European Journal of Nutrition & Food Safety

11(2): 83-97, 2019; Article no.EJNFS.2019.015
ISSN: 2347-5641

Types and Classification of Pesticides Used on Tomatoes Grown in Mwea Irrigation Scheme, Kirinyaga County, Kenya

Momanyi, Violet Nakhungu[1,2*], N. Keraka, Margaret[3], A. Abong'o, Deborah[4] and N. Warutere, Peterson[1]

[1]Department of Environmental and Occupational Health, Kenyatta University, P.O.Box 43844-00100, Nairobi, Kenya.
[2]Kenya Agricultural and Livestock Research Organization, Food Crops Research Centre, KALRO Kabete, P.O.Box 14733-00800, Nairobi, Kenya.
[3]School of Public Health, Kenyatta University, P.O.Box 43844-00100, Nairobi, Kenya.
[4]Department of Chemistry, School of Physical Sciences, College of Biological and Physical Sciences, University of Nairobi, P.O.Box 30197-00100, Nairobi, Kenya.

Authors' contributions

This work was carried out in collaboration among all authors. Author MVN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors NKM, AAD and NWP managed the analyses of the study and managed the literature searches. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/EJNFS/2019/v11i230145
Editor(s):
(1) Dr. R. C. Ranveer, Department of Meat, Poultry and Fish, PG Institute of Post – Harvest Management, Killa – Roha, BSKKV, Dapoli, India.
Reviewers:
(1) R. D. Mavunda, University of Johannesburg, South Africa.
(2) Théodore Munyuli, Busitema University, Uganda.
Complete Peer review History: http://www.sdiarticle4.com/review-history/52696

Original Research Article

Received 09 September 2019
Accepted 19 November 2019
Published 27 November 2019

ABSTRACT

This study evaluated 403 farmers from the open field and greenhouse farms in Mwea Irrigation Scheme on the types and classification of pesticides used to control pests and diseases on tomatoes, in July 2017 to June 2018. Five greenhouse tomato farmers were purposively selected while sample size of 196 open field farmers, calculated using Fisher's formula. Cross-Sectional design using a structured questionnaire, face to face interviews and focus group discussions with 201 farmers in the eight wards, Gathingiri, Tebere, Kangai, Wamumu, Murinduko, Nyangati, Mutithi

**Corresponding author: Email: violetnakmo@yahoo.com, viomomanyi@gmail.com;*

and Thiba. Accuracy of the data was ensured by pre-testing the questionnaire on tomato farmers from a neighbouring Maragua sub-county, errors were corrected, and omissions added to the questionnaire. Descriptive statistics was carried out for frequencies, percentages, means, standard errors, variance and data subjected to T-test at 95% Confidence Interval to determine significant differences between variables. Results from the interviews revealed that farmers applied 57 and 12 pesticides under different trade names on tomatoes in the open field and greenhouse farms respectively. Pyrethroids, carbamates, nicotinoids, organophosphates, and organochlorines were applied on tomatoes among others. The 20 and 12 pesticides mainly used in open field and greenhouse farms were WHO Class II (60%) and WHO Class III (42%), respectively. Farmers heavily relied on different types of pesticides to control a wide range of major pests and diseases as *Tuta absoluta* and blight respectively. Chlorantraniliprole and mancozeb are the main pesticides used in tomatoes. Most pesticides, WHO toxic class II including pyrethroids and carbamates should be used following manufacturers' recommendations to prevent human health risks. Training and awareness by the Ministry of agriculture, Kirinyanga County government are needed on use of less toxic pesticides equally effective in controlling pests and diseases, such as WHO classes III and IV and bio-pesticides with minimal negative effects on human health.

Keywords: Tomato; farmers; pesticides; types; Mwea irrigation scheme; Kirinyaga County.

1. INTRODUCTION

About 20 to 40% of the world's crop production is lost annually to pests and diseases, each year [1]. Diseases cost the global economy around 220 billion and insect pests around 70 US billion dollars [2]. Farmers therefore use different types of pesticides to protect crops against pests and diseases as an effort to increase yields [3]. Production of enough food to meet consumer demand on quality and quantity are almost impossible without the use of pesticides in developed and developing countries [4]. However, despite the usefulness of pesticides negative impacts on the environment and human health ranging from acute to chronic effects such as cancer have been reported [5,6,7].

The world health organization (WHO) classification of pesticides is a system used to distinguish between the more and the less toxic pesticides based on the acute risk to human health which takes into consideration the toxicity of the active ingredient [8]. According to food and agricultural organization FAO and WHO (2016) [9], the WHO hazard classes have been aligned in an appropriate way with the Globally Harmonized System (GHS). The WHO classifies pesticides as extremely hazardous (class 1A), highly hazardous (class 1B), moderately hazardous (class II), slightly hazardous (class III) and class IV as unlikely to present acute hazard [10].

The most common method of classifying pesticides is based on their chemical composition and nature of active ingredient (a.i), or the element bonded to the hydrocarbon system [11]. This classification is useful in determining the mode of application, precautions to be taken during application and the application rates [11]. Basing on this, pesticides are classified as organochlorines, organophosphates, pyrethrins/ pyrethroids, carbamates and organosulfur. Organochlorine pesticides (OCPs) are highly persistent molecules which bio-accumulate and bio-magnify up in the food chain [12]. OCPs are absorbed in fatty tissues of animals more rapidly than they are metabolized and/or excreted and thus increase in concentration as they pass up each trophic hierarchy, hence remain in the environment and food chain long after application [12]. Currently, most of these pesticides have been banned except a few which are under restriction use [12].

Carbamates are fat soluble and are easily absorbed through the skin and transported into the body [13]. They inhibit enzyme cholinesterase essential in the functioning of nerves, which results in the death of insects and also animals [11,14,15].

Organophosphates (OPs) are broad spectrum pesticides controlling a wide range of pests due to their multiple functions [11]. OPs degrade rapidly by hydrolysis on exposure to sunlight and air although small amounts can be detected in food and drinking water [16]. OPs are neurotoxic even at very low levels of exposure as they irreversibly inactivate acetylcholinesterase (AchE) enzyme essential for neurotransmission in the central nervous system, resulting in accumulation of acetylcholine (Ach), which interferes with neuromuscular function [17].

