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# Health risk factors associated with pesticide use by watermelon farmers in Central region, Ghana

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## Abstract

**Background:** The export drive for watermelon production is huge and so is pesticide usage. However, the health and safety of the farmers, as well as threat to the environment lie in the shadow. The purpose of the study is to evaluate watermelon farmers' knowledge and application of pesticides in the Central region of Ghana, to ascertain factors associated with the pesticides application.

**Methods:** A field survey of 300 farmers were conducted in six communities through questionnaire. Logistic regression model was used to describe and explain burning sensation as the response variable and the factors that likely affect appropriate pesticide usage.

**Results:** The results show that farmers were aware of the environmental and health impacts of pesticides use. However, their knowledge of the risks associated with pesticides is not translated into actual practice to avoid the exposure of pesticides. The farmers experienced various levels of health risks symptoms. Health risks symptoms of headache, burning sensation, fever, watering eyes, chest pains, etc., were reported. The most common symptom is burning sensation. A model capturing biosocial factors influencing predisposition to burning sensation was developed. The model revealed that knowledge to identify pests, knowledge to identify diseases and wearing coverall were the most significant factors farmers experienced to influence burning sensation.

**Conclusion:** Significant number of watermelon farmers' experienced health risks symptoms. In order to minimize the health risk symptoms and environmental consequences, educational training programs must involve the farmers and retailers through strong policy intervention.

**Keywords:** Watermelon, Health risk, Smallholder farmers, Pesticides, Exposure

## Background

In controlling pests and diseases affecting fruits and vegetables, food crops (yam, maize, rice, cassava), cocoa and watermelon for cultivation, smallholder farmers in Ghana and in Africa apply various pesticides (Wumbei and Houbraken 2019; Afari-Sefa et al. 2015; Kwadzo et al. 2015; Mattah et al. 2015; Ngowi et al. 2007). Reports from Wumbei and Houbraken (2019) revealed that

smallholder farmers were applying pesticides more than the recommended dose on yam, and do not take into consideration health protection when applying the pesticides in Northern part of Ghana. Similarly, work done by Afari-Sefa et al. (2015) in Ashanti and Western region of Ghana showed that farmers experienced health impacts of pesticides after application. Further, Kwadzo et al. (2015) investigated pesticides use and health hazards among small-scale commercial vegetable growers in the Eastern region of Ghana. The results showed that due to inadequate knowledge on personal protective equipment use during pesticide application, farmers were exposed to health risk factors of skin/eye irritation, but those with

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training and education on pesticide usage had low levels of health effects. The study further showed clearly the impact of education and training in minimizing the negative effects of pesticides and this is consistent with data from Ethiopia (Mesele et al. 2019).

Data from other parts of Africa, Northern Tanzania on pesticides use among smallholder vegetable farmers also demonstrated that vendors often dispensed smaller quantities of pesticides in unlabeled containers, and in addition about one-third of the farmers applied pesticides in mixtures of various doses. About 68% of the farmers reported having felt sick after routine pesticides application (Ngowi et al. 2007). In Botswana, Machekano et al. (2019) reported pesticides residues were detected in 74% of cabbage samples from three vegetable markets (farmgates, vendors and supermarkets), and such public health concerns of excess pesticides residues is also found in Ghana (Donkor et al. 2016; Osei-Fosu et al. 2017).

The above investigations on pesticides application and health impacts are indicating weak law enforcement of pesticides use in Africa, and untrained personnel in use of pesticides application. Generally, the farmers level of education is low and respective African governments are showing lackadaisical action on pesticides registration and control, for swift policy change to demonstrate how serious the problem is. As the pesticides contamination escalates, there is the need for analytical and environmental scientists to understand the sources of the pollution, the socio-behavioral drivers beneath the problem, and how to deal with residues of pesticides in crops and pollution in environmental media of soil and water.

In this study, we investigated pesticides use and application among watermelon farmers in Central region of Ghana. To the best of our knowledge scanty information is available in the literature regarding watermelon farmers' knowledge and behavior towards pesticides application. In this study it is hypothesized that inadequate knowledge in pesticides use would be associated with pesticide health risk factors among smallholder watermelon farmers in the Central region of Ghana. Specifically, our objectives were: (1) to assess farmers' knowledge and practices towards pesticides use; (2) to assess health risk factors associated with pesticides use.

