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Assessment of pesticide residues level in watermelon fruits [*Citrullus lanatus* (Thunberg) Matsumura and Nakai] in Lower, Central and Upper Badibou Districts in North Bank Region, of the Gambia

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All relevant data are within the paper and its Supporting Information files.

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The authors declare no competing interests.

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Abstract: Field and laboratory studies were conducted late 2019 in three districts of the Gambia's North Bank Region; namely, Central Badibou, Lower Badibou and Upper Badibou to ascertain the pesticide residue level in watermelon fruit, determine the insect pest control methods, types of pesticide, frequency of application, and pre-harvest interval observed. Multistage sampling technique was used in selecting the research respondents. Eighty-five (85) farmers were identified; forty-five (45) were randomly selected as research respondents. Data was collected using structured questionnaires. SPSS Software was used to analyse the questionnaires and Gas Chromatograph to determine the pesticide residue level. Data obtained were analysed and compared with the European Union Maximum Residue Limit (MRL). The results of the analysis revealed that the farmers used chemical control method in watermelon production, and applied at frequency of once in every two weeks. Furthermore, the results indicated that the chemical applied at flowering stage and the pre-harvest interval (17-21 days) ranked the highest. The pesticides residues found in the watermelon samples were Dimethoate, Profenophos, Dicofol, Cypermethrin, Lambda-cyhalothrin, Permethrin and Deltamethrin and most were above the MRL. The presence of pesticides residues in the watermelon samples calls for strict regulation on the use of pesticides on watermelon. Further study is recommended in other fruits and vegetables grown in the country especially in the studied region.

1. Introduction

The developing countries are seriously affected by the sky-rocketing of unemployment rates. Agriculture is the backbone of all the developing countries' economies. The production of watermelon by Gambian Farmers has featured prominently irrespective of the uncountable number of challenges faced by farmers amongst other hosts of issues that militate against this lucrative enterprise (Department of Planning Agriculture, 2016). The government's attention should, therefore, be drawn towards addressing challenges faced in watermelon production particularly pesticides and its use.

The sector contributes positively to the Gross Domestic Product (GDP) and employs about 70% of the labour force (Jobarteh and Selmani, 2020). According to the ANR policy (2019-2026), the consumption trend of fruits and vegetables of various kinds in the country is fairly high and likely to continue. Fruits are a concentrated source of natural components, and these natural components are plant-derived materials performing a key role in maintaining human health, especially in disease prevention, growth, and development. Today, plants, and plant-based compounds are the basis of modern pharmaceuticals used for the treatment of various dreadful diseases (Reetu and Tomar, 2017). Fruits such as mango, organs, guava, pear, and watermelon are life-enhancing medicines packed with vitamins, minerals, and antioxidants to human as well as cash crops for export by the growers in The Gambia. Watermelon does not only have the potential of enhancing the health of consumers but also increases the income of farmers (Adeoye *et al.*, 2011).

The production of watermelon is mainly carried out in the rainy season from September to December. It is produced in all the regions of the country; however, North Bank Region and Central River Region are the major growing areas of watermelon in The Gambia. In 2016, a total of one hundred and seventy-four (174) tonnes of watermelon fruits were produced (Department of Planning Agriculture, 2016). The crop is generally susceptible to many insects and diseases but no systematic study has been carried out to determine the damage level. Research has revealed that factors such as the prevalence of insects and diseases, climatic factors such as rainfall, temperature, and soil types hinder the production of watermelon (Adojutelegan *et al.*, 2016). Amongst the problems faced by watermelon farmers, insect pests ranked the highest (Chamo *et al.,* 2016). Farmers used different strategies such as attractants (cocoa butter), food baits, sanitation, botanicals, and chemicals to control fruit flies. Synthetic pesticides are known to be one of the most effective agents for controlling insects and diseases. Amongst various categories of pesticides, the insecticide is considered as the most toxic (Kodandaram *et al.,* 2013). It is becoming a dominant agent for controlling insects and diseases of crops.

Farmers use pesticides such as Carbofuran, chlorpyrifos, diazinon, dimethoate and metalaxyl in the production of crops (Wanwimolruk *et al.,* 2015). Watermelon is very susceptible to insects and diseases such as fusarium wilt, anthracnose, downy mildew virus diseases, gummy stem blight, powdery mildew, bacterial fruit blotch, damping-off, root-knot nematodes, adult striped, spotted cucumber beetle and squash bugs as a result, farmers use pesticides in controlling them (Shrefler *et al*., 2015). The system of continuous application of pesticides may lead to a high level of pesticide residue in the crops (Nguyen *et al.,* 2018). This could have a counterproductive effect on the quality of products to be consumed and placing a farmer's life at risk.