Organosulfur compounds have low toxicity to young insects, a valuable property, thus are used for selective purposes. In Kenya, pyrethroids and carbamates are mainly used to control pests and diseases [18,19].

Tomato (*Lycopercicum esculentum mill*), is the second leading vegetable grown in Kenya as a source of income for small-scale farmers [20,21]. Kenya produces over 340,000 tons annually [22,23]. Kirinyaga County being the leading producer of over 54,000 tons, by the year 2016, of which 80% is produced in Mwea Irrigation Scheme [23]. Tomato is sensitive to pests and diseases and therefore the use of pesticides is unavoidable [24]. This study was carried out to evaluate the types and classification of pesticides farmers apply on tomatoes in Mwea Irrigation Scheme, Kirinyaga County.

2. MATERIALS AND METHODS

2.1 Study Area

The study was conducted in Mwea Irrigation Scheme, one of the prime agricultural regions in Kirinyaga County in the year 2017 (Fig. 1). It lies between latitudes 0.540° and 0.788° South and longitudes 37.228° and 37.497° East. The scheme has approximately 51,444 households with an average density of 341 persons per km^2 within an area of 516.7 km^2 [25]. It has eight wards namely; Gathigiriri, Tebere, Kangai, Wamumu, Murinduko, Nyangati, Mutithi and Thiba (Table 1). The topography of Mwea Irrigation Scheme is relatively uniform and extends over the flat land on the outskirts of Mt. Kenya [25]. The area is well supplied with irrigation water from Rivers Nyamindi and Thiba, making it favourable for tomato farming through the year. The irrigation water is circulated to the farms using a conveyance system with partially lined canal, and basin flood irrigation using earthen canals and application system. The area under irrigation is 260 hectares of which 40 hectares belong to out-growers National Irrigation Board, [26].

2.1.1 The socio-economic characteristics

Kenya produces over 340,000 tons of tomatoes annually [AFA, 2016], Kirinyaga County being the leading producer of over 54,000 tons, by the year 2016, of which over 44,000 tons (80%) valued at Ksh. 1,803,400,000 (approximately 18,000,000 USD), was produced by farmers and the out-growers National Irrigation Board in Mwea Irrigation Scheme [AFA, 2016, NIB, 2019]. The main agricultural products from the scheme are tomatoes, rice and French beans [26] among others shown in Table 1. Table 2 shows the main crops produced by farmers from Mwea Irrigation Scheme.

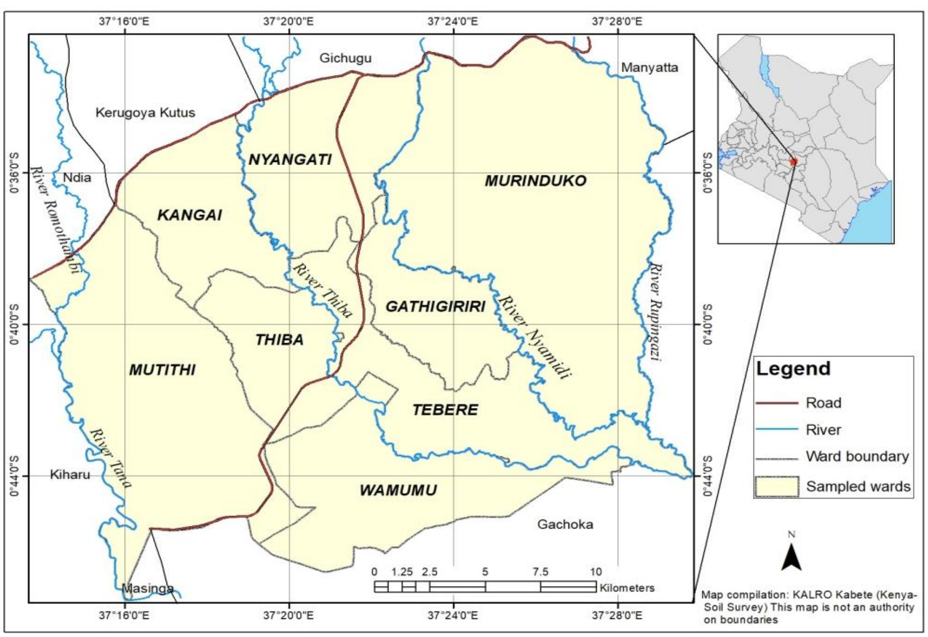

Fig. 1. Map of Mwea irrigation scheme showing sampling points (wards)

Table 1. Description and agricultural activities at the sampling sites

Sampling site/ ward	Altitude (m)	Longitude	Latitude	Agricultural activity
Gathingiri	1151	37.391°E	0.658°S	Tomatoes, French beans, onions maize, beans, rice production, livestock
Tebere	1123	37.388°E	0.699°S	Tomatoes, French bean, onions, maize, beans, rice production, livestock
Kangai	1227	37.301°E	0.616°S	Tomatoes, bananas, coffee, maize, beans, rice production, livestock
Wamumu	1126	37.373°E	0.738°S	Tomatoes, bananas, French beans, onions, water melon, maize, livestock
Murinduko	1176	37.431°E	0.602°S	Tomatoes, French beans, onions, water melon, passion fruit, coffee, maize, livestock
Nyangati	1259	37.348°E	0.591°S	Tomatoes, pawpaw, coffee, maize, rice production, livestock
Mutithi	1160	37.281°E	0.687°S	Tomatoes, maize, beans, rice production, livestock
Thiba	1161	37.329°E	0.678°S	Tomatoes, maize, beans, rice production, livestock

Table 2. Quantities and values of main crops from 220 hectare owned by farmers in Mwea irrigation scheme

Crop	Quantity (tons)	Value Ksh	Value USD ($)
Tomatoes	43,200	1,754,524,800	16,552,120
French beans	37,600	1,547,679,920	14,600,754
Rice	75,000	4,800,000,000	45,2830,019

2.2 The Target Study Population

The study targeted about 403 farmers who have grown tomatoes for more than two years in the open field farms (398) and in greenhouse farms (5), for local consumption in the 8 wards (Fig. 1, Table 1) in Mwea Irrigation Scheme. All the 5 greenhouse and 196 open field farmers (calculated using equations 1 and 2) who were selected randomly using a table of random numbers participated in the study. Farmers in Mwea Irrigation Scheme heavily rely on pesticides (not documented) to control pests and diseases [27].