## Materials and methods

### The study area and data collection

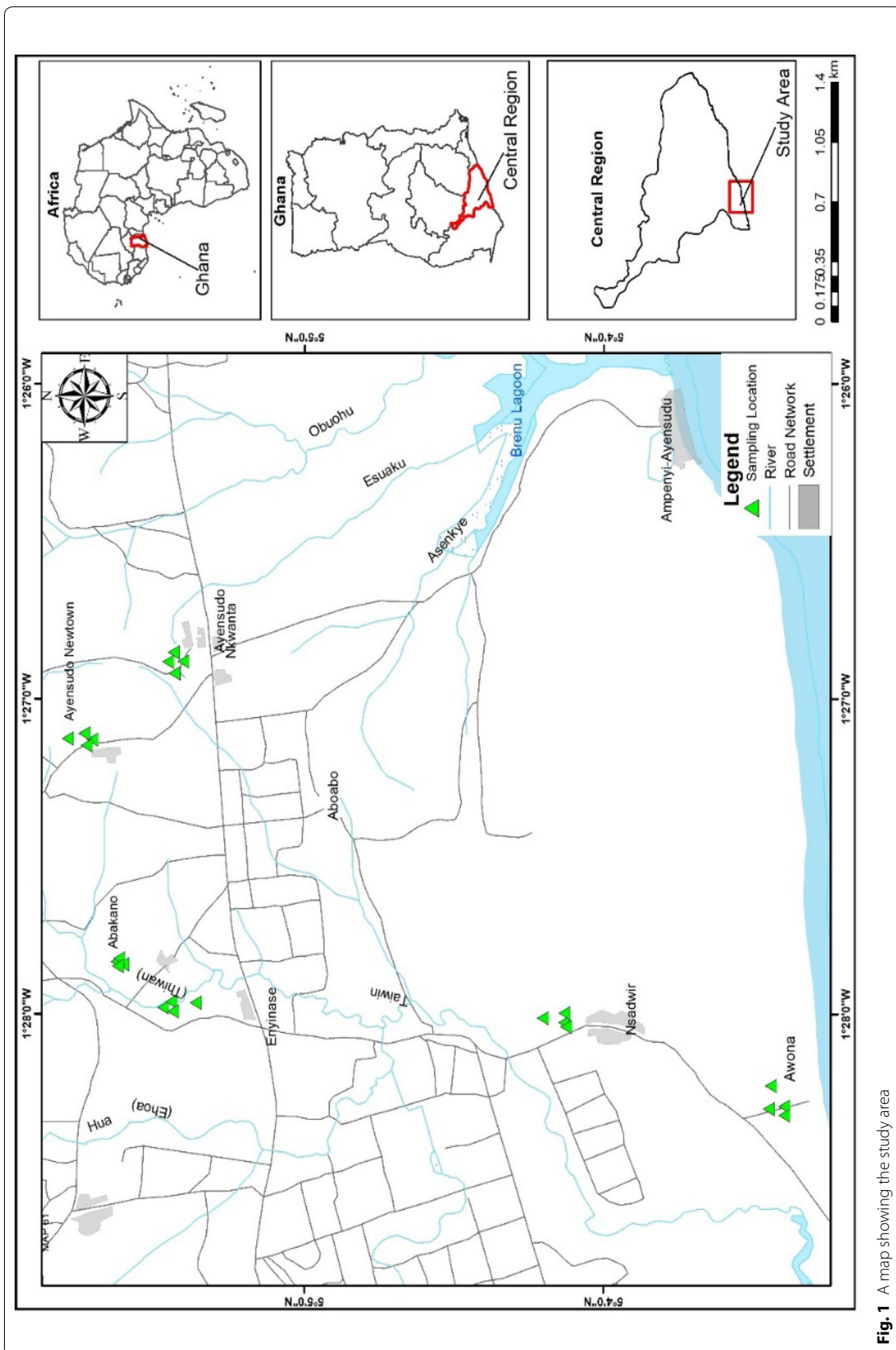
The study was conducted at the Komenda-Edina-Eguafo-Abirem (KEEA) Municipal, which is one of the twenty districts in the Central region of Ghana. The KEEA municipality is situated along the coastal zone with series of lagoons and wetlands. The lagoons include, Brenya, Brenu, Susu, Abrobi and Ankwanda which support a vibrant salt industry (GSS 2014). Elmina as the municipal

capital is a major tourist destination in Ghana, having two UNESCO World Heritage protected sites; the castle of St. George d'Elmina and Fort Coenraadsburg on St. Jago Hill attracts over 100,000 visitors annually (GSS 2014). Agriculture (crop farming) and fishing are major economic activities in the municipality. In particular, the watermelon farming helps to supply watermelon fruits to the residents and tourists who often visit the World Heritage sites. Six communities along the coastal zone and within the district were selected for the study, namely; Nsawir, Awona, Ayensudo-Junction, Enyinase, Abakano and Ayensudo-Newtown. These communities are bounded on the South by the Atlantic Ocean (Gulf of Guinea), the East by the Cape Coast Municipality, the North by the Twifo-Hemang-Lower Denkyira District and the West by the Mpohor-Wassa East District. Annual rainfall ranges between 750 mm and 1000 mm while in the more interior areas, it ranges between 1200 and 1500 mm (Ministry of Food and Agriculture 2015) (Fig. 1).

Descriptive research design was used for this study and data was collected through questionnaire. The questionnaire covered the following areas: demographic profile of farmers, knowledge of pesticide use and health risk factors associated with pesticides application. Three hundred watermelon farmers participated in the study. The population of our study includes all the 700 farmers within the KEEA who benefited from Ministry of Food and Agriculture (MoFA) extension services (anecdotal evidence from extension officer, MoFA). Our target population was watermelon farmers in the KEEA. Based on anecdotal knowledge from the extension officer, our target population was three-hundred and eighty watermelon farmers. However, due to lack of sample frame on the watermelon farmers, we collected data from 300 out of 380 watermelon farmers who were available and willing to participate in the research. The questionnaire was presented in English and majority of participants read and answer the questions themselves. However, for few of the participants, the researcher read out the translated questionnaire in their local language. Majority of the questions had answers available with only a few of them having open ended. In this study the participants were neither coerced nor financially induced to take part in the research. They were informed that the information provided will contribute to the overall knowledge about the effects of pesticide use on their health.

