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Influence of weather parameters on the seasonal incidence of Lablab bean leafminer: *Liriomyza* spp. (Agromyzidae: Diptera)

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Abstract

This study explores the seasonal incidence, symptomatology and impact of leafminer (*Liriomyza* spp.) infestation on lablab (*Lablab purpureus* (L.) Sweet) crop in Tamil Nadu, providing valuable insights into the pests' behaviour and the resulting crop damage. The objective was to assess infestation levels, damage and environmental factors affecting pest behaviour using surveys, correlation and regression analyses. Infestation levels varied significantly, ranging from 20 % to 84 %, with Salem and Erode experiencing lower levels and other districts showing higher infestations. The infestation was higher (84 %) in the Elavadai region of Dharmapuri district and lower (20 %) in the Thathampatti region of Salem district. The highest infestation levels were recorded in February, March and June 2023, with a noticeable decline observed in August and October. The larval mining caused extensive crop damage, significantly impairing photosynthetic efficiency and triggering premature leaf drop. A correlation analysis revealed a strong negative relationship between infestation levels and temperature extremes, indicating that temperature plays a crucial role in pest dynamics. At the same time, relative humidity and rainfall had minimal influence on leafminer incidence. Further regression analysis demonstrated that weather factors accounted for 32.8 % of the variability in infestation levels. The results underscore the importance of understanding seasonal patterns in leafminer occurrence within lablab ecosystems. This knowledge is essential for devising effective integrated pest management strategies supported by field surveys, pest prediction models and molecular techniques. Farmers can effectively manage leafminer infestations and enhance lablab yields by adopting these methods while mitigating the challenges of the global climate.

Keywords

correlation; environmental factors; lablab; leafminer; survey

Introduction

Hyacinth bean is a relatively ignored legume however, it is advantageous and has been recognized for its usefulness as a crop in the past few years (1, 2). It is a diverse legume that can be consumed as a pulse, vegetable, fodder for animals, ornamental plants, or medicinal use (3). This legume is cultivated in all regions of India, including Tamil Nadu and is considered significant in farming. Lablab is the only species in its genus and as such, there was heavy selection for annual weeds or perennial ones and the pest-affected type was also a perennial variety. This crop is ancient, used around 1500 BC in Africa and brought to India through the West (4). Lablab is an economically important leguminous crop as it enriches soil fertility by fixing nitrogen in the soil and most preferred intercrop as it has adaptability to diverse climatic conditions. Lablab is rich in free amino acids, protein, carbohydrate, crude fibre, proline, methionine, tryptophan and trypsin inhibitors (5). It also contains Chikusetsusaponin IV A, a bioactive nutraceutical functioning as a natural flavour enhancer (6).

Abiotic and biotic stresses also influence the yield of lablab. The impact of these factors on the bean ecosystem is ranked in descending order as follows: diseases (20-100 %), harmful insects (20-45 %), weeds (15-45 %), soil nutrients (10-20 %) and environmental factors (10-15 %) (7-11). Among different insect pests, leafminers (*Liriomyza* spp.) are a serious threat to the lablab bean crop as they are notorious miners, directly affecting the photosynthetic rate (12). These pests can adapt to various host plants across different plant families and can readily colonize new hosts. Leafminers during high infestation can cause yield loss from 30-60 %, thus affecting the income of farmers. Leafminer damage affects plant tissues, forming openings that facilitate secondary infections by fungi and bacteria, leading to further deterioration of plant health (12). In the early 1980s, the emergence of insecticide resistance in *Liriomyza* populations contributed to their rapid expansion, turning them from minor pests into significant threats (13, 14). Approximately 300 *Liriomyza* species are found worldwide, with 23 considered economically important (15, 16). Many of these species have expanded into new regions, becoming major pests threatening plant health and agricultural yields.

Abiotic factors, including temperature, humidity and rainfall, considerably impact the population dynamics, development, reproduction, dispersal, migration and behaviour of *Liriomyza*. Infestation levels are generally reduced by higher temperatures and vapour pressure (both maximum, minimum and mean) but are increased with higher relative humidity and rainfall (17,18). The agromyzid leafminer exhibits optimal growth at a stable temperature of 25°C, with developmental rates enhancing as temperatures approach 30°C. However, temperatures exceeding 30°C are generally detrimental, increasing larval mortality (19).