2.2.1 Study design

The study used a Cross-Sectional design whereby a structured questionnaire, face to face interviews and focus group discussions were used for data collection. Accuracy of the data being collected was ensured by pre-testing the questionnaire on tomato growers from the neighbouring Maragua sub-county, Kirinyaga County after which errors were corrected and omissions added to the questionnaire.

2.2.2 Sample size determination

During the period of study, the area had about 398 open field and 5 greenhouse tomato farmers. All the farmers who grew tomatoes in greenhouses were purposively selected to participate while sample size for administering a questionnaire to open field farmers was calculated using Fisher's formula (Equation 1), in Mugenda and Mugenda [28].

$$n = \frac{Z^2pq}{d^2} \quad (1)$$

Where;

n= Sample size when population >10,000
Z^2= Square of standard normal deviate at required confidence level (95%), = 1.96^2
p = Proportion in the target population being studied with desired characteristics
q = 1-P
d **=** maximum tolerable error

Sample size was adjusted using Fisher's equation 2 below, in Mugenda and Mugenda [28] since the population of tomato farmers was less than 10,000.

$$nf = \frac{n}{1 + \frac{n}{N}} \quad (2)$$

Where;

n = The desired sample size if the target population >10,000
N = The estimate of the population size
nf= The desired sample size when the population <10,000

2.3 Statistical Analysis

Data collected was coded, entered in Statistical Package for Social Sciences (SPSS) version 18.0 and Microsoft Excel. Data cleaning was done before analysis to check for errors, outliers and erroneous entries. Descriptive statistics was carried out for frequencies, percentages, means, standard errors and variances. Data was then subjected to T-test at 95% Confidence Interval to determine significant differences between variables.

3. RESULTS

3.1 Farmers who Applied Pesticides on Tomatoes in Open Field and Greenhouses

The majority of the tomato farmers were males (81.2%). The farmers were mainly in the age bracket of 36-45 years followed by the bracket of 46-55 years. The farmers had a mean family size of 4.1. Results indicated that most of the farmers had secondary school education level (46.4%), followed by primary education level (39.3%), and only 2.1% had no formal education. The majority of the farmers were married (95.4%), a few of them were single, divorced or widowed (<1%). Most (48%) of these farmers had 5-10 years of experience in tomato farming followed by 11-20 years' experience (28%). A few (6.1%) had been growing tomatoes for more than 20 years. Table 3 shows the total number of tomato farmers (combined open field and greenhouse farms) per site and the farmers that were interviewed per site. Table 3 shows that Gathingiri, Tebere and Nyangati wards had the highest number of tomato farmers that were also interviewed.

3.2 Types and Classes of Pesticides Applied on Tomatoes in Open Field Farms

Information obtained from farmers through interviews showed that farmers applied 57 different pesticides, under different trade names, on tomatoes in the open field farms during the study period. Out of the 57 pesticides applied on tomatoes in the open field farms, those mainly applied were pyrethroids (27%), carbamates (19%) and organophosphates (12%) as shown in Fig. 2.

However, the twenty (20) pesticides mainly applied on tomatoes in open field farms in Mwea Irrigation Scheme are shown in Table 4. Table 4 shows that an insecticide coragen (Chlorantraniliprole) was mainly applied on tomatoes in the open field farms by 64% of the farmers followed by dynamic (Abamectin) by 40%, a fungicide oshothane (Mancozeb) by 36% and an insecticide duduthrin (Lambda-cyhalothrin) by 32%. Coragen was used to control *tuta absoluta* (leaf miner), dynamec to control *Diuraphis noxia* (aphids) and *Bemisia tabaci* (white flies), duduthrin to control a wide range of insect pests such as *Diuraphis noxia* while oshothane was applied to control blight on tomatoes.

However, Fig. 3 obtained from Table 4 shows that 60% of the 20 pesticides mainly applied on tomatoes in the open field farms were WHO class II considered to be toxic when the manufacturers' specifications are not adhered to [10], and WHO class III (25%) that are slightly toxic.

Table 3. Number of tomato farmers and those interviewed per site

Sampling site/ ward	Number of tomato farmers per site	Farmers interviewed per site
Gathingiri	68	37
Tebere	68	37
Kangai	50	26
Wamumu	38	19
Murinduko	25	12
Nyangati	68	37
Mutithi	48	14
Thiba	38	19

Table 4. The 20 pesticide types and classes mainly applied on tomatoes in the open field farms

Trade / common name of pesticide	Active ingredient (a.i)	WHO classification	Type of pesticide	Group of pesticide	Percentage pesticide use
Coragen	Chlorantraniliprole	IV	Insecticide	Organochlorine	63.8
Dynamec	Abamectin	II	Insecticide	Avermectin	40.3
Oshothane	Mancozeb	III	Fungicide	Dithiocarbamate	36.2
Duduthrin	Lambda-cyhalothrin	II	Insecticide	Pyrethroid	31.6
Tata alpha	Alphamethrin	II	Insecticide	Pyrethroid	25.5
Ranger	Chlorpyrifos	II	Insecticide	Organophosphate	22.4
Deacarid	Abamectin	II	Insecticide	Pyrethroid	19.4
Thunder	Imidacloprid+ Betacyfluthrin	II	Insecticide	Nicotinoid	16.3
Ridomil	Mancozeb+ Metalaxyl	IV	Fungicide	Carbamate	16.3
Abamite	Abamectin	II	Miticide	Avermectin	12.8
Bestox	Alpha-cypermethrin	II	Insecticide	Pyrethroid	12.8
Antracol	Propineb	III	Fungicide	Carbamate	8.7
Belt SC	Flubendiamide	III	Insecticide	Diamide	7.7
Mistress	Mancozeb+ zymoxanil	IV	Fungicide	Carbamate	7.1
Milraz	Propineb+ Cymoxanil	II	Fungicide	Carbamate	6.6
Actara	Thiamethoxam	IV	Insecticide	Neonicotinoid	6.1
Alfatox	Alpha-cypermethrin	II	Insecticide	Pyrethroid	5.6
Prove	Emamectin benzoate	III	Insecticide	Avermectin	5.6
Twiga ace	Acetamiprid	II	Insecticide	Neonicotinoid	5.6
Ambush	Permethrin	II	Insecticide	Pyrethroid	5.1