### Statistical analysis

Univariate analysis involving simple percentage, frequency and mean scores were computed for respondents' socio-demographic variables and knowledge on pesticides. Ranking was computed to gain insight on farmer's need towards pesticide use and health symptoms



**Fig. 1** A map showing the study area

experienced due to pesticides application. Correlation was used to ascertain positive or negative relationships between the response and explanatory variables using Cramer’s v. Multivariate analysis was used to gain further insights on factors associated with the response variable. Specifically, logistic regression model was used to describe and explain the relationship between response variable and explanatory variables. In this study, the researchers considered the outcome variable as burning sensation, since it is the foremost symptoms that majority reported as heat or sharp or prickly pain at any part of the body during or after the application of pesticides. Factors that likely affect appropriate pesticides usage includes but not limited to farmers’ educational level, use of protective clothing, ability to read pesticides manual, ability to identify specific pests and diseases that affect a given fruit such as watermelon. The explanatory variables likely to affect the outcome variable (burning sensation) in this study were respondents educational level, wearing coverall, ability to read manufacturer’s instruction, knowledge to identify watermelon related pests, and knowledge to identify watermelon related diseases. The logistic regression model provides transformed (logit) probability as a linear relationship with the predictor or explanatory variables. The probability (p) of farmers experiencing burning sensation, is such that the logit (p):

$$\log \text{it}(p) = \ln p / 1 - p = \ln (\text{odds ratio}) \tag{1}$$

$$= \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k \tag{2}$$

where p is the probability of burning sensation as affected by sets of explanatory variables and 1-p, the probability of not to be affected; and the odds ratio is the ratio of the two probabilities:  $p/(1 - p)$ ,  $\beta_0$  = the constant of the equation,  $\beta_1$  = the coefficient of the explanatory variables 1. And  $X_1, \dots, X_k$  as sets of explanatory variables. Confidence interval was set at 95%, Hosmer–Lemeshow goodness of fit test was used to find out how well the data fits the logistic model (Hosmer and Lemeshow 2010; Bewick et al. 2005).

For the avoidance of doubts regarding sample distribution and representativeness, bootstrap technique was used to provide additional support. Bootstrap is a resampling method which allows for estimation or approximating the sampling distribution of the statistics. It can be used to measure the accuracy of a given parameter estimate, and to provide additional strength in estimating the stability of the sample result, statistical model, and test parameters of SE (standard error of the mean) and CI (confidence interval). The bootstrap method does not require knowledge of the data generated, but uses the sample information as proxy population. The method

takes a sample with replacement from the original sample and calculates the statistic of interest repeatedly (Islam and Begum 2018). Through this repeatedly resampling approach, bootstrap can be used to quantify the uncertainty associated with a given estimator or statistical method. In this study, the proxy sample population was 300, and large sample size of 2000 was estimated in the bootstrapping. Bootstrapping is known to produce highly accurate results than traditional methods of estimating sample distribution of a statistic of interest, and is found to be applicable for both parametric and non-parametric tests (Efron 1979; Efron and Tibshirani 1993; Wright et al. 2011). All data were coded and analyzed using Statistical Package for Social Sciences (SPSS) version 20 (SPSS Inc, Chicago, IL, USA) and Microsoft Office Excel 2010 (Microsoft Corporation, Redmond, WA, USA). An alpha ( $\alpha$ ) level of  $\leq 0.05$  was used as a criterion for statistical significance.

**Results**

**The Socio-demographic profile**

Table 1 presents the socio-demographic characteristics of farmers. The study revealed that 80% of respondents were males while the remaining 20% were females. It was evident from the results that males dominated in watermelon farming. Majority of the farmers (40.7%) of the respondents had ages between 35 and 49 years and 30%

**Table 1 Socio-demographic profile of farmers**

Variable	Frequency	Percentage
Gender		
Male	240	80.0
Female	60	20
Age (years)		
$\geq 20$	6	2.0
20–34	90	30.0
35–49	122	40.7
$\geq 50$	82	27.3
Educational level		
No formal education	40	13.3
Primary education	152	50.7
Secondary education	100	33.3
Tertiary education	8	2.7
Economic activity of household		
Farming	260	88
Secondary jobs	40	12
Family size		
1–2	10	3.3
2–4	58	19.3
$\geq 5$	226	75.3
None	6	2.0

of the respondents had ages between 20 and 34 years. Only 1.3% of the farmers were less than 20 years while 27.3% were above 50 years. On education, 13.3% of the farmers had no formal education, 50.7% primary education, 33.3% of farmers had secondary level education and 2.7%, with tertiary education.

Most economic activity of the respondents was farming (88%), and other secondary jobs (12.4%) such as being engaged as a casual worker or having a small retailing business in addition to the main farming activity. Majority of respondents have family size of 5 and above (75.3%) and the least family size of respondents was 1 or 2 representing 3.3%. The data of the respondents show that they were smallholder farmers with 30.7% of the farmers with 3–4 acres of land, 5–6 acres (17.3%), 1–2 acres (21.3%) and 26% had more than 6 acres. Watermelon cultivation is their main activity with 74% engaging in it with other food crops like okra (20%) were grown together (data not shown). The main occupation was farming (79.3%), while others (18.7%) engage in other occupation but the least occupation (2%) was both farming and fishing (data not shown).