Cases of indiscriminate use of pesticides and non-adherence to good agricultural practices are very common. For example, some farmers apply chemicals on their fields in the afternoon and pick the fruits early in the next morning for sale in the local markets. These observations suggest that the fruits sold in the markets may have serious pesticide contamination. Most of the farmers in The Gambia, do not consider the so-called Maximum Residue Limit. Thought the Maximum Residue Limit regulation exists in the country, but it is not adhered to.

The production and consumption of watermelon are rapidly increasing in The Gambia. During the peak season of watermelon, the price is affordable to all categories of the population due to the high supply in the market. Most of the children and even some adults when eating watermelon eat it to the core. Sometimes, the remains are given to animals such as goats and sheep. To my knowledge no formal research has been done in the country to determine pesticide residue in watermelon. As a result, it is necessary to assess the pesticide residue in watermelon fruits as this crop in question have numerous health benefits such as it preventing cancer and diabetes due to its high content of lycopene, an antioxidant, lower blood pressure due to its richness in an amino acid. Therefore, this study aimed to determine the methods used in controlling insect pest of watermelon and to assess the concentration of pesticide residue in the watermelon fruits at harvest in the study area.

2. Materials and Methods

The study location

The study was conducted in North Bank Region of the Gambia, located in the Northern part of the River Gambia from October to November 2019. The area is located between latitude 16.01° West and longitude 13.52° North. The Region is one of the five administrative Regions of The Gambia. Its capital is Kerewan and subsequently reorganized as the Kerewan Government Area Council, with none change within the area covered. The area is divided into seven districts, namely, Central Baddibu, Lower Baddibu, Upper Baddibu, Jokadu, Lower Niumi, Upper Niumi and Sajal. The area is peculiar for watermelon production and a large percentage of the population practices farming at a large scale (Figs. 1, 2, and 3).

Research design

The study used qualitative and quantitative methods to collect data. The research methods used were as follows:

Step one: the researcher conducted interviews with the watermelon farmers in the study area (North Bank Region).

Step two: Watermelon samples were collected for pesticide residue analysis.

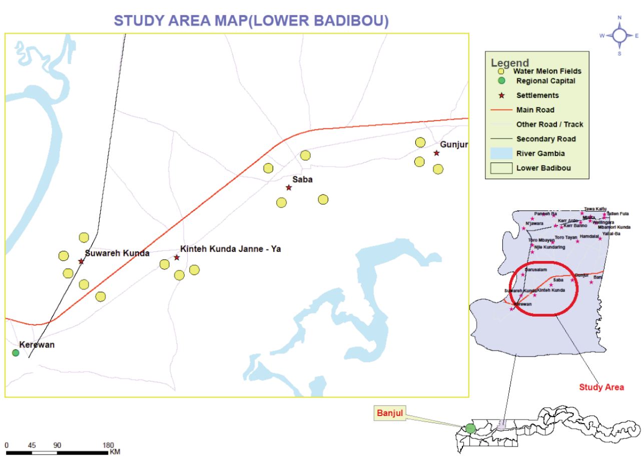

Fig. 1 - Map showing the study areas in Lower Badibou District.

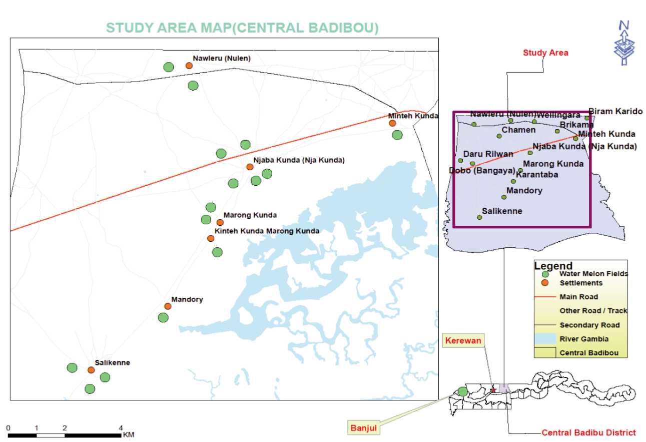

Fig. 2 - Map showing the study areas in Central Badibou District.