Table 5. The main and all pesticide types applied on tomatoes in greenhouse farms

Trade / Common name of Pesticide	Active ingredient (a.i)	WHO Classification	Type of Pesticide	Group of Pesticide	Percentage pesticide use
Belt	Flubendiamide	III	Insecticide	Diamides	20
Coragen	Chlorantraniliprole	IV	Insecticide	Organochlorine	80
Dynamec	Abamectin	II	Insecticide	Avermectin	20
Evisect	Thiocyclam	III	Insecticide	Nereistoxin analogue	80
Funguran	Copper hydroxide	II	Fungicide	Inorganic	20
Karate	Lambda-cyhalothrin	II	Insecticide	Pyrethroid	20
Merit	Imidacloprid	III	Insecticide	Neonicotinoid	20
Oshothane	Mancozeb	III	Fungicide	Dithiocarbamate	20
Ridomil	Metalaxyl-M+Mancozeb	IV	Fungicide	Carbamate	20
Thunder	Imidacloprid+ Betacyfluthrin	II	Insecticide	Nicotinoid	40
Actara	Thiamethoxam	IV	Insecticide	Neonicotinoid	20
Goldazim	Carbendazim	III	Fungicide	Carbamate	20

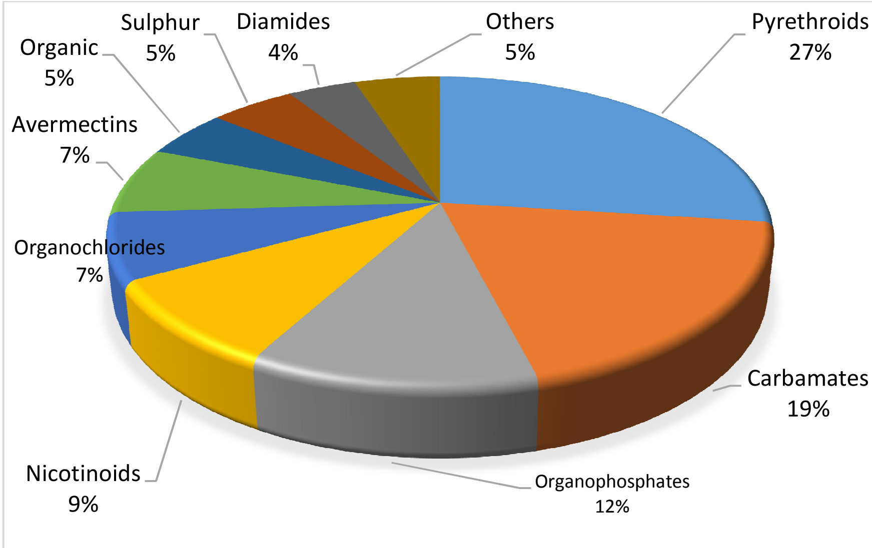

Fig. 2. Percentages of pesticide groups for 57 pesticides used on open field farms

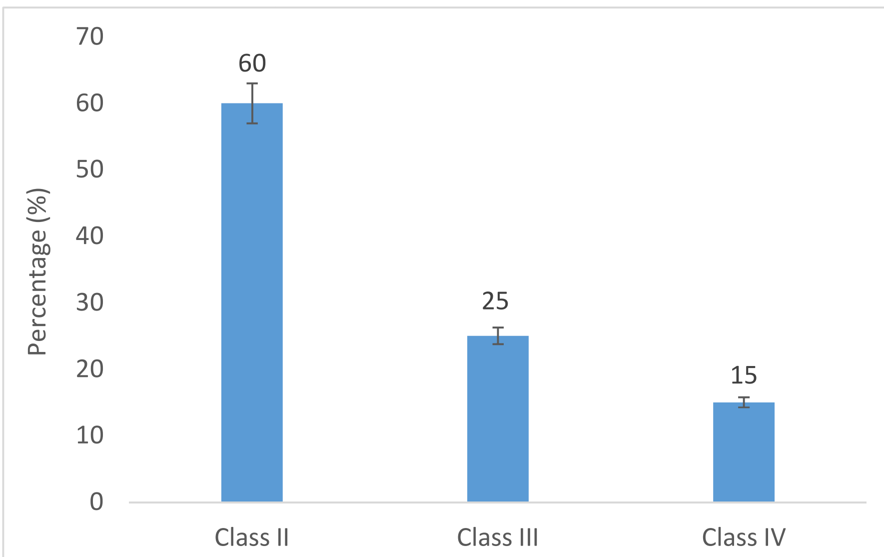

Fig. 3. WHO Percentage, classification of 20 pesticides mainly used on tomatoes in open field farms

3.3 Types and Classes of Pesticides Applied on Tomatoes in the Greenhouses

Results obtained through interviews on all pesticides farmers applied on tomatoes in greenhouses are shown in Table 5. Fig. 4 obtained from Table 5 shows that 33% of the pesticides applied to control pests and diseases in greenhouses were WHO class II that are toxic, 42% were WHO class III that are slightly toxic, while 25% were WHO class IV that are not toxic [10].

Table 5 shows that pesticides mainly applied in greenhouses were insecticides, with similar indication as in open field farms (Table 4) that insect pests are the major problem faced by farmers who grow tomatoes in both the greenhouse and the open field farms in Mwea Irrigation Scheme. Chlorantraniliprole (coragen) mainly applied in the open field farms is also the main pesticide used to control insect pests in the greenhouse farms (Table 5). In addition, Thiocyclam (evisect) was also mainly used in the greenhouses (Table 5).

