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DOCUMENTATION OF INSECT PEST ATTACK AND PESTICIDE USAGE ON NEW PLANTATIONS OF COFFEE (*COFFEA* SPP.) IN SYLHET

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ABSTRACT

Coffee cultivation is emerging as a promising high-value agricultural crop in some areas of Bangladesh, particularly in Sylhet region. But information on insect pest occurrence and pesticide use in newly established coffee plantations remains limited. This study was conducted to document the major insect pests associated with coffee cultivation and assess pesticide usage patterns in Sylhet district. A field survey was carried out across five upazilas of Sylhet district using structured questionnaires, face-to-face interviews, and focus group discussions involving 60 respondents. Data were normalized first and then analyzed using descriptive statistics in R-studio and origin to characterize pest incidence, farmer profiles, and pesticide use practices. The findings revealed that *Coffea arabica* was the predominant coffee species cultivated by 96.67% of farmers. A total of 16 insect pest species were documented from coffee plantations. Coffee berry borer (*Hypothenemus hampei*) and coffee leaf miner (*Leucoptera coffeella*) were identified as the most important pests, reported by 55.00% and 46.67% of respondents, respectively. Other frequently occurring pests included white stem borer (43.33%), mealybug (40.00%), and shot hole borer (38.33%). Functional group analysis showed that sap-sucking insects constituted the dominant pest category (43.75%), followed by stem borers and leaf feeders (18.75% each). The study further revealed extensive dependence on chemical pesticides, with 83.34% of respondents using WHO Class II (moderately hazardous) pesticides, primarily organophosphates, neonicotinoids, and pyrethroids. Notably, 76.67% of farmers had not received any formal training on coffee pest management. The high prevalence of key insect pests, combined with heavy reliance on moderately hazardous pesticides and limited technical knowledge, highlights the urgent need for farmer training, strengthened extension services, and the adoption of integrated pest management strategies to ensure sustainable coffee production in Sylhet.

Keywords: Bangladesh**,** Documentation of Pest diversity; Pesticide hazard; WHO Class.

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INTRODUCTION

Coffee is the most important beverage worldwide, after crude oil (Esquivel and Jimenez 2012). Coffee is widely produced in about 60 tropical and subtropical countries, and coffee is the main export product of some countries (Lashermes *et al*. 2008). According to plant taxonomy, coffee belongs to the Rubiaceae family, which includes about 90 species (Davis 2001). Millions of farmers in Asia, Africa, and Latin America have made it as their main agricultural product (Arunyanark *et al*. 2022). From these coffee species, two species are globally popular: *Coffea arabica* and *Coffea canephora*, accounting for 99% of the world's coffee production (Arunyanark *et al*. 2022). However, Robusta coffee is more widely cultivated in Asian countries due to its tolerance to environmental conditions and high productivity (Harvey *et al*. 2021). Coffee is so popular globally because of its bioactive compounds and various health benefits (Makiso *et al*. 2024). Coffee beans contain several beneficial compounds, such as phenolic compounds and chlorogenic acids, which increase antioxidant activity and cardiovascular health benefits (Farah 2012). Another important component of coffee is Trigonelline, which can provide neuroprotective and metabolic benefits (Konstantinidis *et al*. 2023). Coffee by-products, such as coffee pulp and spent coffee grounds contain dietary fiber and phenolic compounds that can be utilized in food products and functional ingredients (Cañas *et al*. 2020, Papageorgiou *et al*. 2024, Meerasri and Sothornvit 2022). Coffee also contains essential minerals like potassium and magnesium that support physiological functions (Gyedu-Akoto *et al*. 2019). Coffee cultivation has recently gained attention in Bangladesh as a potential high-value crop. The Department of Agricultural Extension (DAE) has initiated coffee plantation activities in several hilly regions of the country, particularly in the north-eastern parts (DAE 2024). Climatic conditions of Bangladesh are considered favorable for coffee cultivation. Currently, coffee is grown in some hilly areas of Sylhet and Moulvibazar districts under the Sylhet division. Among these areas, Sylhet district has emerged as one of the important regions for coffee cultivation in Bangladesh.

Despite the recent rapid expansion of coffee cultivation in Sylhet, scientific information regarding the production areas, insect pest infestations, and pesticide use remains very limited. Insect pests are known to cause serious damage to coffee plants at different growth stages and may significantly affect yield and quality.

Moreover, farmers often indiscriminately apply chemical pesticides for pest management, which may cause human health hazards and environmental pollution. Based on acute oral and dermal toxicity (hazard), the World Health Organization (WHO) classification with color bands is shown in Table 1.

