

Knowledge of Pesticide Use Among Bangladeshi Vegetable Growers: Consequences for Environmental Integrity, Farmer Health, and Sustainable Agriculture

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Abstract

Pesticides are extensively used in Bangladeshi vegetable production to control pests and diseases with little consideration for their impact on the environment and human health, despite the presence of various laws and regulations pertaining to pesticide management. Given this, the research examined pesticide usage practices, knowledge, behaviour, and inclination as well as the impacts of these chemicals on the environment and the health of farmers. The study community used a questionnaire survey, focus group discussions (FGDs), and key informant interviews (KIIs) to collect data. Graphical displays of the health effect were made using the Statistical Package for the Social Sciences (SPSS). Additionally, a likelihood ratio test was used to look at relationships between health problems and factors including education, training level, frequency of pesticide usage, and protective covers. According to the results, 60% of farmers use pesticides, insecticides, and fungicides on a daily or weekly basis without taking the necessary precautions, and 68% rely more on their own experiences and other farmers' advice than on Bangladeshi laws. Harvesting sometimes occurs two to five days following pesticide treatment, especially for plants like long beans and eggplant, which may cause health issues including diarrhoea, headaches, nausea, gastrointestinal problems, and skin diseases. Overuse of pesticides contaminates water and lowers soil fertility, both of which have a detrimental effect on the environment. To address these issues, it is essential to strengthen farmer education and awareness programs, such as neighborhood-based initiatives like Uthan Boithok, and promote organic and sustainable farming practices that support the responsible use of pesticides while safeguarding farmer health and the environment.

Keywords: Pesticide use, Health hazard, PPE, Environmental contamination, Vegetable production

1. Introduction

2. One of the main causes of environmental degradation, which has lately drawn attention, is agriculture (Ali et al., 2024). Chemical inputs increased when the world's agricultural system started to modernise in the beginning of the sixth decade of the previous century (Rahman et al., 2021). Because they significantly boost crop yields and prevent losses brought on by pests, pesticides are crucial to worldwide agriculture (Damalas and Eleftherohorinos, 2011). Every year, over 5 billion kg of pesticides are used worldwide, averting 40% of possible crop losses (Oerke, 2006). Despite this crucial role, the ecosystem and human health are at danger due to pesticides' high toxicity and persistence. Additionally, when pests develop resistance over time, they increase production costs and have unanticipated consequences (Carvalho, 2006; Gavrilescu et al., 2015). The World Health Organization (WHO) has highlighted the long-term health risks associated with pesticide exposure, including cancer, neurological disorders, reproductive impairments, and skin and respiratory problems (WHO, 1990). Pesticides are necessary to boost production and meet the world's expanding food demand, but their extensive usage creates issues for sustainable agriculture by polluting important resources including food, water, and air (Sharma et al., 2010; Zhang et al., 2015). Developing nations account for 99% of pesticide-related illnesses and fatalities, particularly among rural farmers (Miller 2004; Zhang et al. 2011). According to WHO (2009), at least 300,000 people die each year from pesticide poisoning, with low- and middle-income nations accounting for 99% of these fatalities. According to World Bank estimates, 355,000 people died in 2008. However, according to FAO (2005), which cited new data from Sri Lanka, pesticide poisoning may cause up to 300,000 deaths annually in the Asia-Pacific region alone (Gyawali, 2018). Additionally, the UN Environmental Program and the World Health Organization estimate that three million agricultural workers in underdeveloped nations suffer from severe pesticide poisoning each year, with over 18,000 of them dying as a consequence (Miller, 2004). Numerous pesticides have been shown to be endocrine-disrupting substances, which interfere with the

endocrine system's regular operation and may result in disease or abnormalities in the organism and its offspring (McKinlay et al., 2008). For instance, breast cancer is more common in women who reside in regions where the use of agricultural pesticides has been rising (Reynolds et al., 2005). Pesticides and other organic contaminants also have a variety of ecological effects on ecosystems and individual organisms. For example, a research carried out in Sweden discovered that one of the main factors causing biodiversity loss is the usage of pesticides. According to WWF, commercial fish species in heavily contaminated North Sea and UK coastal waters have shown an upsurge in disease, malformations, and tumours throughout the 1970s that are consistent with the consequences of pesticide exposure (FAO, 1996). Pesticide-induced groundwater contamination is a global issue, according to the USGS, as at least 143 distinct pesticides and 21 transformation products, representing all major chemical families, have been discovered in groundwater (Kole and Bagchi, 1995, cited in Aktar et al., 2009). Due to improper application and handling by untrained agricultural labourers, the bulk of pesticide usage in poor nations like Nepal is linked to negative impacts on human health and the environment (Naidoo et al., 2010). Nearly 80% of pesticides used in Vietnamese agriculture are sprayed inappropriately, increasing the burden of environmental hazards, increasing production costs, and lowering bioefficacy, according to Vietnamese study (Nguyen, 2014). An example of the complex link between pesticides, agricultural practices, and their impacts is Bangladesh, a densely populated nation heavily reliant on agriculture. Due to its limited land resources, Bangladesh depends heavily on pesticides; in 2018–2019, agriculture accounted for 13.3% of the nation's GDP (BBS, 2020a). Bangladesh is now the third-largest vegetable grower in the world, with an expected 19.7 million metric tonnes (MT) produced in 2020–2021 (BBS, 2022). In Bangladesh, more than 470,414 hectares of land are used to cultivate a variety of vegetable species, with an annual growth rate of 2.8%. As essential components of a healthy diet, vegetables are particularly susceptible to pests, necessitating strict pest management (BBS, 2010). Although use began in 1951, it was little until the 1960s. However, government initiatives, such as the distribution of free