This study examines the population dynamics of leafminers in lablab, emphasizing the impact of meteorological factors. However, there is limited research on the relationship between *Liriomyza* spp. population dynamics and weather conditions, particularly in lablab crops grown under poly-crop ecosystems. Lablab bean has been cultivated alongside cowpea, sorghum, pearl millet, brinjal, maize, cotton, crucifers, cucurbits, etc., in a polycropping system (20) where most of the crops are typical hosts of *Liriomyza* sp. Hence, studying population dynamics in different crops and cropping systems is necessary. Understanding these pest population dynamics in field conditions is essential for implementing timely management strategies. Effective control measures can be developed by analyzing the seasonal patterns and climatic factors influencing pest behaviour.

Materials and Methods

Survey on incidence of leafminer infestation

A roving survey was undertaken during 2023 in the significant lablab growing regions on the leafminer incidence in Dharmapuri, Krishnagiri, Coimbatore, Erode and Salem districts of Tamil Nadu covering eighteen different locations (Fig. 1). The survey aimed to establish the status of the leafminer pest under diverse weather conditions including semi-arid, tropical wet and dry, subtropical and moderate rainfall regions. Three to four representative locations were selected from each district to ensure thorough representation. Observations at each site focused on assessing the extent and severity of leafminer infestation, considering the influence of prevailing environmental and climatic factors.

Assessment of symptoms and quantification of leafminer infestation

The distinctive symptoms caused by leafminer maggots, such as serpentine mines on leaves, were carefully documented during the survey (Fig. 2A). Observations included the immature stages of the pest, namely maggots, pupae and mature adults (Fig. 2B-2D). At each survey location, 20 randomly selected plants were examined to determine leafminer incidence and the average percentage of infestation was computed. Leaf damage was assessed by counting the plants' mines on the top, middle and bottom leaves. The rate of leaf damage caused by leafminers was calculated using the following formula in Equation 1-2. Additionally, the leafminer infestation index was determined using the scoring method as per the Equation 2 (21, 22). The infestation intensity was categorized based on the percentage of leaf area infested, as shown below:

Percent damage =

(Number of mined leaves / Total number of observed leaves) × 100 (Eqn. 1)

Infestation index =

Sum of all scores / (Number of scores x Maximum score) × 100

Percent leaf area infested	Score	Infestation intensity
0	0	No infestation
1-15	1	Low infestation
16-30	2	Medium infestation
31-50	3	High infestation
>51	4	Severe infestation

(Eqn. 2)

This approach allowed for a systematic evaluation of the percentage of damage and the intensity of infestation in the surveyed areas.

Seasonal incidence of leafminer infestation

The influence of weather parameters, including maximum and minimum temperature (°C), relative humidity (%) and rainfall (mm), on leafminer infestation was investigated in the Kinathukadavu block of Coimbatore district (23). Observations of percent leafminer infestation were recorded fortnightly throughout the cropping season. The standardized scoring method was also followed for the visual rating (0-4) and compared with the percent leafminer infestation. Weather data were sourced from the Department of Agro Climate

Fig. 1. Survey locations covering major lablab growing areas of Tamil Nadu A. Dharmapuri district B. Coimbatore district C. Salem district D. Krishnagiri district E. Erode district.

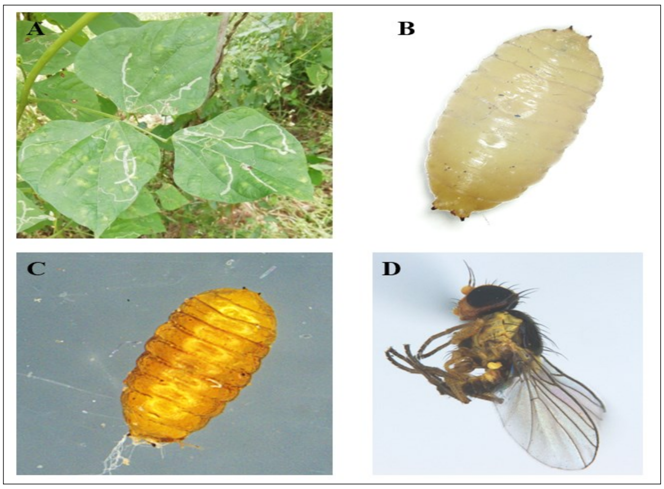


Fig. 2. Symptoms and immature stages of leafminer infesting on lablab. A. Mining on the trifoliate leaves of lablab B. Larval stage C. Pupal stage D. Adult stage.