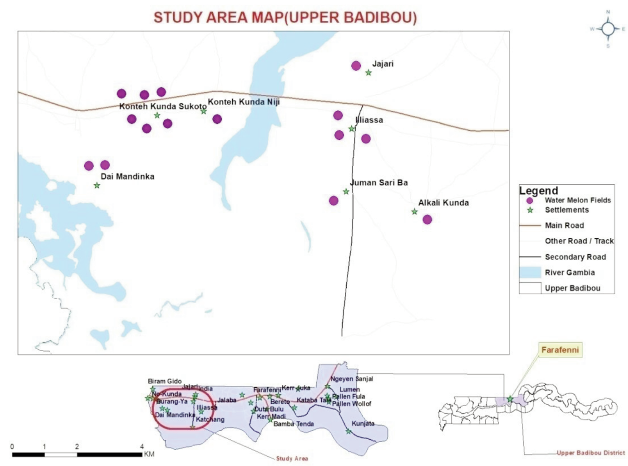

Fig. 3 - Map showing the study areas in Upper Badibou District.

Sampling procedures and sample sizes

Multistage sampling techniques were used in selecting the research respondents (contact farmers). Before the study, the Regional Directorate was contacted for information regarding the production trend of watermelon in the Region. Based on the findings, three districts (Central Badibou, Lower Badibou and Upper Badibou) with the highest number of watermelon growers were selected using purposive sampling. The second stage was the purposive sampling of 37 major watermelon growing villages in the sample districts. Populations of 85 farmers were identified out of which forty-five (45) farmers were randomly selected as research respondents 15 from each district.

Samples of 10 watermelon fruit due for harvesting were randomly collected from (10) different watermelon fields for pesticide residue analysis. The pesticide residues found in the fruits were compared with the European Union Pesticide Maximum Residue Limit standard (Table 1).

Data collection

Data were collected using structured questionnaires designed in English and administered orally in the local languages (Wolof, Mandinka, Fula, and Serer etc.). Before the actual data collection, the questionnaires were validated pre-tested with few

Table 1 - European Union Pesticide Database on maximum residue limit standard

Sample pesticide	Maximum residue limit (MRL) (mg/Kg)
Dimethoate	0.01
Dicofol	0.02
Lambda-Cyhalothrin	0.06
Profenophos	0.01
Deltamethrin	0.02
Permethrin	0.05
Cypermethrin	0.20

Source: European Union Pesticide Database on MRL Standard Latest Update, 2016.

watermelon farmers and adjusted. The demographic characteristics of the farmers (age, education, farming experience, labour source, farm size) and pest control method used by farmers were observed. One watermelon fruit was collected from a total of 10 farmers. During the collection, foil paper, tissue, markers were used. The tissue paper was used to clean the watermelon fruits and wrapped with foil paper to avoid contamination. Samples were labelled using the board marker. The watermelon samples were sent to Ceres Locustox in Dakar for pesticide residue analysis. The field coordinates were taken with GPSMap 60CS GARMIN.

Sample preparation and storage

Individual watermelon fruit samples were cut and chopped with a knife to about 3 cm cube in size. The process was carefully carried out to ensure that the test samples were homogeneous. The samples were blended with a Robot coupe blender 6 to ensure homogeneity. Each time the blender was used for a sample, the content in the machine was cleaned together with all the other equipment used in the process with detergent before another sample was blended to avoid contamination. Precautionary measures were employed to avoid any losses of juice or flesh.

Test portion

Individual test portion sufficient for one analysis was taken as sub-sample from the main test sample. These were immediately prepared for analysis. 10 g of the solution was measured from the homogeneous sample and put into 50 g centrifuge tube. The solution was extracted with the help of the acetonitrile.

Extraction

To determine the concentrations of pesticide residues, the extraction procedure was performed as described by Institut Luxembourgeois de la Normalisation, de l'Accreditation, de la Securite (ILNAS, 2018). The samples were prepared as follows: Ten millilitre (10 ml) of acetonitrile and 100 µl of PCB28 were separately measured and put into the test tube containing the test sample, and agitated by hand vigorously for a minute. Four grams (4 g) of Magnesium sulfate was added for the removal of residual water together with, 1 g of Sodium chlorine, 0.5 g of Na2Hcitrates-squihydrate and 1 g of Na3citrates- dehydrates. The solution was agitated vigorously with the flash shaker for one minute and centrifuged for phase separation for five minutes at a speed of 3000 m/s.

