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Tahreem Nasir
Student, Department of Entomology, Lahore College for Women University, Pakistan

Eman Younas
Department of Biological Sciences, Superior University, Lahore, Punjab, Pakistan.

Corresponding Author:
Tahreem Nasir
Student, Department of Entomology, Lahore College for Women University, Pakistan

Evaluating the efficacy of UV-b and UV-c light traps for non-chemical pest control in greenhouse-grown pea plants (*Pisum sativum*)

Tahreem Nasir and Eman Younas

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Abstract
Pisum sativum (pea) is a nutritionally valuable legume widely cultivated in greenhouse systems. However, its productivity is often compromised by insect pests such as aphids (*Aphididae*) and whiteflies (*Aleyrodidae*). Conventional chemical pesticides, though effective, pose risks including environmental contamination, human health hazards, and the development of pest resistance. In pursuit of sustainable, non-chemical pest control strategies, this study investigates the effectiveness of ultraviolet (UV) light traps specifically UV-B and UV-C wavelengths in managing pest populations in greenhouse-grown pea plants. Fifteen potted *P. sativum* plants were divided into three experimental groups: Group 1 exposed to UV-B light, Group 2 to UV-C light, and Group 3 serving as the untreated control. Over a three-month period, weekly pest counts were conducted across the upper, middle, and lower canopy layers. Results revealed a statistically significant reduction in aphid and whitefly densities, particularly in the upper and middle canopy layers of UV-treated groups, compared to the control. These findings suggest that wavelength-specific UV light traps offer a promising alternative to chemical pesticides for Integrated Pest Management (IPM) in protected horticultural environments.

Keywords: Leguminous, dietary fiber, greenhouse, infestation, IPM, UV lights *Pisum sativum*, Pea plant, Greenhouse pest management, UV light traps, UV-B, UV-C, Aphids, Whiteflies, Sustainable pest control, Integrated pest management (IPM), non-chemical control method, insect population monitoring, protected cultivation, light-based pest control, entomological control strategies

1. Introduction
The pea plant (*Pisum sativum* L.), a member of the Fabaceae family, is a globally significant legume cultivated for its nutritional value and agronomic benefits. As the fourth most important leguminous grain crop worldwide, it plays a vital role in food security and sustainable agriculture due to its high protein content, vitamins, minerals, and nitrogen-fixing capabilities (Villegas-Fernández *et al*., 2021 [1]; Aboelfadel *et al*., 2023) [3]. In Pakistan, where over 1 million hectares are dedicated to pea cultivation, yield remains suboptimal compared to global averages, with Punjab contributing 71% of the national production (Khan *et al*., 2015) [4].

Pea crops are particularly vulnerable to insect pests such as aphids (*Aphididae*), whiteflies (*Aleyrodidae*), leaf miners, thrips, and pea weevils, which collectively cause substantial yield losses through direct feeding, viral transmission, and fungal infections like powdery mildew (Sandhi & Reddy, 2020 [5]; Pobozniak *et al*., 2022) [13]. For instance, leaf miner flies have been reported to cause up to 90% crop damage (Khan *et al*., 2015) [4]. Traditional pest management in pea crops often relies heavily on chemical pesticides, leading to pest resistance, ecological imbalance, and potential health hazards (Abbas *et al*., 2022) [15].

Greenhouse-based agriculture offers enhanced environmental control and season extension, particularly for high-value crops like peas. However, the closed ecosystem of greenhouses also creates favorable conditions for rapid pest multiplication (Park *et al*., 2014) [9]. While integrated pest management (IPM) strategies have introduced biological, cultural, and mechanical interventions, recent research has turned toward physical methods, such as light-based pest control, as sustainable alternatives (Jonason *et al*., 2014 [11]; Pikington *et al*., 2009) [8]. Ultraviolet (UV) light, particularly within UV-A (315-400 nm), UV-B (280-315 nm), and UV-C (<280 nm) bands, has gained traction for pest deterrence and mortality.

Several studies have shown that UV exposure affects insect behavior, physiological development, and immune function (Jenkins, 2009) [19]. However, most of the existing research focuses on UV-A or generalized UV sources, with limited investigation into comparative effects of UV-B and UV-C in protected environments like greenhouses, especially in legume crops such as *P. sativum*.