Table 1. Pesticide classes with their hazards, colour bands and toxicity levels (WHO 2020)

Class	Hazards	Colour bands	LD50 for the rat (mg kg^{-1} body weight)	
			Oral	Dermal
Ia	Extremely hazardous	PMS red 199 C	< 5	< 50
Ib	Highly hazardous	PMS red 199 C	5–50	50–200
II	Moderately hazardous	PMS Yellow C	50–2000	200–2000
III	Slightly hazardous	PMS Blue 293 C	Over 2000	Over 2000
U	Unlikely to present acute hazard	PMS Green 347 C	5000 or higher	

Class Ia and Class Ib are combinedly regarded as Highly Hazardous Pesticides (HHPs) which can cause serious harm to human health, the environment, and agricultural sustainability. Class 1b have high acute toxicity and can cause severe poisoning or death even at relatively low exposure. Class II have moderate acute toxicity that can cause poisoning if improperly handled. Class III have relatively low acute toxicity under normal use. Class U have very low acute toxicity which are unlikely to cause acute health hazards.

Based upon the facts and findings described above, we documented the spatial distribution of newly established coffee plantations in Sylhet district. Present study also documented insect pests attack and insecticides usage pattern on coffee plantations in Sylhet district.

MATERIALS AND METHODS

Survey site: The survey was conducted in the Northeastern Bangladesh with an area of 3490.40 km^2. The research covers five sub-districts, namely Sylhet Sadar, Beanibazar, Fenchuganj, Golapganj, and Gowainghat in Sylhet district (Fig. 1). The district lies between DMS 24°54’ N and 91°52’ E. The AEZ for Sylhet is 20 and 21. The Köppen climatic classification places Sylhet in the tropical monsoon bordering on a humid sub-tropical climate category at higher elevation (BAMIS 2020).

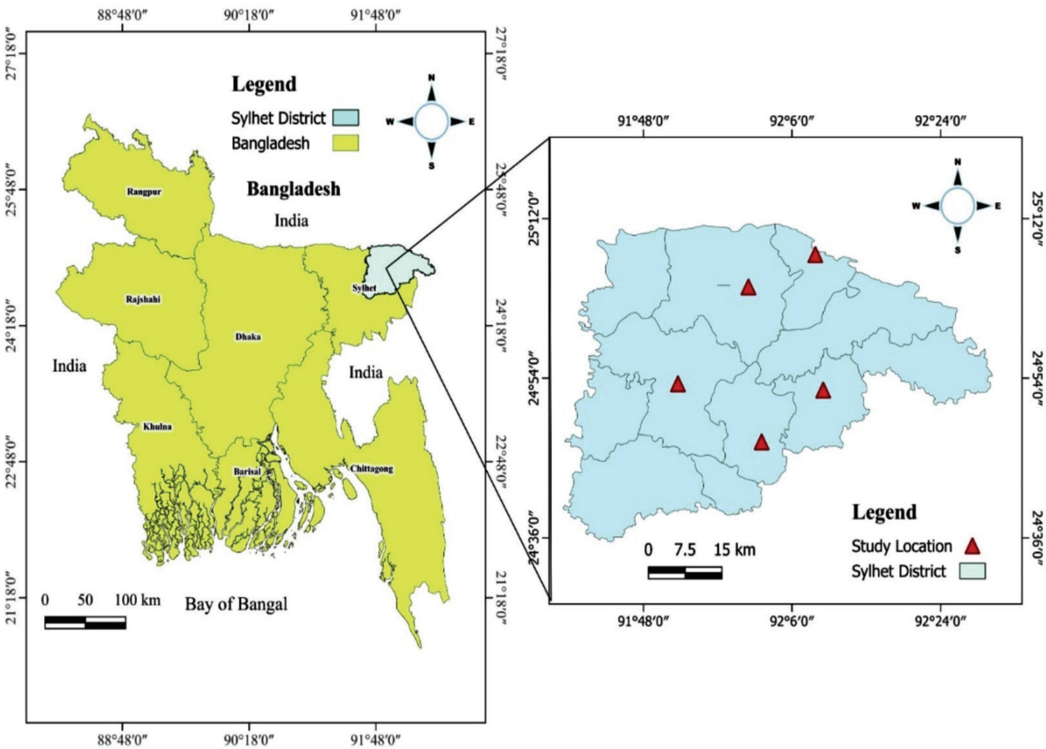

Fig. 1. Map of the study area and the selected Sub-districts under the Sylhet region

Data collection: We randomly selected 60 farmers (N=60) as the respondents via face-to-face interviews using a structured questionnaire and focus group discussion (FGD). The questionnaire was developed in English and translated into Bengali using standard translation methods by an expert translator proficient in both languages and familiar with coffee and local practices. For the selection of the respondents from the five upazilas, the following equation was used to select the total number of respondents.

$$n = \frac{N}{(1 + N\varepsilon^2)}$$

Where, n = sample size, N = the total number of respondents in each area and ε = the desired number of errors (Tuan *et al*. 2014). With a designed number of total 60 respondents i.e., 12 respondents from each upazila were interviewed. Sub-Assistant Agricultural Officer (SAAO), Department of Agricultural Extension (DAE) project personnel, coffee-related workers of the respective surveyed areas were the respondents of the survey works. Printed and laminated coloured photographs of the coffee insect pests were placed to the respondents for their identification. The photographs were also used to confirm whether or not they were able to correctly identify the insect pest species. The printed and laminated coloured photographs of the insect species were given a code against each insect shown. This was done because of the quick recording of the listed insect pests to the questionnaire.