#### Farmers knowledge on pesticides safety and use

Table 2 shows farmers' knowledge on pesticides use and safety with respect to health effects, routes of exposure, environmental impacts, food safety, and pesticides use compliance. The farmers admitted that pesticides are

detrimental to the health (80%) with 144 farmers supporting that all pesticides have the same health effect. In addition, 79.3% of the respondents confirmed that pesticides can be dangerous. Knowledge on the route of entry of the pesticides was clearly understood with 88.7% identifying that pesticides can enter the body through inhalation, 90% of the respondents agreeing of the entry through the skin, and 86% mentioning that pesticides can enter the body through the mouth. 89.3% of the respondents are aware that pesticides residues can be left in the air, pesticides residues can be left in the soil (82%), pesticides residues can be found in groundwater (56.7%), pesticides residues can be found in fruits (54%), pesticides residues can be found in vegetables (66%). 58% farmers responded that they read manufacturer's instructions, with 61.3% farmers said they respect manufacturers notification (Table 2). In addition, 91.3% farmers had no knowledge on any forbidden pesticides but 3.3% of farmers are aware that DDT is a forbidden pesticide, and with 4% of the respondents aware of the existence of forbidden pesticides, however, do not know them by name, and 1.3% did not show any response (data not shown).

#### Pesticides acquisition knowledge and usage

Table 3 shows how the farmers have access to the pesticides, why and how the farmers use the pesticides. The data shows that 52% farmers purchase pesticides at local agrochemical shops in village, while 40.7%

**Table 2 Farmers' knowledge on pesticides safety and use**

Variables	Yes		No		Not sure	
	N	%	N	%	N	%
Health effects						
Pesticides cause negative health effect	240	80.0	28	9.3	32	10.7
All pesticides have the same health effect	144	48.0	110	36.7	46	15.3
Pesticides be dangerous to use	238	79.3	32	10.7	30	10.0
Routes of exposure						
Pesticides enter the body through inhalation	266	88.7	32	10.7	2	0.7
Pesticides enter the body through the skin	270	90.0	16	5.3	14	4.7
Pesticides enter the body through the mouth	258	86.0	40	13.3	2	0.7
Environmental impacts						
Pesticides residues be left in the air	268	89.3	14	4.7	18	6.0
Pesticides residues be left in the soil	246	82.0	22	7.3	32	10.7
Pesticides residues be found in groundwater	170	56.7	96	32.0	34	11.3
Food safety						
Pesticides residues be found in fruit	162	54.0	112	37.3	26	8.7
Pesticides residues be found in vegetable	198	66.0	78	26.0	24	8.0
Pesticides compliance						
Read manufacturer notification	174	58.0	114	38.0	12	4.0
Respect manufacturer regulation	184	61.3	70	23.3	46	15.3

N = number of respondents, (%) indicates percentage



**Table 3** Pesticides acquisition, knowledge and use

Variables	Frequency	Percentage
Access to pesticides		
Agrochemical shops in town	122	40.7
Local agrochemical shops in the village	156	52.0
Extension officers	6	2.0
Cooperative societies	2	0.7
Both agrochemical and local shops	14	4.7
Why use pesticides		
Protect crops against insects	216	72
Make crops grow better	40	13.3
Advised to use pesticides	2	0.6
Make crops grow better	38	12.6
Control weeds	4	1.3
Knowledge to identify common pest disease		
Yes	240	80.0
No	60	20.0
Knowledge to identify common crop disease		
Yes	144	48.0
No	156	52.0
Time to apply pesticides		
Presence of pest	208	69.3
Degree of pest infestation	16	5.3
Date of planting	66	22.0
On calendar spray schedules	10	3.3
Knowledge of pesticides application methods and rate		
Agrochemical shops	86	28.7
Extension officers	48	16.0
Pesticides labels on packages	40	13.3
Fellow farmers	104	34.7
Both agrochemical shops and extension officers	2	0.7
Both agrochemical shops and fellow farmers	4	1.3
Own experience	16	5.3
Dilute pesticide before application		
Mix more than one types of pesticides with water in container	264	88.0
Mix one type of pesticides with water in a container	32	10.7
Depending on the instructions on the label	4	1.3

acquire theirs at agrochemical shops in town. The data shows that, 72% of the farmers use pesticides to protect crops against insects while 13.3% use it for better crop growth. Also, 12.6% of the farmers use pesticides because of insects as well as to make crops grow better. Only few farmers (1.3% and 0.6%) use pesticides because of both insects and to control weeds; because the individual was advised. 80% of the farmers were able to identify common pest disease but 52% were unable to identify common crop disease. 69.3% of the farmers apply pesticides at the presence of pest but 5.3% use it during the degree of pest infestation. 3.3% of

the farmers administer pesticides on calendar spraying schedules where as 22% apply pesticides using the date of planting. The knowledge of pesticides application methods and rates were obtained from fellow farmers (34.7%), agrochemical shops (28.7%), extension officers (16%), pesticides labels on packages (13.3%), own experience (5.3%). Before spraying, 88% of the respondents' mix more than one types of pesticides with water in container, 10.7% dilute one type of pesticide with water in a container and 1.3% use the instructions labeled on the container (Table 3).