1.1 Research gap and study aim
Despite growing interest in light-based pest management, there remains a lack of empirical studies evaluating wavelength-specific UV light traps (UV-B vs. UV-C) under greenhouse conditions for legume crops. This study aims to bridge that gap by investigating the effectiveness of UV-B and UV-C light traps in suppressing pest populations (specifically aphids and whiteflies) in greenhouse-grown pea plants. The findings are expected to inform sustainable pest control strategies and contribute to broader IPM frameworks in protected horticulture.

2. Review of literature
Ultraviolet radiation is a physical tool increasingly explored for its effects on insect development and behavior. Khan *et al*. (2021) [20] demonstrated that UV-A radiation significantly impairs the immune function of *Bemisia tabaci* (whitefly) nymphs, reducing growth and increasing mortality, particularly in early instars. Their findings also indicated a complex interaction between UV-A exposure and biological control agents such as *Encarsia formosa*, with prolonged exposure reducing parasitism efficiency while leaving adult emergence unaffected.

Explored the long-term physiological responses of red and green morphs of pea aphids to UV-B radiation over eight generations. Their results showed consistent decreases in protein content and increases in glycogen and trehalose levels, indicating a stress response. Notably, enzyme activity involved in oxidative defense was also altered, suggesting that UV-B exposure could affect the aphids' adaptability and fitness.

Meneghini *et al*. (2014) [12] and Jonason *et al*. (2014) [11] highlighted that insects exhibit species-specific attraction to different light wavelengths, including ultraviolet spectra, making UV light traps a promising avenue for pest control. Pachkin *et al*. (2022) [17] and Sakai & Osakabe (2010) [16] further emphasized the importance of wavelength specificity, noting that trap efficiency can be enhanced by tailoring light types to pest phototactic behavior.

While these studies confirm the potential of UV radiation as a non-chemical pest deterrent, most have been conducted under controlled laboratory settings or focused on single UV bands. Moreover, few have explored comparative studies using UV-B and UV-C light traps within real-world greenhouse settings, particularly in economically significant crops like *P. sativum*. This study builds on existing findings by assessing how both UV-B and UV-C light traps influence pest dynamics in a greenhouse-grown pea crop, addressing a notable gap in applied entomological research.

3. Materials and Methods
3.1 Experimental Site
The study was conducted in a controlled greenhouse environment at Lahore College for Women University, Lahore, Pakistan, during the period from November 2021 to March 2022. This season was selected due to its suitability for pea cultivation and natural aphid infestation.

3.2 Cultivation of *Pisum sativum*
Certified seeds of pea (*Pisum sativum*) were procured from Ahmed Garden Farm and Nursery, Lahore. The seeds were sown in individual containers (12 cm diameter × 20 cm depth) filled with a 1:1 mixture of vermicompost and garden soil. The experimental design consisted of three treatment groups Group A, Group B, and Group C with each group comprising five replicate plants (e.g., Plant 1, Plant 2 and Plant 5).

3.3 Environmental Control and Monitoring
Key environmental parameters such as temperature, humidity, and soil pH were monitored and regulated to ensure uniform growth conditions across all groups. Plants received 5-7 hours of natural sunlight daily.

- Average daytime temperature ranged from 18.2°C to 27°C, and nighttime temperatures ranged from 5.9°C to 11°C.
- Relative humidity was maintained between 55% and 67% using natural ventilation and supplemental exhaust fans.
- Blackout screens were used to regulate light intensity.

These controls aimed to minimize confounding environmental effects on plant growth and pest infestation.

3.4 Pest Monitoring and Quantification
The infestation of aphids and whiteflies was recorded weekly. A standardized visual inspection method was employed across all groups (A, B, and C).

- For each plant (N=5 per group), three leaves (top, middle, and bottom) were selected for pest counting.
- The number of adult aphids and whiteflies per leaf was recorded using a magnifying glass, and the average number per leaf was calculated.
- Both pre-treatment and post-treatment data were documented to evaluate treatment efficacy.