pesticides before to 1974 and substantial subsidies thereafter, have led to a rise in pesticide consumption among vegetable farmers (Amin and Bashu, 2004). Since then, the country has registered 84 active compounds and 242 trade names for pesticides in different formulations to protect crops and vegetables (Ara et al., 2014), indicating a notable increase in usage. Bangladesh's usage of pesticides rose from 758 metric tonnes in 1960 to 48,690 metric tonnes in 2008, according to sources, suggesting a growing dependence on these chemical treatments (Islam et al., 2016; Miah et al., 2014). But excessive use of pesticides, particularly those that are prohibited, raises concerns about their potential effects on human health and the environment (IRIN, 2010). The concerning finding that 900 farmers out of every 100,000 had pesticide poisoning is a consequence of the extensive usage of organophosphate pesticides (Dasgupta and Meisner, 2005). According to reports from Bangladesh, soil and water contain very high levels of carbamate and organophosphate pesticides (Chowdhury et al., 2012; Shammi et al., 2014). Farmers' poor self-defence tactics, lack of understanding, and excessive use of pesticides are the causes of these alarming numbers (Goldner et al., 2010). The World Bank claims that excessive pesticide use is a common issue among Bangladeshi vegetable producers, particularly those who cultivate eggplants and beans (Dasgupta and Meisner, 2005). Additionally, both legal and illicit extremely hazardous pesticides are often used by Bangladeshi farmers, which has detrimental consequences on both human health and the environment (Meisner, 2004; Robinson et al., 2007; Shammi et al., 2020). Additionally, it has been shown that more than 47% of Bangladeshi farmers who grow mangoes, potatoes, beans, eggplant, cabbage, sugarcane, and Boro (winter rice) misuse pesticides. This misuse presents a potentially dangerous issue for the environment and farmers' health since only 4% of farmers have received official training in pesticide usage or management, while over 87% openly acknowledge to using pesticides carelessly (Dasgupta, 2007). Despite the fact that research from all across the globe indicates several links between agricultural practices and products and environmental health issues, public policy efforts have often focused on agriculture and health independently (Sarkar et al., 2012). This is true even if workplace safety and health have gained

importance recently (Cecchini et al., 2018). The overuse of pesticides in Bangladesh, together with the ignorance and lack of protective conduct of vegetable growers, has a substantial detrimental impact on human health and the environment that is yet mostly ignored. Given this, this research made an effort to assess the use of pesticides in vegetable cultivation, including methods, health risks, and farmer perceptions of the impact of pesticides on the environment. It also produced specific recommendations for protecting the environment and using pesticides in a safer manner.

3. Materials and methods

4. Both primary and secondary data were used in this investigation. A questionnaire survey, focus groups, and key informant discussions were used to gather primary data in two agricultural villages—one in Godagari Upazila, Rajshahi district, and the other in Manirapur Upazila, Jashore district—that were chosen for their intensive vegetable-growing features (Fig. 1). Okra (*Abelmoschus esculentus*), cauliflower (*Brassica oleracea* var. *botrytis*), eggplant (*Solanum melongena*), tomato (*Lycopersicon esculentum*), pumpkin (*Cucurbita pepo*), cucumber (*Cucumis sativus*), white spot arum (*Amorphophallus*), radish (*Raphanus sativus*), chilli (*Capsicum annum* L.), cabbage (*Brassica oleracea* var. *capitata*), long beans (*Vigna unguiculata*), and papaya (*Carica papaya*). Important informants were agricultural officials, local leaders, and educators; 191 respondents were specially chosen from among active vegetable farmers, pesticide dealers, and merchants for the questionnaire survey and focus group talks. A range of statistical methods, including descriptive and analytical statistics, were then used to analyse and evaluate the data. Descriptive statistics were used to display the frequency distribution and percentages of the variables, while likelihood ratio tests and other analytical statistics were used to show the relationship between the distinctive characteristics of vegetable growers, including gender, education, training, safety precautions, and health risks. Finally, the impacts of pesticide pollution on the ecosystem were examined using a binary logistic regression model. Because this technique predicts a binary outcome, such whether perceived environmental quality is changing (yes/no), it

is appropriate in circumstances where linear regression would break its error assumptions and yield out-of-range probability (Hosmer et al., 2013; Peng et al., 2002).

