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Farmers' Compliance to Pesticide Use Standards in Mwea Irrigation Scheme, Kirinyaga County, Kenya

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Abstract:** Kirinyaga County is the leading producer of tomatoes in Kenya and farmers heavily rely on pesticides to control pests and diseases. The aim of the study was to evaluate the farmers' compliance to pesticide use standards. The study was conducted in Kirinyaga County at Mwea Irrigation Scheme between July 2017 and June 2018. The study used a Cross-Sectional design that included 203 farmers (198 from open field, 5 from greenhouse farms) who grow tomatoes and use pesticides consistently for at least 2 years. Out of 20 pesticides mainly applied in open field farms, 16 were applied at significantly (P <0.05, 0.01, 0.001) higher rates and tomatoes sprayed with 19 of the pesticides were harvested at significantly (P <0.05, 0.01, 0.001) shorter Pre-Harvest Intervals, than recommended by the manufactures. On the other hand, out of all, 12, pesticides applied on in greenhouses, 3 were applied at significantly higher rates, and tomatoes sprayed with 2 pesticides were harvested at shorter durations than specified by the manufacturers. Farmers did not comply with the laid down standards. Non-compliance was due to ignorance, intentional and reliance on neighbor's and their own, information. The study recommends frequent education and training for farmers by Ministry of Agriculture Livestock and Fisheries on safe use of pesticides to help improve on compliance to pesticide use standards.

***Keywords:** Farmers, Compliance, Pesticides, Risks, Rate, Pre-harvest time Interval*

I. INTRODUCTION

Farmers use different types of pesticides to protect crops against losses of about 20 to 40% from pests and diseases as an effort to increase production in order to meet the increasing demands from consumers (Nakato, *et al*., 2015). However, non-compliance to laid down pesticide use standards has become a major risk to the environment and human health (Mustapha, *et al*., 2017; WHO, 2016; Bolon and Rousseaux, 2014) worldwide and in East Africa (Akinloye *et al*., 2011). About 3 million cases of acute pesticide poisoning have been reported worldwide, with about 220,000 deaths, the majority being in developing countries (Bempah, *et*. *al*., 2011). This has been due to use of toxic pesticides and poor pesticide handling practices (Fantke, *et al*., 2014) such, illiteracy among farmers, lack of awareness about the danger of misuse, the difficulty of extrapolating the dosage from a hectare to small areas, unsuitability of products in respect of the problem source, and lack of knowledge on pest and disease control (Fantke, *et al*., 2014).

Tomato (*Lycopercicum esculentum mill*) is among the most important vegetables grown in many parts of Kenya, whose production plays an important role in income generation for small-scale farmers, foreign exchange earnings as well as creation of employment (Mwangi *et al*., 2015). It is the second leading vegetable in Kenya in terms of value after potato (Sigei, *et al*., 2014). Global production of tomatoes is about 177 million tonnes (Horti daily, 2018), about 17.2MT in Africa, and Kenya is ranked 6th with a production of over 340,000 tonnes annually (Howtodoit, 2016; AFA, 2016). Kirinyaga County is the leading producer in Kenya of over 54,000 tonnes by the year 2016, of which about 80% is produced in Mwea Irrigation Scheme (AFA, 2016). Use of pesticides on tomatoes that are sensitive to pests and diseases is unavoidable (Hossain et al., 2013) though heavy and overuse has been reported in Mwea (Mueke, 2015). The aim of this study was to evaluate the farmers' compliance to pesticide use standards by tomato farmers in Kirinyaga County in Kenya.

II. METHODOLOGY

A. STUDY AREA

The study was conducted in Mwea Irrigation Scheme (Figure 2.1) in the year 2017, one of the prime agricultural regions in Kirinyaga County. It lies between latitudes 0.540^o and 0.788^o South and longitudes 37.228^o and 37.497^o East. The scheme is served by eight wards, Gathigiriri, Tebere, Kangai, Wamumu, Murinduko, Nyangati, Mutithi and Thiba (Table 2.1). Mwea Irrigation Scheme has approximately 51,444 households with an average density of 341 persons per km^2 within an area of 516.7km^2 (KNBS, 2010). Its topography is relatively uniform and extends over the flat land on the outskirts of Mt. Kenya. The study area is well supplied with irrigation water from Rivers Nyamindi and Thiba, which makes it favourable for tomato farming through the year.

