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Article

Pesticide residue contamination in eggplant and hyacinth bean at eight different regions of Bangladesh

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Abstract: Eggplant and hyacinth bean are essential vegetable crops due to their nutritional value but are highly susceptible to various insect pests. Farmers often apply pesticides indiscriminately, disregarding the recommended pre-harvest intervals. This practice raises concerns about potential pesticide residue contamination in vegetables. The present study aimed to assess pesticide residues in eggplant and hyacinth bean. Samples were collected from eight regions of Bangladesh. Pesticide residues in the samples were assessed through gas chromatography, utilizing both a flame thermionic detector (FTD) and an electron capture detector (ECD). Among the total analyzed samples, a significant portion was found to be contaminated, with residues of cypermethrin, diazinon, quinalphos, fenitrothion, and malathion detected in over half of the samples. Among these, 15 samples (30%) exceeded the maximum residue limit (MRL) set by FAO/WHO. From the 26 eggplant samples, 15 contained residues of cypermethrin, quinalphos, and diazinon, with 7 samples (26.92%) exceeding MRLs. Four samples had cypermethrin residues ranging from 0.532–0.623 mg/kg, and one sample contained 0.703 mg/kg diazinon, both above MRLs. Additionally, two samples from Bogura and Rangpur had multiple pesticide residues above MRL. Of the 24 hyacinth bean samples, 15 were contaminated with cypermethrin, diazinon, quinalphos, fenitrothion, and malathion. Among these, 8 samples (33.33%) exceeded MRLs with residues ranging from 0.533–0.561 mg/kg for cypermethrin, 0.543–0.610 mg/kg for diazinon, 0.120–0.240 mg/kg for fenitrothion, 0.414 mg/kg for quinalphos, and 0.529 mg/kg for malathion. Two hyacinth bean samples from Rangpur and Jashore contained multiple pesticide residues exceeding MRLs. The current status of pesticide residue contamination in these vegetables is highlighted by this analysis, which also emphasizes that residues over MRLs provide serious health concerns to humans and may result in a number of dangerous disorders.

Keywords: gas chromatography; FTD; ECD; MRL; pesticide contamination

1. Introduction

In Bangladesh, eggplant (*Solanum melongena* L.) and hyacinth bean (*Lablab purpureus*) are popular and widely cultivated. There are 53 different insect pests that target eggplant, but the most dangerous and damaging ones include the eggplant shoot and fruit borer, white fly, aphids, and spider mites (Javed *et al*., 2017; Kumar *et al*., 2019; Dash *et al*., 2020). Nine insect pests and one mite species feed on the hyacinth bean in Bangladesh (Amin

et al., 2023). The legume pod borer (*Maruca vitrata febricius*) is the most destructive pest of legume crops especially hyacinth bean and beans (Brown and Hazzard, 2021; Kenneth *et al*., 2024). To defend crops against insect attacks, several researchers recommended using chemical pesticides (Deepak *et al*., 2017; Sen *et al*., 2017; Satyanarayana and Arunakumara, 2017; Singh, 2019; Rahman *et al*., 2019; Nayak *et al*., 2022). According to reports, farmers use pesticides often, sometimes daily, to combat the severe insect pest attacks on hyacinth beans and eggplant (Rashid *et al*., 2013; Ahmed *et al*., 2016a). Sometimes persistent pesticides creates several problems on humans as well as non-target organisms and the environment (Nayak *et al*., 2022). Therefore, pesticide residue in food has become a concern for consumer safety, although people are unaware of the extent to which pesticide residue has been absorbed in the food they consume. Pesticide residues in vegetables were studied by certain researchers in Bangladesh, however the results were insufficient to address the consumer's concern about food safety (Ahmed *et al*., 2016b; Ahmed *et al*., 2016c; Aktar *et al*., 2017; Ahmed *et al*., 2018; Begum *et al*., 2019; Ahmed *et al*., 2019; Begum *et al*., 2020; Ahmed *et al*., 2020; Ahmed *et al*., 2021., Ahmed *et al*., 2022). They found about 10-15% vegetables were contaminated by chemical pesticides which were above MRL. Consumers are entitled to know the level of pesticide contamination in the vegetables they purchase.