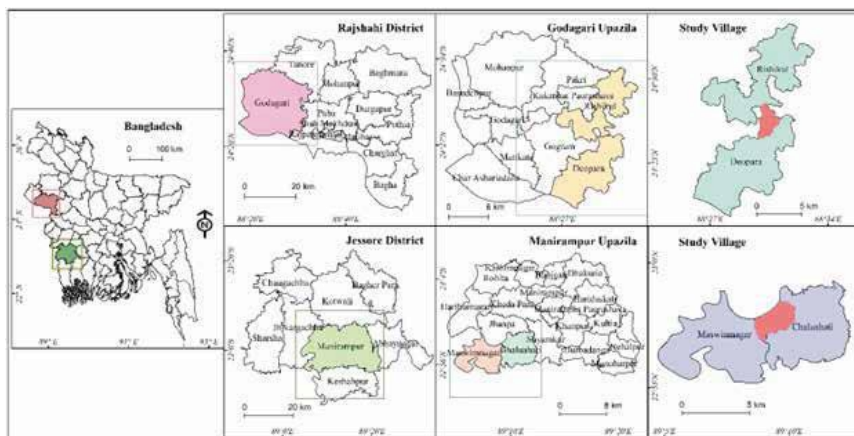


Fig 1. Study area map

5. Results and discussions

The majority of the time, the demographics of the farmers—specifically, their age, sex, and level of education—determine how pesticide usage affects the environment and human health (Shammi et al., 2020; Nguyen, 2017). Given this viewpoint, the analysis of farmers' demographic trends is shown graphically as follows:

5.1 Demographic profile and experiences of the vegetable growers

Figure 2 displays the demographic information of the vegetable producers who took part in the study's interviews. The data provides insight into the age groups, educational attainment, gender distribution, and experiences with pesticide usage of the individuals.

Gender Similar patterns were seen in the study region, where farming methods are dominated by men. 97.91 percent of responders were men and only 2.09 percent were women.

Age Similar trends were seen in the research area, where males predominate in farming practices. Just 2.09 percent of responses were female, compared to 97.91 percent who were male.

5.1.1

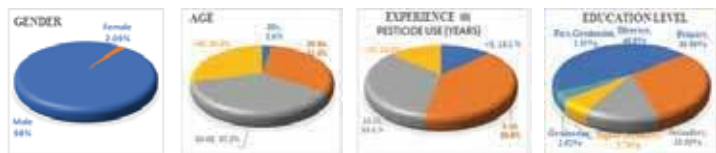


Fig 2. Demographic Characteristics of the interviewed vegetable growers

Experience in Pesticide Use The length of time that each person had used pesticides varied. Five to ten years of experience accounted for 39.80% of the biggest group. Nonetheless, a surprising 13.6% of persons have worked with pesticides for more than 15 years. Furthermore, 33.5% have used pesticides for ten to twenty-five years.

Education Level The vegetable growers' educational backgrounds also differed. A significant portion of farmers (46.60%) lack literacy, and those with less education (30.89%), mostly from basic school, come next. Farmers' perceptions of the health risks associated with using chemical pesticides are influenced by a variety of factors, including age, agricultural experience, education level, farm size, yield, average income, and membership in agricultural organisations (Liu et al., 2021; Bakhsh et al., 2017). Ghalavandi et al. (2018) underlined the need of suitable knowledge and education in order to handle pesticides properly at every stage, including acquisition, formulation, storage, spraying, and correct garbage disposal. Janmaimool and Watanabe (2014) similarly validated the influence of prior experience, attitude, mental norm, perceived ability to regulate risk, and sociodemographic characteristics (age, gender, education, socioeconomic level, and membership in organisations) on health-risk perception, while Ahmadipour and Nakhei (2024) showed a significant correlation between education and pesticide-related health risks.

5.1.2 Tradition of pesticide use and knowledge of the vegetable growers Pesticides and chemical fertilisers are examples of agrochemicals that are widely used in agriculture, particularly by small and intensive farmers like those in Bangladesh, a densely populated country whose economy is heavily reliant on agriculture (BBS 2016; BBS 2020b; WB 2016a). Table 1 displays farmers' responses to questions on their knowledge and pesticide use habits. Approximately