3.5 UV Light Sources
Two types of ultraviolet (UV) light sources were selected for pest control experimentation:-

- **UV-B:** 280-315 nm wavelength
- **UV-C:** 100-280 nm wavelength

UV lamps were suspended at a height of 35 cm above the plant canopy within the greenhouse.

3.6 UV Light Treatment Protocol
Plants were treated as follows:

- **Group A (UV-B exposure):** Plants were exposed to UV-B light **twice a week** for **3 hours per session**.
- **Group B (UV-C exposure):** Plants were exposed to UV-C light **twice a week** for **2-3 minutes per session**.
- **Group C (Control):** No UV light exposure; plants received natural light only.

After each treatment, aphid and whitefly populations were counted on the selected leaf layers as described in section 3.4. The mean population count was used to compare treatment effectiveness across groups.

4. Results
4.1 Seed plantation
In the last week of January, nine pots were sown with pea seeds and placed in the green house for testing purposes.

Fig 1: Showing the pea seeds planted in pots.

4.2 Pest infestation in pea plants

The first pest to attack the pea plant was a caterpillar known as *Cydia nigricana*. Later the occurrence of two sucking insect pests, aphid (*Aphis fabae*) and whitefly (*Trialeurodes vaporarium*) on pea plants was detected, as shown in Fig. 4.2. The first aphid sighting came in the last week of January, with a mean density of 1.22 aphids per leaf. Following that, there was a progressive increase with a mean population of 4.77 aphids per leaf, followed by an increase in the last week of March with 8.88 aphids per leaf.

The first incidence whitefly was observed in the last week of February, with a mean density of 1.11 whiteflies per leaf. Following that, a modest increase was recorded in the second week of March with 2.88 whitefly per leaf, peaking at 5.0 aphids/leaf in the last week of March. By the end of March, the aphid and whitefly populations had reached their peak.

Fig 2: Showing the pest incidence in pea plants *(a) caterpillar (Cydia nigricana) (b) aphid (Aphis fabae) (c) whitefly (Trialeurodes vaporarium).*

4.3 Exposure to UV-B and UV-C lights

Fig 3: Showing pea plants of group A and B exposed to UV lights (a) UV-B (280315nm) and (b) UV-C (100-280nm).

4.4 Impact of UV-B and UV-C lights on pest population

The main purpose of this treatment was to reduce insect density by exposing the plants to various UV lights. In the

green house UV was increased artificially by using special lights i.e. UV B and UV C. Aphid densities were measured weekly following UV treatment, as shown in Tables 4.4.1.1 and 4.4.1.2. Because they were directly exposed to the UV light, UV therapy had a considerable influence on reducing the quantity of aphids present on the upper layer leaves. The bulk of aphids were identified on lower leaves in the pea pots, indicating that UV was only efficient in lowering the aphid population on top leaves. It was observed that the location of aphid could mediate UV effects, aphids that feed on the underside of leaves were protected from negative effect of UV rays.

Table 4: Represents the average population of aphids when exposed to UV-B and UV-C lights in February.

Weeks	UV Equipped	No of aphids/leaf					
		Before treating with UV			After treating with UV		
		Upper layer leaves	Middle layer leaves	Lower layer leaves	Upper layer leaves	Middle layer leaves	Lower layer leaves
Week 1	UV B	13	15	16	7	11	14
Mean		1.44	1.66	1.77	0.77	1.22	1.55
S.D±S.E		0.527±0.175	0.534±0.166	0.833±0.277	0.432±0.132	0.440±0.146	0.527±0.175
Week 2	UV C	15	17	22	7	12	17
Mean		1.66	1.88	2.44	0.77	1.33	1.88
S.D±S.E		0.5±0.166	0.833±0.277	0.881±0.293	0.833±0.277	1±0.333	1.833±0.677
Week 3	UV B	17	24	31	12	22	33
Mean		1.88	2.66	3.44	1.33	2.44	3.66
S.D±S.E		0.833±0.277	1±0.332	1.130±0.376	0.766±0.288	1.130±0.376	1.512±0.547
Week 4	UV C	20	26	36	14	29	38
Mean		2.22	2.88	4.0	1.55	3.22	4.22
S.D±S.E		0.971±0.323	0.781±0.260	1.118±0.372	0.527±0.175	1.201±0.400	1.402±0.844