Only three fungicides, Copper hydroxide (funguran), mancozeb (oshothane) and Metalaxyl-M+Mancozeb (ridomil gold) were used to control disease causing fungi *Phytophthora infestans* (late blight) and *Alternaria sp* (early blight) in the greenhouse farms (Table 5). However, results in Fig. 5 obtained from Table 4 show that pesticides mainly applied in greenhouses were carbamates (25%) and nicotinoids (25%).

3.4 Pests and Diseases that Affect Tomatoes in Mwea Irrigation Scheme

Seven insect pests and three diseases that mainly affect tomatoes grown in open field and greenhouse farms in Mwea Irrigation Scheme are shown in Figs. 6, 7 and 8 respectively.

3.4.1 Pests and diseases that affect tomatoes in open field farms

The insect pests and diseases farmers controlled on tomatoes in the open field farms are shown in Figs. 6 and 7 respectively. The pesticides used to control insect pests and diseases on tomatoes in open field farms are shown in Table 4. Results in Fig. 6 show that 92.3%, 80.6% and 63.8% of the pests controlled in open field farms are *Tuta absoluta* (leaf miner), mites and *Bemisia tabaci* (white flies) respectively, an indication that the three insect pests are the major problem in open field farms.

The diseases farmers controlled on tomatoes in open field farms are displayed in Fig. 7. Results in Fig. 7 show that blight was the main disease controlled by 95% of the farmers who grow tomatoes in open field farms. However, powdery mildew and rust were other diseases farmers controlled.

3.4.2 Pests and diseases that affect tomatoes in greenhouses

Insect pests that were controlled in greenhouse farms are shown in Fig. 8, and insecticides used to control the insect pests are shown in Table 5. Results in Fig. 8 show that *Bemisia tabaci* (whiteflies) were a common and major problem to all greenhouse farmers, while *Tuta absoluta* (leaf miner) and *Diuraphis noxia* (aphids) were controlled by 80% of the farmers, an indication that there are a severity of insect pest attack in greenhouses, similar to open field farms (Fig. 6).

However, blight and powdery mildew were the only diseases controlled in greenhouses using fungicides shown in Table 5. Farmers started applying fungicides from the nursery immediately after transplanting the crop to prevent attack from diseases.

4. DISCUSSION

4.1 Pesticide Types Applied on Tomatoes in Mwea Irrigation Scheme

Tomatoes are sensitive to pests and diseases and use of pesticides is unavoidable [24]. However, farmers applied different types of pesticides in Mwea Irrigation Scheme. Insecticides mainly used were coragen, dynamic and evisect while fungicides mainly used were oshothane, ridomil and antracol. However, the hazards posed on human health and environment has raised concerns about the safety of pesticides [29]. Results from the study show that 99.5% of farmers used different types and WHO classes of pesticides on the open field (Table 4, Fig. 2) and in greenhouse farms (Table 5, Fig. 4) to control specific insect pests and diseases (Figs. 6, 7 and 8), which were a major problem in Mwea Irrigation Scheme. Similar results indicating use of insecticides and fungicides to control enormous pests and diseases on tomatoes was reported by Mueke [27] in Mwea sub-county; in Tanzania [30], major horticultural zones in Kenya [18,19], and other African countries [31,32].

Farmers in Mwea Irrigation Scheme mainly used WHO class II pesticides on open field farms and WHO class III in greenhouses respectively (Figs. 4 and 5). The pesticides used were mainly carbamates, organophosphates, nicotinoids and pyrethroids because of their effectiveness in controlling pests and diseases. Similar findings were reported by [18] in Kathiani District, Kenya that farmers mainly applied pyrethroids and carbamates on vegetables. WHO class II pesticides are toxic and their residues are likely to remain in the crop when used inappropriately [30]. Toxicological studies [33,34] have revealed that some pesticides (eaten in food) could cause human health effects ranging from short-term, such as headache, nausea and diarrhoea, to long-term effects, such as cancer, teratogenesis and damage to the immune system, among others have been linked to pesticides [7,35,36]. Incidents of poisoning after consuming crops contaminated with pesticides have been attributed to misuse or negligence in observing the safety intervals before harvesting the crop [37]. Food safety is an area of concern for low and middle income countries where regulatory, surveillance and control systems are unable to address the range of potential hazards [38]. Similar results were reported by Kariathi et al. [30] that farmers in Tanzania heavily applied WHO Class 11 pesticides which contaminated tomatoes that were consumed locally.

Exotic, (example *Lyco*persicum *esculentum* Elium *cepa*) or indigenous (example *Amaranthus hybridus*, *Corchorus olitorius*) vegetable production is widely distributed across Africa, including Kenya [39]. However, consumption in sub-Sahara Africa is below the expected minimum of 400 g per day [40].Kenya produces over 4 million metric tons of vegetables valued at over 640 million US Dollars, the leading in production and value being Irish potatoes, tomatoes and cabbages [41].