Research Centre (ACRC), Directorate of Crop Management, Tamil Nadu Agricultural University, Coimbatore.

The collected data were analyzed to evaluate the relationship between weather variables and leafminer population dynamics. Correlation coefficients were calculated to assess the seasonal impact of each weather parameter on leafminer infestation. Regression analysis was further conducted to quantify the contribution of individual weather factors to the variation in infestation levels observed during the cropping season.

Statistical analysis

The infestation data (percentage of damaged leaves) were subjected to one-way ANOVA to determine the significant differences between the locations. Correlation and regression studies were conducted to assess the relationship between weather parameters and the percent infestation using the SPSS statistical software version (SPSS 16.0). The Pearson correlation coefficient at a 95 % confidence interval was used to assess the strength of the relationship between individual weather parameters and leafminer infestation percentage. Similarly, the multiple linear regression model at 95 % confidence interval provided adjusted R^2 values for predicting variability in infestation levels due to various weather parameters.

Results

Survey on incidence and quantification of leafminer infestation

The locations surveyed covered the major lablab growing districts of Tamil Nadu. The leafminer infestation in these locations ranged from 20 % to 84 %. The damage was lower in the areas of Salem and Erode and higher in the other three districts. The infestation index and percent infestation showed similar results in all the districts surveyed. The infestation peaked during February, March and June 2023 and reduced during August and October 2023 (Table 1).

Assessment of symptoms

Characteristic mines created by *Liriomyza* were observed across all surveyed locations (Fig. 2A). The larvae feed on the leafs' upper part, tunnelling through the green palisade tissue to form mines. These mines were generally off-white, with fragmented black lines of frass running along their length.

Table 1. *Liriomyza* infestation at different sampling coordinates in Tamil Nadu, India (Year: 2023)

Zone	District	Location collected	Longitude	Latitude	Survey month	Cropping pattern	Temp (°C)		Rainfall (mm)	Rainy days	Infestation index (%)
							Max.	Min.			
North western	Dharmapuri	Elavadai	12.1560°N	78.3785°E	March	Monocrop	37	19	41	13	84^{ab}
		Pappireddipatti	12.1557°N	78.3786°E	February	Monocrop	36	18	0.8	1	70^{e}
		Vedarampatti	12.1629°N	78.2916°E	February	Monocrop	36	18	0.8	1	64^{f}
	Krishnagiri	Thiruvalluvar nagar	12.5155°N	78.2164°E	August	Monocrop	38	23	42	16	78^{c}
		Marigampalli	12.5055°N	78.1355°E	August	Monocrop	38	23	42	16	62^{f}
		Alapatti	12.5058°N	78.0814°E	August	Monocrop	38	23	42	16	76^{d}
		Chikkapoovathi	12.5035°N	78.0732°E	August	Monocrop	38	23	42	16	82^{b}
	Salem	Thathampatti	11.6742°N	78.2039°E	August	Monocrop	37	24	65	15	20^{l}
		Karpagam	11.7032°N	78.2129°E	August	Monocrop	37	24	65	15	30^{k}
		Valaiyakkaranur	11.7042°N	78.2111°E	August	Monocrop	37	24	65	15	34^{j}
Western	Coimbatore	Sattakkal Pudur	10.8215°N	76.9285°E	February	Intercrop with banana	34	19	3.1	2	82^{b}
		Kurunallipalayam	10.8529°N	77.1128°E	February	Monocrop	34	19	3.1	2	76^{d}
		Thillai nagar	10.9771°N	76.8213°E	March	Monocrop	36	18	28	6	72^{de}
		Thondamuthur	10.9949°N	76.7834°E	May	Monocrop	37	24	60	11	44^{i}
	Erode	Talamalai	11.5362°N	77.1157°E	October	Monocrop	37	22	83	21	32^{jk}
		Thoppampalayam	11.4630°N	77.1461°E	June	Monocrop	41	24	57	27	54^{h}
		Pasur	11.2831°N	77.1224°E	June	Intercrop with banana	41	24	57	27	84^{a}
		Sellappavpalayam	11.3239°N	77.1490°E	June	Monocrop	41	24	57	27	58^{g}
										SEd	0.7697
										CD (0.05)	1.6240

Infestation index followed by different letters within a column indicate significant differences (P < 0.05; LSD (Least significant difference test))

Prolonged feeding in a concentrated area caused mine discolouration, appearing as black and brown patches, typical signs of leafminer infestation (Fig. 2). The lower foliage exhibited a higher density of mines than the middle and upper leaves. The physiological and physical properties of the trifoliate leaf influenced the configuration of the mines. The mines were host-specific and identifying species based solely on mine patterns proved challenging.