### Practices on use of protective wear, storage and disposal of pesticides

The responses of pesticide applicators to questions related to use of protective wear, disposal of empty containers, storage location of pesticides, washing of sprayers and period of last spraying before selling are presented in Table 4. On the question of the reason for not using protective wear during pesticides application, about one-fourth (39%) of the respondents gave the high

cost of buying personal protective gear as the main contributing factor. Similarly, about 13.3% of the respondents were reluctant to use protective wear due to general lethargy and feel discomfort especially in the hot and humid climate of the study area. Also from observations, there existed no monitoring mechanism to ensure continue use.

With reference to the disposal of empty pesticides containers after use, interestingly, the respondents used

**Table 4 Use of protective wear; disposal of empty containers after use; storage location of pesticides; washing of sprayers; and period of last spraying before selling**

Variables	Frequency	Percentage
Reason for not using protective wear		
No response	30	10
High buying cost	118	39.3
Do not feel comfortable in them	40	13.3
Do not have it	32	10.7
Not interested	12	4.0
Others	68	22.7
Disposal of empty pesticides container		
Put in other uses	62	20.7
Throw away on the farm	140	46.7
Throw away in the village	52	17.3
Bury in the ground on the farm	26	8.7
Burn on the farm	18	6
Others	2	0.7
Disposal of remnant of pesticides after end of application		
On field	230	76.7
Throw in river, lakes or irrigation canal	4	1.3
Leave it for next spraying time	24	8.0
Apply on the farm again	6	2.0
Other	36	12.1
Pesticides storage by respondents		
Animal houses	2	1.3
Living room	140	46.7
In the bush	84	28
In the kitchen	48	16
In the food store	2	0.7
Others	24	7.4
Where they wash sprayers after application of pesticides		
In the river, lake or irrigation canal	52	17.3
At home using tap or bucket water	66	22.0
Do not wash	22	7.3
On the farm with the leftover water	160	53.3
Period for last spraying to selling of crops		
1–2 days	28	9.3
3–6 days	100	33.3
1 week	42	14.0
> 1 week	130	43.3

unscientific way of disposal, as 45.7% of them throw away empty pesticides containers on their farms. This social behavior coupled with disposal of remnant pesticides after end of application accounted for 76.7% of the respondent's behavior. Thus, this is suggesting that pesticides ecological impacts may be coming from these sources.

When asked how they stored pesticides, several practices emerged. Almost, one-fourth of the respondents (46.7%) stored pesticides in their living rooms. This is followed closely by 28% of the respondents stating that they stored the pesticides in the bush, which has no guarantee of safety to the environment or public health. Surprisingly however, some of the farmers (16%) reported storing the pesticides in the kitchen. Pesticides stored in the home can easily contaminate drinking water and food and can threaten the health and safety of growing children in the home.

Bizarrely, when asked where they wash the sprayers after application of pesticides, more than half of the respondents (53.3%) indicated that they wash on farms, and with 17.3% stating that they wash the sprayers in rivers, lakes or irrigation canal. Incidentally some of the sources of drinking water of the community is from the same river that they pollute. In addition, the water bodies are the source of fish and many habitats of aquatic organisms. The above methods of storing disposing of pesticides containers need critical interventions, so that awareness of public health concerns and safety during pesticide application can be enhanced (Jin et al. 2017; Jallow et al. 2017).

With reference to the last spraying to the selling of crops, several observations came to the fore. About one-third (33.3%) of the respondents sell the crops after spraying between 3 and 6 days. Majority of the respondents, about one-fourth (43.3%) stated, selling the crop after 1 week spraying (Table 4). The varying responses from the farmers indicate the inconsistencies with regulatory practices and the dangers of pesticides residues on crops from the local farmers. Anecdotal evidence shows that there are no regulatory agents at the point of sales cross-checking the public health safety of watermelons release

for public consumption. Watermelons are transported directly from the farm gate to the nearest urban road for distribution to market centers across the country.

#### Famers need towards pesticides use

In order to promote appropriate use of pesticides among the respondents, their need was assessed by asking them to respond to a number of questions related to their pesticides knowledge need, knowledge on minimal health risk, precaution to be taken, limit use of pesticides etc.

Farmers responses include the option on a scale of 1 to 5; strongly disagree (1), disagree (2), don't know (3), agree (4), and strongly agree (5). As presented in Table 5, what farmers' need the most to achieve proper pesticides use was precautions in pesticides use with a mean score of 4.31 and ranked the highest on the scale, and with 99.3% of the respondents agree and strongly agree on the question. The second need of the farmers was pesticides use to protect crops with a mean score of 3.41. These first-two scores implied that the respondents desire is to know more about pesticide and the need to know how pesticide helps to protect their crops against pests and disease infestation. Key intervention needed is training regarding pesticides usage so as to enforce the necessary precaution required by the farmers.

As shown on Table 5, the 4th and the 5th scores suggest lack of clear understanding of the respondents on the need of pesticides effects on human health and the need to limit the use of pesticides. The median score for pesticides knowledge needed is 3.38 on the five point Likert scale, implying that the respondents have the desire to know more about pesticides and its' application.