Purification

One millilitre of the solution was pipette and separately placed into 2 ml test tubes containing 150 mg $MgSO_4$ and 25 mg Primary Secondary Amine Sorbent (PSA). The solutions were centrifuged for five minutes at the speed of 3000 revolution/min. One (1 ml) was then transferred to another test tube and 5% solution of formic acid added to improve the storage stability of certain base sensitive pesticides. In addition, a control was prepared alongside, which has the entire additive except the watermelon sample.

Data analysis

Data were analyzed using Statistical Package for Social Science (SPSS) windows software version 20. The pesticides residue analysis was done using the Gas Chromatograph as described by Institut Luxembourgeois de la normalisation, de l'accreditation, de la securite (ILNAS, 2018).

3. Results and Discussion

Demographic characteristics of the watermelon farmers in the study area

The demographic characteristics of the research respondents were presented in Table 2. The result derived shows that all respondents were 100% male. Gender is very fundamental when it comes to the production of a certain type of crops in The Gambia. Traditionally men are attributed to watermelon production due to its tediousness. This finding is similar with Adeoye *et al.* (2011) who indicated the dominance of male fork in watermelon production in

Nigeria. The watermelon growers were predominantly youths and middle-aged individuals as 62% of the respondents were not more than 50 years old (Table 2). Age determines strength, therefore; it plays an important role in any meaningful production. Watermelon production is very tedious and rigorous as a result the middle-age individuals are the most people venturing into it. During the research, it was found out that some old age had to reduce their farm size due to the tediousness of the work. This is in agreement with (Adeoye *et al.,* 2011) who stated that age is crucial to carrying out activities such as mounting knapsack sprayer at the back, which most of the farmers used in the study area.

Majority of the research respondents did not have formal education, amongst them Arabic education ranked the highest 60%, followed by secondary education, (24.4%), primary education (6.7%), tertiary education (4.4%) and illiterate (4.4%). This shows that the level of conventional education is very low among the watermelon farmers in the study area (Table 2). Most of the pesticides are labelled either in English or in French; as a result, the respondents could not read the pesticide label. This might be responsible for the high concentration of pesticide residue in the watermelon fruits from the study area. Mubushar *et al.* (2019) reported the inappropriate use of pesticide due to high level of illiteracy.

Watermelon production was dominated by less experienced farmers, 1-5 years experience (55.6%), 6-10 years (24.4%), 11-15 years (11.1%) and 16 years above (8.9%). This could be attributed to the fact that the majority of the watermelon farmers in the study area are in the middle age. Therefore, the inexperience of the watermelon farmers might have caused poor handling and frequent application of pesticides (Eyhorn *et al.,* 2015), which could have led to the high concentration of pesticide residue in watermelon fruits.

Table 2 - Demographic characteristic of the watermelon farmers

Personal characteristics	Categories	Percentage (%)
Sex	Male	100
	Female	0
Age	20-30 years	13.3
	31-40 years	31.1
	41-50 years	31.2
	51-60 above	24.4
Educational qualification	Primary	6.8
	Secondary	24.4
	Illiterate	4.4
	Tertiary	4.4
	Arabic	60
Experience	1-5 years	55.6
	6-10 years	24.4
	11-15years	11.1
	16 above	8.9

NS = not significant by the Tukey test ($p<0.05$).

Control methods of insect pest practiced by watermelon farmers in the study area

The various methods of pest management practised by respondents are shown in figure 4. Chemical control method had the highest in the study area (88.9%) followed by Botanical (6.7%), and Integrated Pest Management (4.4%). This was attributed to the believed that chemical is readily available and required less labour as compared to other control methods (Fig. 4). The results manifested that chemical control method was predominantly practised. According to the farmers, the pesticides are easy to use and readily available. Some farmers practised other control methods but they claimed to be difficult and time-consuming. For example, to have enough of neem solution to cover a hectare of land is not easy, which compelled majority of the farmers to practised chemical control method. This in line with Padmajani *et al.* (2014) who reported the easy use agro-chemical by farmers despite knowing other control methods.

