Stakeholder views on harmful effects of herbicides in four communities in Birim South District, Ghana

Abstract

The study investigated stakeholder perceptions of the harmful effects of herbicides in four communities within the Birim South District of Ghana. It seeks to understand the views of Junior High School students, their teachers, and local farmers concerning the health and environmental risks posed by herbicides. A cross-sectional survey involving 90 students, 30 teachers, and 60 farmers was conducted using a structured questionnaire with close-ended items. Descriptive analysis showed that all respondent groups agreed on the harmful effects of herbicides, particularly on water contamination, soil fertility, and health. The study highlighted a strong consensus among respondents regarding the adverse impacts of herbicides on plant biodiversity, wildlife, and air quality. However, discrepancies emerged concerning knowledge of air pollution and specific health risks like endocrine disruption. Farmers exhibited the highest awareness of herbicide-related risks compared to teachers and students. Concerns were also raised about the involvement of children in herbicide application, with evidence suggesting potential negative impacts on their academic performance and health. The findings call for enhanced educational programs targeting all stakeholders to correct misconceptions and promote safer herbicide practices.

Keywords: Herbicides, harmful effects, stakeholder perceptions, environmental impact, health risks, Ghana, education.

Introduction

Historically, in the immediate past, weed management in Ghana and other parts of the world was mainly achieved through manual methods, including hand-pulling and mechanical tillage. Though such weed control mechanisms were labour-intensive, they presented fewer ecological and health risks (Khattak*et al*., 2024).Currently, the introduction of herbicides like glyphosate has revolutionized the way farmers approach weed control, offering an effective and time-saving alternative. Despite these benefits, there are hazards associated with herbicide use, particularly its effects on soil health, water quality, and biodiversity (Woyessa, 2022). For example, herbicide residues can disrupt soil microbial communities, essential for nutrient cycling, thereby degrading soil fertility and jeopardizing future agricultural productivity (Van Dam, 2024). Furthermore, Tiwari *et al*. (2024)emphasized that herbicide runoff into nearby water bodies can cause contamination, adversely affecting aquatic ecosystems and public water supplies.

The health implications of herbicide exposure are particularly alarming. According to McGaha (2024) chemical compounds in herbicides such as organophosphates have been linked to various health issues, including endocrine disruption, respiratory problems, and even cancer. These health risks are especially concerning in rural farming communities, where children frequently assist with farming tasks and are consequently exposed to these harmful chemicals from an early age. Long-term exposure to herbicides during critical developmental stages can lead to cognitive deficits and other neurological problems, severely affecting children's health and academic performance (McGaha, 2024; Poole & Boland, 2024). The socioeconomic implications are significant, as these health challenges often hinder children's ability to attend school consistently, thereby compromising their educational prospects and future opportunities.

Moreover, the improper use of herbicides due to insufficient knowledge about safe handling practices worsens these risks. Many smallholder farmers, particularly in developing regions, lack access to adequate training and education on the correct application and disposal of herbicides, leading to unsafe practices that heighten both environmental contamination and personal exposure (Tengiz *et al*., 2024). As herbicide usage becomes more prevalent, the need for widespread education on their safe use becomes increasingly urgent.

Despite the numerous health and environmental risks associated with application of herbicides people including school children all over Ghana continue using it because it makes weed control easier. This situation is very common in farming communities including Birim South Municipality of Ghana. It is common to hear stories of applicators using the wrong dose of herbicides. In some cases cocktails are used and not scientifically done. This suggests that most of the applicators lack the right knowledge that would enable them do the right application. It is expected that possession of the right knowledge about herbicide application by applicators would help them to appropriately apply them. If that is not done, they would continue to do the wrong applications leading do die consequences. Hence, this study seeks to explore the perspectives of farmers, teachers, and students from four communities within the Birim South Municipality on the harmful effects of herbicide use. By examining the views of these key stakeholders, there would be informed understanding of the health and environmental risks associated with herbicides, while also considering the socio-educational implications of children’s exposure to these chemicals. This would help promote safer agriculture, particularly in contexts where children are actively involved in farming activities.

Purpose of the study

The purpose of the study was to determine the opinions of stakeholders, including farmers, students, and teachers, about the harmful effects of herbicides in four communities within the Birim South Municipality, Ghana.

Objectives

The specific objectives of the study were to:

1. ascertain respondents’ views on the general harmful effects of herbicides,
2. assess the views of respondents specifically about the effects of herbicides on children’s education.

Research questions

The study was guided by the following research questions:

1. What views do respondents have on the general harmful effects of herbicides?
2. What views do respondents have specifically about the effects of herbicides on children’s education?

Hypothesis

Null hypothesis 1 (H_{01}): There is no statistically significant difference in the views of respondents on general harmful effects of herbicides.

Null hypothesis 2 (H_{02}): There is no statistically significant difference in the views of respondents aboutthe likely effects of herbicides on children's education.

Alternate Hypothesis

Null hypothesis 1 (Ha_1): There is statistically significant difference in the views of respondents on general harmful effects of herbicides.

Null hypothesis 2 (Ha_2): There is statistically significant difference in the views of respondents aboutthe likely effects of herbicides on children's education

METHODOLOGY

Study Area

The study focused on four rural communities located in the Birim South District, Eastern Region of Ghana, an area characterized by agricultural activities. These communities were selected based on their heavy dependence on agriculture and the prevalent use of herbicides. The district covers a land area of approximately 725.99 square kilometres, with Akim Swedru serving as the administrative capital (Ghana Statistical Service, 2014). This location was selected due to its geographic relevance and historical issues with agricultural practices involving agrochemicals. The four communities were Akim Swedru, AkimAwisa, AkimApaaso, and AkimAsawase. Additionally, the district hosts 25 public Junior High Schools.

Study Design:A cross-sectional surveydesign was utilized to gather quantitative data from students, teachers and farmers regarding their perceptions of the harmful impacts of herbicide. The survey methodology allowed for the efficient collection of data from a relatively large population within a limited time frame (Saunders, 2014).

Population: The target population were all Junior High School students (8,293), all Junior High School teachers (295) and all farmers in the Birim South District in 2023.These demographic groups were chosen because they represent critical stakeholders affected by and involved in herbicide application in their daily lives, directly through farming or indirectly through proximity to agricultural zones. The accessible population were all Junior High School Students (891), all Junior High School Teachers (60) and all farmers in the four selected communities in 2023.

Sample and sampling: A multistage sampling technique was employed. The first stage involved purposively selecting the four communities due to their reliance on agriculture and known herbicide use patterns. In the second stage, a simple random sampling method was used to select JHS students and teachers, while convenience sampling was applied to farmers. This mixed sampling method ensured that the sample was representative, while also accounting for the practical difficulties in accessing all potential respondents in rural settings (Sulaiman-Hill & Thompson,2011).