48% of farmers only use pesticides when necessary to control pests, whereas 34% and 18% use them daily and weekly, respectively. The frequency of pesticide use also varies by vegetable variety; farmers who grow long beans and eggplant are primarily responsible for the frequent use of pesticides, frequently applying an excessive dose in the belief that increased application leads to increased output. Pesticide misuse is prevalent among Bangladeshi vegetable producers, especially those who cultivate beans and eggplant, according to similar findings from earlier World Bank study (Dasgupta and Meisner 2005). Insecticides were the most often used pesticide input (42.93%); fungicides (31.41%) and herbicides (22.51%) were more frequently used than rodenticides (3.14%). More than 85% of farmers use both fungicides and insecticides, with overdose still being widespread. A variety of factors influence farmers' decisions regarding the use of pesticides; 40.31% relied primarily on recommendations from other farmers and 28.80% on their own experience; proposals from pesticide retailers (16.75%) were also significant; labelling guidelines (8.38%) and recommendations from agricultural authorities (5.76%) had a smaller impact, with very few farmers adhering to agriculture officers' recommendations. Similar findings from a previous research (Chowdhury et al. 2013a) indicate that rather than following government guidelines, the majority of Bangladeshi farmers choose their pesticides based on their own experience and the advice of pesticide dealers. Additionally, farmers had different preferences about when to apply pesticides: application at the primary stage of an attack (31.93%) or when needed (42.41%) was more common than application before an attack (24.60%) and after the severe stage of an attack (1.04%). However, even this more appropriate practice is still underutilised. 30.37% of farmers sprayed pesticides on an empty stomach, while 69.63% did so on a full stomach, indicating that many farmers continue to neglect the proper manner to apply pesticides. The majority of respondents (94.90%) favoured spraying, with just 5.09% selecting granular techniques. The time between final spraying and harvesting is equally significant: the majority of respondents reported intervals of 2–5 days (38.21%) and 5–10 days (28.78%), while smaller shares reported intervals of less than 2 days (20.41%) or more than 10

days (12.56%). This pattern is probably related to the 84.19% of farmers who do not have sufficient training on pesticide use and its effects on human health. In contrast, 54.8% of vegetables had a preharvest interval of 8 to 15 days, while 31.4% had less than 7 days, according to a prior research of small-scale commercial vegetable producers in Vietnam (Nguyen et al. 2017).

5.1.3 Table 1. Vegetable farmers' custom of using pesticides

Variables	Response (%)	Variables	Response (%)
Pesticide usage frequency		Pesticide usage types	
Daily	34.03	Insecticides	42.93
Weekly	18.33	Fungicides	31.41
Used when needed	47.64	Herbicides	22.51
		Rodenticides	3.15
Pesticide application based on		When should pesticides be applied?	
Personal experience	28.80	Before Attacking	24.60
Agricultural officer's suggestion	5.76	Primary Stage of Attacking	31.93
Labeling instruction	8.38	Following the Severe Stage of Attacking	1.06
Fellow farmer's suggestion	40.31	When needed	42.41
Pesticide retailer's suggestions	16.75		
Prefer method of pesticide applications		Pesticide application with	
Granular	5.09	Empty stomach	30.37
Spray	94.91	Full Stomach	69.63
Interval Between Spraying and Harvesting		Training received?	
<2	20.41	Yes	15.81
2-5	38.21	no	84.19
5-10	28.78		
>10	12.56		

5.2 The behavior of vegetable growers during pesticide application

6. Even though conduct is shaped by a complex array of factors that are neither completely understood nor consistent across settings, attitudes toward the environment have an effect on behaviour, which is impacted by information and knowledge. Table 2 shows how vegetable growers apply pesticides: the majority (76.97%) do not take safety measures, while those who do use masks (22.45%), full shirts (40.14%), or towels over their faces (37.41%). According to Yang et al. (2014), protective measures taken before, during, or after pesticide application are believed to effectively reduce farmers' risk; however, 71% of farmers in a similar survey did not wear enough protective clothing, with the majority of those who did relying on a full shirt and a towel over their faces (Nguyen et al. 2017). According to Bondori et

al. (2018), a survey carried out in Iran's Moghan Plain area found that around half of farmers wore minimal personal protection equipment, with long-sleeved shirts being the most common item. Additionally, farmers' negative perceptions of pesticides coincided with a rise in the usage of personal protective equipment. Following the use of pesticides, farmers did a number of actions, including changing clothing (23.04%), washing their hands with water alone (38.22%), cleaning their hands with mud and water (11.51%), washing their hands with soap (19.89%), taking a shower (5.25%), and doing nothing (2.09%). Similar findings were discovered in a prior research conducted in Oman, where applicators (South Asian labourers, including those from Bangladesh) handled partly used pesticides problematically, with 14.9% putting them in their beds and 81.1% storing them in other areas of the home. When spraying pesticides, personal protective equipment (PPE) such nose masks and eye protection was seldom employed (Esechie and Ibitayo, 2011).

Table 2. Pesticide use behavior among vegetable growers

Variables	Total responses (%)	Variables	Total responses (%)
Taking safety measures during spray?	23.03	Types of safety cover taken	37.41
Yes	76.97	Towel on face with a few cloths	22.45
No		Mask with normal cloth	40.14
Preventive precautions conducted immediately following pesticide use	23.04	Pesticide bottle and packet after use	
Change dress	38.22	Burned	13.08
Wash hands with only water	11.51	Left in the field	76.96
Wash hands with mud and water	19.89	Preserve for further use	9.96
Wash hands with soap	5.25		
Take shower	2.09		
Do nothing			
Disposal technique of the remained pesticides			
Unloaded on the ground	30.01		
Kept for the next spray	16.50		
Until finished, spray continuously	53.49		