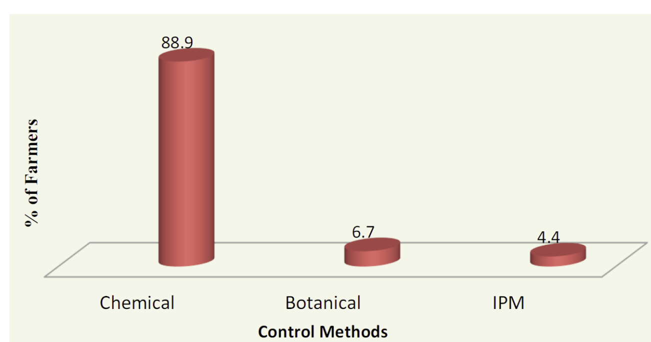

Fig. 4 - Control methods of insect pest practiced by watermelon farmers.

The frequency of application of the pesticides by watermelon farmers in the study area

Figure 5 revealed the frequency of pesticide application during watermelon production in the study area. The result revealed that majority of the respondents applied pesticide once every two weeks

(44.4%) followed by those who applied once every week (31.1%). The respondents who applied pesticide once every three weeks were 17.8% and the lowest percentage (6.7%) of respondents were found to applied pesticide once in a month.

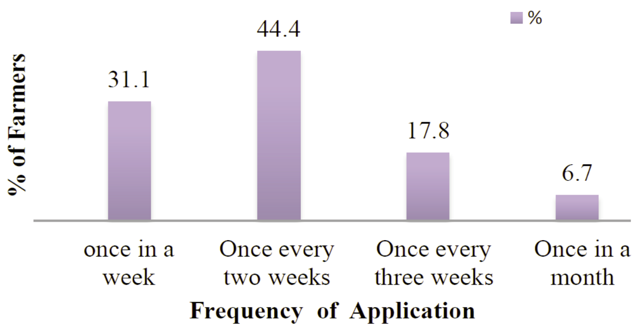

Fig. 5 - Percentage frequency of pesticide application in the study area.

The pre-harvest interval observed by the watermelon farmers in the study area

Figure 6 showed the pre-harvest interval observed in the watermelon growing areas. Most of the respondents (46.7%) observed pre-harvest interval of 16-20 days, followed by 17.8% of the respondents who observed pre-harvest interval above 21 days. The lowest percentages (11.1%) of respondents were found to observe pre-harvest interval of 6-10 days.

Pesticide residue concentration levels detected in the watermelon samples

The potential contamination of watermelon fruits with the different pesticides used in the study area was investigated. The results detected seven pesticides that happen to fall in the same class of pesticides, insecticide in the watermelon fruits that were subjected to analysis. The insecticides detected were; Dimethoate, Profenophos, Dicofol, Cypermethrin, Lambda-cyhalothrin, Permethrin, and Deltamethrin.

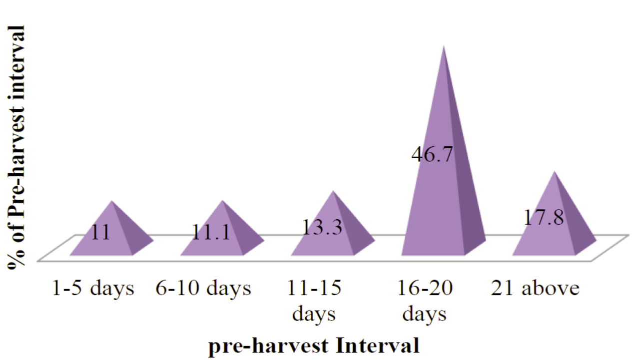

Fig. 6 - Pre- harvest intervals observed in the study area.

The Dimethoate and Profenophos are in the pesticide group of organophosphate, whereas Dicofol belongs to the organochlorine. Cypermethrin, Lambda-cyhalothrin, Permethrin, and Deltamethrin belong to the pyrethroids.

The various levels of dimethoate residues detected in the watermelon samples are shown in figure 7. The test result indicated that there was high pesticide residue concentration of dimethoate in all the watermelon samples compared to the European Union Maximum Residue Limit (0.01 mg/kg) except in sample 6 which recorded (0.01 mg/kg). In samples 1 and 2 the residue level recorded were 0.8 mg/kg, whilst samples 4 and 10 recorded 1 mg/kg. The highest concentration of Dimethoate was found in samples 3, 5, 7, 8, and 9 with 2 mg/kg. The present of dimethoate residue in watermelon was reported by Omoyajowo *et al.* (2017) in his research on the Assessment of Pesticide Residue Levels in common fruits consumed in Lagos State, Nigeria. If the MRL exceeds its limit it can cause various health problems to consumers. Ngoula *et al.* (2014) stated that high dose of dimethoate disrupts spermatogenesis and reduce fertility in test animal.