The sample size included 90 students, selected from the second and third years of six schools (15 from each school), 30 teachers, and 60 farmers from the selected communities. The sample size for each group of respondents was determined using Cochran's formula (Cochran, 1977), which is commonly used to calculate adequate sample sizes for surveys.

Research Instruments

The instrument used to collect data for the study was a researcher–designed questionnaire. The questionnaire comprised fourteen items in total, designed to capture respondents' perceptions regarding the harmful effects of herbicides and their impact on children's education. Among these items,six were Likert scale items, all utilizing a 5-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree,"The remaining eight items were close-ended, allowing respondents to select one or more answers from a predefined set of options.To ensure consistency and facilitate comparison, the same questionnaire was administered across all three respondent groups.

The questionnaire was reviewed by three agricultural experts and pilot-tested with a small sample of respondents (ten students, five teachers, and ten farmers) from the study area to confirm its validity and reliability. Those who took part in the pilot test did not take part in the main study. A Cronbach’s Alpha reliability coefficient of 0.78 was obtained. An instrument is said to be reliable when it provides consistent results of what it measures (Thanasegaran, 2009). Moreover, according to Gizaw *et al.*(2022), a value greater than or equal to 0.7 is acceptable.

Data Collection

The researchers directly distributed the questionnaires to the selected students, teachers, and farmers. Both students and teachers were allotted one hour to complete the questionnaires, which were promptly collected after completion. For the farmers, the researchers focused on selecting individuals proficient in English to ensure they could complete the questionnaires independently. They were also given sufficient time to complete the questionnaires, which were collected immediately afterwards. In all instances, a 100% response rate was achieved.

Data analysis

The collected data were coded and analyzed using SPSS software version 27. Weighted means were calculated for the Likert-scale items, and decision points were established. To compare the responses of students, farmers, and teachers, a one-way analysis of variance (ANOVA) was conducted, with a significance threshold set at $p = 0.05$. For the multiple-choice questions where respondents could select more than one option, frequencies and percentage frequencies were used to compare the responses across the three groups.

Ethical considerations

Prior to data collection, participants were thoroughly informed about the study’s objectives, methodology, and any possible risks, following the ethical guidelines of informed consent as highlighted by Resnik (2020). Consent was obtained from all individuals involved, including head teachers and parents of the students and teachers. Participation was entirely voluntary, and participants had the option to withdraw at any time without facing any negative consequences. To maintain confidentiality, all responses were anonymized, ensuring that participants' identities were safeguarded. In line with data protection protocols (Resnick, 2023), the collected information was securely stored to prevent unauthorized access and protect participants' privacy.

RESULTS AND DISCUSSIONS

Research question 1: What views do respondents have on the general harmful effects of herbicides?

Table 1 presents the views expressed by respondents on the general harmful effects of herbicides. The results show that the majority of students, teachers, and farmers generally agreed on the harmful effects of herbicides. Specifically, students and teachers both "strongly agreed" (Mean = 4.5) that herbicides have harmful effects, while farmers agreed (Mean = 4.4). This suggests that there is a high level of awareness among all respondent groups regarding the general harmfulness of herbicides.For the item concerning the negative effects of herbicides on plant biodiversity and wildlife, all respondent groups (students: Mean = 4.3, teachers: Mean = 4.3, farmers: Mean = 4.2) were in agreement. This uniformity indicates a shared understanding of herbicides' ecological impact.

However, for the item on herbicide contribution to air pollution, a notable difference emerged. Students (Mean = 4.3) and farmers (Mean = 4.3) agreed more strongly than teachers (Mean = 3.9), who still agreed but with a lower mean score. The ANOVA results (Table 2) confirm that these differences are significant ($F = 3.47$, $p = 0.03$) at the 0.05 level of probability, indicating that teachers were less convinced about the extent of air pollution caused by herbicides compared to students and farmers. Moreover, for this item, both students and farmers exhibited the highest knowledge. The implication of teachers exhibiting the lowest knowledge is concerning, as teachers play a key role in educating and influencing young minds (See & Arthur, 2011). If their understanding of the environmental impacts is limited, they may not effectively instil the necessary awareness and precautionary behaviours in their students, potentially leading to future generations being less informed about sustainable agricultural practices.

All respondent groups agreed that herbicides can kill useful organisms, like insect pollinators and predators, with similar mean scores (students: Mean = 4.1, teachers: Mean = 4.1, farmers: Mean = 4.2). Likewise, all groups agreed that non-selective chemical herbicides damage crops and reduce yield, as shown by the relatively close mean scores (students: Mean = 4.2, teachers: Mean = 4.1, farmers: Mean = 4.2).

Table 1. Respondents' views on general harmful effects of herbicides

S/N	Item	**Students** (N=90)			**Teachers** (N=30)			**Farmers** (N=60)		
		Mean	**Sd**	**Decision**	**Mean**	**Sd**	**Decision**	**Mean**	**Sd**	**Decision**
1	Herbicides have harmful effects.	4.5a	0.60	Strongly Agree	4.5a	0.63	Strongly Agree	4.4a	0.50	Agree
2	Herbicides have negative effects on both plant biodiversity and wildlife.	4.3a	0.67	Agree	4.3a	0.47	Agree	4.2a	0.39	Agree
3	The use of herbicides can contribute to air pollution	4.3a	0.71	Agree	3.9b	0.94	Agree	4.3a	0.45	Agree
4	Herbicides can kill useful organisms like insect pollinators and predators.	4.1a	0.91	Agree	4.1a	0.68	Agree	4.2a	0.40	Agree
5	Non-selective chemical herbicides damage crops and reduce yield.	4.2a	0.87	Agree	4.1a	0.64	Agree	4.2a	0.40	Agree

Decision point for means: *SA = Strongly Agree = 4.5-5.0; A = Agree = 3.5-4.4; NS = Not Sure= 2.5-3.4; D = Disagree= 1.5-2.4; SD = Strongly Disagree = 1-1.4; Sd = Standard Deviation.*

NOTE: Same letters attached to means in a row signifies no significant difference.

Table 2. ANOVA results of views on the harmful effects of herbicides

Item	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
The use of herbicides contributes to air pollution	Groups	3.250	2	1.625	3.47	0.03
	Error	82.950	177	0.469		
	Total	86.200	179			

The mean difference is significant at 0.05

In Figure 1, 100% of farmers, 86.67% of teachers, and 54.44% of students agreed that herbicides lead to water contamination. Zaller *et al.* (2021) documented the leaching of herbicides like glyphosate into water bodies, resulting in pollution that often exceeds recommended safety levels. When herbicides are applied to crops or vegetation, they can enter nearby water bodies through runoff, leaching, or drift. Wato *et al.* (2020) describe runoff as the movement of herbicide residues via rain or irrigation water into streams, rivers, and lakes, while Pérez-Lucas *et al.* (2019) explain leaching as the downward movement of herbicides through soil, potentially contaminating groundwater sources. Herbicides such as atrazine, glyphosate, and 2,4-D are known to persist in aquatic environments (Góngora-Echeverría *et al*., 2019), with atrazine detected far from its application site, sometimes exceeding safety limits for drinking water (Urseler *et al.*, 2022).

