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RESEARCH ARTICLE

Assessment of coloured sticky traps for the monitoring of flea beetles (*Phyllotreta* spp.) (Coleoptera: Chrysomelidae) in radish crop

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Abstract

Flea beetles (*Phyllotreta* spp.) are herbivores that feed on *Brassica* plants and pose a significant threat, leading to considerable economic losses. Considering the increasing infestation of flea beetles in radish-growing areas across India, this study evaluated the effectiveness of coloured sticky traps - yellow, blue and white - in monitoring adult flea beetle, *Phyllotreta chotanica* Duvivier, populations in a radish field. The population density of flea beetles and percent leaf infestation was assessed weekly during trap capture observations across the radish crop cycle, from sowing to harvest. Blue traps were the most effective, with a peak of 7.00 ± 2.92 beetles per week at 49 days after sowing (DAS) and a mean of 4.89 beetles/week. Yellow traps also performed well, peaking at 7.00 ± 1.69 at 56 DAS, with a mean of 4.53 beetles/week. White traps were the least effective, with a mean of 2.89 beetles/week. Our findings indicate that blue and yellow traps captured the highest number of adult flea beetles, consistent with prior research demonstrating a preference for blue and yellow traps in agricultural settings. This study supports blue and yellow sticky traps as one of the better-integrated pest management (IPM) tools to implement as a prophylactic method of pest control for flea beetles in radish cultivation.

Keywords

coloured sticky traps; flea beetle; *Phyllotreta* spp.; radish

Introduction

Flea beetles of the genus *Phyllotreta* (Coleoptera: Chrysomelidae) are economically significant pests globally, primarily affecting plants in the Brassicaceae family. About 250 species occur worldwide (1), only 12 species are documented in India (2-4). These beetles preferentially target various plant families, including Brassicaceae, Resedaceae, Cleomaceae, Limnanthaceae, Capparaceae and Tropaeolaceae (5). Adult flea beetles undergo hibernation in wooded areas and become active in early spring, laying eggs in soil or on plant parts. The grubs emerge, feeding on the roots of seedlings before pupating underground, typically completing one to two generations annually. While both grub and adult stages cause damage, but most significant impact is observed in adult stage, which cause distinctive "shot-hole" damage on leaves, leading to reduced crop yield and quality (6).

Globally, radish (*Raphanus sativus* L.) is cultivated in several countries, including China, Japan, the United States and parts of Europe. This root vegetable is valued for its rapid growth and nutritional benefits, but is increasingly threatened by flea beetle infestations, resulting in substantial economic losses. India ranks second in vegetable production, contributing significantly to global yields. The Ministry of Agriculture and Farmers Welfare's 2023-24 report indicates that India produces approximately 3146 metric tons (MT) of radish across 200 hectares (ha), with Tamil Nadu cultivating radish in area of 4.76 ha giving a yield of about 167.84 MT. The primary radish-producing states include West Bengal, Bihar, Assam, Haryana, Madhya Pradesh, Odisha, Punjab, Chhattisgarh, Uttar Pradesh, Jharkhand, Tamil Nadu and Jammu & Kashmir. The severity of flea beetle damage increases with population density, posing challenges for cruciferous crop growers worldwide.

Recent reports suggest that striped flea beetle (*Phyllotreta striolata*) can cause considerable damage to radish and mustard crops, with leaf infestations reaching 63% and root infestations at 54% in Haryana and Delhi (7). Such damage not only affects plant growth but also reduces marketability, leading to economic losses (6). The researchers investigated flea beetle species diversity in cruciferous crops across various agroecological zones in Kashmir and found that, among the four species identified, adults of *P. striolata* were the most abundant, inflicting moderate to severe damage on Brassica crops (8). Another researcher evaluated the type of flea beetle species in cruciferous crops in Rajasthan. *Phyllotreta chotanica* Duvivier and *Chaetocnema basalis* Baly (Coleoptera: Chrysomelidae) were identified as the predominant species affecting mustard and radish (9).