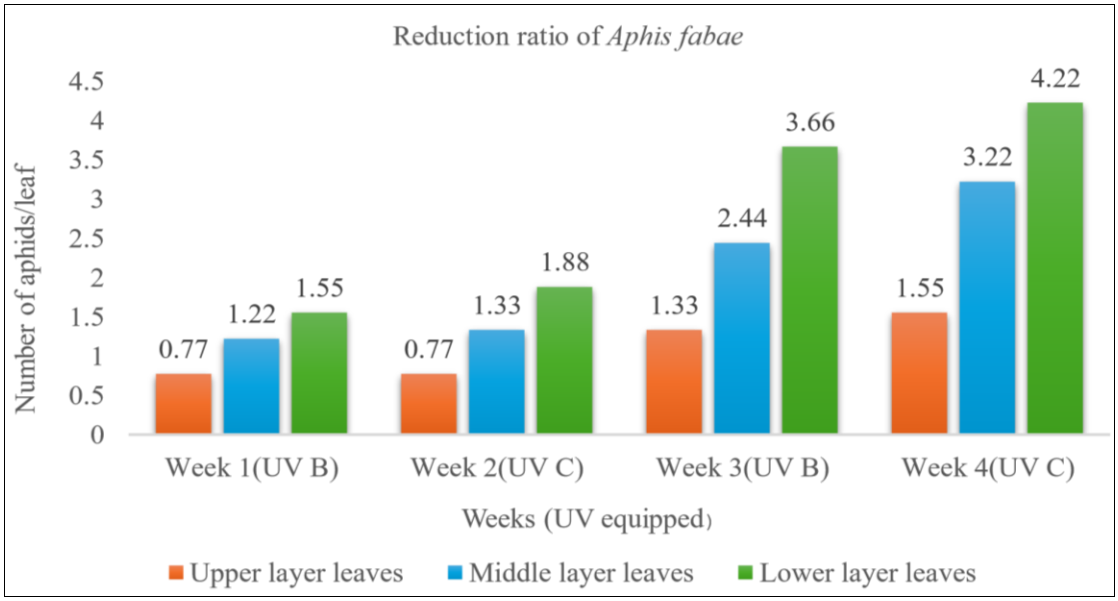

Fig 4: Showing the decrease in the population density of aphids when exposed to UV lights in February.

Table 5: Represents the average population of aphids when exposed to UV-B and UV-C lights in March.

Weeks	UV equipped	No of aphids/leaf					
		Before treating with UV			After treating with UV		
		Upper layer leaves	Middle layer leaves	Lower layer leaves	Upper layer leaves	Middle layer leaves	Lower layer leaves
Week 1	UV B	20	32	42	14	35	45
Mean		2.22	3.55	4.66	1.55	3.88	5.0
S.D±S.E		0.971±0.323	1.013±0.337	1.322±0.440	0.521±0.175	1.364±0.454	1.411±0.471
Week 2	UV C	22	41	49	17	43	53
Mean		2.44	4.55	5.44	1.88	4.77	5.88
S.D±S.E		1.011±0.337	1.333±0.444	1.231±0.412	0.833±0.277	1.481±0.493	1.051±0.351
Week 3	UV B	25	46	56	23	49	60
Mean		2.77	5.11	6.22	2.55	5.44	6.66
S.D±S.E		1.561±0.521	3.480±1.160	2.041±0.682	1.011±0.337	3.395±1.131	2.541±0.849
Week 4	UV C	31	53	64	27	57	67
Mean		3.44	5.88	7.11	3.0	6.33	7.44
S.D±S.E		1.131±0.376	2.059±1.019	2.666±0.881	0.866±0.288	2.692±0.897	3±1.001