#### Use of protective wears and health risk

Respondents were asked to indicate the protective measures they use during pesticides application. These measures were the use of gloves to protect the hand, use of goggles to protect the eyes against incidental and accidental pesticides droplets to affect the eyes, wearing special boots, oral or nose masks for protection against inhalation and wearing coverall. The use of protective measures during pesticides application is presented in

**Table 5** Farmers need towards pesticides use

Variables	Strongly disagree	Disagree	Don't know	Agree	Strongly agree	Mean score	Rank
Precautions in pesticides use	–	2 (0.7)	–	202 (67.3)	96 (32.0)	4.31	1st
Pesticides protect crops	–	2 (0.7)	–	172 (57.3)	126 (42)	3.41	2nd
Pesticides knowledge	2 (0.7)	10 (3.3)	16 (5.3)	150 (50.0)	122 (40.7)	3.38	3rd
Limit use of pesticides	6 (20)	48 (16.0)	–	210 (70.0)	36 (12)	2.92	4th
Knowledge on minimal health risks	32 (10.7)	62 (20.7)	4 (2.7)	158 (52.7)	44 (14.7)	2.73	5th

Values in parenthesis indicate percentages



**Table 6 Use of protective measures during pesticides application**

Protective Gears	Yes	Percentage	No	Percentage
Gloves	80	26.7	220	73.4
Goggles	44	14.7	256	85.3
Something on the head	154	51.3	146	48.7
Special boots	188	62.7	112	37.3
Oral/nose masks	64	21.3	236	78.7
Coverall	90	30.0	210	70.0

Table 6. A majority 73.4% of the respondents reported they do not use gloves during pesticides spraying. Similarly, 85.3% reported not using goggles to protect their eyes during application. On the other hand, 51.3% reported they use something to cover the head, and 62.7% also on the affirmative that they wear special boots.

Further, 78.7% reported not using oral or nose masks and 70% of the responses indicated not wearing coverall before spraying the crops with pesticides. The result in Table 6 shows clearly that the farmers were most likely exposed to health risks due to pesticides application since basic personal protection is inappropriately addressed.

#### Health risk symptoms experienced due to pesticides use

Pesticides can cause health risks and damages during short term application and long term use. Several health symptoms were reported by the respondents which is buttressing that, the farmers lack critical use of protective measures during spraying. As seen in Table 7, the most frequently reported symptoms were burning sensation (78%), headaches (67%), weakness (60.7%), fever (64%), watering eyes (60.7%), itching and skin irritation (63%), and chest pain (68%). The ranking of burning

**Table 7 Health symptoms experienced due to pesticides use**

Symptoms	No	Yes	Rank
Burning sensation	66	234	1st
Chest pain	94	206	2nd
Headache	98	202	3rd
Fever	108	192	4th
Itching and skin irritation	112	188	5th
Weakness	118	182	6th
Watering eyes	118	182	6th
Dizziness	166	134	7th
Skin rashes	168	132	8th
Forgetfulness	240	60	9th
Diarrhea	254	46	10th
Vomiting	272	28	11th

sensation as number one, suggested that it is a common issue and burning sensation is a function of several drivers leading to health risk predisposition. These drivers could be biosocial or biophysical factors. These factors must be tested to help elucidate clearly the contributing risk variables.

#### Relationship between burning sensation and explanatory variables

From literature factors such as gender, age, use of PPEs, education, farm size, knowledge of pest and diseases presence, and years of farming experience (Lorenz et al. 2012; Kwadzo et al. 2015; Wumbei and Houbraken 2019) may influence on watermelon farmers' experience of burning sensation when applying pesticides. Correlation between burning sensation and various explanatory variables were computed using Cramer's  $v$  and presented in Table 8. The result of the association between burning sensation and explanatory variables indicated positive, negative and one ambiguous relationships, although some were not significant. This implies that various explanatory variables have some relationship with the dependent variable and therefore deem appropriate in the logistic model, which was tested in Table 9. Four factors were significant ( $p < 0.05$ ), which are gender, age, knowledge to identify crop pest and knowledge to identify crop disease to burning sensation. In contrast, low educational level, reading to manufacturer instruction and wearing coverall showed no significant relationship with burning sensation during pesticide usage.

#### Logistic regression modeling

There are several factors that might cause farmers to be predisposed to health risks. Burning sensation is taken as a dependent variable since it is one of the first signs or symptoms that the farmers will experience as a result of not wearing protective gears and/or with other variables. We modeled the factors that might be the drivers

**Table 8 Correlation relationship between burning sensation and explanatory variables**

Variables	Sign	Significance
Gender	Ambiguous ( $\pm$ )	s
Age	+	s
Low educational	+	ns
Reading manufacturer's instruction	+	ns
Knowledge to identity crop pest	-	s
Knowledge to identity crop disease	+	s
Wearing of cover all	-	ns

Significant for coefficient:  $p < 0.05$ ; s for significant and ns for non-significant; + and - signs indicate positive or negative correlation

**Table 9** Factors likely to predispose burning sensation using logistic regression model

Variables	Estimated parameter (B)	Standard error (SE)	Wald	p-value	95% CI	
					Lower	Upper
Read manufacturer's instructions	-0.169	0.299	0.321	0.571	0.470	1.516
Knowledge to identify pest	-0.941	0.426	4.882	0.027*	0.169	0.899
Knowledge to identify disease	0.795	0.299	7.091	0.008**	1.234	3.976
Wear coverall	-0.634	0.311	4.161	0.041*	0.289	0.975
Low education	-0.450	0.311	2.089	0.138	0.346	1.174