To combat these issues, non-chemical pest management techniques, including coloured sticky traps, are increasingly being used in pest control strategies. These traps leverage flea beetles' visual preferences for effective monitoring and control, which makes them a sustainable option widely adopted in Integrated Pest Management (IPM) programs across various regions such as North America, Europe and Asia. Research has shown that flea beetles exhibit a preference for yellow and white traps over other colours, such as red or blue, particularly in canola fields in the USA (10-12). Yellow sticky traps have proven particularly effective for detecting early emergence and monitoring population peaks of flea beetles. Their attraction to yellow is attributed to spectral sensitivity, as the colour mimics flowers and pollen, providing visual cues associated with food and oviposition sites (13).

This study investigates the effectiveness of coloured sticky traps in managing *Phyllotreta* populations in radish fields in India. The present research work addresses the following questions: 1) How do flea beetles respond to different coloured traps? 2) Which colour trap is most effective for monitoring flea beetles? 3) At which growth stage of the radish crop are flea beetles most responsive to these traps? 4) Is there a relationship between trap catches and field infestation levels? This research work aims to contribute to development of sustainable pest management strategies and enhance IPM strategies for radish cultivation globally.

Materials and Methods

Study area and experimental layout

The field experiment was conducted in a farmer's field cultivating a radish crop in Narasipuram, Coimbatore, Tamil Nadu, India (Latitude: 10.9725° N, Longitude: 76.7648° E). The investigation was carried out during the warm and dry climatic conditions of February and March 2024, aligning with the optimal cultivation period for radish in this agro-climatic zone. The experimental area covered one acre. The study was conducted from sowing to harvest, with the crop maintained without any pesticide spray.

Trap placement and arrangement

The experiment was conducted with yellow, blue and white sticky traps as treatments with eight replications under Randomized Block Design (RBD). The commercially available blue (21 cm × 29 cm) and yellow (21 cm × 29 cm) sticky traps were used for the study (Fig. 1A and 1B). Meanwhile, the white sticky traps (Fig. 1C) were locally prepared using white foam board sheets of 3 mm thickness. The boards were cut into a 21 cm × 29 cm rectangular shape and castor oil was used as an adhesive agent for sticky purposes. All traps were installed during sowing leaving 3-4 m from the field border and positioned 12-15 cm above the crop canopy by securing them to 1.5 m tall bamboo stakes (Fig. 1D and 1E). The height of the stakes was adjusted regularly to ensure the traps remained 12-15 cm above the crop canopy throughout the study. Eight traps of each colour were installed as replications, positioned in zigzag manner to ensure comprehensive coverage of the entire cropped area. The traps were positioned in all four directions, with two traps per direction. Each trap covered an area of 170 m^2. The field was evenly infested mainly with flea beetle *Phyllotreta chotanica* Duviver.

Observations were recorded at seven-day intervals throughout the crop period, from sowing to harvest. The number of flea beetles captured on each sticky trap beetles trapped was noted (Fig. 2A, 2B and 2C). For yellow and blue traps, previously trapped insects were marked to ensure they were not counted in subsequent observations; only newly captured insects were included in the count. For white traps, fresh traps coated with castor oil were installed in place of the previous ones at weekly intervals. The count of trapped insects was determined by counting the specimens collected from these replaced traps. The data were analysed statistically using GRAPES software (14).

Percentage of leaf infestation

The entire field was divided into several subplots, from which 10 random subplots were selected for observation. In each subplot, 10 random radish plants were chosen and for each plant, the total number of leaves and the number of damaged leaves were recorded. The percentage of leaf infestation was calculated using the formula: the number of damaged leaves divided by the total number of leaves per plant, multiplied by 100 (7). Infestation percentages were recorded at seven-day intervals, with observations made on the same days the sticky traps were set for the study.