The larval stages of *Liriomyza* exhibited distinct morphological changes, with the maggots appearing translucent during the first instar and transitioning to a yellow-orange colour in the later stages (Fig. 2B). Pupation occurred outside the leaf tissue either on the surface of the leaf or on the soil, with the larvae transforming into golden-brown pupae (Fig. 2C). The adult flies were small and characterized by a yellow head and scutellum, while the thorax and abdomen were predominantly grey and black. The ventral surface and legs were yellow and the wings were clear and transparent (Fig. 2D). Female flies used their ovipositors to pierce host plant leaves, creating wounds that functioned as feeding sites for both sexes or as oviposition sites.

Seasonal incidence of leafminer infestation

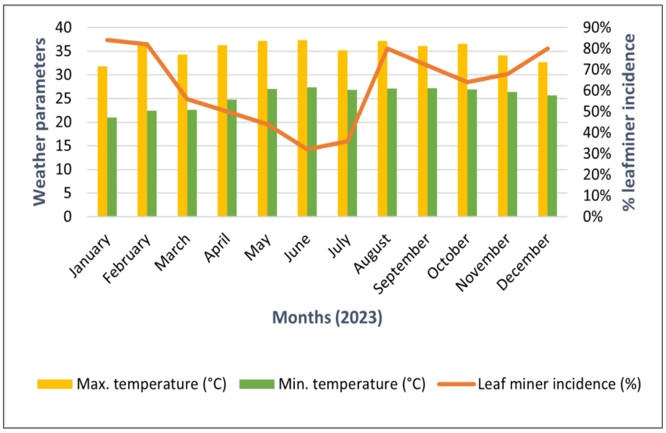
The seasonal incidence of leafminer infestation on lablab crops in the Kinathukadavu block of Coimbatore district was analyzed in relation to abiotic factors such as maximum and minimum temperatures, relative humidity and rainfall for the year 2023. Correlation coefficients and multiple regression analyses were employed to explore these relationships. The correlation matrix depicting the influence of weather parameters on leafminer infestation in the lablab ecosystem is shown in Table 2. The table indicates that relative humidity and rainfall did not significantly affect leafminer incidence. However, both maximum and minimum temperatures significantly correlated with leafminer damage. The correlation analysis revealed a negative correlation between temperature and relative humidity with leafminer damage. At the same time, rainfall showed a positive relationship (Fig. 3). These findings suggest an inverse relationship between temperature and leafminer population in the field, with rainfall contributing minimally or insignificantly to leafminer incidence.

Regression analysis was performed to evaluate the influence of individual weather factors on the variation in leafminer infestation levels in the lablab bean. The study included multiple independent variables (maximum and minimum temperatures, relative humidity and rainfall), with leafminer incidence as the dependent variable. The results indicate that weather parameters contributed 32.80 % to the variation in the leafminer population, with the prediction

Table 2. Correlation matrix and multiple linear regression model: Influence of weather parameters on the population of leafminers in lablab ecosystem (Location: Kinathukadavu block of Coimbatore district)

	Leafminer incidence (%)	Maximum temperature (°C) (X1)	Minimum temperature (°C) (X2)	Relative humidity (%) (X3)	Rainfall (mm) (X4)	Regression coefficients
Leafminer incidence (%)	1					Constant = 0.972
Maximum temperature (°C) (X1)	-0.449**	1				-0.039
Minimum temperature (°C) (X2)	-0.430**	0.580	1			-0.108
Relative humidity (%) (X3)	-0.083 (NS)	-0.062	0.737	1		-0.014
Rainfall (mm) (X4)	0.146(NS)	-0.296	0.183	0.490	1	0.005

**significant at 1 % level of significance; NS - non-significant; Multiple linear regression equation: $Y = 0.972 - 0.039\,X_1 - 0.108\,X_2 - 0.014\,X_3 + 0.005\,X_4$; Coefficient of determination(R^2)=0.328.