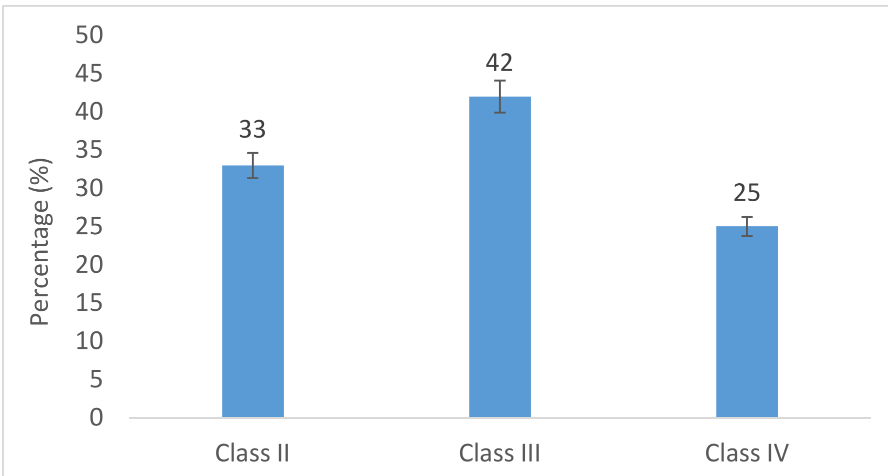

Fig. 4. WHO percentage classification of pesticides used in greenhouses

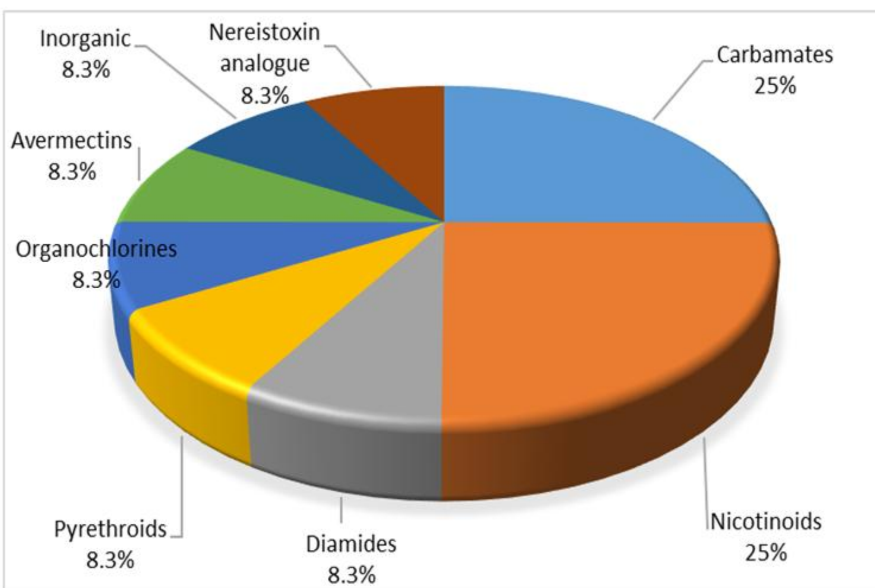

Fig. 5. Percentage group of pesticides used in greenhouses

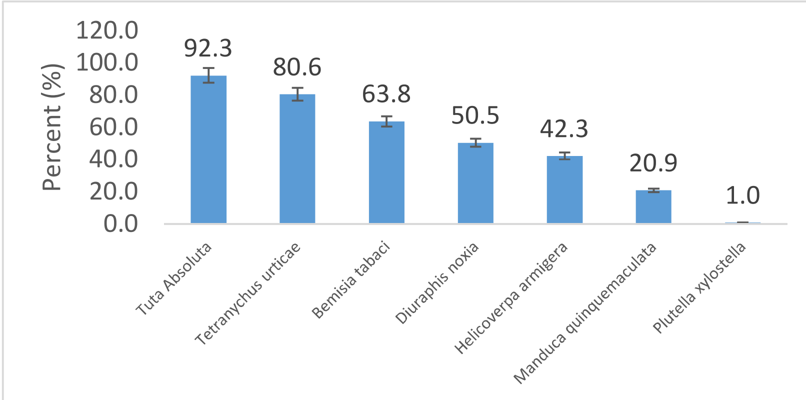

Fig. 6. Percentage of insect pests controlled in open field farms

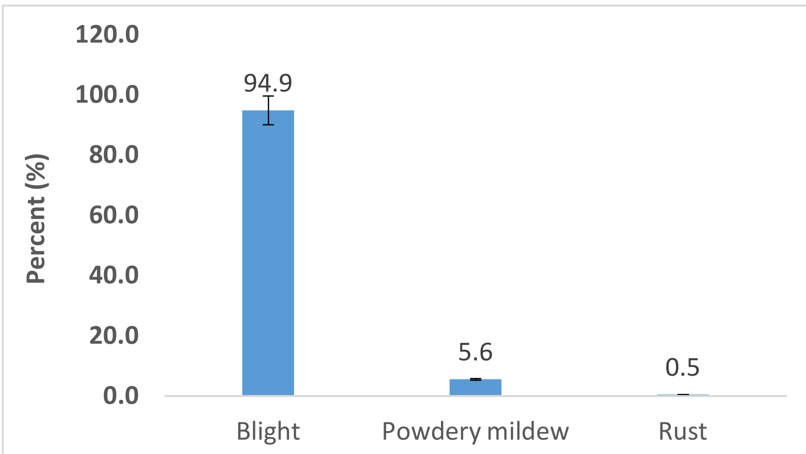

Fig. 7. Percentage of diseases controlled in open field farms

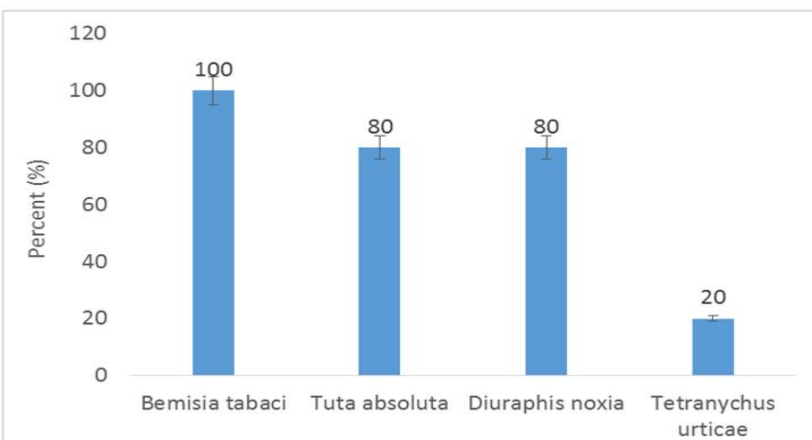

Fig. 8. The percentage of insect pests controlled in greenhouses

Different types of vegetables are consumed daily in the diet [42,43] to provide vitamins, antioxidants, carotene, ascorbic acid, riboflavin, folic acid and minerals like calcium, iron and phosphorus that protect our bodies against diseases [42,43] such as cancers, diabetes, and heart diseases [44]. Since farmers in mwea irrigation scheme mainly use who class ii pesticides to control pests and diseases on vegetables such as tomatoes [45], pesticide residues may remain in the vegetables at the time of consumption when toxic who class ii are used without adhering to specified recommendations by the manufactures [30]. Eating such vegetables with pesticide residues, in the daily diet, could cause acute or chronic negative effects to the health of the consumers [7].