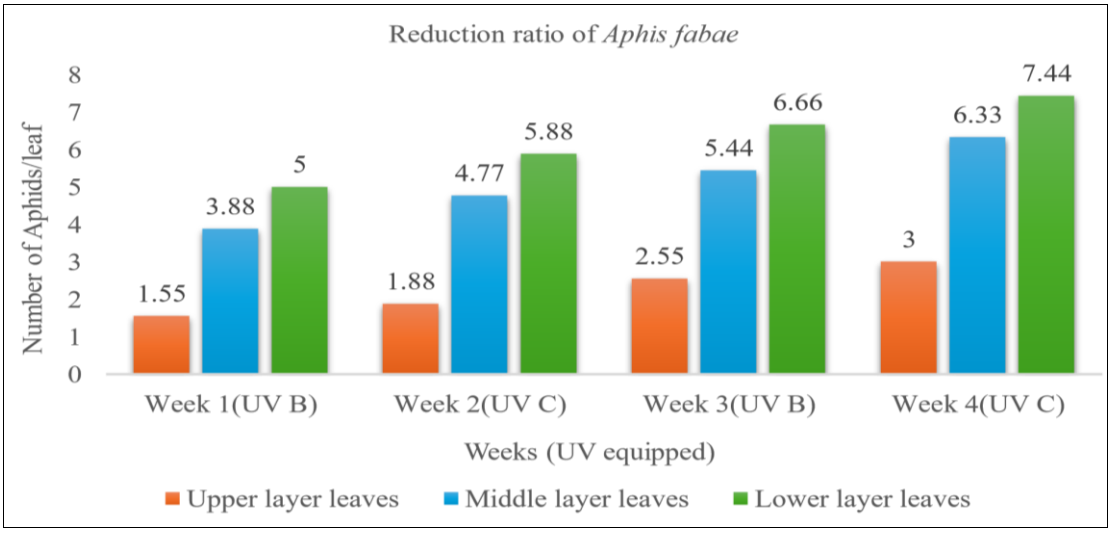

Fig 5: Showing the reduction in the population density of aphids after exposure to UV lights in March.

Table 6: Represents the population density of whiteflies when exposed to UV-B and UV-C lights in March.

Weeks	UV equipped	No of whiteflies/leaf					
		Before treating with UV			After treating with UV		
		Upper layer leaves	Middle layer leaves	Lower layer leaves	Upper layer leaves	Middle layer leaves	Lower layer leaves
Week 1	UV B	11	15	18	7	12	17
Mean		1.22	1.66	2.0	0.77	1.33	1.88
S.D±S.E		0.444±0.146	0.511±0.166	1±0.333	0.833±0.277	1.021±0.454	0.835±0.253
Week 2	UV C	13	17	22	9	18	26
Mean		1.44	1.88	2.44	1.0	2.0	2.88
S.D±S.E		0.521±0.175	0.833±0.277	1.132±0.376	1±0.333	1.481±0.493	0.784±0.260
Week 3	UV B	14	21	31	10	17	27
Mean		1.55	2.33	3.44	1.11	1.88	3.0
S.D±S.E		0.521±0.175	0.866±0.288	1.135±0.376	1.052±0.351	0.833±0.277	1.221±0.408
Week 4	UV C	13	21	35	6	17	30
Mean		1.44	2.33	3.88	0.66	1.88	3.33
S.D±S.E		0.522±0.175	0.866±0.288	1.361±0.454	0.704±0.235	0.833±0.277	1±0.333