Data analysis: The collected data were first normalized to ensure consistency and suitability for statistical analysis. Subsequently, descriptive statistics, including frequency counts, percentages, means, and standard deviations, were used to summarize the outcomes effectively. Data analysis was performed using R-Studio (Version 2026.04.0), while QGIS (Version 3.44.4-Solothurn) and OriginPro (Version 10.1.0.178) were used to create the study area map and various visually informative graphs and charts.

RESULTS

Demographic characteristics of the respondents: From the field survey, socio-economic characteristics (age, gender, education level and coffee cultivation experience) of the 60 respondents from five upazilas of Sylhet district were recorded to understand their personal and professional background (Table 2). The mean age of the respondents was 43.51±6.43 years. It was observed that the majority (76.67%) of the respondents belonged to the 36–50-year age group, whereas 15.00% were above 50 years and only 8.33% were within the 20-35 years age group. Most respondents were male (98.33%), while only 1.67% were female. The mean education level of the respondents was 0.90±1.21 (based on ordinal scoring of education categories). The study revealed that most of the respondents were illiterate (55.01%), followed by those with primary education (18.33%). A smaller proportion of respondents had completed secondary (13.33%) and higher secondary education (8.33%), while only 5.00% had a graduate degree. Moreover, the mean experience of the respondents in coffee cultivation was 5.75±3.00 years. About 41.67% of the respondents had less than 5 years of experience in coffee cultivation, whereas 51.66% and 6.67% had 5-10 years and more than 10 years of cultivation experience, respectively. The distribution of coffee varieties shows that the vast majority of respondents cultivated *Coffea arabica* (96.67%), while only a small proportion grew *Coffea canephora* (3.33%).

Table 2. Demographic characteristics of the respondents from the five selected upazilas of Sylhet district (N=60)

Factor(s)	Category	Frequency (n)	Percentage (%)	Mean	SD
Gender	Male	59	98.33	–	–
	Female	1	1.67		
Age (years)	20–35	5	8.33	43.51	6.43
	36–50	46	76.67		
	>50	9	15.00		
Education level	Illiterate	33	55.01	0.90	1.21
	Primary	11	18.33		
	Secondary	8	13.33		
	Higher secondary	5	8.33		
	Graduate	3	5.00		
Experience in coffee plantation (years)	<5	25	41.67	5.75	3.00
	5–10	31	51.66		
	>10	4	6.67		
Variety of Cultivated Coffee	*Coffea arabica*	58	96.67	0.97	0.18
	Coffea canephora	2	3.33		
Training	Yes	14	23.33	0.23	0.42
	No	46	76.67		

Major pests of coffee plantations: Respondents from the study areas in Sylhet district reported a total of 16 insect pests infesting coffee plantations (Table 3), including coffee berry borer (*Hypothenemus hampei*), coffee leaf miner (*Leucoptera coffeella*), shot hole borer (*Xylosandrus compactus*), white stem borer (*Xylotrechus quadripes*), green scale (*Coccus viridis*), red borer (*Zeuzera coffeae*), brown scale (*Saissetia coffeae*), mealybug (*Planococcus lilacinus / P. citri*), coffee grasshopper (*Zonocerus variegatus*), coffee caterpillar (*Epicampoptera* spp.), termite (*Isoptera* spp.), antestia bug (*Antestiopsis lineaticollis*), coffee bean weevil (*Araecerus fasciculatus*), leafhopper (*Empoasca* spp.), coffee plant bug (*Helopeltis antonii*), and glassy wing sharpshooter (*Homalodisca vitripennis*). Among these, coffee berry borer and coffee leaf miner were identified as the most destructive pests, reported by 55.00% and 46.67% of respondents, respectively, mainly attacking fruits and leaves. White stem borer (43.33%), mealybug (40.00%), and shot hole borer (38.33%) were also frequently observed, affecting stems, roots, leaves, and bark. Termite infestation was reported by 8.33% of respondents, while green scale and leafhopper were each noted by 5.00%. Minor pests such as red borer, brown scale, coffee grasshopper, and coffee plant bug were reported by 3.33% of respondents. The least-observed pests (1.67%) included the coffee caterpillar, antestia bug, coffee bean weevil, and glassy-winged sharpshooter. Overall, these pests were found to infest different plant parts including leaves, flowers, fruits, seeds, stems, and roots. Finally, only 23.33% of respondents received training on coffee pest management, while the rest (76.67%) reported negative responses (not receiving any training).

