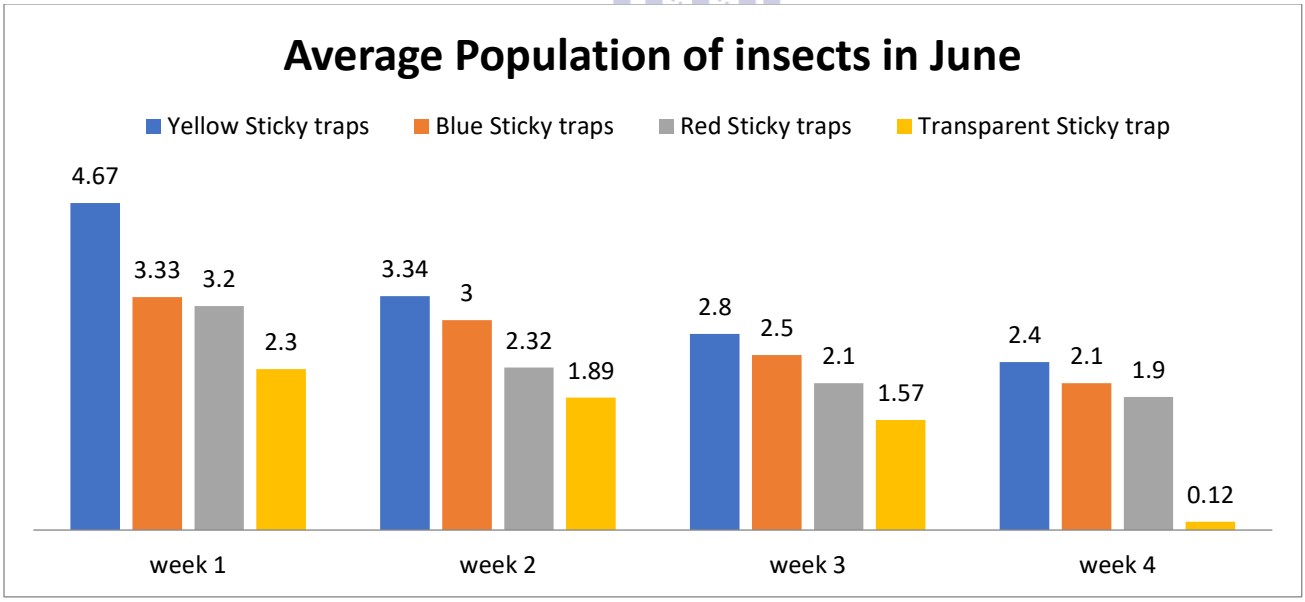
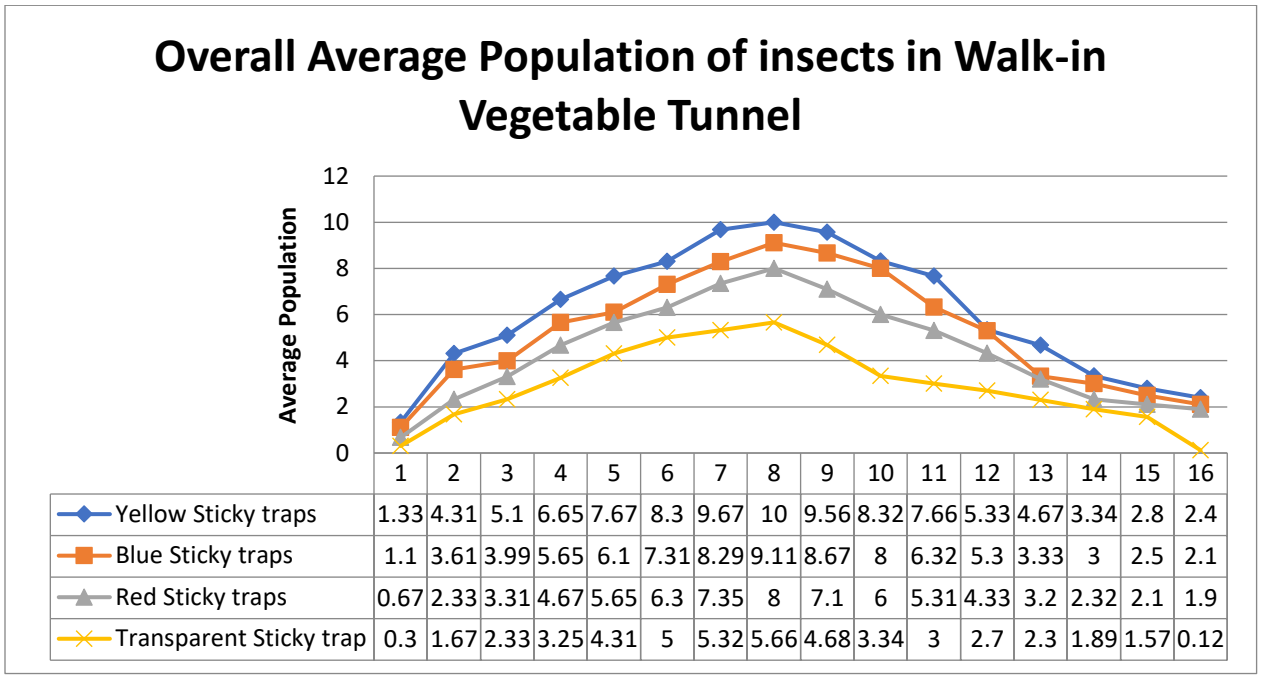