Field assessment of flea beetle adult population

The entire field was divided into multiple subplots, from which 10 subplots were randomly selected for observation. In each selected subplot, 10 radish plants were chosen at random and the number of adult flea beetles present on each plant was

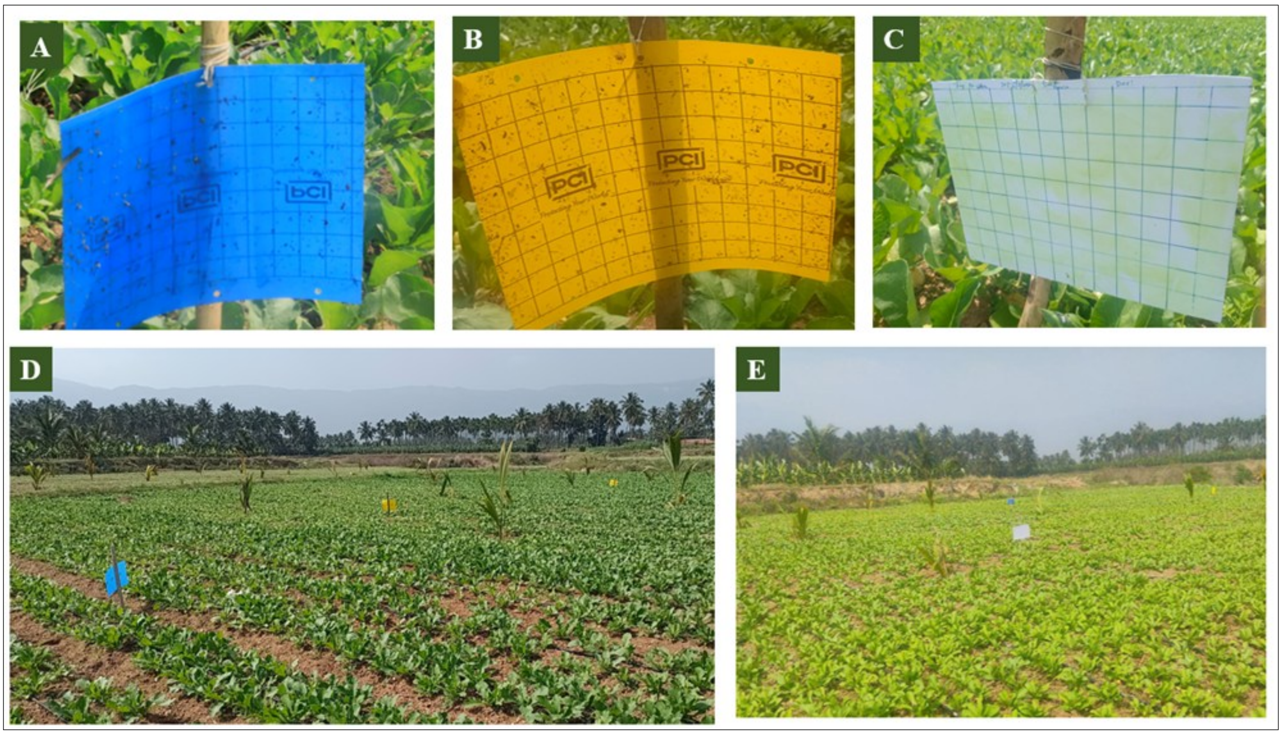

Fig. 1. Different coloured sticky traps installed in the field A- Blue sticky trap; B - Yellow sticky trap; C - White sticky trap; D & E - Field installation of coloured sticky traps.