Table 3. Major insect pests associated with coffee plantations in Sylhet district (N=60)

Sl.	Common name	Scientific name / Order / Family	Infested plant parts	Respondents (%)
1	Coffee leaf miner	*Leucoptera coffeella* (Lyonetiidae, Lepidoptera)	Tender leaf, Older leaf	46.67
2	Coffee berry borer	*Hypothenemus hampei* (Curculionidae, Coleoptera)	Fruit	55.00
3	Shot hole borer	*Xylosandrus compactus* (Curculionidae, Coleoptera)	Stem	38.33
4	White stem borer	*Xylotrechus quadripes* (Cerambycidae, Coleoptera)	Stem, Bark	43.33
5	Green scale	*Coccus viridis* (Coccidae, Hemiptera)	Older leaf, Tender leaf, Stem	5.00
6	Red borer	*Zeuzera coffeae* (Cossidae, Lepidoptera)	Stem, Bark	3.33
7	Brown scale	*Saissetia coffeae* (Coccidae, Hemiptera)	Older leaf, Tender leaf, Stem	3.33
8	Mealy bug	*Planococcus lilacinus / P. citri* (Pseudococcidae, Hemiptera)	Root, Tender leaf, Stem	40.00
9	Coffee grasshopper	*Zonocerus variegatus* (Pyrgomorphidae, Orthoptera)	Older leaf, Tender leaf	3.33
10	Coffee caterpillar	*Epicampoptera* spp. (Notodontidae, Lepidoptera)	Older leaf	1.67
11	Termite	*Isoptera* spp. (Termitoidae, Blattodea)	Root, Stem, Bark	8.33

Sl.	Common name	Scientific name / Order / Family	Infested plant parts	Respondents (%)
12	Antestia bug	*Antestiopsis lineaticollis* (Pentatomidae, Hemiptera)	Flower, Fruit, Tender leaf	1.67
13	Coffee bean weevil	*Araecerus fasciculatus* (Anthribidae, Coleoptera)	Seed	1.67
14	Leafhopper	*Empoasca* spp. (Cicadellidae, Hemiptera)	Older leaf, Tender leaf	5.00
15	Coffee plant bug	*Helopeltis antonii* (Miridae, Hemiptera)	Tender leaf, Fruit	3.33
16	Glassy wing sharpshooter	*Homalodisca vitripennis* (Cicadellidae, Hemiptera)	Older leaf	1.67

Relative abundance of coffee pest functional groups: Figure 2 presents the distribution of coffee insect pests by functional groups based on 16 recorded species in Sylhet district. Sap-sucking insects were the most dominant group, accounting for 43.75% of the total pests. Stem borers and leaf feeders (chewers) each contributed 18.75%, while fruit borers and root feeders represented 12.50% and 6.25%, respectively. This pattern indicates that sap-sucking insects exert the highest pest pressure on coffee plants in the surveyed areas.

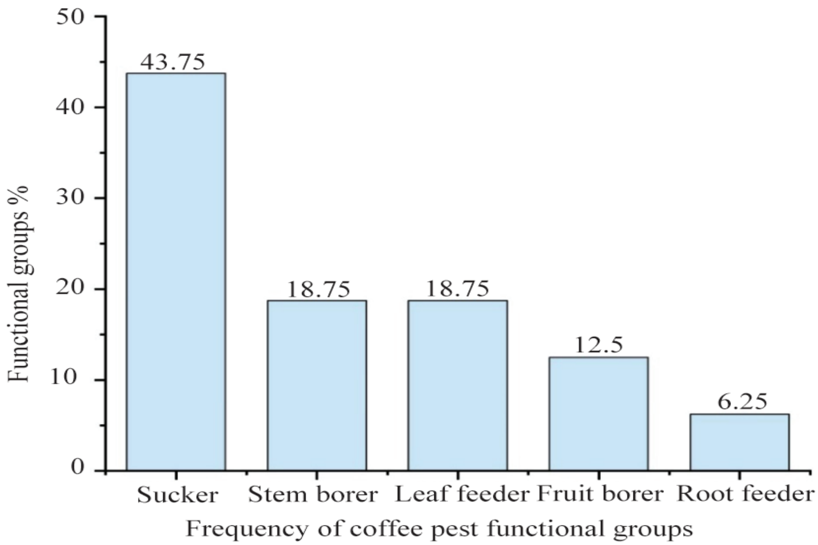

Fig. 2. Percentage distribution of coffee insect pest functional groups in Sylhet district, showing dominance of sap-sucking insects followed by stem borers, leaf feeders, fruit borers, and root feeders

Distribution of pesticide groups and hazard classes: Table 4 shows that a wide range of pesticides are used on coffee plantations of Sylhet district. Insecticides are the most commonly used group. Most pesticides belong to WHO Class II (moderately hazardous), with a few from Class Ib, Class III, and Class U. The major chemical groups include organophosphates, neonicotinoids, pyrethroids, and their mixtures. Fungicides and herbicides such as propiconazole, mancozeb, and glyphosate are also used. Overall, the results indicate a strong dependence on moderately hazardous chemical pesticides for pest management.