Hosmer and Lemeshow test = (0.55,  $p > 0.05$ )

\* Indicates statistically significant level  $p < 0.05$ ; \*\*  $p < 0.01$

influencing burning sensation using logistic regression. In this model, our explanatory variables were ability to read manufacturer's instructions, knowledge to identify pest, knowledge to identify diseases, wearing coverall, and low education (no formal and/or primary education). These variables were selected after testing for multicollinearity among several variables. The explanatory variables were found to have a tolerance level of at least 0.953, and in addition these variables were retained since they yielded a good fit model with Hosmer and Lemeshow test greater than 0.5. The logistic model is presented in Eqs. (1) and (2), respectively. The burning sensation is a dichotomous dependent variable and specified as Yes = 1 and 0 = otherwise. And as in Eq. (2),  $X_1, \dots, X_k$  are the explanatory variables and with coefficient  $\beta$ . Using Eq. (2) we run the model and presented the result in Table 9. The Hosmer and Lemeshow test = 0.55,  $p > 0.05$  indicating that the model is well fit and confirms the significance of some of the selected explanatory variable at  $p < 0.05$ . Also, the Wald tests of the explanatory variables are all greater than zero indicating that the parameters are associated with the dependent variable.

In Table 9 and from the model, three main explanatory variables were found to be statistically significant to influence the farmers' likelihood to experience burning sensation in their usage of agrochemicals. The coefficient for farmers with knowledge to identify pest is negative and significant ( $\beta = -0.941$ , C.I. = 0.169–0.899;  $p = 0.027$ ). Thus, the coefficient indicates that if a farmer has knowledge to identify pest, he or she would have a lower probability in experiencing a burning sensation during pesticide application. Conversely, the coefficient for the farmers with knowledge to identify disease is positive and significant ( $\beta = 0.795$ , C.I. = 1.234–3.976,  $p = 0.008$ ), which is surprising since farmers' knowledge to identify disease should be associated with less likelihood to experience burning sensation during pesticides application. This observation might likely be due to the fact that farmers' ability to identify disease is more difficult and

required technical expertise. On the other hand, the coefficient for wearing coverall was negative and significant ( $\beta = -0.634$ , C.I. = 0.285–0.975,  $p = 0.041$ ). Thus indicating that, farmers wearing coverall are 0.63 times less likely to experience burning sensation than farmers who do not wear coverall. Although low education and ability to read manufacturers' instructions were expected to influence the farmer's likelihood to experience burning sensation during pesticides application, their estimated parameters were not significant but with positive association with the outcome variable. However, in this case the variables are not significant because education is componential in structure since continuous education is critical in achieving appropriate agronomic practices. Farmers low level of education might have accounted for the non-significant of their ability to read manufacturer's instructions. Intervention strategy like regular training is needed to have reduce impacts on burning sensation during pesticide application.

#### Bootstrapping the model statistics

In order to confirm the model statistics, and avoid doubts of sample distribution, bootstrapping was used as an additional technique to measure the accuracy of the logistic parameter estimates. Table 10 shows the result of the bootstrapping. In this study, a sample size of 300 as obtained from the survey is used as a proxy population. The bootstrap method estimates the sampling distribution empirically using the given sample size and estimate the parameters on large scale of 2000 sample size. In this way, bootstrapping serves as an internal replication mechanism for assessing the stability and replicability of sample results (Efron 1985; Thompson 1993). The results show that there are no differences between the standard errors in Table 9 for logistic regression and that of the bootstrap method in Table 10. In addition, the p-values were identical as predicted by both logistic regression and bootstrap method. The obvious implication is that

**Table 10 Bootstrap results generated after 2000 samples using proxy sample population**

Variables	Estimated parameter (B)	Standard error (SE)	p-value	95% CI	
				Lower	Upper
Read manufacturer's instructions	-0.169	0.330	0.604	-0.854	0.445
Knowledge to identify pest	-0.941	0.608	0.037*	-2.223	-0.128
Knowledge to identify disease	0.795	0.310	0.007**	0.230	1.465
Wear coverall	-0.634	0.325	0.038*	-1.295	-0.024
Low education	0.450	0.313	0.136	-0.125	1.108

Hosmer and Lemeshow test = (0.55,  $p > 0.05$ )

\* Indicates statistically significant level  $p < 0.05$ ; \*\*  $p < 0.01$

the sample size distribution and parameter estimates were accurate and correctly predicted by the model.

## Discussion

In order to have sound educational policies and strategies, it is necessary to understand farmers level of knowledge and practices regarding pesticides application. This is to prevent ecological damage and health risk among watermelon farmers. In this study, a considerable number of farmers with more than 60% (no formal and primary level) of education, were engaged in pesticide application. Their level of understanding the hazards associated with pesticide use was so poor. Majority of the farmers (Table 2) indicated that they know the hazards and the health impacts associated with pesticides application. However, that understanding did not reflect or translate into precautionary measures that must be put in place i.e. wearing of protective gears and reading manufacturer's instruction before pesticide use. Our result is consistent with report from Wumbei and Houbraken (2019) in which yam farmers were exposed to various levels of pesticide hazards. Similar nature of exposure was recorded by Strong et al. 2008 in which the authors called for multiple stakeholder engagement in order to have a holistic approach in controlling the exposure. On the other hand, Feola and Binder (2010) described the farmers' attitudes of knowing the hazardous nature of pesticides and still engaged in such dangerous practices without precautionary measures due to lack of understanding social norms. Although factors associated with social norms were not addressed in this study, it is concurred that structural changes are needed to have behavioral change at a collective and systematic level.