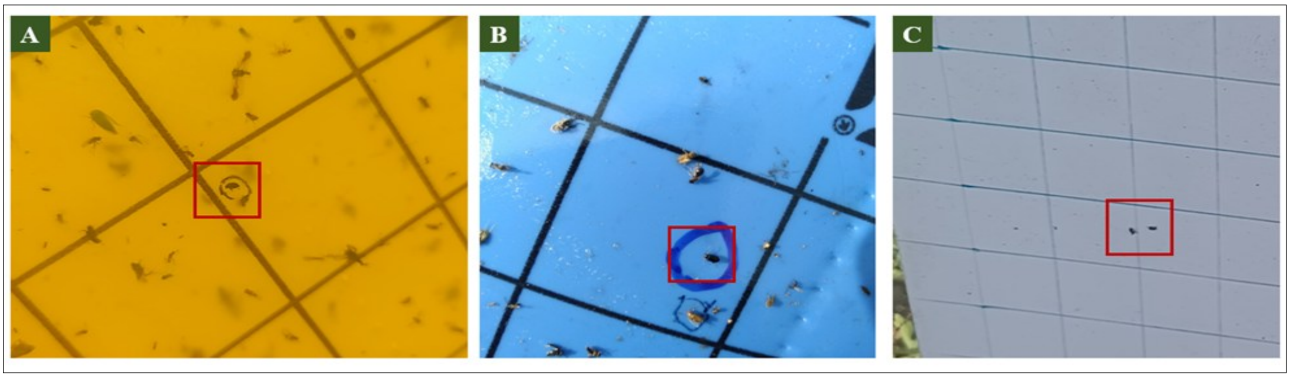

Fig. 2. Flea beetles trapped in yellow (A), blue (B) and white (C) sticky traps.

recorded (7). The adult population was recorded at seven-day intervals, corresponding to the days when observations were made for the sticky trap study and expressed as number per plant.

Statistical analysis

Data were analysed using analysis of variance (ANOVA) and treatment means were statistically compared using the Least Significant Difference (LSD) test at the $p < 0.05$ level. GRAPES software was employed for statistical analysis of sticky trap counts as well to establish correlations with crop age, percentage of leaf infestation and adult flea beetle population in the field throughout the study (14).

Results

Efficiency of coloured sticky traps

The study evaluated the efficacy of yellow, blue and white sticky traps in capturing flea beetles, *P. chotanica*. The results show significant variations in the effectiveness of the different coloured sticky traps *viz*., yellow, blue and white, in capturing flea beetles at various stages of the crop cycle from 7 to 56 DAS. The number of flea beetles captured by the traps varied considerably depending on the trap colour and the growth stage of the radish crop. The data on flea beetle captures concerning the different coloured sticky traps at weekly intervals are presented in Table 1 and graphically represented in Fig. 3.

Yellow traps were highly effective, especially in the later stages of the crop, capturing the highest number of insects at 49 DAS (6.37 ± 2.06 insects/week) and 56 DAS (7.00 ± 1.69 insects/week). Early in the crop period, they showed reasonable effectiveness, capturing an average of 3.00 ± 0.92 insects at 7 DAS. The mean capture rate over the entire period was 4.53 insects/week, underscoring their reliability for flea beetle management.

Similarly, blue sticky traps demonstrated consistent effectiveness across all stages, peaking at 49 DAS (7.00 ± 2.92 insects/week) and showing strong performance at 42 DAS (5.12 ± 1.64 insects/week). Their mean capture rate of 4.89 insects/week was slightly higher than yellow traps, particularly during the mid-crop stages (e.g., 14 and 42 DAS). These results suggest that blue sticky traps can be equally effective or even superior in some phases.

White traps consistently captured fewer flea beetles than the yellow and blue traps, with the highest captures recorded at 49 DAS (3.87 ± 1.24) and the lowest at 7 DAS (2.12 ± 0.35). The mean capture for white traps was 2.89 insects/week, indicating that they were the least effective among the three colours.

Table 1. Evaluation of flea beetle attraction to different coloured sticky traps in radish