Table 4. Common pesticide groups used for coffee pest management in Sylhet district (N = 60)

Types	WHO Class	Chemical Group(s)	Common Name(s)	Trade Name(s)
Insecticide	Class Ib	Carbamate	Carbofuran	Carbofuran 3G
Insecticide	Class II	Organophosphate	Chlorpyrifos	Chlorpyriphos 20EC
Insecticide	Class II	Organophosphate	Chlorpyrifos	Dursban 20EC
Insecticide	Class II	Organophosphate	Quinalphos	Kinalux 25EC
Insecticide	Class II	Neonicotinoid	Imidacloprid	Admire 20SL
Insecticide	Class II	Neonicotinoid	Thiacloprid	Helocide 24SC
Insecticide	Class II	Neonicotinoid	Imidacloprid	Imitaf 20SL
Insecticide	Class II	Neonicotinoid	Acetamiprid	Platinum 20SP
Insecticide	Class II	Neonicotinoid + Pyrethroid	Acetamiprid + Cypermethrin	Juti 30SL
Insecticide	Class II	Neonicotinoid + Pyrethroid	Thiamethoxam + Lambda-cyhalothrin	Lamix 24.7SC
Insecticide	Class II	Neonicotinoid + Pyrethroid	Imidacloprid + Lambda-cyhalothrin	Roland 20SC
Insecticide	Class II	Neonicotinoid + Pyrethroid	Imidacloprid + Cypermethrin	Stroke 50EC
Insecticide	Class II	Neonicotinoid + Pyrethroid	Imidacloprid + Lambda-cyhalothrin	Wicket 30SC
Insecticide	Class II	Neonicotinoid + Phenylpyrazole + Pyrethroid	Imidacloprid + Fipronil + Deltamethrin	Proloy 32SC
Insecticide	Class II	Pyrethroid	Lambda-cyhalothrin	Karate 2.5EC
Insecticide	Class II	Pyrethroid	Cypermethrin	Ripcord 10EC
Insecticide	Class II	Pyrethroid + Organophosphate	Cypermethrin + Dimethoate	Merger 45EC

Types	WHO Class	Chemical Group(s)	Common Name(s)	Trade Name(s)
Insecticide	Class II	Pyrethroid + Phenylpyrazole	Fipronil + Lambda-cyhalothrin	Otova 10EC
Insecticide	Class III	Organophosphate	Malathion	Fyfanon 57EC
Fungicide	Class II	Triazole	Propiconazole (25%)	Tilt 250 EC
Fungicide	Class U	Dithiocarbamate	Mancozeb 80%	Zebco 80 WP
Fungicide	Class U	Dithiocarbamate / Morpholine / Cyanoacetamide-oxime	Mancozeb 64% + Dimethomorph 10% + Cymoxanil 8%	Spiner 82 WP
Herbicide	Class III	Phosphonomethyl	Glyphosate	Sun Up

***Percentage distribution of pesticide use based on WHO hazard classes**:* Figure 3 shows the percentage of pesticide use based on WHO hazard classes. The majority of respondents (83.34%) used Class II pesticides. A smaller proportion (8.33%) used Class III pesticides. Only 5.00% of respondents used Class Ib pesticides. The least used group was Class U, with 3.33%. This indicates a strong reliance on moderately hazardous pesticides in the study area.

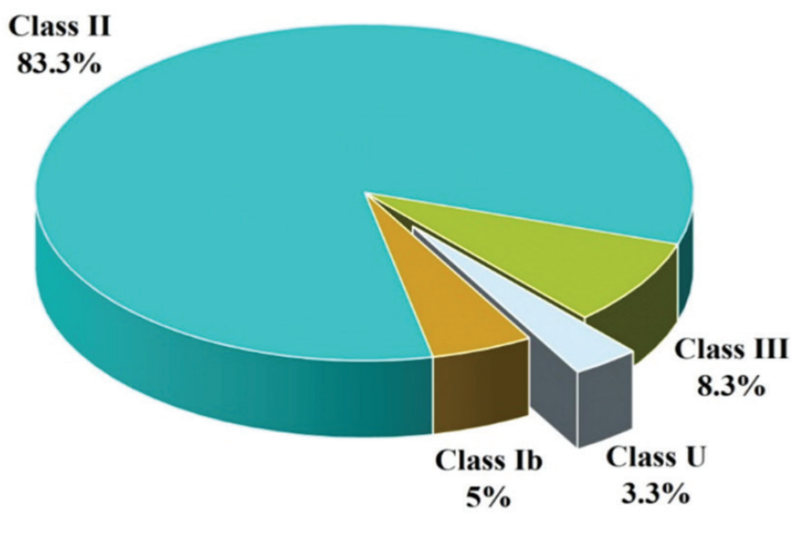

Fig. 3. Percentage distribution of pesticide usage based on WHO hazard classes in coffee plantations of Sylhet district, showing dominance of Class II pesticides followed by Class III, Class Ib, and Class U

DISCUSSION

The socio-demographic profile of coffee producers in Sylhet, characterized by a mean age of 43.51 years, suggests a workforce in its peak productive years (Torrez *et al*. 2023). This age distribution is consistent with middle-aged farmer profiles documented in the Philippines, where the average age of coffee smallholders is recorded at 43 years (Rodolfo *et al*. 2016). Similar trends are observed in developing countries, including Brazil and Honduras, where fewer young individuals are entering agriculture (Buys *et al*. 2023). The high rate of illiteracy (55.01%) identified in the current study presents a formidable obstacle to the adoption of modern agricultural technologies. Illiterate farmers struggle to comprehend technical information, reducing their likelihood of adopting new practices (Idisi *et al*. 2025). This educational deficit is notably more severe than that of coffee farmers in Vietnam, who average over nine years of formal education, enabling them to better engage with digital monitoring and certification protocols (Noreen 2026). Furthermore, the near-total male dominance (98.33%) in Sylhet coffee farming contrasts with more gender-inclusive systems in parts of Ethiopia and Indonesia, where women frequently manage post-harvest activities (Pascucci 2024). Even, Training programs have led to an 80% increase in farmers' knowledge and skills, directly correlating with improved coffee quality and income (Matoneng *et al*. 2025).