Figure 4.9 Average numbers of insects on insect traps in Walk-in Vegetables Tunnels at different weeks of June



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Yellow Sticky traps	1.33	4.31	5.1	6.65	7.67	8.3	9.67	10	9.56	8.32	7.66	5.33	4.67	3.34	2.8	2.4
Blue Sticky traps	1.1	3.61	3.99	5.65	6.1	7.31	8.29	9.11	8.67	8	6.32	5.3	3.33	3	2.5	2.1
Red Sticky traps	0.67	2.33	3.31	4.67	5.65	6.3	7.35	8	7.1	6	5.31	4.33	3.2	2.32	2.1	1.9
Transparent Sticky trap	0.3	1.67	2.33	3.25	4.31	5	5.32	5.66	4.68	3.34	3	2.7	2.3	1.89	1.57	0.12

Figure 10 Comparison of average number of insects captured on different colored sticky traps over different weeks in Walk-in tunnel during the study period

Discussion

The present study highlights the effectiveness of insect traps as a crucial tool for monitoring and managing pest populations in low-tunnel and walk-in-tunnel vegetable production systems. The findings demonstrated that trap-based monitoring not only provided reliable insights into pest incidence and population dynamics but also served as an important component for implementing timely management strategies. The findings of Lu *et al.* (2012), who examined the effects of yellow sticky traps on the population dynamics of the sweet potato whitefly in both semi-field and full field environments, corroborated the findings of the current study trial. By using yellow sticky traps, the number of whiteflies' nymphs and adults was significantly reduced under the former situation. Whiteflies were significantly fewer in greenhouses using the insect control method than in the check plot. Although nearly comparable populations of whitefly nymphs and adults were seen in the treated and check plots, there was no discernible decrease in the population incidence of whiteflies in the field. Although yellow sticky traps are not appropriate for field use, they were an efficient method of controlling whiteflies in greenhouse settings. The current research trial's results, which showed a trend of a relatively higher quantity of insects on yellow traps, were consistent with those of Buffington *et al.* (2021), who assessed the trapping potential of yellow, white, and blue pan traps. The average number of captures on the different colored traps varied considerably. According to the current investigation, which supported the findings of both studies, a comparatively higher number of insects were caught on yellow traps than on the other traps. The ability of yellow and blue sticky traps to capture insect pests on tomato crops was investigated by Zulkifli *et al.* (2024). Two colored traps were used: six blue and six yellow sticky traps. The research trial's findings showed that the average number of insects captured on the insect traps varied remarkably. According to the current study, yellow sticky traps were shown to be relatively more effective than blue sticky traps, which supported the findings.

In our study, a much higher number of insects were found on the sticky traps in the walk-in

tunnel than in the low tunnel. Ingwell *et al.* (2017), which examined insect pest populations in high tunnels and field production over two years for three crops, cucumber, broccoli, and tomato, supported our findings. Aphids and whiteflies are among the greenhouse pests that are more prevalent in high tunnels than in field plots. The crucifer caterpillar complex, which comprises the imported cabbage looper, cabbageworm, and diamondback moth, was also more abundant in high tunnels. Cucumber beetles that were spotted and striped were more prevalent in high tunnels. The findings of Stephenson *et al.* (2019), who examined the effects of high tunnels on populations of aphids, thrips, and whiteflies on tomatoes grown in both field and high tunnel conditions for the spring and fall seasons of two production years, corroborated the results of the current study's relatively high insect population. Data on plant growth and environmental variables were collected. High tunnel production led to an increase in whitefly populations. In the current study, comparatively less insect populations were observed in the low tunnel as opposed to the high tunnel. The findings of Acharya *et al.* (2020), who investigated the effect of low tunnel on the incidence of insect variety, were in agreement with the research findings. Low tunnels were observed to reduce insect infestations in the current study. Furthermore, the decreased insect damage indicates that low tunnels may be a useful tool for sustainable vegetable production. The findings of Tian *et al* (2023) were consistent with the rapid proliferation observed in high tunnels as opposed to low tunnels.

Conclusion

The findings revealed that yellow sticky traps were the most effective, followed by blue, red, and transparent traps. This clearly indicates that trap color plays a critical role in insect attraction, with yellow being the most attractive, thus making it the most suitable choice for monitoring and managing pest populations in vegetable production systems.

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