In this study, 56.67% of teachers, 31.67% of farmers, and 12.22% of students recognized that herbicides could trigger algal blooms. Pitois*et al.* (2001) explained that herbicides can promote eutrophication, depleting oxygen in water bodies and harming aquatic life. Algal blooms occur when excess nutrients, often released by herbicides like glyphosate, stimulate rapid algae growth (Dabney & Patiño, 2018). Glyphosate, which contains phosphorus, can contribute directly to nutrient loading in aquatic systems, further exacerbating the problem (Watson *et al*., 2015).

Additionally, 86.67% of teachers, 71.67% of farmers, and 61.11% of students acknowledged the toxicity of herbicides to aquatic plants and animals, echoing the findings of Mitsou *et al.* (2006). Many herbicides, designed to disrupt plant growthalso negatively affect non-target aquatic plants and algae, which are essential to aquatic ecosystems. The loss of these primary producers can have cascading effects throughout the food chain, impacting herbivores and their predators (Sánchez-Bayo, 2021). Herbicides like atrazine have been shown to cause reproductive and developmental issues in amphibians, even at low concentrations (Solomon *et al*., 2008), while herbicides such as 2,4-D can cause abnormalities in fish, including growth defects and behavioural changes (Sarikaya & Yılmaz, 2003). These effects highlight the far-reaching consequences of herbicide use on aquatic biodiversity and the sustainability of fisheries.

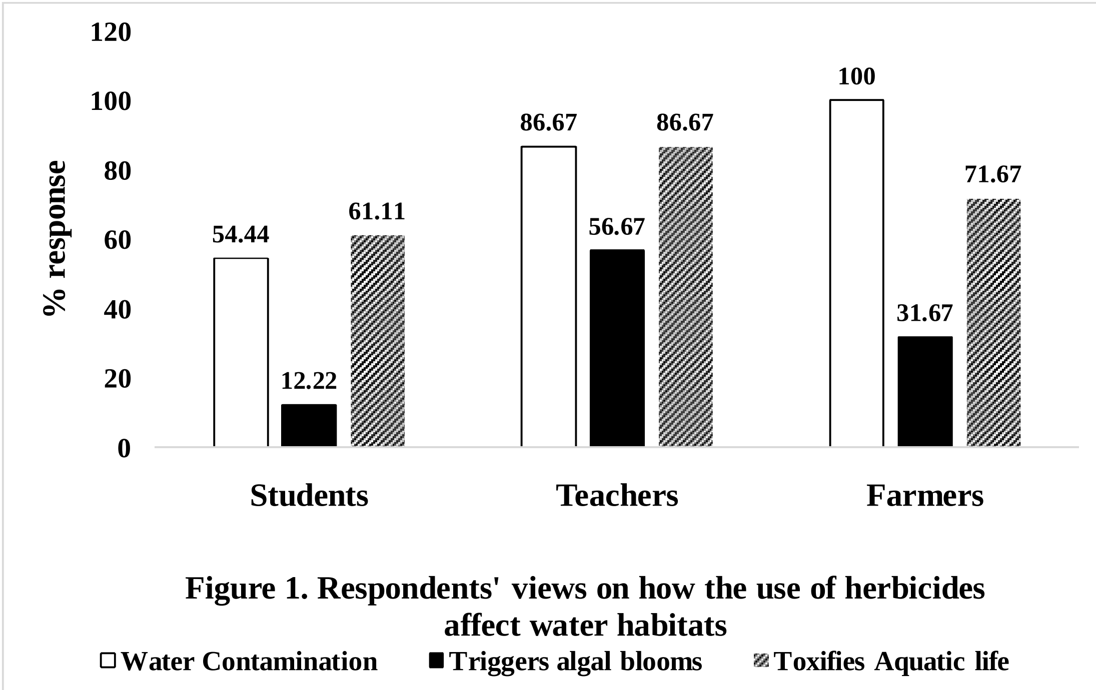

Figure 1. Respondents' views on how the use of herbicides affect water habitats

Regarding soil, 87.78% of students, 70% of farmers, and 56.67% of teachers were aware that herbicides reduce soil fertility (Figure 2). Mitsou*et al*. (2006) found that herbicides negatively affect soil microbial communities and organic carbon content. Herbicides, particularly synthetic ones, can alter the microbial community structure in the soil (Lo, 2010). Soil microorganisms, such as bacteria, fungi, and earthworms are crucial for decomposing organic matter and recycling nutrients. When herbicides are applied, they can reduce the population of these beneficial microorganisms, thereby slowing down the decomposition process. For instance, glyphosate, a widely used herbicide, has been shown to inhibit the growth of beneficial soil bacteria such as Pseudomonas, which plays a vital role in nitrogen fixation (Ahemad & Khan 2012). Without these microorganisms, the nutrient content in the soil diminishes, leading to decreased soil fertility and, consequently, lower crop yields.

Disruption of soil nutrient cycles was another major concern, recognized by 85% of farmers, 83.33% of teachers, and 52.22% of students. This finding corroborates that of Arden-Clarke and Hodges(1988) who demonstrated the inhibition of soil enzymes involved in nutrient cycling. Chemicals from herbicides interfere with the processes of nitrogen fixation and mineralization by harming the microorganisms responsible for these functions (Meena *et al*., 2020). For instance, a study by Mohamed *et al*. (2021) reveal that the use of herbicides like glyphosate has been shown to reduce the activity of nitrogen-fixing bacteria, such as Rhizobium, in the soil. This disruption can lead to a decrease in the availability of nitrogen, an essential nutrient for plants.

The impact of herbicides on soil erosion and pH imbalance was also highlighted. In all, 56.67% of teachers and 28.33% of farmers recognized soil erosion, while 73.33% of teachers and 63.33% of farmers acknowledged soil pH imbalance. Studies by Brühl and Zaller (2021) confirm these effects, illustrating how herbicides reduce vegetation cover and alter soil structure, making soil more prone to erosion and pH changes. When herbicides kill off vegetation, including weedsindiscriminately, the soil is left exposed and vulnerable to erosion by wind and water. The loss of vegetative cover accelerates soil erosion, particularly in sloped agricultural lands or regions with high rainfall (Sun *et al.*, 2013). Over time, this erosion depletes the soil of its most nutrient-rich layers, leaving behind less fertile subsoil that is often incapable of supporting robust plant growth. Herbicides can lead to pH imbalances, making the soil either too acidic or too alkaline for optimal plant growth (Alengebawy*et al*., 2021). Acidification of soil due to herbicide use can result in the leaching of essential nutrients like calcium and magnesium, making them less available to plants (Yadav*et al*., 2020). Additionally, an imbalanced pH can inhibit the activity of soil enzymes and beneficial microorganisms, further impairing soil health and fertility (Wei *et al*., 2024). However, low recognition of these effects by students shows a lack of knowledge regarding the effects.