The documentation of 16 insect pests in Sylhet highlights a complex agro-ecological challenge for local producers (Parija *et al*. 2025). The coffee berry borer, identified by 55.00% of respondents as the most destructive pest, stand as the primary biological threat to coffee globally, causing annual economic losses exceeding $500 million (Johnson *et al*. 2020, Moreno-Ramirez *et al*. 2024). The high prevalence of Coffee bean borer in Sylhet is a characteristic shared with Ethiopian coffee systems, where infestation levels often vary by altitude and management intensity (Azeez 2025). Similarly, the prominence of the coffee leaf miner in the study area (46.67%) aligns with its status as a major pest in neotropical countries like Brazil and Colombia, where it accounts for yield losses of up to 70% (Dantas *et al*. 2021). The identified dominance of sap-sucking insects (43.75%) suggests high pest pressure that mirrors the biological dynamics of shaded coffee agroforestry systems in Indonesia (Sunanto *et al*. 2024).

Pest management in Sylhet is defined by an overwhelming reliance on WHO Class II (moderately hazardous) chemical pesticides (Global Coffee Platform 2021). The frequent use of organophosphate and neonicotinoid insecticides reflects intensive agricultural production systems similar to those reported in Vietnam and Brazil, where high crop yields have historically been supported by substantial pesticide inputs (Jardim *et al*. 2018). Despite their effectiveness, these substances pose significant occupational health risks, as evidenced by reports of acute pesticide poisoning among plantation workers in India (Ssekkadde *et al.* 2026). The lack of Integrated Pest Management (IPM) training in Sylhet (76.67% untrained) is far more acute than in Honduras, where government-led programs have reached 87% of smallholders (USDA 2023). This training gap is a critical vulnerability that has been linked to the misuse of banned pesticides in other developing regions (Henry and Feola 2013).

Finally, the livelihood vulnerability of Sylhet farmers, driven by low education and limited technical support, parallels the socio-economic pressures faced by Ethiopian smallholders who lack diversified income streams (Teferra 2022). Furthermore, climate change is expected to aggravate these pressures, as seen in Tanzania where rising temperatures have caused pests like the CBB to migrate to higher elevations (Jaramillo *et al*. 2011). To improve the sustainability of the Sylhet coffee industry, policymakers must implement participatory training models, which have successfully promoted non-chemical pest management in Central America (Aristizábal *et al*. 2023).

CONCLUSION

Coffee cultivation in Sylhet district is expanding rapidly, with Coffea arabica being the predominant species grown by farmers. The study documented 16 insect pest species, among which coffee berry borer and coffee leaf miner were identified as the most important pests affecting coffee production. Sap-sucking insects constituted the dominant pest functional group, indicating substantial pest pressure in the surveyed plantations. Pest management was heavily dependent on WHO Class II pesticides, while the majority of farmers lacked formal training in coffee pest management. The combination of high pest incidence, extensive pesticide use, and limited technical knowledge highlights the need for strengthened extension services and integrated pest management programs. Adoption of sustainable pest management practices will be essential for improving the productivity, environmental safety, and long-term sustainability for the emerging coffee sector in Sylhet.

REFERENCES

ARISTIZÁBAL, L. F., JOHNSON, M. A., MARIÑO, Y. A., BAYMAN, P. & WRIGHT, M. G. 2023. Establishing an integrated pest management program for coffee berry borer (*Hypothenemus hampei*) in Hawaii and Puerto Rico coffee agroecosystems: achievements and challenges. *Insects*. **14**(7): 603. https://doi.org/10.3390/insects14070603.

ARUNYANARK, A., ROONPRAPANT, P., SRIDOKCHAN, W., PAKOKTOM, T. & CHUTTEANG C. 2022. Effect of water deficit and propagation methods on physiological responses of Robusta coffee (*Coffea canephora*) varieties. *Agric. Nat. Resour*. **56**(6): 1123-1134. DOI: doi.org/10.34044/j.anres.2022.56.6.07.

Azeez, O. M. 2025. Insect pests and its control of Coffee - A Review. *Paper Recycling Ann Rev Resear.* **12**(5): 555847.DOI: 10.19080/ARR.2025.12.555848.