On the issue of access and acquisition of pesticides, majority of the farmers (92.7%) buy the pesticides from local agrochemical shops in town and village. Thus suggesting that agrochemical shop retailers must be

included in the chain of educational training regarding pesticides distribution and their proper usage. Retailers are necessary because the farmer-extension officer ratio is so low within the region and the country and can help prevent the misconception of application rate error to avoid repetition and error propagation. Extension services and related programs have been noted to improve farmers condition (Danso-Abbeam et al. 2018). As can be observed that 88% of the farmers mixed more than one type of pesticides with water before spraying. This practice must be unlearned as information across the region is indicating negative impacts of pesticides use on bees' pollination (Thompson 2010; Johnson et al. 2010).

Table 4 shows clearly that farmers acclaimed knowledge regarding hazards of pesticide is not translated into actual practice as can be seen with the manner they dispose empty pesticides containers, where they store pesticides and how they wash the sprayers after use. Surprisingly and troubling is the fact that they put the empty container to other use, and even stored the pesticides in the living room by almost half of the respondents (46.7%). These actions predispose the growing child in the family to severe risks if expose to the hazards. On the contrary in developed countries, critical control points were established where empty containers, pesticides leftovers and other waste related to pesticides are picked by competent organizations for safe disposal (Devi 2009; Jin et al. 2017). Further, and bizarrely to the environment, the respondents wash the sprayers after use in rivers, lakes or irrigation canals and throw empty or unused container on farms and in the nearby bushes. This appalling behavior and practices are the sources of pesticides contamination in the environment and strong regulatory practices and policies must be formulated and enacted to control the behavior. In most of the rural communities, rivers, lakes are the sources of drinking water and contamination by this approach must not be allowed. In addition,

the ecological organisms would be affected if the intensity of these actions are not curtailed.

It is not surprising that the farmers reported health symptoms (headache, chest pain, weakness, etc.) during pesticide application. Burning sensation was first in ranking by the farmers followed by chest pain. A closer look at burning sensation revealed that it is the common symptom, but dependent on several explanatory variables. Logistic regression was used to model burning sensation and the associated explanatory variables to gain further insights regarding selected biosocial factors influencing burning sensation. The modeling (Table 9) revealed that factors likely to predispose burning sensation were knowledge to identify pests, knowledge to identify diseases, and wearing coverall. These variables were expected and shows clearly that farmers own intrinsic attributes such as ability to identify pest and diseases, and wearing coverall are within the reach of the farmers and can be managed effectively to minimize the burning sensation. In another study involving cocoa farmers, Okoffo et al. (2016) found educational level to be significant with respect to decision in wearing personal protective equipment. On the contrary in this study, low education was not significant. This might be due to strong social norms which was described by Feola and Binder (2010) and must be taken into account to have a behavioral change at collective and systematic level. Furthermore, educational training can help through policy intervention in addressing the health symptoms. In order to be sure of the modeling result of the sample size/distribution and estimation of the parameters, bootstrapping method was added as an internal mechanism to support the model. The result (Table 10) confirmed the strength and accuracy of the parameters estimated.

## Conclusions

Watermelon production in Ghana is increasing due to export drive of the country. Similarly, the use of pesticide is growing to control pests and diseases by farmers in general. Understanding and documenting pesticide use is a prerequisite for any meaningful policy interventions. We investigated pesticides use by watermelon farmers in six communities in the Central region, Ghana. The result shows that farmers have knowledge and understanding of the hazardous nature of pesticides use. However, the knowledge about the environmental and health hazards of pesticide use is not translated into actual practice. Health hazards were reported and experienced by the farmers with various levels of symptoms. Burning sensation is the foremost symptom experienced by the farmers. Factors underlining and explanatory to the burning sensation were modeled. The most probable variables influencing burning sensation were knowledge to identify

pests, knowledge to identify diseases, and wearing coverall. The implication is that educational training programs should be enhanced; extension services must be increased. The current farmer-extension officer ratio in Ghana is low and insufficient to cause any critical mass influence on farmers regarding the use of pesticides. The extension services and capacity should therefore be enhanced to increase the educational information flow. Pesticides retailers must be brought into the equation of pesticides education to augment the proper use of pesticides. The current approach of unregulated buying and usage without scientific base demands new policy interventions. With sound policy, health risk impacts on the farmers and ecological implication and its' consequences would be minimized.

## Abbreviations

MoFA: Ministry of Food and Agriculture; SPSS: Statistical Package for Social Sciences.

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## Authors' contributions

MKM conceived and designed the work with APG, MK and DED validated the method section. All authors MKM; MK, APG, and DED participated in the analysis, validation and writing of the paper. All authors read and approved the final manuscript.

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## Availability of data and materials

Part of the data that supports the findings are included in the manuscript. However, the raw data of the study are available from the corresponding author upon request.

## Ethics approval and consent to participate

All participants agreed to participate in the research study, and they were free to participate with or without reservation.

## Consent for publication

Consent to publish individual data in any form was obtained from the Watermelon farmers interviewed.

## Competing interests

The authors declare that they have no competing interests.

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