Coloured sticky trap	Mean number of insects trapped in sticky traps [x ± SE]*										
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	49 DAS	56 DAS	Mean	SE	CD (0.05)
Yellow sticky trap	3.00±0.92^{a}	2.62±0.51^{b}	4.50±0.53^{a}	4.62±0.74^{a}	4.62±1.06^{a}	3.50±1.41^{b}	6.37±2.06^{a}	7.00±1.69^{a}	4.53	0.632	1.270
Blue sticky trap	2.87±0.64^{a}	3.87±0.83^{a}	4.37±1.06^{a}	4.75±0.70^{a}	5.00±1.30^{a}	5.12±1.64^{a}	7.00±2.92^{a}	6.12±2.10^{a}	4.89	0.787	1.582
White sticky trap	2.12±0.35^{b}	3.12±0.83^{ab}	2.50±0.53^{b}	2.87±0.64^{b}	2.62±0.74^{b}	3.12±1.12^{b}	3.87±1.24^{b}	2.87±1.12^{b}	2.89	0.455	0.914
Mean	2.67	3.21	3.79	4.08	4.08	3.92	5.75	5.33			
SE	0.28	0.40	0.34	0.37	0.43	0.71	1.10	0.53			
CD (p<0.05)	0.60	0.86	0.73	0.79	0.93	1.53	2.37	1.13			

*Mean of eight replications; SE - Standard error; DAS - Days after sowing; CD - Critical difference; Figures in a column means followed by a common letter are not significantly different by LSD (p<0.05) The level of significance for CD values will be indicated as * or **

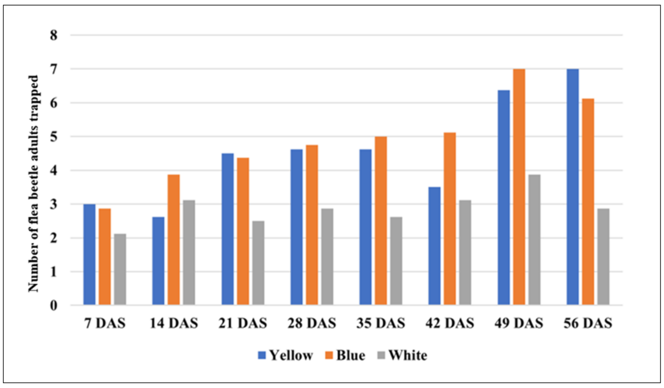

Fig. 3. Number of flea beetle adults trapped on different coloured sticky traps at various crop stages.

Throughout the observation period, the performance of the coloured traps regarding flea beetle captures was ranked as follows: blue > yellow > white. This trend was consistent across all sampling periods, indicating that blue and yellow sticky traps were the most effective in managing flea beetle populations throughout the crop growth stage.

Flea beetle population and leaf infestation in relation to age of radish crop

The data presented in Table 2 shows a progressive increase in leaf infestation by flea beetles as the radish crop matures. The percentage of leaf infestation and the number of adult flea beetles per plant showed a consistent increase from 7 DAS to 56 DAS.

At 7 DAS, there were an average of 0.96 adult flea beetles per plant and the leaf infestation was 17.84%. The leaf infestation increased to 20.79% as the crop age increased to 14 days, with the mean flea beetle of 1.06 per plant. When the crop reached 21 days, both the leaf infestation and flea beetle populations rose to 27.66% and 1.14 adults per plant. At 28 DAS, the percentage of leaf infestation was 30.55% and there were 1.32 flea beetles per plant. While, at 35 DAS, the infestation rate slightly increased to 31.64% with the adult population of 1.60 per plant. The most significant increase was seen at 42 DAS, where leaf infestation surged to 35.28% and adult beetle counts increased to 2.98 per plant, indicating rise in beetle activity during this period. By 49 DAS, infestation levels reached 39.26%, with 1.64 adults per plant and at 56 DAS, the peak infestation level of 44.98% was observed, along with a mean of 1.74 adults per plant.

Relationship between crop age, leaf infestation, flea beetle population and trap counts on sticky traps

The correlation analysis revealed a strong positive relationship between crop age and the leaf infestation (r = 0.93, ***p<0.001) but no significant relationship with mean number of flea beetles observed per plant (r = 0.64), indicating an increase in flea beetle