Pesticides are widely used in modern agriculture to improve crop productivity and manage pest infestations (Haque *et al*., 2018; Bulugahapitiya *et al*., 2021; Alam *et al*., 2023). However, their improper use and persistence in the environment pose significant risks to human health and ecosystems. Studies have documented the presence of pesticide residues in various food crops, including vegetables, which are a vital part of the human diet (Khanom *et al*., 2023). Research focusing on pesticide residue analysis in vegetables such as yard long beans, hyacinth beans, and eggplants has provided insights into the levels of contamination and highlighted the need for safer agricultural practices (Rahman *et al*., 2020; Tasnim *et al*., 2022). Moreover, investigations into the degradation, pre-harvest intervals, and alternative pest control methods, such as botanical and microbial pesticides, are critical for developing sustainable pest management strategies.

Pesticide residues in vegetables, particularly eggplant and hyacinth bean, present a critical challenge to food safety and public health in Bangladesh. These vegetables, integral to the local diet, are often subject to indiscriminate pesticide application, leading to residues that may exceed maximum residue limits (MRLs). Despite the health implications, systematic data on the contamination levels across different regions remains scarce, hindering effective monitoring and regulation. In order to determine if pesticide residues in eggplant and hyacinth bean samples from different parts of Bangladesh exceed MRLs, this study aims to examine the prevalence and amounts of these residues. In light of this, the current study was conducted to ascertain the pesticide residue levels in hyacinth beans and eggplant from eight distinct locations in Bangladesh. This study highlights the need for improved pesticide regulation, farmer education on safe usage, and regular monitoring programs to ensure food safety and protect public health.

2. Materials and Methods

2.1. Ethical approval

No human intervention was required as the study solely involved edible vegetables. Verbal consent was obtained from vegetable retailers at local markets before collecting the samples. The research underwent evaluation by an expert panel during an internal review workshop and received formal approval from the Director of Research at the Bangladesh Agricultural Research Institute (BARI).

2.2. Study area

Vegetable samples were sourced from eight regions across Bangladesh, namely Bogura, Cumilla, Dhaka, Gazipur, Jashore, Khagrachari, Rajshahi, and Rangpur. Laboratory analysis of these samples was conducted at the Pesticide Analytical Laboratory, an ISO/IEC 17025:2017 accredited facility, under the Division of Entomology at the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh (Figure 1).

2.3. Chemicals used in pesticide analysis

Various chemicals and reagents were utilized in the pesticide analysis. The reagents, including n-hexane and sodium sulfate, as well as pesticide standards for synthetic pyrethroid (cypermethrin) and organophosphorus pesticides, were procured from Sigma-Aldrich Laborchemikalien, GmbH, Seelze, Germany, through Bangladesh Scientific Pvt. Ltd., Dhaka, Bangladesh.