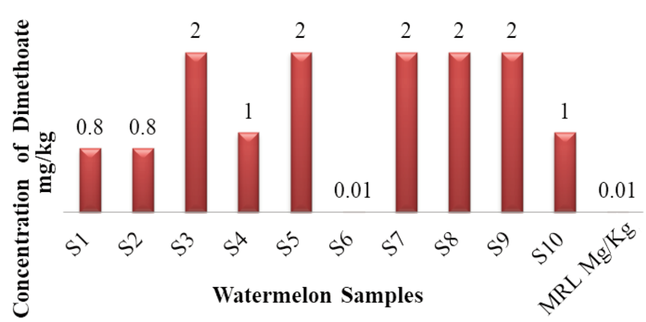

Fig. 7 - Residue level of dimethoate in watermelon samples.

Figure 8 presents the dicofol residues detected in the various watermelon sample analysed for pesticide residue. The findings revealed that watermelon samples were all found to have some amount of insecticide residues of dicofol and were all above the European Union Maximum Residue Limit which is 0.02 mg/kg. Sample 2 and 10 registered (0.3 mg/kg), sample 8 registered (0.4 mg/kg), sample 1 registered (0.5 mg/kg), sample 9 registered (0.7 mg/kg), samples 3, 4, 6, and 7 registered (0.8 mg/kg) and sample 5 registered the highest pesticide residue of (1 mg/kg).

Figure 9 presents the residue of lambda-cyhalothrin detected in the various watermelon samples. Lambda-cyhalothrin residue was found in all the watermelon samples that were subjected to analysis. Sample 1 recorded (0.006 mg/kg) while sample 2, 3, 4, 5, 6, 7, 8, 9 and 10 recorded 0. 009 mg/kg and they were all found to be below the European Union Maximum Residue Limit which happened to be 0.06 mg/kg.

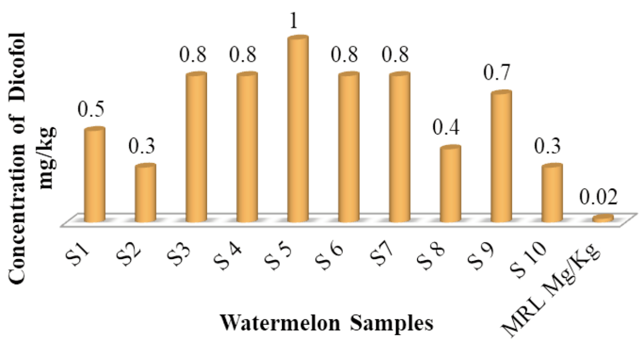

Fig. 8 - Pesticide residue level of dicofol in watermelon samples.

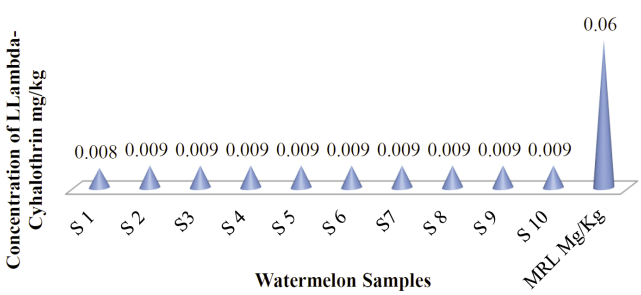

Fig. 9 - Pesticide residue level of lambda-cyhalothrin in watermelon samples.

The Profenophos residue level detected in the watermelon samples is shown in (Fig. 10). Profenophos was found in all the watermelon subjected to analysis. Samples 3, 4, 6, 7, 8, 9, and 10 had pesticides residue concentration level of 0.06 mg/kg, while sample 1, 2, and 5 had 0.05 mg/kg, when compared to the Maximum Residue Limit standard of 0.01 mg/kg of the European Union, they were all found to be above the residue limit.