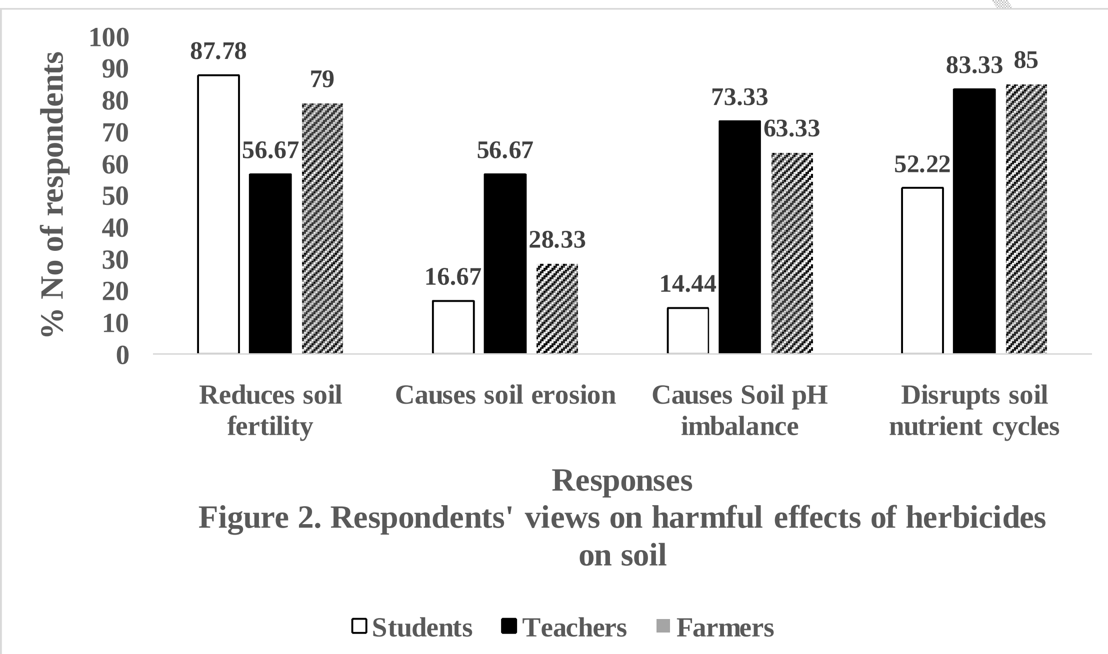

Figure 2. Respondents' views on harmful effects of herbicides on soil

From Figure 3, 50% of the students, 76.67% of teachers, and 85% of farmers identified disruption of microbial communities as a harmful effect, aligning with Allison and Martiny (2008) who emphasized that herbicides can alter the composition and function of soil microbial communities, which are vital for nutrient cycling, organic matter decomposition, and overall soil fertility. Herbicides, particularly those containing glyphosate, can alter the diversity and abundance of soil microorganisms (Newman *et al*., 2016). Glyphosate, the active ingredient in many herbicides targets the shikimate pathway in plants, a biochemical pathway that is also present in many soil microbes (Newman *et al*., 2016). As a result, glyphosate application can reduce microbial diversity, inhibit the growth of beneficial soil bacteria, and favour the proliferation of resistant or harmful microbial species.

Additionally, the detrimental impact on earthworms and soil invertebrates was recognized by significant proportions of respondents, supported by studies that detail the harm herbicides inflict on non-target soil organisms. Boutin (2020) documented how herbicides can reduce earthworm populations, thereby diminishing their beneficial effects on soil health. According to Menta (2012), the loss of earthworms and other invertebrates can lead to poorer soil aeration, reduced organic matter decomposition, and ultimately a decline in soil fertility and crop productivity. Soil invertebrates, such as nematodes, collembolans, and mites, are also affected by herbicides (Gunstone *et al*., 2021), by reducing the abundance and diversity of these organisms, leading to a decrease in soil health and resilience. Gunstone *et al*. (2021) emphasized that these invertebrates are involved in decomposing organic matter, controlling pest populations, and maintaining soil structure.

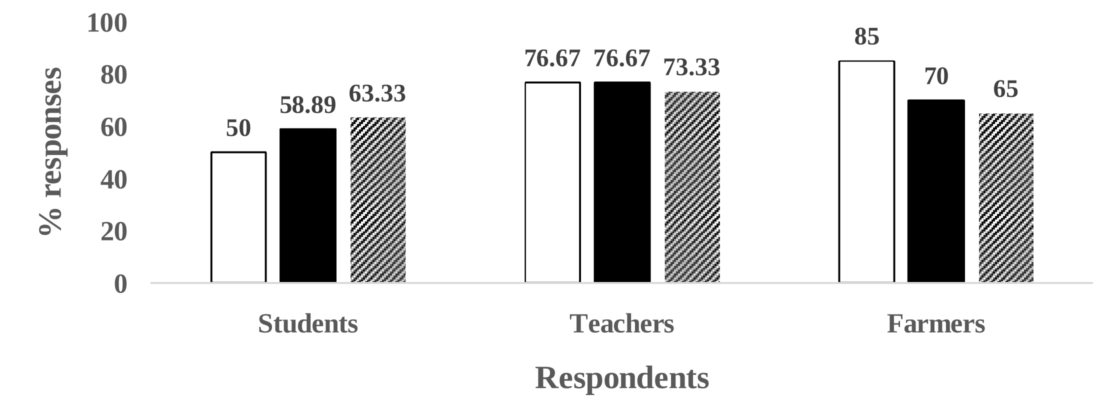

Figure 3. Respondents' views on harmful effects of herbicides on soil organisms

Regarding insect pollinators, the data in Figure 4 shows a strong awareness of direct toxicity (60% of farmers, 73.33% of teachers, and 63.33% of students) and loss of habitat (78.33% of farmers, 73.33% of teachers, and 48.89% of students). Research supports these concerns, highlighting how herbicides can kill pollinators and reduce their foraging resources, which is critical for their survival and ecosystem functions (Boutin, 2020). For example, herbicides like glyphosate have been shown to significantly reduce the availability of nectar and pollen sources, thereby threatening the survival of pollinator species (Devi*et al.*,2021). When pollinators such as bees, come into contact with herbicide-treated plants, they can absorb these chemicals through their cuticle or ingest them while foraging on contaminated nectar and pollen. This exposure can impair their neurological functions, disrupt their foraging behaviour, and ultimately lead to death (Manzoor & Pervez, 2021).