BAMIS (BANGLADESH AGRO-METEOROLOGICAL INFORMATION SYSTEMS). 2020. Bangladesh agro-meteorological information portal, agro-meteorological information systems development project, department of agricultural extension (DAE), Dhaka. https://www.bamis.gov.bd/home/.

BUYS, D. R., ROBERTSON, M. N. & GREEN, J. J. 2023. The aging agricultural workforce: Opportunities for policy development and intervention. *PP&AR.* **33**(3): 105-110.

CAÑAS, S., REBOLLO-HERNANZ, M., CANO-MUÑOZ, P., AGUILERA, Y., BENÍTEZ, V., BRAOJOS, C., ... & MARTIN-CABREJAS, M. A. 2020. Critical evaluation of coffee pulp as an innovative antioxidant dietary fiber ingredient: nutritional value, functional properties, and acute and sub-chronic toxicity. *In:* Proceedings (Vol. 60, No. 1). MDPI.

DAE (Department of Agricultural Extension). 2024. Agriculture Information Centre, Department of Agricultural Extension, Sylhet Sadar Office.

DANTAS, J., MOTTA, I. O., VIDAL, L. A., NASCIMENTO, E. F. M. B., BILIO, J., PUPE, J. M., VEIGA, A., A CARVALHO, C., LOPES, R. B., ROCHA, T. L., SILVA, L. P., PUJOL-LUZ, J. R. & LBUQUERQUE, É. V. S. 2021. A comprehensive review of the coffee leaf miner *Leucoptera coffeella* (Lepidoptera: Lyonetiidae)—A major pests for the coffee crop in Brazil and others neotropical countries. *Insects.* **12**(12): 1130. https://doi.org/10.3390/insects12121130.

DAVIS, A. P. 2001. Two new species of *Coffea L*. (Rubiaceae) from eastern Madagascar. Kew Bulletin, 479-489. https://doi.org/10.2307/4110970.

ESQUIVEL, P. & JIMENEZ V. M. 2012. Functional properties of coffee and coffee by-products. *Food Res. Intl*. **46**(2): 488-495. 10.1016/j.foodres.2011.05.028.

FARAH, A. 2012. Coffee constituents. Coffee: Emerging health effects and disease prevention. Jhon Wily and Sons. **1**: 22-58.

GLOBAL COFFEE PLATFORM. 2021. GCP policy brief: Pesticide usage and hazard class in Vietnam. GCP Publications.

GYEDU-AKOTO, E., OPOKU, S. Y. & OFOSU-AGYEI E. 2019. Proximate, mineral composition and sensory evaluation of coffee and kola flavoured biscuits. *Nutri. Food Sci.* **49**(4): 752-761. https://doi.org/10.1108/NFS-10-2018-0270.

HARVEY, C.A., PRITTS, A.A., ZWETSLOOT, M.J. ET AL. 2021. Transformation of coffee-growing landscapes across Latin America. A review. *Agron. Sustain. Dev*. **41**: 62. https://doi.org/10.1007/s13593-021-00712-0.

HENRY, D. & FEOLA, G. 2013. Pesticide-handling practices of smallholder coffee farmers in Eastern Jamaica. *J. Agric. Rural Develop. Tropics and Subtropics.* **114**: 59-67. http://nbn-resolving.de/urn:nbn:de:hebis:34-2013030542613.

IDISI, P. O., ADEAGBO, B. A., MADUEKWE, I. M., AJIBOLA, A. O. & HARUNA, S. O. 2025. Empirical Drivers of Modern Technology Adoption among Farmers in Nigeria. *Intl J. Multidis. Res. Growth Eval.* **6**(1): 1180-1188. https://doi.org/10.54660/.IJMRGE.2025.6.1.1180-1188.

JARAMILLO, J., MUCHUGU, E., VEGA, F. E., DAVIS, A., BORGEMEISTER, C. & CHABI-OLAYE, A. 2011. Some like it hot: the influence and implications of climate change on coffee berry borer (*Hypothenemus hampei*) and coffee production in East Africa. *PloS one*. **6**(9): e24528. https://doi.org/10.1371/journal.pone.0024528.

JARDIM, A. N. O., BRITO, A. P., DONKERSGOED, G. V., BOON, P. E. & CALDAS, E. D. 2018. Dietary cumulative acute risk assessment of organophosphorus, carbamates and pyrethroids insecticides for the Brazilian population. *Food Chem. Toxicol*. 112: 108-117. DOI: 10.1016/j.fct.2017.12.010.

JOHNSON, M. A., RUIZ-DIAZ, C. P., MANOUKIS, N. C. & RODRIGUES, J. C. V. 2020. Coffee berry borer (*Hypothenemus hampei*), a global pest of coffee: Perspectives from historical and recent invasions, and future priorities. *Insects.* **11**(12): 882. https://doi.org/10.3390/insects11120882.

KONSTANTINIDIS, N., FRANKE, H., SCHWARZ, S. & LACHENMEIER, D. W. 2023. Risk Assessment of Trigonelline in Coffee and Coffee By-Products. *Molecules.* **28**(8): 3460. https://doi.org/10.3390/molecules28083460.