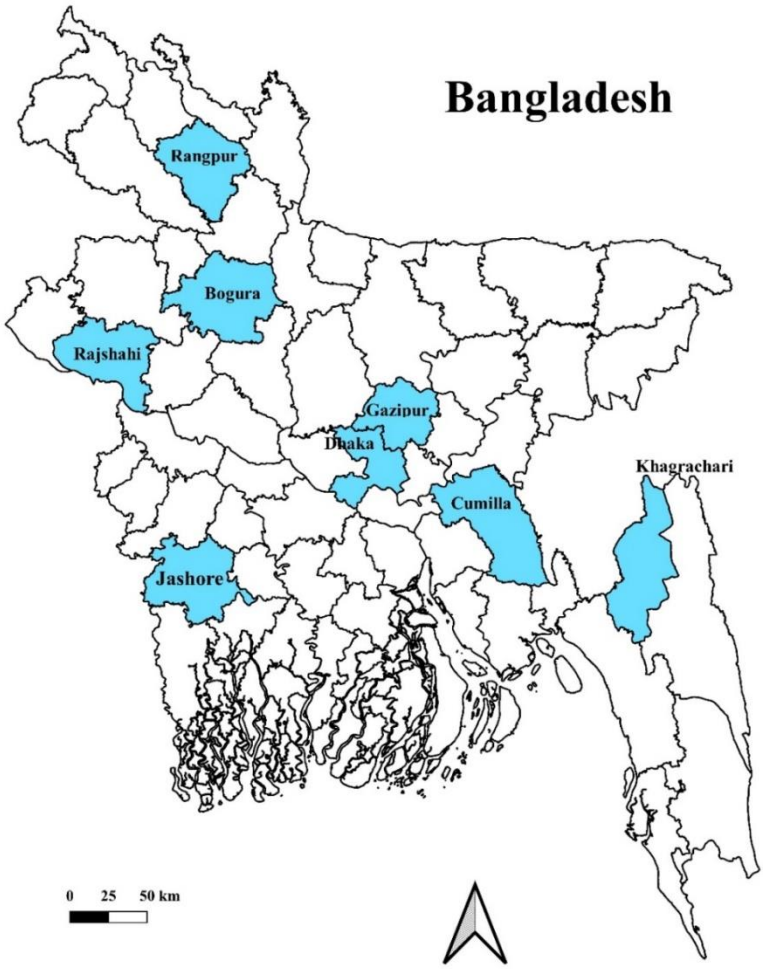

Figure 1. The samples were collected from eight different regions of Bangladesh.

2.4. Collection of vegetable samples from different regions

A total of 50 samples, comprising 26 eggplants and 24 hyacinth beans, were collected from markets in eight different regions. The primary criteria for selecting the vegetables were their edible size at harvest. Sampling was conducted following the Codex guideline (2024), which aligns with Commission Directive 2002/63/EC and Commission Directive 79/700/EEC. Each sample weighed 1 kg. Before being analyzed, the obtained samples were kept in a refrigerator at -20 °C after being swiftly transferred to the lab in a cooled box.

2.5. Extraction, separation and cleanup of samples

Sample extraction, separation, and cleanup were performed following the methodology outlined by William and George (2005), with minor modifications described by Ahmed *et al*. (2016a).

2.6. Detection and quantification of pesticide residue in samples

A Shimadzu GC-2010 gas chromatograph (Japan) with a Flame Thermionic Detector (FTD) for detecting diazinon, quinalphos, fenitrothion, and malathion and Electron Capture Detector (ECD) for detecting cypermethrin were used to analyze the concentrated extracts in accordance with the technique of Ahmed *et al*. (2016a).

2.7. Statistical analysis

The collected data were analyzed using SPSS (latest version) for descriptive and inferential statistics. Descriptive statistics were employed to summarize the pesticide residue levels, while inferential analyses were conducted to compare residue levels across different vegetables and regions. For spatial analysis and visualization of pesticide contamination, QGIS version 3.40.0 was utilized to map the distribution of residues across the sampling regions.

3. Results

Of the 26 analyzed eggplant samples, 15 were found to be contaminated with varying levels of three pesticides, cypermethrin, diazinon, and quinalphos (Table 1). Nine samples contained residues of a single pesticide, while six exhibited multiple pesticide residues. Quinalphos was detected in five samples from three locations (Bogura, Jashore, and Khagrachari), diazinon in six samples from five locations (Bogura, Cumilla, Jashore, Khagrachari, and Rangpur), and cypermethrin in 12 samples from seven locations (Bogura, Cumilla, Dhaka, Gazipur, Jashore, Khagrachari, and Rangpur).

In Bogura, two of the four samples contained multi-pesticide residues (0.592 mg/kg cypermethrin with 0.274 mg/kg quinalphos, and 0.139 mg/kg diazinon with 0.540 mg/kg quinalphos), both exceeding the MRL. Cumilla had three contaminated samples, one with 0.623 mg/kg cypermethrin and another with 0.703 mg/kg diazinon, both above MRL. A third sample had residues of 0.114 mg/kg cypermethrin and 0.427 mg/kg diazinon, both below MRL. In Dhaka, two of the three samples contained cypermethrin residues (0.096 mg/kg and 0.064 mg/kg) below MRL, while the third sample was residue-free.

Of the four Gazipur samples, three had cypermethrin residues (0.025 mg/kg, 0.061 mg/kg, and 0.035 mg/kg), all below MRL, with one sample showing no residues. In Jashore, three out of four samples were contaminated, including one with multiple pesticide residues (0.169 mg/kg cypermethrin and 0.135 mg/kg diazinon) below MRL. Another contained 0.029 mg/kg quinalphos (below MRL), and the third had 0.532 mg/kg cypermethrin, exceeding MRL.

In Khagrachari, one of two samples had multiple pesticide residues (0.096 mg/kg cypermethrin, 0.018 mg/kg diazinon, and 0.015 mg/kg quinalphos), all below MRL, while the other sample was residue-free. Rangpur had one contaminated sample with 0.537 mg/kg cypermethrin exceeding MRL, while the other two samples were residue-free. No pesticide residues were detected in the Rajshahi samples, and none of the analyzed samples contained fenitrothion or malathion residues.