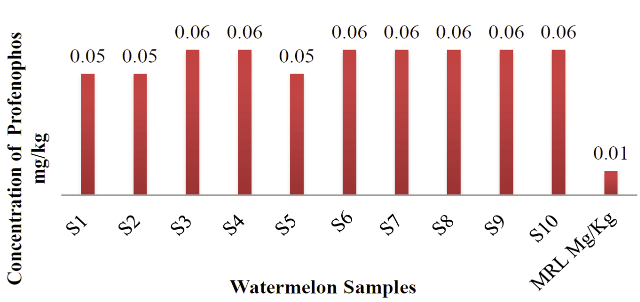

Fig. 10 - Pesticide residue levels of profenophos in watermelon samples.

Figure 11 indicates the deltamethrin residue level detected in the watermelon samples. Deltamethrin residues were present in all the watermelon samples; Sample 1 recorded (0.1 mg/kg), samples 2, 6, 8, and 10 recorded (0.2 mg/kg), samples 3, 4, 5, and 7 recorded (0.3 mg/kg). Sample 9 recorded the highest concentration level of (1 mg/kg). Compared with the European Union MRLof 0.02 mg/kg; all the samples were above the MRL.

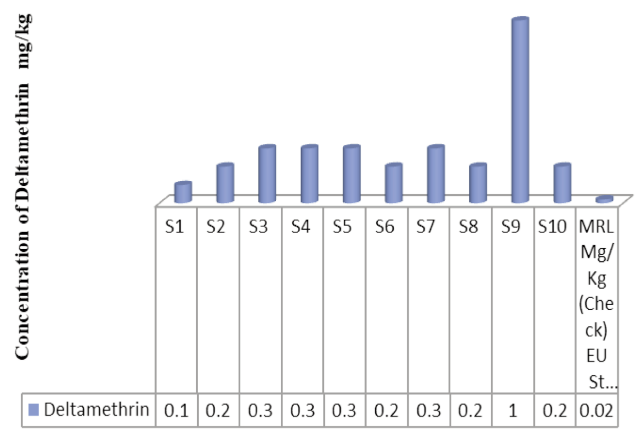

Fig. 11 - Pesticide residual level of deltamethrine in watermelon samples.

The Permethrin residue detected in the various watermelon samples are presented in figure 12. The Permethrin was found in all the watermelon samples and there concentrations were above the European Union Maximum Residue Limit of 0.05 mg/kg. The highest concentration of Permethrin was observed in sample 5 with (1.5 mg/kg), followed by sample 8 (1.4 mg/kg), while samples 4, 9 and 10 recorded 1 mg/kg (Fig. 12).

Figure 13 presents the residue of Cypermethrin detected in the various watermelon samples. Cypermethrin was found in all the watermelon sam-

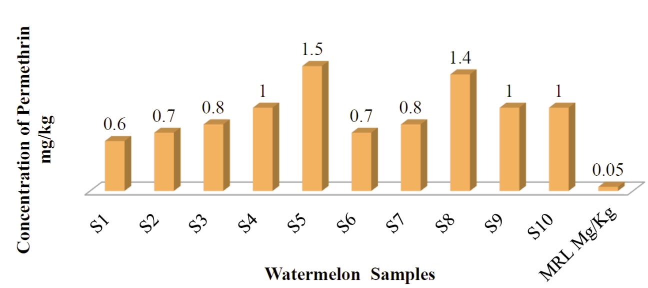

Fig. 12 - Pesticide residue level of permethrine in watermelon samples.

ples and were all below the European Union MRL of 0.2 mg/kg. The concentration of cypermethrin varied from 0.008 mg/kg to 0.08 mg/kg.

Effects of frequency of pesticide application and pre-harvest interval on pesticide residue level in the watermelon fruits.

In figure 14 the effect of the frequency of application of dimethoate on pesticide residue detected in watermelon fruits are shown. The watermelon fruit samples that received one application of dimethoate in every week had the highest concentration (1.5 mg/kg). The application of pesticides once every month had the lowest residue with 0.8 mg/kg. Frequency of application has great impact on the pesticide residue found in the watermelon fruits. This shows that before the dose of one application is neutralised another dose is applied again. This might be one of the main reasons why some of the watermelon fruits were highly contaminated with pesticides.