Many herbicides target broadleaf plants, which include a variety of flowering species that serve as essential food sources for pollinators (Bohnenblust *et al*., 2016). When these plants are eliminated, the diversity and abundance of flowers that provide nectar and pollen are significantly reduced. This reduction forces pollinators to travel greater distances to find adequate food, which can increase energy expenditure and decrease overall fitness. Bohnenblust *et al*. (2016) further explained that the loss of floral diversity also affects the diet quality of pollinators, leading to malnutrition and weakened immune systems.The destruction of hedgerows, wildflower meadows, and other natural habitats through herbicide use further aggravates this issue (Imran *et al.*, 2023). As these habitats are lost, pollinators face increased difficulty in finding suitable nesting sites and are more vulnerable to predators and environmental stressors. This does not only affect the pollinators themselves but also has cascading effects on entire ecosystems, as pollinators play a critical role in the reproduction of many plants and the production of food crops (Osman&Shebl, 2020).

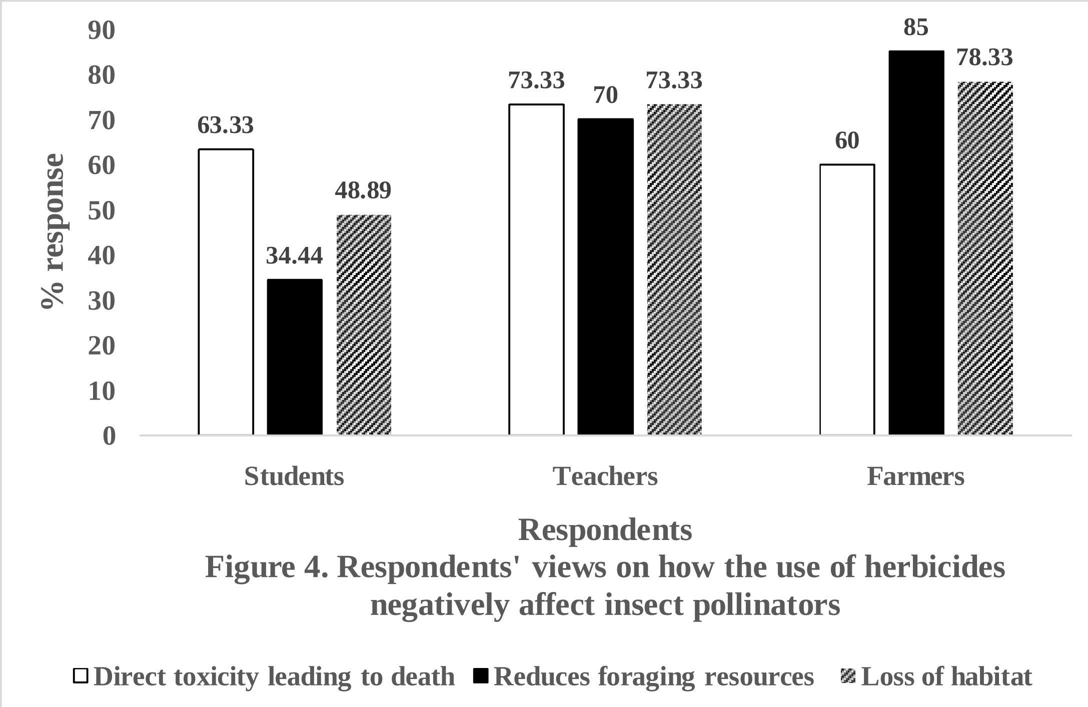

Figure 4. Respondents' views on how the use of herbicides negatively affect insect pollinators

Respondents' views about the effects of herbicide-treated crops on human health reveal concerns about cancer, endocrine disruption, and infertility (Figure 5). A significant portion of respondents linked herbicides to cancer risk (80% of farmers, 76.67% of teachers, and 64.44% of students), reflecting findings from Morrison*et al*. (1992). Their studies established a link between herbicide exposure and increased cancer risk, particularly non-Hodgkin lymphoma. A meta-analysis conducted by Morrison*et al*. (1992) further supported this, reporting a 41% increased risk of non-Hodgkin lymphoma among individuals with high exposure to glyphosate. Additionally, the International Agency for Research on Cancer (IARC, 2015), a branch of the World Health Organization (WHO), classified glyphosate as "probably carcinogenic to humans" (Group 2A) in 2015. This classification was based on studies showing an association between glyphosate exposure and non-Hodgkin lymphoma, a type of cancer that affects the lymphatic system (Zhang *et al*., 2019).

Concerns about endocrine disruption were also noted, particularly by teachers (63.33%) and students (48.89%). This corroborates views of Bigsby*et al.* (1999)that certain herbicides, such as atrazine have the potential to disrupt the endocrine system, affecting hormone balance and potentially leading to long-term health consequences.Herbicides have been implicated in the disruption of the endocrine system, which is responsible for regulating hormones in the body. Endocrine-disrupting chemicals (EDCs) can interfere with the normal functioning of the endocrine system, leading to a range of health issues. Atrazine, another commonly used herbicide, has been shown to act as an endocrine disruptor. Studies demonstrated that atrazine can interfere with the production and regulation of hormones, particularly those involved in reproductive processes.In humans, epidemiological studies have suggested a link between atrazine exposure and reproductive health problems, such as menstrual irregularities and decreased fertility (Fucic*et al*., 2021).

The recognition of infertility as a risk associated with herbicide exposure, especially among farmers (70%) and teachers (80%) further underscores the serious concerns surrounding these chemicals. Fucic*et al*. (2021) highlighted the potential of herbicides to affect reproductive health, particularly in men, through mechanisms that disrupt normal hormonal functions. The disruption of the endocrine system by herbicides has also been linked to infertility in humans. As mentioned earlier, atrazine has been shown to affect reproductive hormones, which can have direct implications for fertility. A study examined the impact of herbicide exposure on male fertility and found out that men with higher levels of herbicides in their urine had lower sperm counts and reduced sperm quality (Fucic*et al*., 2021). This suggests that exposure to certain herbicides may impair male fertility by affecting sperm production and function. The fact that fewer students (17.78%) recognize this risk could point to a gap in knowledge that needs to be addressed through more comprehensive public health messaging and education.