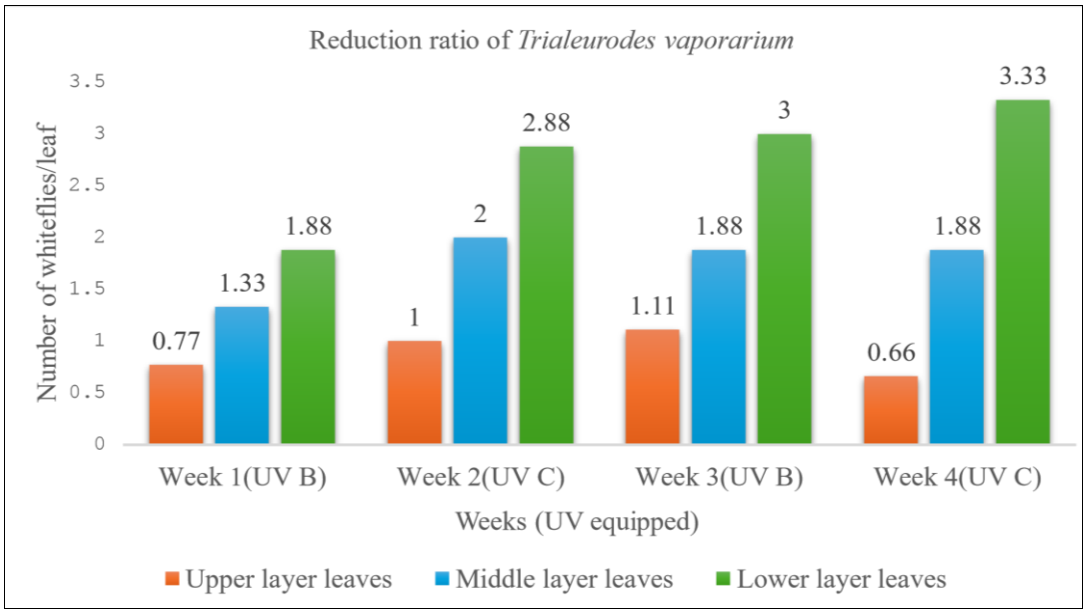

Fig 6: Showing the decrease in population density of whiteflies when exposed to UV lights in March.

4.4.2 Reduction in number of aphids and whiteflies

The results reveal that UV light had a considerable influence on the aphid and whitefly populations on the top leaves and less effect on the middle leaves. Twelve hours after the exposure, the population density of aphids and whiteflies was estimated. UV light exposure dramatically reduced aphid and whitefly survival rates in upper leaves but had a much smaller effect on population density in middle leaves and lower leaves. The population density of aphids in leaves of upper layer was 1.44 in the first week of February, but it was considerably reduced to 0.77 following the exposure to UV radiation. Similarly, the density of whiteflies in upper layer leaves was 1.22, which later reduced to 0.77 whiteflies/leaf.

4.5 Group C plants Sprayed with pesticide

Fig 7: Showing plants of group C sprayed with pesticide

Table depicted that the number of aphids in the treatment increased with highest population density (2.33 aphids/leaf). The insecticide chosen (Lambda Cyhalothrin 15% WP) has the potential and considerable effect on reduction of aphid and whitefly populations. Three sprays of Lambda Cyhalothrin 15% WP at varied concentrations (0.5ml/L, 1.0ML/L, and 1.5ml/L) were given at 15-day intervals, and a steady decline was seen. Counting pre-treated data revealed that aphids were distributed relatively uniformly in all pea pots. Aphid populations were dramatically reduced when insecticides were applied. After 1st spray, a significant result was found from pesticides at 1 DAT.

In the case of whitefly, 1.11 whiteflies were counted per leaf before treatment, however this number was drastically decreased to 0.66 after insecticide was sprayed on pea plants. The pesticides chosen had a considerable influence on the reduction of whiteflies. Similar decreasing tendencies in whiteflies were observed as with aphids. The average number of aphids per leaf was lowered even further in the second and third sprays. It was discovered that the pesticide had the greatest efficacy in terms of reducing aphid numbers.

4.5.1 Reduction in pest population by pesticide spray

Table 7: Mean mortality of aphid as treated by pesticide (Lambda Cyhalothrin 15% WP) at various concentrations in February and March.

Pesticide (Lambda Cyhalothrin 15% WP) concentrations	No of aphids/leaf					
	Before pesticide spray			After pesticide spray		
	Upper layer leaves	Middle layer leaves	Lower layer leaves	Upper layer leaves	Middle layer leaves	Lower layer leaves
0.5ml/L	13	17	21	7	8	13
Mean	1.44	1.88	2.33	0.77	0.88	1.44
S.D±S.E	0.521±0.175	0.833±0.277	0.863±0.288	0.527±0.175	0.833±0.277	0.440±0.146
1.0ml/L	12	14	21	5	7	11
Mean	1.33	1.55	2.33	0.55	0.77	1.22
S.D±S.E	1±0.333	0.527±0.175	0.863±0.288	0.527±0.175	0.833±0.277	0.440±0.146
1.5ml/L	10	12	18	4	5	10
Mean	1.11	1.33	2.0	0.44	0.55	1.11
S.D±S.E	1.051±0.351	1±0.333	2.542±0.632	0.527±0.175	0.527±0.175	1.054±0.351