Table 1. Residue levels of pesticides in eggplant collected from eight different regions of Bangladesh.

Sample ID		Residue levels of detected pesticides (mg kg^{-1})				
Location	**Code***	**Cypermethrin**	**Diazinon**	**Quinalphos**	**Fenitrothion**	**Malathion**
Bogura	BFF1	0.592	-	0.274	-	-
	BFF2	-	0.139	0.540	-	-
	BMB1	-	-	-	-	-
	BMB2	-	-	0.170	-	-
Cumilla	CFF1	-	0.703	-	-	-
	CFF2	0.114	0.427	-	-	-
	CMB1	-	-	-	-	-
	CMB2	0.623	-	-	-	-
Dhaka	DMB1	0.096	-	-	-	-
	DMB2	0.064	-	-	-	-
	DMB3	-	-	-	-	-
Gazipur	GMB1	-	-	-	-	-
	GMB2	0.025	-	-	-	-
	GFF1	0.061	-	-	-	-
	GFF2	0.035	-	-	-	-
Jashore	JMB1	-	-	0.029	-	-
	JMB2	-	-	-	-	-
	JFF1	0.169	0.135	-	-	-
	JJFF2	0.532	-	-	-	-
Khagrachari	KMB1	0.096	0.018	0.015	-	-
	KMB2	-	-	-	-	-
Rajshahi	RaMB1	-	-	-	-	-
	RaMB2	-	-	-	-	-
Rangpur	RFF1	-	-	-	-	-
	RFF2	0.537	0.204	-	-	-
	RMB1	-	-	-	-	-

-: Not detected; MRLs (mg kg^{-1}) of cypermethrin and quinalphos in eggplant: 0.2; MRL (mg kg^{-1}) of diazinon in eggplant; 0.5 and MRL (mg kg^{-1}) of fenitrothion in hyacinth bean: 0.1 MRL (mg kg^{-1}) of malathion in eggplant: 0.3 set by Joint FAO/WHO Standards Program, Codex Alimentarius Commission, and Codex Committee on Pesticide Residue (1993). *BFF1, BFF2, BMB1, BMB2: Eggplant sample ID of Bogura; CFF1, CFF2, CMB1, CMB2: Eggplant sample ID of Cumilla; DMB1, DMB2, DMB3: Eggplant sample ID of Dhaka; GMB1, GMB2, GMFF1, GMFF2: Eggplant sample ID of Gazipur; JMB1, JMB2, JFF1, JFF2: Eggplant sample ID of Jashore; KMB1, KMB2: Khagrachari; RaMB1, RaMB2: Eggplant sample ID of Rajshahi; RFF1, RFF2, RMB1: Eggplant sample ID of Rangpur.

In the case of hyacinth bean, 15 out of 24 analyzed samples were found to be contaminated with one or more of the five tested pesticides (Table 2). Twelve samples contained residues of a single pesticide, while three exhibited multiple pesticide residues. Among these, four samples were contaminated with cypermethrin. Two samples had cypermethrin levels exceeding the MRL, 0.533 mg/kg from Jashore and 0.561 mg/kg from Rangpur. The remaining four samples, one each from Rajshahi and Bogura and two from Cumilla, had residues below the MRL.

Diazinon was detected in four samples, with two exceeding the MRL, 0.610 mg/kg from Jashore and 0.543 mg/kg from Cumilla. The other two, from Rangpur (0.153 mg/kg) and Gazipur (0.495 mg/kg), were below the MRL. Quinalphos residues were found in three samples, with one sample from Bogura (0.414 mg/kg) exceeding the MRL, while residues in samples from Rangpur (0.055 mg/kg) and Jashore (0.054 mg/kg) were below the MRL.

Fenitrothion was present in three samples, with two exceeding the MRL, 0.120 mg/kg from Rajshahi and 0.240 mg/kg from Bogura. A third sample from Bogura contained 0.091 mg/kg, which was below the MRL. Malathion was detected in two samples: one from Cumilla (0.529 mg/kg) exceeded the MRL, while the other from Gazipur (0.190 mg/kg) was below the MRL.

Two samples exhibited multiple pesticide residues. One sample from Rangpur contained 0.561 mg/kg cypermethrin along with 0.055 mg/kg quinalphos, exceeding the MRL. Another sample from Bogura had 0.231 mg/kg cypermethrin and 0.091 mg/kg fenitrothion, both below the MRL. No contamination was detected in the hyacinth bean samples collected from Khagrachari.