5. CONCLUSION

The study established and documented a wide range of pests and diseases that attack tomatoes both in the open field farms and in greenhouses in Mwea Irrigation Scheme. The results revealed that the main insect pests of tomatoes in the scheme are *Bemisia tabaci* (whiteflies), *Tuta absoluta* (leaf miner) and *Diuraphis noxia* (aphids), and blight is the main disease. Due to heavy infestation of pests and diseases on tomatoes farmers heavily use many different types of synthetic pesticides, mainly insecticides and fungicides, to control them. However, most of the pesticides used on tomatoes were WHO class II that were mainly pyrethroids, carbamates, nicotinoids and organophosphates. WHO class II pesticides are toxic and should be used as specified by the manufacturers. Compliance to the pesticide use standards will prevent occurrence of their residues in the tomatoes and other vegetables and this will minimize pesticide residue effects on human health. From the results of this study, it would be important to frequently monitor and evaluate the residue levels of pesticides in all vegetables grown in Mwea Irrigation Scheme to determine their safety. Likewise, there is the need for promotion and awareness creation by Ministry of agriculture livestock and fisheries (MALF) and Kirinyaga County government on use of less toxic pesticides that are equally effective in controlling pests and diseases. Less toxic pesticides are those in WHO class III and IV and bio-pesticides that have minimal negative effects on human health.

CONSENT AND ETHICAL APPROVAL

Permission to do this research was sought from Kenyatta University (KU) graduate school, KU Ethics Committee and National Commission for Science, Technology and Innovation (NACOSTI). Permission to do research in Mwea Irrigation Scheme was obtained from the Kirinyaga County Director of Agriculture. Thereafter, pre-visits were made to the study area to discuss the issue with the agricultural officers.

Informed consent was sought from individual participants after explaining objectives of the study and ensuring them confidentiality throughout the study. Only those who were willing to participate by signing the informed consent form were allowed and recruited in the study. Verbal permission was sought from participants to take photographs used in the study. Protection of research participants' confidentiality was observed and guaranteed by not indicating their names on the questionnaire. Participants were also assured that every information obtained would be kept secret and will only be used by the researcher for the intended purpose (PHD studies). Farmers who were not willing to participate in the study were assured of no victimization from any office.

ACKNOWLEDGEMENTS

We acknowledge the research assistant Mr. Benson Mwangi from Mwea Sub-county agricultural office who greatly helped to identify farmers for this study and Reinpeter and Thuranira for data analysis.

COMPETING INTERESTS

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

1. FAO. Food and Agriculture Organization. New standards to curb the global spread of plant pests and diseases. Available:http://www.fao.org/news/story/en/item/1187738/icode/
2. Savary S, Ficke A, Aubatot JN. Crop losses due to diseases and their implications for global food production

losses and food security. Article in Food Security; 2012.
DOI: 10.1007/s12571-012-0200-5
Available:https://rootbiome.tamu.edu//wp-content/uploads/sites/38/2015/06/2016-Ficke-et-al-CropLosses-FoodSecurity-Research-gate

3. Nakano VE, Kussumi TA, Lemes VRR, Kimura I, de A, Rocha SB, Alaburda J, de Oliveira MCC, Ribeiro RA, Faria ALR, Waldhelm KC. Evaluation of pesticide residues in oranges from São Paulo, Brazil. Food Science and Technology. Campinas. 2016;36(1):40-48.
4. Popp J, Peto K, Nagy J. Pesticide productivity and food security. A review. Agro. Sustain. Dev. 2013;33:243-255.
5. WHO. World Health Organization. Pesticide residues in food. Online Q&A. (Accessed 15th September 2018)
Available:www.who.int/features/99/87/en
6. Bolon B, Rousseaux CG. Teratogens and teratogenetic mechanisms in mouse developmental pathology. Chapter 5 in Pathology of the Developing Mouse. Asystemic Approach. CCR Press; 2014.
7. Botwe BO, Ntow WJ, Nyarko E, Kelderman P. Evaluation of occupational and dietary exposures to current-use agricultural pesticides in Ghana; 2012.
(Accessed 30th October 2018)
Availlable:http://creativecommons.org/licences
8. IPCS. International Programme on Chemical Safety. The WHO recommended classification of pesticides by hazard and guidelines to classification.
(Accessed 8th April 2017)
Availlable:htttp://www.who.int/ipcs/publications/pesticides_hazard
9. FAO and WHO. International code of conduct on pesticide management. Guidelines on Highly Hazardous Pesticides. (Accessed 5th March 2016)
Available:www.fao.org
10. WHO. The World Health Organization recommended classification of pesticides by hazard and guidelines to classification. (Accessed 20th October 2019)
Available:http://www.who.int/ipcs/publications/pesticides_hazardpdf
11. Yadav IC, Devi NL. Pesticides classification and its impact on human and environment.
(Accessed 10th March 2016)
Avaiable:https://www.researchgate.net/publication
12. Randhawa N, Gulland F, Ylitalo GM, DeLong R, Mazet JAK. Sentinel California sea lions provide insight into legacy organochlorine exposure trends and their association with cancer and infectious disease. Elsevia, One Health. 2015;1:37-43.
13. Jennifer H, Christina W, Robert E, Stephen H. Organophosphate and carbamate insecticide poisoning. Summer Newsletter; 1998.
Available:https://www.addl.purdue.edu/newsletters/1998/summer/organos.html
14. Minghui L, Puyu L, Wang L, Feng M, Han L. Determination and dissipation of fipronil and its metabolites in peanut and soil. J. Agric. Food Chem. 2015;63(18):4435-4443.
15. Ye X, Zhang S. Detection of carbamate pesticides based on MWNTs- chitosan modified carbon nanotube electrode biosensor with immobilized acetylcholinesterase. Scientific Journal of Frontier Chemical Development. 2015; 5(2):13-20.
16. Lia X, Zhanga H, Jia Y, Zhenga Z, Bianb Q, Zhuc G. Immunochemical and molecular characteristics of monoclonal antibodies against organophosphorus pesticides and effect of hapten structures on immunoassay selectivity. Food and Agricultural Immunology.
(Accessed 15th May 2017)
Availlable:http://www.tandfonline.com/doi/pdf
17. Dawson BJ, Galvin KBJ, Thorne SP, Rohlman SD. Organophosphorus pesticide exposure and neurobehavioral performance in Latino children living in an orchard community. ELSEVIA, Neuro Toxicology. 2016;53:165-172.
18. Mutuku M, Njogyu P, Nyaga G. Assessment of pesticide use and application practices in tomato based agrosystems in Kaliluni sub location, Kathiani District, Kenya. Jounal of Agriculture, Science and Technology. 2014;16(2):34-44.
19. Macharia I, Mithofer D, Waibel H. Pesticide handling practices by vegetable farmers in Kenya. Environ Dev Sustain. 2013;15:887-902.
20. Mwangi MW, Kimenju JW, Narla RD, Kariuki GM, Muiru WM. Tomato management practices and diseases occurrence in Mwea West Sub County. West Sub County. Journal of Natural