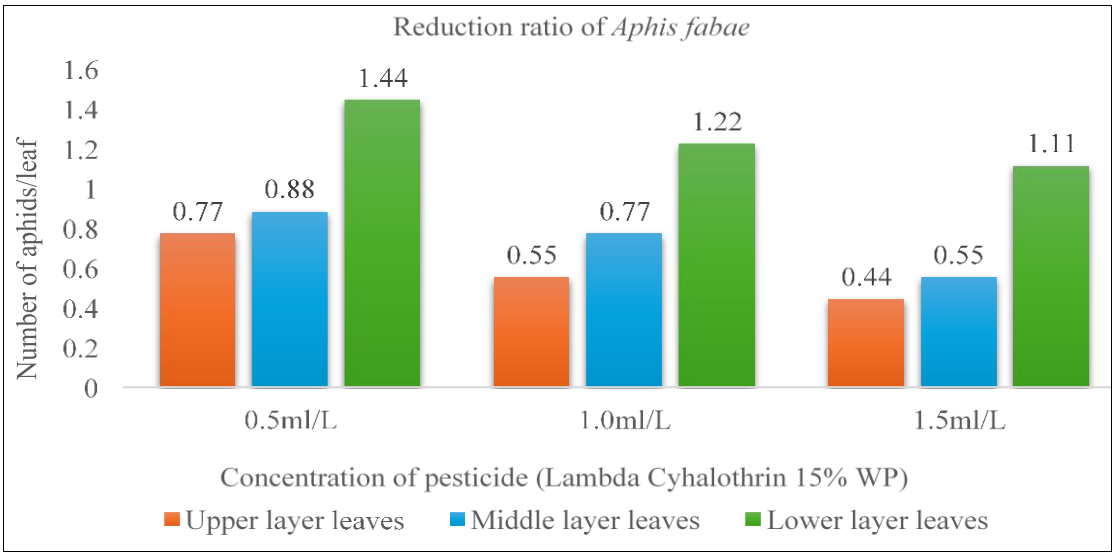

Fig 8: Represents the reduction in aphid population with pesticide (Lambda Cyhalothrin 15% WP) spray.

Table 8: Population density of whiteflies on pea plant treated with pesticide in March.

Pesticide (Lambda Cyhalothrin 15% WP) concentration	No of whiteflies/leaf					
	Before pesticide spray			After pesticide spray		
	Upper layer leaves	Middle layer leaves	Lower layer leaves	Upper layer leaves	Middle layer leaves	Lower layer leaves
1.5 ml/L	10	15	17	6	9	11
Mean	1.11	1.66	1.88	0.66	1.0	1.22
S.D±S.E	1.054±0.351	0.866±0.288	0.833±0.277	0.707±0.235	1±0.333	0.440±0.146