Table 2. Residue levels of pesticides in hyacinth bean collected from eight different regions of Bangladesh.

Sample ID		Residue levels of detected pesticides (mg kg^{-1})				
Location	**Code***	**Cypermethrin**	**Diazinon**	**Quinalphos**	**Fenitrothion**	**Malathion**
Bogura	BFH1	0.231	-	-	0.091	-
	BFH2	-	-	0.414	-	-
	BMH3	-	-	-	0.240	-
Cumilla	CFH1	-	0.543	-	-	-
	CFH2	-	-	-	-	0.529
	CMH3	0.083	-	-	-	-
	CMH4	0.201	-	-	-	-
Dhaka	DMH1	-	-	-	-	-
	DMH2	-	-	-	-	-
Gazipur	GFH1	-	-	-	-	0.190
	GFH2	-	0.495	-	-	-
	GMH3	-	-	-	-	-
	GMH4	-	-	-	-	-
Jashore	JFH1	-	0.610	-	-	-
	JFH2	-	-	-	-	-
	JMH3	0.533	-	0.054	-	-
	JMH4	-	-	-	-	-
Khagrachari	KMH1	-	-	-	-	-
	KMH2	-	-	-	-	-
Rajshahi	RaFH1	0.054	-	-	-	-
	RaFH2	-	-	-	0.120	-
Rangpur	RFH1	-	0.153	-	-	-
	RFH2	-	-	-	-	-
	RMH1	0.561	-	0.055	-	-

-: Not detected; MRL (mg kg^{-1}) of cypermethrin, diazinon and malathion in hyacinth bean: 0.5; MRL (mg kg^{-1}) of quinalphos in hyacinth bean; 0.2 and MRL (mg kg^{-1}) of fenitrothion in hyacinth bean: 0.1 set by Joint FAO/WHO Standards Program, Codex Alimentarius Commission Codex Committee on Pesticide Residue (1993). *BFH1, BFH2, BFH3: Hyacinth bean sample ID of Bogura; CFH1,CFH2, CFH3, CMH4: Hyacinth bean sample ID of Comilla; DMH1, DMH2: Hyacinth bean sample ID of Dhaka; GFH1, GFH2, GMH3, GMH4: Hyacinth bean sample ID of Gazipur; JFH1,JFH2, JMH3, JMH4: Hyacinth bean sample ID of Jashore; KMH1, KMH2:Khagrachari; RaFH1, RAFH2: Hyacinth bean sample ID of Rajshahi; RFH1, RFH2, RMH2: Hyacinth bean sample ID of Rangpur.

4. Discussion

Samples of eggplant and hyacinth beans were gathered from eight different parts of Bangladesh, and the residue levels of six widely used pesticides were evaluated. Of the 50 samples that were examined, 60% had residues of cypermethrin, diazinon, quinalphos, fenitrothion, and malathion, and 30% had levels higher than the MRL established by the WHO and FAO in 1993 (FAO/WHO, 1993). Among the eggplant samples, 57.69% contained residues of cypermethrin, diazinon, and quinalphos, with 26.92% exceeding the MRL. Three eggplant samples had multiple pesticide residues, two from Bogura with 0.592 mg/kg cypermethrin and 0.274 mg/kg quinalphos, and 0.540 mg/kg quinalphos with 0.139 mg/kg diazinon (both above MRL), and one from Khagrachari with 0.096 mg/kg cypermethrin, 0.018 mg/kg diazinon, and 0.015 mg/kg quinalphos (below MRL). Cypermethrin was detected in 12 samples with concentrations of 0.025–0.623 mg/kg, of which four (from Bogura, Cumilla, Jashore, and Rangpur) exceeded MRL. Diazinon was found in six samples at 0.018–0.703 mg/kg, with one from Cumilla exceeding the MRL. Quinalphos was detected in five samples (0.015–0.540 mg/kg), with one from Bogura exceeding the MRL. No fenitrothion or malathion residues were found in the eggplant samples. Eggplant samples were particularly affected, with 57.69% showing residues of cypermethrin, diazinon, and quinalphos, and 26.92% exceeding MRLs. Notably, three eggplant samples contained multiple pesticide residues, including two from Bogura with concentrations significantly exceeding the MRLs, and one from Khagrachari with residues below the MRL. Cypermethrin was the most frequently detected pesticide, present in 12 samples at levels ranging from 0.025 to 0.623 mg/kg, of which four exceeded MRLs. Diazinon was found in six samples, with one from Cumilla surpassing the MRL, while quinalphos was detected in five samples, with one from Bogura exceeding the limit. Fenitrothion and malathion residues were absent in eggplant samples, suggesting a varied application of pesticides across the regions (Tasnim *et al*., 2022). These findings indicate the prevalence of pesticide misuse, highlighting the need for stricter regulations and awareness to ensure food safety.