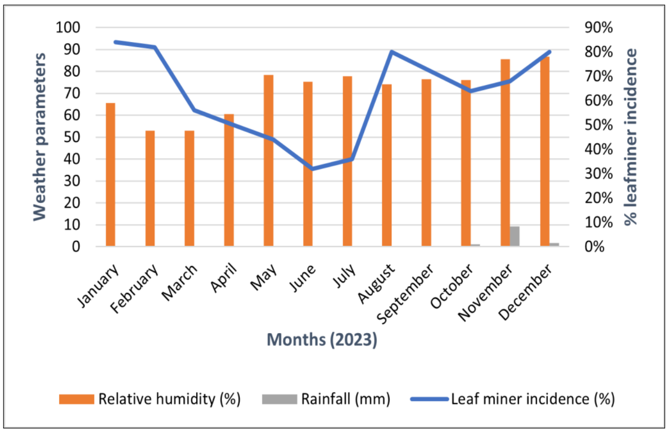


Fig. 3. Leafminer infestation on lablab at Kinathukadavu block of Coimbatore district in relation to climatic factors.

model equation being Y = 0.972 - 0.039 X1 - 0.108 X2 - 0.014 X3 + 0.005 X4 (Table 2). The highest infestation observed in the survey was 84 %, recorded in areas where the average monthly temperature ranged from 37°C to 41°C. However, some variations were noted, possibly due to increased rainfall and more rainy days. Similarly, lablab intercropped with bananas at Pasur and Sattakkal Pudur showed a high infestation of 84 and 82 %, which might be influenced by the cooler microclimate under banana cultivation. This suggests that agronomic practices may also impact leafminer incidence apart from weather conditions.

Discussion

The present study provided valuable insights into the seasonal incidence, symptomatology and quantification of leafminer infestation in the major lablab growing areas of Tamil Nadu. The findings underscore the significant variation in infestation levels across surveyed locations and offer critical information for developing targeted management strategies. The survey revealed that leafminer infestation varied widely, ranging from 20 % to 84 % across the districts. Lower levels of damage were recorded in Salem and Erode, likely due to favourable abiotic or biotic factors in these regions that suppressed leafminer populations. In contrast, higher infestation levels were observed in other districts, suggesting potential hotspots for leafminer activity. Infestation peaked during February, March and June 2023, with a reduction in infestation during August and October 2023. These temporal patterns in infestation underscore the importance of considering seasonal dynamics when implementing control measures (24). The research on *Liriomyza huidobrensis* and other *Liriomyza* species in Peru, China and Argentina emphasized the influence of climate change on leafminer invasions (25, 26, 27). In Peru, global trade facilitated the origin of *L. huidobrensis* confirmed by genetic analysis (27). A group of *Liriomyza* species adapted to cooler regions has now expanded to rising temperatures in China (26). Biotic factors like parasitoid community changes altered the leafminer incidence in Argentina (25). Climate change plays a major role in altering the leafminer behaviour causing displacement of species and thus targeted management strategies should be adopted. The characteristic mines formed by *Liriomyza* leafminers were consistently observed across all surveyed locations. These larval mines in the palisade parenchyma have been shown to reduce photosynthetic efficiency by up to 62 % (28), often leading to premature leaf drop in heavily infested plants. Excessive mining on a single host plant produced a distinct stippled appearance on the foliage. The primary damage resulted from larval mining, which decreased shading and increased the likelihood of sunscald on exposed fruits. Additionally, these wounds created entry points for bacterial and fungal pathogens, compounding crop losses (29). Research indicates that mine patterns alone were insufficient for accurately identifying leafminer flies (30). In polyphagous agromyzid species, mine configuration was shaped by various factors, including the host plant species, the leafs' physical and physiological condition and the number of larvae on the same leaf (31).

The distinct morphological features of *Liriomyza* across various life stages provide additional diagnostic criteria for identifying infestations, as noted in similar morphological studies (30, 32). The larvae, upon hatching, were around 0.5 mm in length and expanded to approximately 3.0 mm at full maturity, exhibiting the typical morphological traits of agromyzids. The pupae were cylindrical and oval-shaped, measuring about 2.0 mm long, with a slightly flattened ventral side and prominent anterior and posterior spiracles (33). However, the cryptic nature of adult *Liriomyza* species, which were small (1–3 mm) and predominantly black with yellow frons and scutellum, pose significant challenges for accurate species identification within the genus (32).