6.1 Trends of pesticide use among vegetable growers

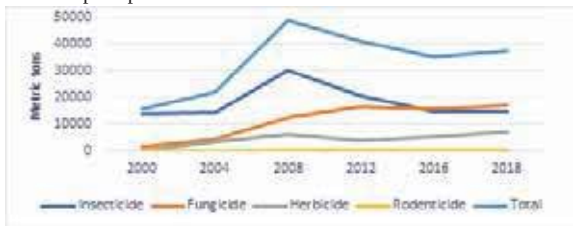
7. By shielding crops from pests and diseases, pesticides are crucial to maintaining high yields in vegetable farming (Khatun et al., 2023; Mahugija et al., 2017; Tudi et al., 2021). With little land available to feed a large population, Bangladesh heavily relies on the intensive application of chemical inputs to increase crop yield. Farmers

commonly use pesticides instead of fertilisers to cultivate traditional and new rice varieties, potatoes, spices, vegetables, and cotton (Rahman, 2013). Trends in the use of various pesticides in Bangladesh from 2000 to 2018 are shown in Fig. 3, which is divided into five categories: insecticides, fungicides, herbicides, rodenticides, and total use. Before falling to 37,187.28 MT in 2018—still significantly over the 2000 level—total pesticide consumption increased quickly from 15632.24 MT to a peak of 48690.19 MT in 2008. While fungicide use increased steadily from 1,220.06 MT in 2000 to 16,087.97 MT in 2018, indicating the growing significance of fungal disease control in agriculture, insecticide use grew sharply from 13,430.71 MT in 2000 to 30,115.18 MT in 2008, peaking alongside total use, but then steadily declined to 14,838.29 MT in 2018. Vegetable growers gave the following answers when asked how they felt about the rise in pesticide use: Pesticide usage in vegetable farming has significantly increased over time, according to 76% of farmers (Fig. 4), whereas 19% said it is declining. Similar results have been seen in several studies. Bangladesh's consumption of pesticides has alarmingly increased, from 19,000 MT in 2000 to over 37,000 MT in 2022, according to Islam et al. (2015, cited in Begum et al. 2025). A significant rise in vegetable production is the reason for this growth.



Fig. 3. Total pesticide consumption from 2000 to 2018 in Bangladesh (Mt)

Fig 4. Farmer's perception on



pesticide use propensity in vegetable farming
Source: Bangladesh Crop Protection Association

Similarly, the data in Fig.5 show that pesticide use has increased for all vegetables over the past five years, in both concentration per 10 liters of water and total volume per acre. Vegetables like eggplant, long bean, and yard-long bean now use double the previous amount and even for crops like bitter gourd and chilis, where acreage use remained low, concentration levels have risen. This trend highlights a notable intensification of pesticide application in the study area.

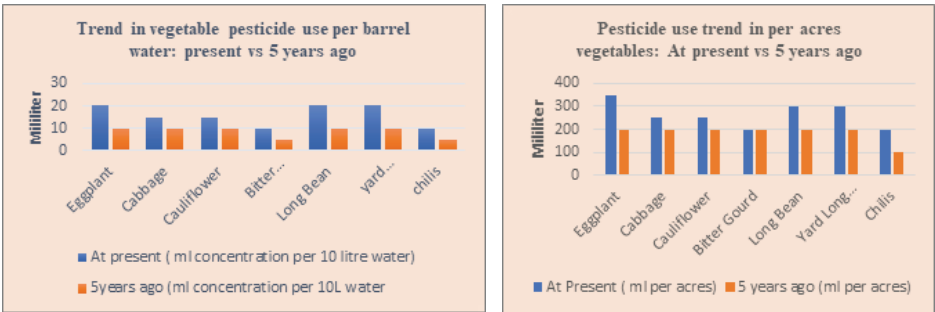


Fig 5: Trend of pesticide usage in the vegetables of the study area.

The common names, active ingredients, WHO risk classifications, and application objectives of the main pesticides used by farmers in the study area are also included in Table 3. Most insecticides, like Alco 550 EC and Heron 5 EC, are categorised as moderately hazardous (Class II); some, like Goldazim 500 SC and Amistar 250 SC, are categorised as low hazard (Class U); pesticides based on abamectin are labelled with UK guidelines, indicating special handling instructions; and some entries, like Uppercllem and Amistar, do not have WHO

classifications. The graphic also includes the weed-targeting herbicide Roundup 480 SC, which is classified as Class III (quite dangerous). Despite the chart displaying commonly used pesticides and their hazard categories, field observations made during the research also revealed the use of banned pesticides, such as Ultima 40 WG and Diazinon 14G. Under international accords like the Stockholm Agreement, certain pesticides used in Bangladesh are on lists of prohibited or restricted chemicals, including dichlorvos, dicotophos, disulfoton, ethyl parathion, methyl parathion, mercury compounds, monocrotophos, and phosphamidon. This raises grave concerns about harmful agricultural methods, a lack of knowledge, and insufficient enforcement of regulations in the research region.