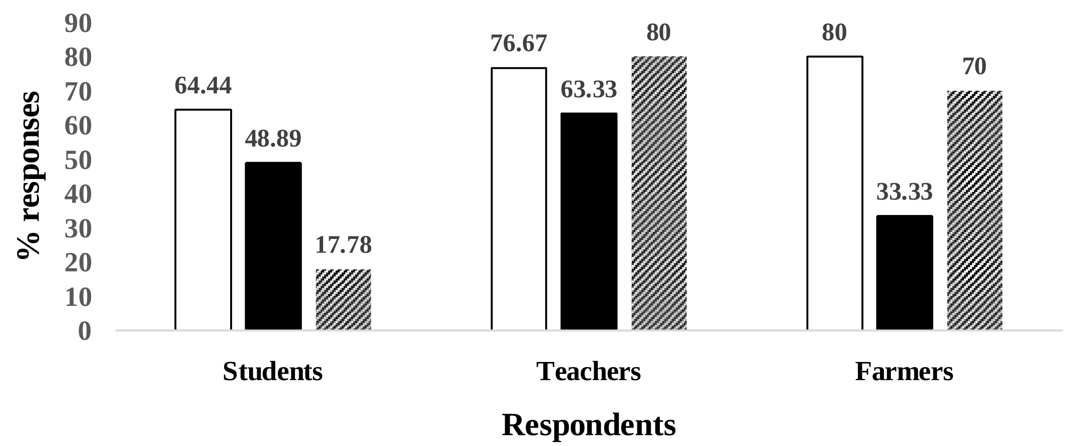

Figure 5. Respondents' views on harmful effects of herbicide treated crops on human consumers

In Figure 6, 100% of farmers, 86.67% of teachers, and 74.44% of students, respectively, agreed that herbicides pose risks such as skin irritation to those applying them. According to Gupta (2018), skin and respiratory problems are commonly reported among agricultural workers exposed to herbicides. Skin irritation is one of the most frequent health concerns associated with herbicide application, especially when protective equipment is not used. Herbicides, such as those containing glyphosate can cause dermatological reactions, including redness, rashes, and itching (Gupta, 2018). These reactions occur when the chemicals penetrate the skin, leading to an inflammatory response. O'Malley *et al*. (2020) noted that prolonged exposure could lead to dermatitis, characterized by inflamed and painful skin.

Similarly, 71.67% of farmers, 70% of teachers, and 58.89% of students reported that herbicides contribute to respiratory issues. Herbicides, particularly in spray or powder form can be inhaled and cause respiratory problems, especially those containing paraquat, a highly toxic chemical (Nurulain*et al*., 2017). Inhalation of paraquat has been linked to conditions such as lung inflammation, fibrosis, and acute respiratory distress syndrome (Subbiah &

Tiwari, 2021). Even less toxic herbicides can cause symptoms like coughing and throat irritation (Richter, 2002). This underscores the importance of using respiratory protection during herbicide application (Garrigou*et al.*, 2020).

Though less frequently reported, blindness and nausea were also recognized as potential risks. Blindness can occur when herbicides come into contact with the eyes, causing damage to the cornea (Jaga &Dharmani, 2006). Paraquat, in particular, is known for causing irreversible eye damage due to oxidative stress (Jaga &Dharmani, 2006). Nausea, often caused by inhalation or accidental ingestion of herbicides like 2,4-D, results in gastrointestinal disturbances (Gupta, 2018). These findings highlight the need for protective measures, such as eyewear and proper handling of herbicides, to prevent these serious health issues (Hasanuzzaman*et al.*, 2020).

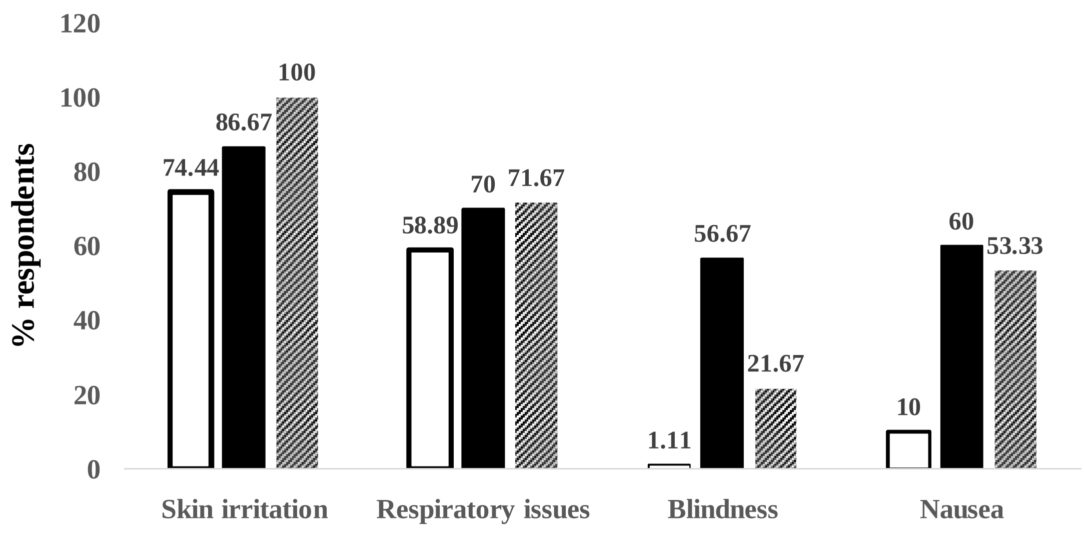

Figure 6. Respondents' views on harmful effects of herbicides on persons applying it

Research question 2: What views do respondents have specifically about the effects of herbicides on children's education?

Views expressed by respondents on the impact of herbicides on children's education are presented in Table 3.The results show that the majority of students (mean = 3.9), teachers (mean = 3.8), and farmers (mean = 4.0) agree that the use of herbicides in agricultural areas can have negative impacts on children's education. All groups fell within the "Agree" range based on the decision points for means.

In Table 4, the results of the ANOVA analysis further support the absence of significant differences in views among students, teachers, and farmers regarding the likely effects of herbicides on children's education (p=0.31). This suggests that all three groups (students, teachers, and farmers) shared similar views on the negative impacts of herbicides on children's education.

Table 3. Responses to the item "The use of herbicides in agricultural areas can have negative impact(s) on children's education"

S/N	**Students** (N=90)			**Teachers** (N=30)			**Farmers** (N=60)		
	Mean	**Sd**	**Decision**	**Mean**	**Sd**	**Decision**	**Mean**	**Sd**	**Decision**
12	3.9a	0.77	Agree	3.8a	0.55	Agree	4.0a	0.00	Agree

Decision point for means: *SA = Strongly Agree = 4.5-5.0; A = Agree = 3.5-4.4; NS = Not Sure= 2.5-3.4; D = Disagree= 1.5-2.4; SD = Strongly Disagree = 1-1.4; Sd = Standard Deviation.*

NOTE: Same letters attached to means in a row signifies no significant difference.

Table 4. ANOVA results on the likely effects of herbicides on children's education

Item	Source of variation	Sum of Squares	df	Mean Square	F	Sig.
The use of herbicides in agricultural areas can have negative impact(s) on children's education	Groups	0.822	2	0.411	1.17	0.31
	Error	62.089	177	0.351		
	Total	62.911	179			

The resultsin Figure 7 displayed a significant concern by respondents about the impact of herbicide application by children themselves on their education. A substantial majority of farmers (95%) and teachers (70%) indicated that such practices inhibit academic intelligence, compared to 18.89% of students. This discrepancy may be attributed to a lack of awareness among students about the neurotoxic effects of herbicides. Grandjean (2015) emphasized the vulnerability of the developing brain to environmental toxins, which can impair cognitive development and academic performance.Chronic exposure, even at low levels, has been associated with cognitive impairments, including memory deficits, reduced attention span, and lower IQ levels in children. These cognitive impairments directly impact a child's ability to learn and perform academically, leading to long-term consequences on their educational outcomes.