The correlation analysis between weather parameters and leafminer incidence showed a significant negative correlation with maximum and minimum temperatures, while relative humidity and rainfall had no significant effect on the damage potential of leafminers on lablab beans. Meteorological factors such as maximum temperature, morning relative humidity and evening relative humidity had no significant relationship with the mean population of leafminers on bitter gourd (34). The correlation studies also indicated that the number of mines, larvae and percentage of damaged leaves on tomatoes showed a significant negative correlation with the maximum, minimum and mean temperatures and morning, evening and mean vapor pressure and vapour pressure deficit (17, 18, 35). On the other hand, leafminer infestation was positively correlated with evaporation, influencing the leafminer population by 51 % (18). A significant negative correlation was reported between the seasonal abundance of leafminers, mean and total rainfall and the number of rainy days (23). In contrast, morning and evening relative humidity exhibited a non-significant negative correlation.

Temperature significantly influences the development, distribution and ecological interactions of various *Liriomyza* species. In tropical highlands with average minimum temperatures below 22°C, *L. huidobrensis* thrived, whereas *L. sativae* exhibited adaptability across a broader temperature range (21-36 °C), suggesting a temperature-dependent competitive exclusion dynamic where *L. sativae* emerged at lower temperatures in the absence of *L. huidobrensis* (36). The developmental thresholds and survival rates also varied between species; *L. huidobrensis* showed slower larval development at higher temperatures but faster pupal development at cooler temperatures, with its lower developmental threshold ranging from 7.3 °C to 8.1 °C, compared to *L. trifolii* (9.9 °C to 10.7 °C) (37, 38). On the other hand, *L. sativae* favoured the adaxial surface of leaves for egg-laying and showed decreasing adult longevity with increasing temperature and humidity while maintaining constant oviposition rates between 18 °C and 30 °C (39). These highlight the complex interaction between temperature and host factors in influencing the ecology of leafminer species, providing important insights for their management in response to changing climatic conditions.

The results of this study emphasize the need for management strategies tailored to specific locations and seasons. The identified peak infestation periods suggest that control efforts should be heightened in February, March and June. Moreover, the host-specific mine patterns and the challenges in species-level identification underline the importance of using molecular tools for precise identification and monitoring. Integrated Pest Management (IPM) strategies are crucial in managing leafminer infestations during peak infestation. These strategies include using leafminer-free planting materials, employing trap cropping with alternate host plants and utilizing yellow sticky traps for monitoring. In addition, plant-based extracts like azadirachtin and biological control agents such as *Neochrysocharis* sp., *Chrysocharis* sp. and *Diglyphus* sp. offer effective control measures. Furthermore, the need-based application of insecticides helps maintain leafminer populations at manageable levels.

This study provides insights into the leafminers' behaviour under varying climatic conditions, helping to optimize pesticide use and improve control strategies for lablab infestations. Identifying species based on mining symptoms is a significant limitation due to the overlapping of mines. Molecular techniques such as DNA barcoding using the mitochondrial cytochrome oxidase gene can help overcome misidentifications (40). By adopting integrated pest management practices, including field monitoring, pest forecasting and environmentally sustainable control measures involving biological control agents, growers can more effectively manage the pest and mitigate the impact of climate factors.

Conclusion

This study comprehensively evaluates leafminer infestations in lablab crops across Tamil Nadu, revealing notable spatial and seasonal variations, with peak infestations observed during February, March and June. A significant negative correlation was found between infestation levels, temperature extremes and relative humidity, highlighting the role of environmental factors in pest dynamics. The larval mining caused extensive damage, reducing photosynthetic efficiency, triggering premature leaf drop and increasing vulnerability to secondary infections. The findings emphasize the need for integrated pest management strategies, including field monitoring, pest forecasting and molecular tools for precise identification, to optimize pesticide use and mitigate the impact of climate variability on crop productivity. Further studies should focus on using resistant plants to cultivate and monitor leafminer dynamics through yellow sticky traps. Additionally, environment-friendly approaches such as applying biological control agents like parasitoids and botanicals can help prevent the leafminer incidence.

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Authors' contributions

SA carried out conceptualization, methodology, formal analysis and drafting of the original draft. TE involved in framing methodology, formal study and in original draft preparation. MM carried out conceptualization, methodology, supervision and drafting of the original draft. MS involved in supervision, review, editing and resource acquisition. RS conceived the study and participated in framing the methodology, formal analysis and review and editing. NMB involved in supervision, review, editing and resource acquisition. SV carried out supervision, review, and editing. AK carried out a statistical analysis. NAT involved in review and editing. All authors read and approved the final manuscript.

Compliance with ethical standards

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Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

While preparing this work, the author(s) used ChatGPT to edit the language. After using this tool/service, the author (s) reviewed and edited the content as needed and take(s) full responsibility for the publications' content.

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