LASHERMES, P., ANDRADE, A.C. & ETIENNE, H. 2008. Genomics of Coffee One of the World's Largest Traded Commodities. *In:* Moore, P.H., Ming, R. (eds) Genomics of Tropical Crop Plants. Plant Genetics and Genomics: Crops and Models, vol 1. Springer, New York, NY. https://doi.org/10.1007/978-0-387-71219-2_9.

MAKISO, M. U., TOLA, Y. B., OGAH, O. & ENDALE, F. L. 2024. Bioactive compounds in coffee and their role in lowering the risk of major public health consequences: A review. *Food Sci. Nutri.* **12**(2): 734-764. https://doi.org/10.1002/fsn3.3848.

MATONENG, O. W., KERAF, F. M., GELLU, L. P., FEKA, W. V., PAKAENONI, G., YUNITI, I. G. A. D. & YUESTI, A. 2025. Implementasi teknologi tepat guna solar dyer house dan peningkatan mutu dan nilai tambah kopi rakyat di desa suanae. Mejuajua: *Jurnal Pengabdian pada Masyarakat*. **5**(2): 275-287.

MEERASRI, J. & SOTHORNVIT, R. 2022. Novel development of coffee oil extracted from spent coffee grounds as a butter substitute in bakery products. *J. Food Process. Preserv*. **46**(7): e16687. https://doi.org/10.1111/jfpp.16687

MORENO-RAMIREZ, N., BIANCHI, F. J. J. A., MANZANO, M. R. & DICKE, M. 2024. Ecology and management of the coffee berry borer (*Hypothenemus hampei*): the potential of biological control. *BioControl.* **69**: 199–214. https://doi.org/10.1007/s10526-024-10253-6.

NOREEN, L. 2026. Climate variability and coffee yields in Brazil, Vietnam, and Ethiopia: A Panel Data Analysis. Published by Swedish University of Agricultural Sciences, Faculty of Natural Resources and Agricultural Sciences, Department of Economics. pp 1-38. noreen-l-20260217.pdf.

PAPAGEORGIOU, C., DERMESONLOUOGLOU, E., TSIMOGIANNIS, D. & TAOUKIS, P. 2024. Enrichment of Bakery Products with Antioxidant and Dietary Fiber Ingredients Obtained from Spent Coffee Ground. *Appl. Sci.* **14**(16): 6863. https://doi.org/10.3390/app14166863.

PARIJA, S., PANDA, A. & DAS, A. 2025. Agri Articles. E-Magazine. 5: 03. Agri Articles – (e-Magazine for Agricultural Articles).

PASCUCCI, F. 2024. Sustainability in the coffee supply chain. Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-72502-9.

RODOLFO, R. A., CALSIYAO, I. S., DUCLAYAN, R. M. & HIMSON, J. A. 2016. Coffee farmers socio-economic status, problems encountered and potential intervention in Kalinga, Philippines. *Intl J. Soc. Sci. Human. Res.* **4**(1): 577–583.

SSEKKADDE, P., JONITZ, V. M. J., ATUHAIRE, A., BRUGGER, C., DALVIE, M. A., ROTHER, H. A. & FUHRIMANN, S. 2026. Behavior change through educational interventions and text messaging to improve personal protective equipment use during pesticide handling among smallholder farmers in Uganda: A cluster randomized controlled trial. *J. Environ. Manage.* **400**: 128760. https://doi.org/10.1016/j.jenvman.2026.128760.

SUNANTO, YUNIARSIH, E. T., HANIFA, A. P., BASIR NAPPU, M., HERNIWATI, SALIM & RAHMATIAH. 2024. The impact of sustainable technology adoption on coffee farming in Tana Toraja, Indonesia: A call for comprehensive support. In: IOP Conference Series: *Earth Environ. Sci.* **1364**(1): 012016. IOP Publishing. doi:10.1088/1755-1315/1364/1/012016.

TEFERRA, T. F. 2022. The cost of postharvest losses in Ethiopia: Economic and food security implications. *Heliyon*. **8**(3): https://doi.org/10.1016/j.heliyon.2022.e09077.

TORREZ, V., BENAVIDES-FRIAS, C., JACOBI, J. ET AL. 2023. Ecological quality as a coffee quality enhancer. A review. *Agron. Sustain. Dev.* **43**: 19. https://doi.org/10.1007/s13593-023-00874-z.

TUAN, T. H., MY, N. H. D., ANH, L. T. Q. & TOAN, N. V. 2014. Using contingent valuation method to estimate the WTP for mangrove restoration under the context of climate change: A case study of Thi Nai lagoon, Quy Nhon city, Vietnam. Ocean & coastal management. **95**: 198-212. https://doi.org/10.1016/j.ocecoaman.2014.04.008.

USDA (United States Department of Agriculture). 2023. Honduras coffee annual report 2023. GAIN Report No. HO2023-0003.

WHO (World Health Organization). 2020. WHO recommended classification of pesticides by hazard and guidelines to classification, 2019 edition. Geneva: World Health Organization; 2020. License: CC BY-NC-SA 3.0 IGO.