Table 2. Relationship between crop age and leaf infestation by flea beetle

Crop age during observation	Percent of leaf infestation by adult beetles*	Mean number of adults observed per plant*
7 DAS	(17.84±5.400)^{f}	(0.96±0.114)^{e}
14 DAS	(20.79±3.430)^{ef}	(1.06±0.207)^{de}
21 DAS	(27.66±4.263)^{de}	(1.14±0.230)^{de}
28 DAS	(30.55±6.053)^{cd}	(1.32±0.217)^{cd}
35 DAS	(31.64±7.760)^{cd}	(1.6±0.283)^{bc}
42 DAS	(35.28±4.864)^{bc}	(2.98±0.356)^{a}
49 DAS	(39.26±3.428)^{ab}	(1.64±0.182)^{b}
56 DAS	(44.98±4.935)^{a}	(1.74±0.152)^{b}
Mean	31.00	1.555
SE	3.419	0.144
CD (P<0.05)	7.003	0.296

*Mean of ten replications; SE - Standard error; DAS - Days after sowing; CD - Critical difference

Figures in a column means followed by a common letter are not significantly different by LSD (p<0.05)

leaf infestation as the crop matures. Blue and yellow sticky traps showed significant correlations with crop age (r = 0.93, ***p<0.001 and r = 0.83, *p<0.05, respectively), demonstrating their increased effectiveness in capturing flea beetles over time, while white traps exhibited a weaker, non-significant correlation (r = 0.60). Leaf infestation had a significant correlation with blue and yellow traps (r = 0.92, **p<0.01, r = 0.88, **p<0.01, respectively), suggesting stronger trapping efficiency when there was an increase in leaf infestation, further highlighting their effectiveness in managing flea beetle populations as infestation levels rise. While the white traps did not show any significant relationship with leaf infestation, which showed moderate but non-significant correlations with other variables, indicating lower efficiency compared to yellow and blue traps.

Discussion

The examination of different coloured sticky traps in attracting the flea beetles infesting radish provided a valuable insight into their efficacy. The results indicate that the coloured sticky traps, particularly blue and yellow, play a significant role in capturing flea beetles at various growth stages of radish. The differences in trapping efficiency are critical for understanding the role of visual cues in flea beetle behaviour and highlight the importance of colour selection for effective pest monitoring and devising management strategies to minimize crop damage, particularly during peak infestation periods.

The blue sticky traps outperformed both yellow and white traps in attracting flea beetle adults throughout the crop growth stages, with the highest mean flea beetle capture (4.89

insects/week). It coincided with the critical infestation period between 35 and 56 DAS, when flea beetle activity and leaf infestation in radish were at their peak. The strong correlation between trap counts and leaf infestation percentages (r = 0.92, **p<0.01) further highlights the efficiency of blue traps in identifying areas of high infestation, making them valuable for timely intervention.

Yellow sticky traps were also highly effective, particularly from 28 DAS onward, though they were slightly less efficient than blue traps. The yellow traps were most effective during mid-to-late crop stages, especially at 49 and 56 DAS. These results align with existing research, which indicates that yellow is highly attractive to a wide range of insect pests, including flea beetles, due to its association with flowering plants and the reflective properties of yellow wavelengths (13).

Our findings indicate that flea beetles were highly attracted to blue sticky traps, followed by yellow sticky traps. This aligns with previous studies, which have shown the effectiveness of yellow and blue traps in capturing various insect pests due to their spectral sensitivity (15, 16). Specifically, other studies demonstrated that thrips are attracted to these colours, with yellow traps being particularly effective due to their resemblance to flowers and pollen, key attractants for many insect species (17, 18). These observations further support the species-specific responses of pests to different trap colours in IPM strategies.

The high capture rates in yellow and blue traps throughout the crop period suggest these traps are effective tools for monitoring and managing flea beetle populations in radish fields. Yellow sticky traps are recommended to be installed at a density of 10 traps/ha, positioned 12–15 cm above the plant canopy, to optimize capture rates (6). This aligns with the findings of the current study, where yellow traps and blue sticky trap consistently captured the most flea beetles. The strong correlations between crop age, flea beetle abundance and leaf infestation percentage emphasize the importance of strategically placing traps as the crop matures. As crop age increased, the number of flea beetles and leaf infestations also rose, with the highest trap counts occurring in blue (r = 0.93, ***p<0.001) and yellow (r = 0.83, *p<0.05) traps (Table 3).