Sciences Research. 2015;5(20):119-124.
21. Sigei KG, Ng'eno KH, Kibe MA, Mwangi M, Mutai CM. Challenges and strategies to improve tomato competitiveness along the tomato value chain in Kenya. International Journal of Business and Management. 2014;9(9):205-212.
22. Howtodoit. Tomato Varieties in Kenya and Greenhouse Tomato Farming; 2016. Available:http://www.howtodiys.com/tomato-varieties-in-kenya-greenhouse-farming
23. AFA. Agriculture and Food Authority. Horticultural Crops Directorate. Horticulture Validated Report of 2015-2016.
24. Hossain S, Hossain A, Rahman A, Islam M, Rahman A, Adyel TM. Health risk assessment of pesticide residues via dietary intake of market vegetables from Dhaka. Bangladesh. Foods. 2013;2:64-75.
25. KNBS. Kenya National Bureau of Statistics. Population Census; 2009.
26. NIB. National Irrigation Board. Mwea Irrigation Scheme. (Accessed 25th June 2018) Available:https://nib.or.ke/index.php/schemes/mwea-irrigation-scheme
27. Mueke PM. Insect pest incidences and yields of tomatoes grown in high tunnel and in open fields in Mwea Division, Kirinyaga County, Kenya. (Accessed 20th September 2015) Availlable:http://ir-libraryku.ac.ke/handle/123456789/11977
28. Mugenda OM, Mugenda AG. Research Methods. Quantitative and qualitative approaches. African Centre for Technology Studies, Nairobi. ACTS Press. 1999;43-44.
29. Verger PJP, Boobis AR. Reevaluate pesticides for food safety. Science. 2013;341:717-718.
30. Kariathi V, Kassim N, Kimanya M. Pesticide exposure from fresh tomatoes and its relationship with pesticide application practices in Meru district. Kariathi et al. Cogent Food & Agriculture. 2016;2:1196808.
31. de-Bon H, Huat J, Parrot L, Sinzogan A, Thibaud M, Malezieux E, Vayssieres JF. Pesticide risks from fruit and vegetable pest management by small farmers in Sub-Sahara Africa. Agron. Sustain. Dev. 2014;34:723-736.
32. Oesterlund AH, Thompson JF, Sekimpi DK, Mazii J, Racheal A, Jors E. Pesticide knowledge, practice and attitude and how it affects the health of small-scale farmers in Uganda: A cross-sectional study. Afri Health Sci. 2014;14(2):420-433.
33. Ojha A, Srivastava N. *In vitro* studies on organophosphate pesticides induced oxidative DNA damage in rat lymphocytes. Mut Res Gen Toxicol Environ Mut. 2014;761:10–17.
34. Dabrowski JM, Shadung JM, Wepener V. Prioritizing agricultural pesticides used in South Africa based on their environmental mobility and potential human health effects. Environ Int J. 2014;62:31-40.
35. Lozowicka B. Health risk for children and adults consuming apples with pesticide residue. Sci Tot Environ. 2015;502:184-98.
36. Mengliang Y, Jiyun N, Zhixia L, Yang C, Lijing Z, Guofeng X, Zhen Y. Health risks of consuming apples with carbendazim, imidacloprid, and thiophanate-methyl in the Chinese population: Risk assessment based on a nonparametric probabilistic evaluation model. Human and Ecological Risk Assessment: An International Journal. 2016;22(4):1106-1121.
37. Akinloye OA, Adamson I, Ademuyiwa O, Arowolo TA. Occurence of paraquat in some Nigerian crops, vegetables and fruits. Journal of Environmental Chemistry and Entomology. 2011;3(7):195-198.
38. Global Panel. Assuring safe food systems: Policy options for a healthier food supply. Policy Brief No. 5; 2016.
39. Maina S, Maina M. Vegetables in East Africa. Elewa Publications. Farming Resources Series. 2008;1-5.
40. WHO and FAO. Fruit and vegetables for health: Report of a Joint FAO/WHO Workshop. Kobe, Japan. Geneva; 2004.
41. Match Maker Associates. Horticulture study phase 1: Mapping of production of fruits and Vegetables in Kenya, 2017 Annual Report. Available:www.agroberichtenbuitenland.nl
42. Chowdhury ZAM, Jahan I, Karim N, Alam KM, Rahman AM. Moniruzzaman M, Gan HS, Fakhruddin ANM. Determination of carbamate and organophosphorus pesticides in vegetable samples and the efficiency of gamma-radiation in their removal. BioMed Research International; 2014. Article ID 145159.
43. Sheela K, Kamal GN, Vijayaiakshmi D, Ueeta MY, Roopa BP. Proximate analysis of underutilized green leafy vegetables in Southern Karnataka. Journal of Human Ecology. 2004;15(3):227-229.

44. Agbogidi OM, Akpomorine MO. Health and nutritional benefits of bitter leaf (*Vernonia amygdalina* Del.). International Journal of Applied Pharmaceutical Sciences and Bio Medical Sciences. 2013;2(3):164-170.

45. Momanyi VN, Keraka M, Abong'o DA, Warutere P. Farmers' compliance to pesticide use standards in Mwea irrigation scheme, Kirinyaga County, Kenya. IJIRAS. 2019;6(10):6.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/52696