The residues of the five tested pesticides were found in 62.50% of the 24 evaluated samples for hyacinth beans, with 33.33% of them surpassing the MRL. Remainder levels in eight tainted samples were higher than the MRL, 0.533–0.561 mg/kg cypermethrin, 0.543–0.610 mg/kg diazinon, 0.120–0.240 mg/kg fenitrothion, 0.414 mg/kg quinalphos, and 0.529 mg/kg malathion, including two multi-residue samples from Rangpur and Jashore. Other detected residues of cypermethrin (0.054–0.231 mg/kg) were below the MRL. Jashore, Cumilla, Bogura, and Rangpur samples had higher pesticide residues compared to other locations. Detected fenitrothion and quinalphos levels were double the MRL set by FAO/WHO, indicating that multiple pesticides were used on both vegetables. Hyacinth bean exhibited higher pesticide residue levels than eggplant. The analysis of hyacinth bean samples showed widespread pesticide contamination, with more than half of the samples containing residues and approximately one-third exceeding the MRLs established by FAO and WHO. Pesticides such as cypermethrin, diazinon, fenitrothion, quinalphos, and malathion were detected, with some levels surpassing the permissible limits. Notably, multi-residue contamination was observed in samples from Rangpur and Jashore. Cypermethrin residues in some samples remained within safe limits, while others exceeded them. Samples from Jashore, Cumilla, Bogura, and Rangpur were found to have higher contamination compared to other regions. The presence of fenitrothion and quinalphos residues at concentrations well above the permissible limits highlights improper pesticide use (Khanom *et al*., 2023).

Previous studies support these findings. Tasnim *et al*. (2022) reported that 20% of hyacinth bean, 13% of cauliflower, and 27% of yard-long bean samples exceeded EU-MRLs. Rahman *et al*. (2013) found 26% of vegetable samples, including eggplant and cauliflower, contaminated with quinalphos, chlorpyrifos, and dimethoate residues above MRL. Bhandari *et al*. (2019) observed 4% eggplant, 19% chili, and 44% tomato samples exceeding EU-MRLs with residues of omethoate, chlorpyrifos, triazophos, and carbendazim. Hasan and Rahman (2019) detected dimethoate residues in beans from Dhaka and Jashore exceeding MRL, and quinalphos residues in eggplant samples from Dhaka markets. Ahmed *et al*. (2014) reported that 34.67% of hyacinth bean samples were contaminated, with 12% exceeding MRL. Ahmed *et al*. (2016) also noted 23.40% of yard-long bean and cauliflower samples exceeding MRLs with single and multiple pesticide residues. These findings align with the present study, though methods differed.

Pesticide residues exceeding MRLs in vegetables are undesirable for safe food production, and their presence in tested samples suggests misuse or irrational application. This study highlights the current pesticide contamination levels in selected vegetables, emphasizing the need for awareness among consumers, policy planners, and researchers regarding pesticide use and food safety.

5. Conclusions

The study found pesticide residues in eggplant and hyacinth bean, with several samples exceeding safety limits, highlighting improper pesticide use and poor pre-harvest interval practices. Cypermethrin and diazinon were prevalent, with higher levels of quinalphos and fenitrothion in specific regions. These findings emphasize the need for farmer education on safe pesticide use and regular national monitoring programs. Future research should explore sustainable pest management alternatives and assess long-term impacts on health and the environment.

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Data availability

All relevant data are within the manuscript.

Conflict of interest

None to declare.

Authors' contribution

Md. Sultan Ahmed: conceptualization and execution of study, writing-original draft preparation; Mohammad Dalower Hossain Prodhan: methodology, writing-review and editing; Md. Sultan Ahmed: methodology; Afroza Begum and Marina Afroze: assisted in the laboratory works; Nirmal Kumar Dutta: writing-review and editing. All authors have read and approved the final manuscript.

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