In figure 15 the effect of observing pre-harvest interval on pesticide residue in watermelon fruits are shown. Pre-harvest interval, which is the period between the time of application and period of harvest for the consumption of plant product, is recommended for each and every pesticide used on crops. The highest residue of dimethoate was found in fruits with pre-harvest interval 1 to 5 days (1.8 mg/kg) while the lowest residue of dimethoate was observed in the watermelon samples with pre-harvest interval of 21 days above (0.7 mg/kg). Most of the chemical products used by farmers on watermelon have pre-harvest interval of three to four weeks. Islam and Haque (2018) reported the importance of observing proper pre-harvest interval as it reduces the pesticide residue. Therefore, pre-harvest intervals have a great influence on the residue concentration of fruits and vegetables.

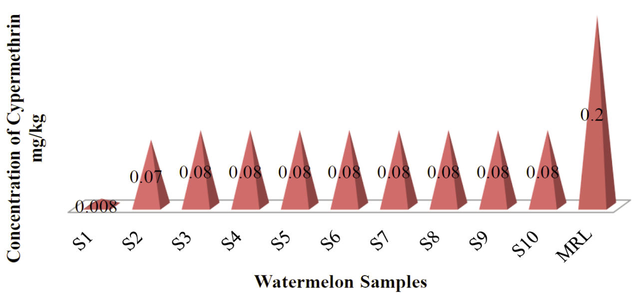

Fig. 13 - Pesticide residual level of cypermethrin in watermelon samples.

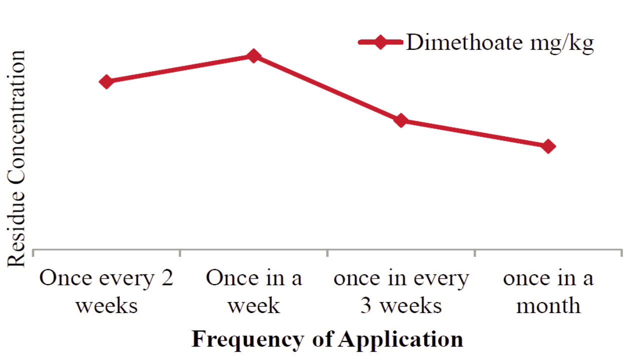

Fig. 14 - Effect of the frequent application of pesticide on pesticide residue in watermelon fruit.

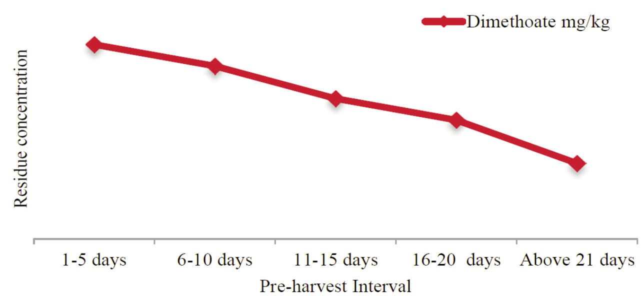

Fig. 15 - Effect of pre-harvest interval on the pesticide residue

4. Conclusions

Few pesticides residues were detected in all the watermelon samples analysed for pesticides residue the study and it was an indication that most of the fruits were contaminated with pesticides such as Dimethoate, Profenophos, Dicofol, Cypermethrine, Lambda-cyhalothrin, Permethrin and Deltamethrin. The residue level of most these insecticides were found to be above the recommended MRL. The frequency of pesticide application and the pre-harvest interval were found to have influence on the pesticide residue concentration in the watermelon fruits from the study area. The study further revealed that most of the respondents were illiterate and has less experience in watermelon production. Base on the findings from the study the following recommendation are made:

- farmers observe a pre-harvest interval of above 21 days to avoid high residue concentration in the watermelon fruits.
- farmers to use Cypermethrin and Lambda-cyhalothrin in the production of watermelon because they are easily degradable by the heat.

further research on other fruits and vegetables grown in the country should be conducted by encouraging the student to take up such research topics.
farmers should be educated and encouraged on other alternative pest control methods by setting up demonstration plot beside farmer field to demonstrate effectiveness of other methods.
the extension workers and farmers must be trained on the judicious use of pesticide through farmer field schools initiatives.
the promotion of the use and production of non-persistent pesticides and put more tax on persistent pesticides to reduce its importation
Responsible Sectors/Agency to put strict measures in the illegal entry of pesticide by closely monitoring the entry points and pesticide vendors.
pesticides residue regulation policy should be formulated and make sure it is strictly implemented by the responsible agencies.
the laboratory of the National Research Institute and the University of The Gambia be equipped with all relevant equipment to facilitate research in the country.

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