Disease problems linked to herbicide exposure, which eventually affect academic work, were noted by 48.89% of students, 43.33% of teachers, and 50% of farmers. This aligns with findings by Alarcon*et al*. (2005), who reported associations between pesticide exposure and various adverse health effects. Children exposed to herbicides are at increased risk of respiratory issues, as documented by Mamane*et al.* (2015), which can lead to increased absenteeism and diminished academic performance.These health issues can cause frequent absences from school, disrupt their learning process, and make it difficult for them to keep up with their peers. However, the relatively low level of response by the three groups of respondents raises concerns about their level of knowledge so far as the item is concerned. This calls for more education on disease problems associated with children being exposed to herbicides.

The results also indicate that herbicide application by children on school-going days affects their school attendance, with 57.77% of students, 56.67% of teachers, and 40% of farmers acknowledging this issue. Mamane*et al*. (2015) highlight the impact of pesticide exposure on respiratory health, which corroborates these findings, suggesting that such exposure can lead to increased absenteeism due to health problems.Agricultural work, including the application of herbicides, is often labour-intensive and time-consuming, leaving children with little time to attend school or complete their homework (Nyatuka, 2015). In many rural areas, children are expected to contribute to the family's agricultural activities, which often takes precedence over their education (Elder Jr & Conger, 2000). As a result, these children may miss school frequently, leading to gaps in their learning and a higher likelihood of falling behind academically. Moreover, the physical toll of herbicide application can leave children too tired or ill to attend school (Sarwar, 2016), further exacerbating the issue. Despite all these negative effects of children's involvement in herbicide application on their school attendance, the responses, especially from farmers are not all that encouraging. This again points out high levels of lack of knowledge with regard to this, especially the farmers. In any case, many of these farmers use their wards on their farms and may not see anything wrong in involving them in herbicide application.

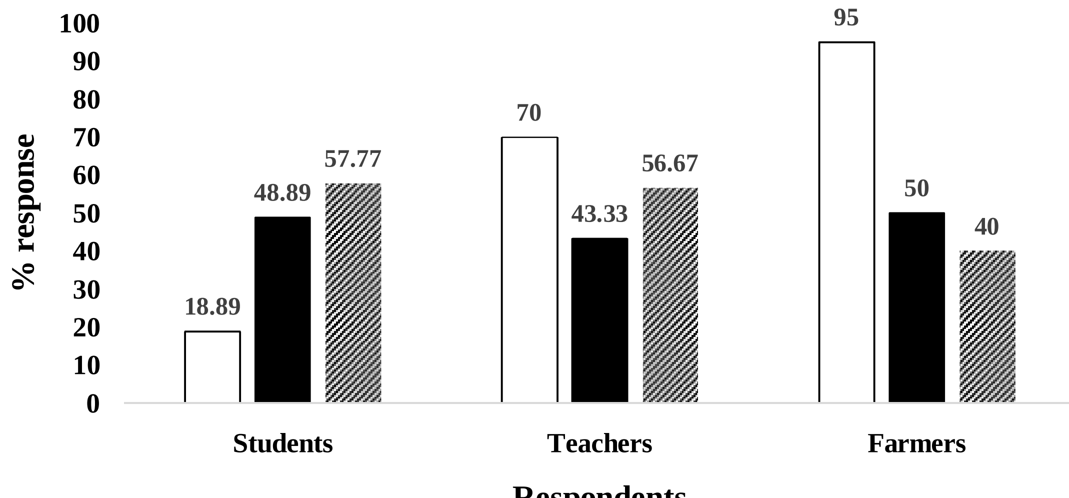

Figure 7. Responses on how application of herbicides by children affect their education

In Figure 8, respondents highlighted several measures to mitigate the negative impacts of herbicides on children's health and education. "Strict regulations on herbicide use near schools and residential areas" was supported by 70% of teachers, 38.33% of farmers, and 32.22% of students. Alarcon*et al.* (2005) advocated for stringent regulatory measures to minimize herbicide drift and exposure, thereby protecting vulnerable populations such as children.A study conducted in California found that children living near agricultural fields where herbicides were frequently applied had higher rates of autism spectrum disorders and other neurodevelopmental problems (Alarcon*et al.*, 2005). In response, many regions have established legal frameworks to limit herbicide application near schools and residential areas. Meanwhile, for this study, apart from teachers farmers and students themselves largely did not know that making strict regulations on herbicide use near schools and residential areas would be beneficial to school children. This is worrying, for such farmers would not care establishing farms very close to schools where they would apply herbicides to the detriment of the children. This suggests that educational and Municipal authorities in the Birim South Municipality have to up their game by organising awareness education programmes for all stakeholders in the Municipality on harmful effects of herbicides on school children whose schools are close to farms. This would help to reorient everyone in the municipality about the need to site farms away from schools.

Encouraging the adoption of organic and safer alternatives in agriculture was a measure supported by 66.67% of students, 31.67% of farmers, and 30% of teachers.It very interesting that students rather exhibited high knowledge in this case. It is difficult to explain because teachers teach these students and they were expected to exhibit higher knowledge than the students. On the other hand, that of farmers may not be taken too seriously because they have not been exposed to alternatives that are organic. The common thing is that those of them who use herbicides normally use the chemical herbicides. Meanwhile, Reganold, and Wachter, (2016) indicate that organic farming practices result in lower pesticide residues, which can significantly reduce health risks and promote sustainable farming practices.Promoting the use of organic and safer alternatives to traditional herbicides is another effective strategy to reduce children's exposure to harmful chemicals. Organic farming practices avoid synthetic herbicides, relying instead on natural weed management techniques and organic-approved substances.

Regular monitoring of herbicide residues in crops was deemed important by 70% of teachers, 65% of farmers, and 14.44% of students. Obviously, the students might not be all that conversant with issue such as this and would need more education on it. This measure is critical for ensuring food safety, as highlighted by Benbrook (2020), who emphasized the importance of routine testing to identify potential contamination and inform regulatory decisions.The World Health Organization (WHO, 2014) emphasizes the importance of residue monitoring programs as a means of assessing and managing the risks associated with pesticide use. A report from the European Food Safety Authority (EFSA, 2018) highlighted that residue levels in some fruits and vegetables exceeded the safety limits, posing potential health risks to children. Such findings have prompted authorities to tighten regulations and enhance monitoring efforts, ensuring that agricultural products meet safety standards before reaching consumers.

Health education programs for parents, teachers, and children were supported by 90% of farmers, 64.44% of students, and 56.67% of teachers. Afshari *et al*. (2021) suggest that such programs can lead to positive behavioural changes, raising awareness about the risks associated with herbicide exposure and promoting safer practices.The United States Environmental Protection Agency (EPA) supports educational initiatives that teach families and educators how to minimize exposure, such as by washing fruits and vegetables thoroughly and avoiding areas where herbicides have been applied.