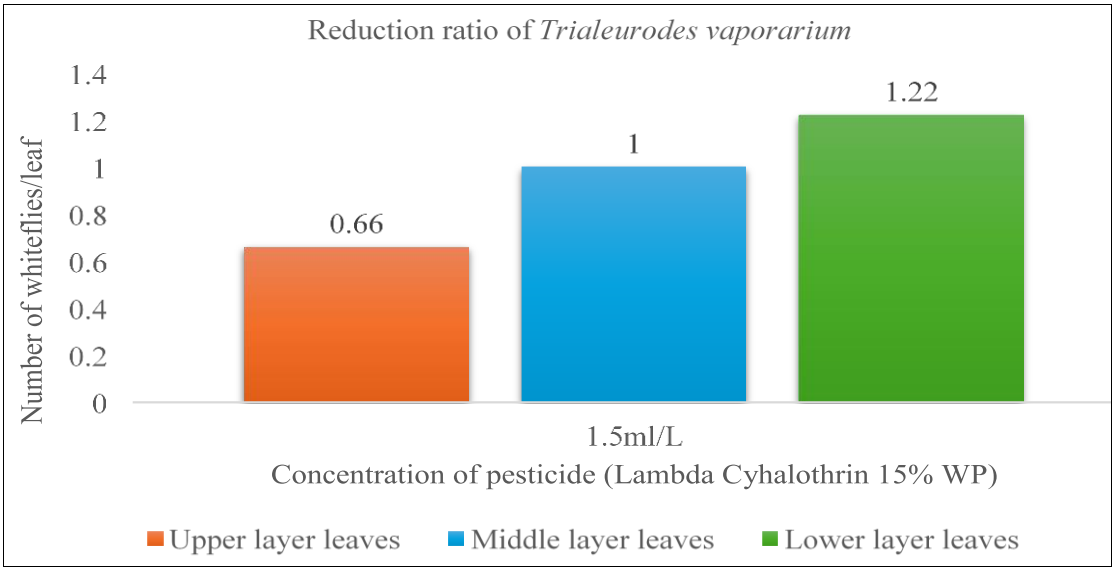

Fig 9: Represents the mortality of whiteflies treated by pesticide spray.

4.6 Fruit stage of pea plant

Fruit was only obtained from plants of group C sprayed with pesticides.

Fig 10: Showing the first pod of pea plant.

4. Discussion

This study evaluated the response of aphids and whiteflies to two distinct ultraviolet light treatments UV-B (280-315 nm) and UV-C (100-280 nm) applied to *Pisum sativum* plants under greenhouse conditions. Results indicated that UV-C treatment induced higher mortality than UV-B, with the greatest mortality observed in the upper canopy, where the maximum aphid and whitefly densities reached 3.0 and 0.66 individuals per leaf, respectively.

The shorter-wavelength UV-C radiation exhibited pronounced insecticidal effects, particularly against adult *Trialeurodes vaporariorum*. This finding aligns with previous studies demonstrating the lethality of high-energy UV radiation when exposure duration or proximity increases (Paul *et al*., 2003 [22]; Diaz *et al*., 2007 [24]; Calderon *et al*., 2007) [28]. In this experiment, mortality rates escalated significantly with increasing exposure time: from 21.28% at 30 seconds to 60.83% at 12 minutes at a height of 90 cm, and from 28.33% to 70.47% at a 70 cm distance. These results underscore that both duration and proximity are critical determinants of UV radiation effectiveness in pest suppression.

UV radiation provides an eco-friendly alternative to chemical pesticides, especially as many aphid species are naturally oriented toward UV-rich environments. Interestingly, aphid density varied significantly across the upper, middle, and lower leaf strata, with lower mortality in aphids residing on the abaxial (underside) surfaces. This distribution likely reflects UV attenuation through plant tissues, reducing exposure levels on shaded surfaces. Aphids located beneath leaves likely experienced sub-lethal UV exposure, supporting the notion that spatial positioning can buffer insect populations against radiation stress (Döring *et al*., 2007 [25]; Ohtsuka *et al*., 2009 [26]; Onzo *et al*., 2010) [23].

Furthermore, the present study is consistent with previous findings that UV-B can negatively impact both adult insects and their eggs, although protection under leaf surfaces mitigates these effects. While UV-B and UV-C treatments both showed insecticidal activity, the sheltering behavior of aphids particularly their tendency to occupy the abaxial leaf surface represents a natural defense mechanism, enabling population persistence despite treatment (Guerra *et al*., 2004 [27]; Fauki *et al*., 2007).

Overall, the data demonstrate that UV-induced pest mortality increases with longer exposure durations and closer proximity, making UV a potent tool for integrated pest management. While UV-C showed higher lethality, UV-B may offer a more practical and plant-safe option for routine use, especially in enclosed environments like greenhouses.

5. Conclusion

The growing inefficacy of chemical insecticides, due to insect resistance and associated health and environmental risks, necessitates the exploration of alternative pest control

strategies. This study confirms that UV radiation, particularly UV-C, is a viable non-chemical method for managing aphid and whitefly populations in greenhouse environments.

UV-B, though less lethal, presents a safer long-term application option due to its minimal phytotoxicity, making it suitable for static installations in sensitive crop environments. Conversely, UV-C can be used effectively with controlled, short-duration exposures, even in UV-sensitive crops, without adversely affecting plant size or yield.

The integration of LED and UV lighting systems into horticultural practices offers a sustainable and pesticide-free solution for pest control in greenhouses and potentially in open-field agriculture. This strategy supports the development of healthier crop production systems and contributes to reducing chemical inputs in modern agriculture.

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