Additionally, the correlation between percent leaf infestation and flea beetle counts in blue (r = 0.92, **p<0.01) and yellow (r = 0.88, **p<0.01) traps underscore the value of these traps as part of an IPM approach. Sticky traps not only serve as effective monitoring tools, but can also be used in conjunction with eco-friendly pest control methods, such as entomopathogenic fungi or natural predators, to manage flea beetle populations (19). These findings reinforce earlier work, which highlighted the effectiveness of yellow sticky traps for capturing *Phyllotreta* spp. in radish crops (20). White sticky traps were the least effective in capturing flea beetles, with an average capture of 2.89 insects per trap. The weak correlations between white trap counts, crop age (r = 0.60) and leaf infestation levels (r = 0.54) indicate that white traps are less suitable for flea beetle monitoring. The poor performance of white traps suggests that flea beetles rely more heavily on other visual cues, such as specific wavelengths emitted by blue and yellow, to locate host plants. The results suggest that colour preference is critical in insect pest management, noting that pests tend to avoid neutral colours like white in preference for visually stimulating colours. Therefore, white traps should not be recommended for monitoring flea beetles in radish crops.

The strong performance of blue and yellow traps suggests their potential for use in an IPM program, where early detection and monitoring are critical for timely intervention. Yellow traps were less effective than blue traps in the earlier stages of crop growth (7–21 DAS), where the number of beetles captured was consistently lower. This suggests that while yellow traps are reliable during peak beetle activity, they may not be as effective for monitoring early-stage infestations when flea beetle populations are just beginning to establish. Incorporating attractants, such as semiochemicals or plant volatiles, could enhance trap efficacy during early infestations, improving detection and enabling timely pest management interventions.

Conclusion

Blue sticky traps proved to be the most effective in capturing flea beetles throughout the radish crop cycle, followed closely by yellow traps. In contrast, white traps were significantly less effective and are not recommended for flea beetle monitoring. These findings provide critical insights for farmers and pest management professionals to enhance flea beetle monitoring and control strategies in radish and other cruciferous crops. The integration of blue and yellow sticky traps into IPM strategies is essential for the effective management of flea beetle populations in radish crops, reducing reliance on chemical interventions and promoting sustainable agricultural practices. Future studies could investigate the potential for combining blue and yellow sticky traps with other non-chemical pest control strategies, such as biological control agents, to further enhance their

Table 3. Correlation between the crop age, flea beetle population, leaf infestation and trapping of flea beetles in different colour sticky trap

Parameters	Crop age	Percent leaf infestation	No. of adults/ plant	Trap count		
				Yellow sticky trap	Blue sticky trap	White sticky trap
Crop age	**1**					
Percent leaf infestation	0.99***	**1**				
No. of adult/ plant	0.64	0.58	**1**			
Trap count- yellow sticky trap	0.83*	0.88**	0.14	**1**		
Blue sticky trap	0.93***	0.92**	0.47	0.85**	**1**	
White sticky trap	0.60	0.54	0.39	0.40	0.77*	**1**

*** Correlation is significant at 0.001 level (two tailed)

** Correlation is significant at 0.01 level (two tailed)

* Correlation is significant at 0.05 level (two tailed)

Error df = 14

effectiveness in IPM programs. Additionally, exploring the influence of environmental factors, such as light intensity and trap placement, could help optimize the performance of coloured sticky traps in different cropping systems. Future studies should focus on integrating sticky traps with biological controls, optimizing trap designs and evaluating their broader application across crops and agro-climatic conditions.

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Authors' contributions

BC, MS, PSS, MM, SH and KG were involved in the conceptualization and participated in the methodology. BC conducted the formal analysis and investigation. BC was responsible for writing the original draft and MS contributed to reviewing and editing. Supervision was provided by MS, PSS and MM. The first draft of the manuscript was written by BC and all authors provided comments on previous versions. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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