Convention, the Basel Convention, and the Rotterdam Convention (Chowdhury et al., 2018; Meisner, 2004; Begum et al., 2025).

Table 3: Different types of pesticides used by farmers of the study area

Common name	Active ingredients	WHO class	Application
Alco 550 EC	Chlorpyrifos 50% and cypermethrin 5%	ii	Maggots, sap-sucking, and soil-dwelling pests
Goldazim 500 SC	Carbendazim 50%	U	Red rust, Sigatoka, powdery mildew
Heron 5 EC	Lufenuron	ii	Jab insects, bed bugs, brown insect
Toximate 1.8 EC	Abamectin	UK	Spiders
Salvation 32.5 SC	Abamectin	UK	Late blight
Upperclm 5 SG	Emamectin benzoate		Insects, aphids, and fruit borers
Amistar 250 SC	Azoxystrobin	U	Vegetable, rice, cotton, and tree nut diseases, including leaf spots, blights, and powdery mildew.
Roundup 480 SC	Glyphosate	iii	Weeds

7.1 Health Impacts of Pesticide Use on Farmers: Symptoms, Treatment, and Contributing Factors

8. Farmers in the study area had a number of health issues during or after using pesticides. Gastric issues were the most often reported health condition among farmers, with 39.3% of respondents. Skin issues, diarrhoea, and poisoning were reported less often but were nonetheless noteworthy at 8.4%, 9.9%, and 7.8%, respectively; headaches and nausea were also rather prevalent, affecting 19.9% and 14.7% of farmers, respectively. Skin irritation (70.3%), burning (39.2%),

headache (33.8%), vomiting (29.7%), and salivation (21.6%) were among the health problems linked to pesticide exposure, according to an Oman study (Esechie and Ibitayo 2011). Tobacco use by farmers during pesticide spraying seems to worsen these health problems: a significant portion of farmers (36.1%) reported using tobacco during pesticide spraying, mostly via smoking, with other tobacco use accounting for the remaining proportion. However, a major concern is that the majority of farmers (65.4%) did not seek medical attention when they had pesticide-related health problems; instead, self-treatment was the most common approach, used by 54.5% of farmers; village doctors and community clinics were used less frequently, at 18.3% and 12.0%, respectively (Table 4).

Table 4: Farmers’ health issues and their treatment techniques

Variables	Total responses	Variables	Total responses
Farmers experienced health problems	39.3	Visit the health complex	
Gastric	19.9	Yes	34.6
Headache	14.7	No	65.4
Nausea	8.4		
Skin problem	9.9		
Diarrhea	7.8		
Poisoning			
Addiction during spray		Pesticide-related health issues treatment method	
Smoking	36.1	Self-treatment	54.5
Remain of tobacco	13.6	Village doctor	18.3
Betel leaf	4.2	Community clinic	12.0
No addiction	46.1	Napa, omeprazole	6.3
		Health complex	8.9

Table 5 shows the findings of a likelihood ratio test that looked at the relationship between farmers' traits and the prevalence of health issues due to pesticides. The statistical significance of variables including gender, age, education, training, protective measures, and frequency of pesticide usage was evaluated by this test. The results also demonstrate a substantial correlation between education level, training, preventative measures, and frequency of pesticide use and health problems experienced by farmers during or after pesticide application. Education

had a substantial impact at the $p<0.01$ level, indicating that higher education may reduce health risks, while training and the use of preventive measures were very significant ($p<0.001$), showing their critical role in avoiding health challenges. The danger of repeated exposure was further highlighted by a strong connection ($p<0.001$) between the frequency of pesticide use and health consequences. Gender was only marginally associated ($p=0.036$), while age was not significantly connected ($p=0.083$). These findings are in line with those of Nguyen et al. (2017), who also identified education, protective gear, and pesticide frequency as important contributing factors.

Table 5: Characteristics of Farmers and Health Issues Associated with Pesticide Use

Farmer’s characteristics	Likelihood ratio test		
	Value	df	P value
Gender	11.935	5	.036
Age	23.051	15	.083
Education level	40.03	18	.01
Training	35.406	5	<0.001
Types of Protective Measures	29.96	10	0.001
Frequency of pesticide use	35.19	10	<0.001

Significant association at $p<0.01$ and $p<0.001$ levels respectively

8.1 Farmers’ perception of the impact of pesticides on vegetable farming and the environment

9. Table 6 summarises vegetable growers' views of the environmental impact of pesticide use, and Table 7 presents the results of a binary logistic regression model that identifies which of these beliefs significantly impacts the notion that overall environmental quality is declining. The majority of farmers claim that the usage of pesticides results in water pollution (67.0%), pest resistance (63.9%), soil fertility loss (68.1%), and pest incidence (62.8%). This is consistent with other research showing that although pesticides increase vegetable yield, overuse of them presents a serious risk to agriculture and the environment (Kapka-Skrzypczak et al. 2011; Shorma et al. 2014). However, only air contamination—reported by 41.8% of respondents—was positively and significantly linked with the perception of environmental degradation, according to regression analysis ($B = 0.853$, $p = 0.009$). Perceptions of water contamination