The establishment of buffer zones between agricultural fields and schools was supported by 86.67% of farmers, 63.33% of teachers, but only 2.22% of students. Again, it is obvious that students were highly ignorant about this and there should be deliberate efforts to educate all and sundry in the Municipality about usefulness of establishing buffer zones between agricultural fields and schools. Research by Afshari*et al*. (2021) demonstrates that buffer zones effectively reduce pesticide concentrations near schools, contributing to safer environments for children.A study in North California by Salvesen *et al*. (2010) found that establishing buffer zones of at least 150 meters significantly reduced the concentration of airborne herbicides near schools. Buffer zones act as a physical barrier, minimizing the likelihood of herbicides reaching areas where children spend a significant amount of time.

"Prohibiting schoolchildren from applying herbicides" was supported by 68.33% of farmers, 63.33% of students, and 33.33% of teachers. It is once again surprising that majority of the teachers were not in agreement with this. This raises a serious concern that needs further investigation. The work of Owens and Feldman (2009)emphasizes the need to protect children from unnecessary risks associated with pesticide/herbicide exposure.Children are not only more vulnerable to the toxic effects of herbicides, but they may also lack the necessary understanding and skills to handle these chemicals safely. Hurley *et al*. (2014) recommended that trained adults/personnel should apply herbicides, particularly in settings like schools. This measure is supported by evidence showing that improper handling of herbicides, even in small amounts, can lead to acute poisoning or long-term health issues in children.

The perceptions of teachers, farmers, and students underscore the critical importance of regulatory measures, safer agricultural practices, regular monitoring, and comprehensive health education to mitigate these risks.

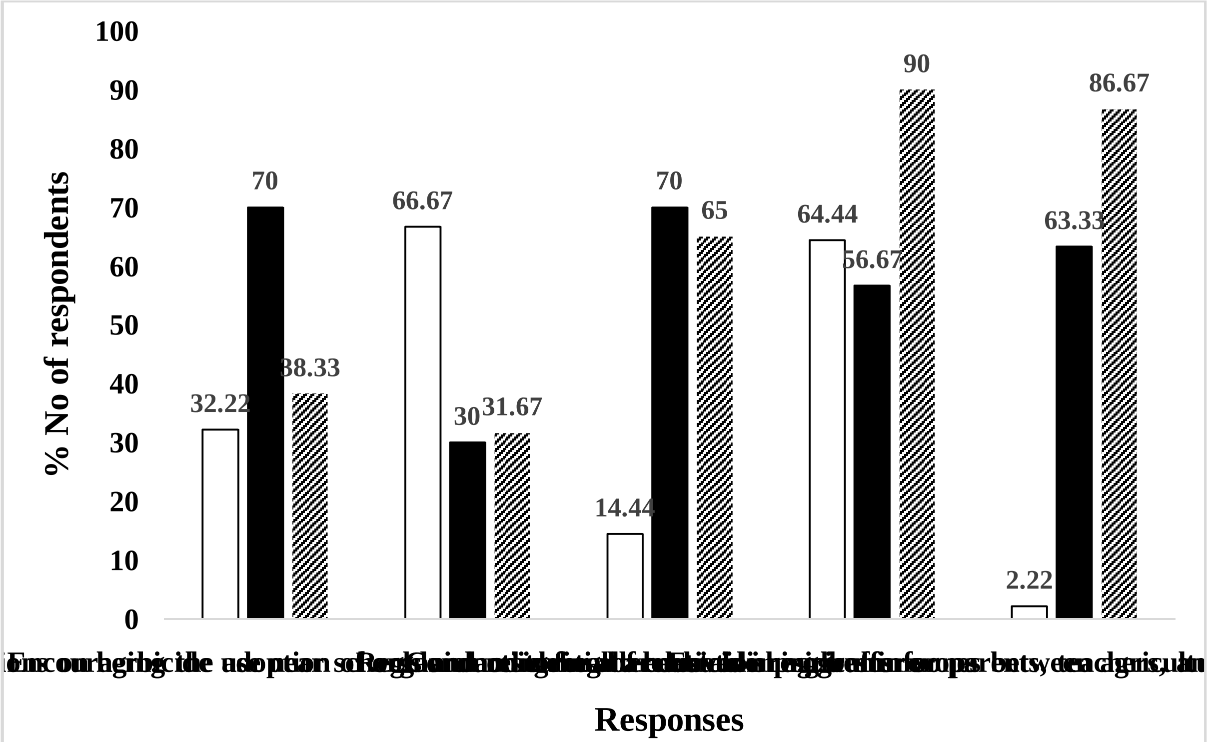

Figure 8. Responses on measures to safeguard children's health and education from potential risks of herbicides

Conclusions

1. All categories of respondents recognized the harmful effects of herbicides. However, farmers were slightly more aware of most of these effects than students and teachers.
2. Respondents generally agreed that herbicides negatively impact plant biodiversity, wildlife, and air quality. However, students and farmers exhibited higher concern about air pollution than teachers.
3. Farmers exhibited the highest awareness of the risks posed by herbicides to water contamination and soil fertility. Teachers and students were aware but showed less concern compared to farmers.
4. While all respondent groups agreed that herbicides pose risks to aquatic life, soil organisms, and pollinators, farmers and teachers demonstrated slightly higher awareness than students.
5. Respondents were united in their belief that herbicide use negatively impacts children’s education, with no significant difference in views among the three groups.
6. Farmers exhibited the strongest agreement that herbicides contribute to health problems such as cancer and respiratory issues, followed by teachers and students.
7. Although all groups supported the need for regulations on herbicide use near schools, teachers were the most vocal in supporting this measure, followed by farmers and students.

8. The responses reflected a general need for more education and awareness, particularly among students, about the harmful effects of herbicides and the importance of safer agricultural practices.

Implications of the findings

1. Stakeholders in the Municipality need to be educated by agricultural extension officers on the safe use and application of herbicides, with a focus on protecting themselves and their environment. This includes the proper use of protective equipment and safe herbicide handling practices to minimize health risks.
2. Schools should incorporate more detailed lessons on environmental and health impacts of herbicides into their curricula to ensure that students are better informed. This will foster early awareness and promote responsible agricultural practices in future generations.
3. Municipal authorities should implement stricter regulations and monitoring on the use of herbicides, particularly in areas close to schools and residential zones. This will help mitigate risks associated with herbicide exposure, especially among children.

Recommendation for further research

- Further research should be conducted to explore the long-term health impacts of herbicide exposure on children, particularly in agricultural areas, to provide evidence for better regulation and protection measures.
- It is recommended that a comparative study be undertaken to evaluate the effectiveness of alternative, non-chemical weed control methods in different farming communities, focusing on their environmental impact and sustainability.

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1.

2.

3.

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