($B = -1.036$, $p = 0.003$), decreased soil fertility ($B = -0.762$, $p = 0.027$), and developing pest resistance ($B = -0.922$, $p = 0.006$) showed significant but negative associations, suggesting an inverse or complex relationship, even though pest incidence was not statistically significant ($p = 0.663$). The whole model was statistically significant despite having a poor explanatory power ($-2LL = 231.26$, Nagelkerke $R^2 = 0.213$). These findings suggest that, despite their broad awareness of the many environmental consequences of pesticide use, farmers are cognitively unable to discriminate between specific agricultural issues and more widespread environmental degradation, most likely as a result of overlapping or related perspectives. This highlights the need to address how pesticides affect the quality of water, soil, and air as well as the need of targeted awareness and education to align farmers' understanding of specific chemical impacts with overall environmental outcomes. Similar claims have been made in earlier studies: according to Swedish research, pesticide use is one of the most significant factors affecting biodiversity, and according to WWF, commercial fish species in the North Sea and the UK's coastal waters have seen an increase in illness, deformities, and tumours since the 1970s, which is consistent with effects known to be brought on by chemical exposure (FAO 1996). Glotfelty and Schomburg (1989) also point out that every pesticide application causes some drift, even when utilising ground-based equipment. As a consequence, pesticides may contaminate soil, water, and air, which are the most important elements of the ecosystem, changing its quality.

Table 6: Perception of the vegetable growers on the environmental impacts of pesticide use

Variables	Frequency	Yes (%)	Mean	SD
Increasing insect incidence?	120	62.8	.63	.48
Increasing insect resistance?	122	63.9	.64	.48
Decreasing soil fertility?	130	68.1	.68	.46
Is air contamination increasing?	79	41.4	.59	.49
Is water contamination increasing?	128	67.0	.67	.47

Table 7: Result of the Binary Logistic Regression

Do You Think Environmental Quality is Changing Due to Pesticide Contamination? (Dependent variable)

Variables in the equation

Explanatory variables	B	S.E.	Wald	df	Sig.
Increasing pest incidence	.147	.339	.189	1	.663
Water pollution	-1.036	.348	8.893	1	.003
Air contamination	.853	.328	6.764	1	.009
Reducing soil fertility	-.762	.344	4.890	1	.027
Developing pest resistance	-.922	.339	7.418	1	.006
Constant	.949	.391	5.890	1	.015

-2 log likelihood=231.26, Nagelkerke R Square=.213, level of significan-ce=0.0

9.1 Measures to improve farmers' safety behavior and pesticide-related environmental issues

Addressing the widespread use of pesticides and fertilisers is crucial in Bangladesh, since agriculture is essential to the lives of a densely populated community (BBS 2016; BBS 2020b; WB 2016a). It is crucial to address farmers' views of pesticide-related dangers since they are important stakeholders in reducing environmental pollution and protecting their own and their families' health. The following suggestions are made in order to increase awareness and encourage safer pesticide use in rural areas:

Education and Training Provide farmers and merchants with specialised training on the use, handling, and safety of pesticides. Work together with agricultural extension agencies to provide frequent training sessions that focus on the correct use of pesticides and the hazards involved. Additionally, these initiatives must to emphasise how crucial it is to follow safe pre-harvest times.

Awareness Campaigns: Start public education programs in rural areas to educate farmers about the possible harm that pesticides may do to the environment and human health. Spread knowledge about safe pesticide techniques and their advantages using a range of media platforms, including as radio, television, and community gatherings.

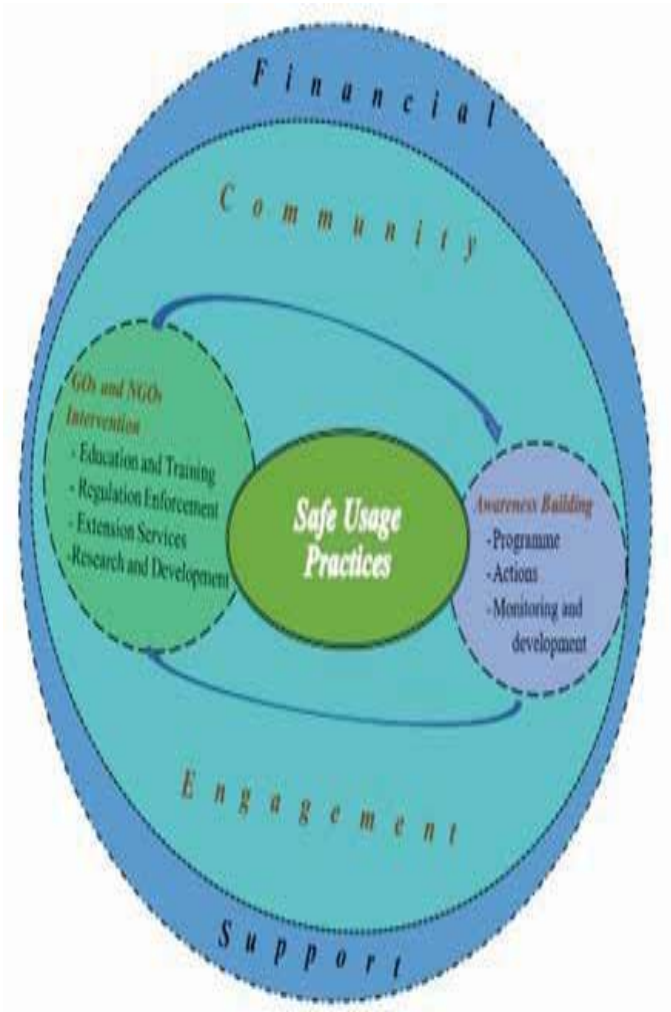


Fig 6: Safe Usage Practices Framework

Safe Usage Practices Stress the adoption of safe pesticide usage procedures, such as the use of protective gear, clothes, and recommended doses. Encourage the use of Integrated Pest Management (IPM) strategies, which lessen the need for chemical pesticides (Fig 6).

9.1.2

Regulation and Enforcement: bolster the implementation of current pesticide laws, such as Bangladesh's Pesticides (Amendment) Act, 2009. When required, create stricter laws to fill up the gaps and resolve ambiguities in pesticide control. Boost fines for noncompliance and make sure regulatory bodies have the resources to monitor and execute the law.

Extension Services: To continue providing farmers with timely information, training, and technical guidance, agricultural extension services should be strengthened and upgraded. In addition to educating farmers in the field on the proper use of safe pesticides and the sustainable production of field crops, the DAE runs programs like Integrated Pest Management (IPM) and the Farmer Field Schools (FFS), which also aid in the general promotion of environmentally friendly practices. To improve their knowledge of ecologically friendly, sustainable agricultural practices, such as crop rotation, organic farming, and biopesticides, these services must be expanded.

Financial Support Seek financing for farmer training initiatives and the adoption of safe pesticide techniques from both governmental and non-governmental sources. Urge the private sector to spend money on the creation of safer, more environmentally friendly insecticides.

9.1.3 .

9.1.4 NGO and Donor Interventions: Collaborate with non-governmental organizations (NGOs) and donor-funded initiatives like UTHAN BOITHOK (yard meeting) and Integrated Pest Management (IPM) to further promote responsible pesticide use. These organizations can play a significant role in providing resources, expertise, and advocacy for sustainable agriculture.

9.1.5 Research and Development: Invest in research and development efforts to identify and promote low-toxicity, eco-friendly alternatives to highly and moderately toxic pesticides. Encourage local universities and research institutions to engage in research that benefits both farmers and

the environment.

9.1.6 Monitoring and Reporting: Establish a robust monitoring and reporting system for pesticide residues in agricultural produce. This will help to ensure compliance with safety standards and enable timely corrective actions when contamination is detected.

9.1.7 Community Engagement: Engage local communities and farmers in discussions and decision-making processes related to pesticide use and environmental protection. Encourage community-driven initiatives to reduce pesticide risks and promote sustainable farming practices.

Conclusion

According to the report, pesticides are the most common way of controlling pests in Bangladeshi vegetable production, yet they are often seen as dangerous, endangering the environment, crop quality, and consumer health. The results unsettlingly demonstrate that farmers are seriously vulnerable to these dangers and endanger the ecosystem as a whole. Due to a lack of training, an over-reliance on pesticides, a lack of understanding of the hazards associated with pesticides, poor literacy rates, and a lack of information of personal protective equipment, pesticide pollution of the environment and its detrimental effects on farmers' health are urgent problems. Promoting personal protection equipment (PPE), thorough training in pesticide application, and a concentrated effort to enhance education are all necessary to address these problems. Raising farmers' understanding of the dangers pesticides pose to their health and the environment requires correcting pesticide handling procedures, strengthening oversight of prohibited chemicals, and creating comprehensive training programs. Sustainable vegetable growing requires effective regulation of pesticide usage, promotion of organic or non-chemical pest management methods, and simplification of the procedure for prohibiting dangerous chemicals. In order for Bangladesh to achieve sustainable agriculture in the future, funding for alternative methods like organic vegetable cultivation and the implementation of integrated pest management (IPM) techniques must be allocated. To assist guarantee farmers' safety, the government must collaborate with NGOs and take the lead in offering training on pesticide use. A paradigm change in agriculture is desperately needed, one that

focuses on significantly lowering the use of chemical pesticides for the sake of public health, the environment, and the larger economy, given the negative effects that chemical pesticides have on human health and the environment. By providing a thorough evaluation of pesticide usage patterns, farmers' knowledge and awareness, related health and environmental effects, and the socioeconomic factors of pesticide dependency in Bangladeshi vegetable growing, this study adds to the body of current literature. Future studies should concentrate on analysing the long-term effects of pesticide exposure on health and the environment, as well as the efficacy and uptake of integrated pest management (IPM) and other sustainable pest control options among farmers.

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