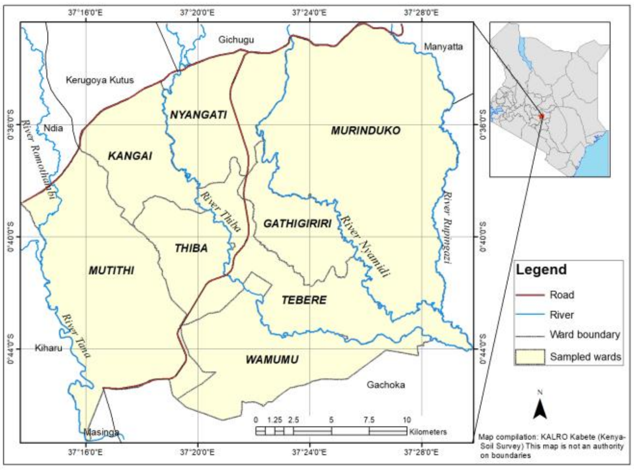

Figure 2.1: Map of Mwea Irrigation Scheme showing sampling sites (wards)

Name of ward	Altitude (m)	Longitude	Latitude
Gathingiri	1151	37.391^{o}E	0.658^{o}S
Tebere	1123	37.388^{o}E	0.699^{o}S
Kangai	1227	37.301^{o}E	0.616^{o}S
Wamumu	1126	37.373^{o}E	0.738^{o}S
Murinduko	1176	37.431^{o}E	0.602^{o}S
Nyangati	1259	37.348^{o}E	0.591^{o}S
Mutithi	1160	37.281^{o}E	0.687^{o}S
Thiba	1161	37.329^{o}E	0.678^{o}S

Table 2.1: Coordinates of sampling sites

B. TARGET 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 Mwea Irrigation Scheme. Farmers heavily rely on pesticides to control pests and diseases (Mueke, 2015) to produce over 80% of tomatoes in Kirinyaga County (MOA, 2014). The farmers grow other food crops such as maize and beans. Cash crops include; rice, French beans, onions, among other horticultural crops (NIB, 2018).

C. STUDY DESIGN

The study used a Cross-Sectional design that combined qualitative and quantitative methods where 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 to tomato growers from a neighbouring Maragua sub-county in Kirinyaga County after which errors were corrected and omissions added to the questionnaire.

A Cross-Sectional design was used in the study. 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 a neighbouring Murang'a County after which errors were corrected and omissions added to the questionnaire.

D. SAMPLE SIZE DETERMINATION

During the study period, the area had about 398 open field and 5 greenhouse tomato farmers. A few farmers who grew tomatoes in greenhouses were all purposively selected to participate while sample size for administering the questionnaire to open field farmers was calculated using Fisher's formula (1), in Mugenda and Mugenda, 1999.

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

Where;

n= The desired sample size for target population >10,000

Z^2 = Square of standard normal deviate at required confidence level (95%), = 1.96^2

p = Proportion in the target population that has desired characteristics being measured, e.g 0.5

q = 1-P, (1-0.5)

d = maximum tolerable error, e.g 5%

The sample size was adjusted using Fisher's equation (2), in Mugenda and Mugenda, 1999, since the population of tomato farmers was less than 10,000

$$nf = \frac{n}{1 + \frac{n}{N}} \qquad \ldots\ldots.(2)$$

Where;

n= The desired sample size for population >10,000

N = the estimate of the population size

nf = the desired sample size (when the population <10,000)

E. STATISTICAL ANALYSIS

Qualitative 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. Quantitative data was subjected to T-test at 95% Confidence Interval to determine significant differences between variables.

III. RESULTS

Most of the open field farmers were males (81.2%), in the age bracket of 36-45 years and had a mean family size of 4.09. In addition, the farmers had secondary school education level (46.4%), were married (95.4%), and 47.4% had 5-10 years of experience in tomato farming. However, most (60%) of the farmers who grew tomatoes in greenhouse farms were in the age bracket of 26-35, had a family size of 4 (Table 3.2), all had tertiary education level, were married (60%) and had 5-10 years of experience in tomato farming (Table 3.2).

Characteristic	Open field farmers n=196	Green house farmers (n=5)	Total (n=201)
Gender			
Female	35 (17.8)	3 (60)	38 (18.9)
Male	161 (82.2)	2 (40)	163 (81.1)
Age			
19-28	15 (7.7)	0 (0)	15 (7.5)
29-35	39 (19.9)	3 (60)	42 (20.9)
36-45	69 (35.2)	0 (0)	69 (34.3)
46-55	47 (24.0)	1 (20)	48 (23.9)
>55	26 (13.3)	1 (20)	27 (13.4)
Education level			
None	4 (2.1)	0 (0)	4 (2.0)
Primary	77 (39.3)	0 (0)	77 (38.3)
Secondary	91 (46.4)	0 (0)	91 (45.3)
Tertiary	24 (12.2)	5 (100)	29 (14.4)
Marital status			
Single	7 (3.6)	1 (20)	8 (4.0)
Married	187 (95.4)	3 (60)	190 (94.5)
Divorced	1 (0.5)	0 (0)	1 (0.5)
Widowed	1 (0.5)	1 (20)	2 (1.0)
Mean family size	4.09	4	
Years of experience in tomato farming			
<5 years	34 (17.3)	2 (40)	36 (17.9)
5 - 10 years	93 (47.4)	3 (60)	96 (47.8)
11 – 20 years	57 (29.1)	0 (0)	57 (28.4)
>20years	12 (6.1)	0 (0)	12 (6.0)

Figures in brackets are percentage of farmers

Table 3.2: Socio-demographic information for the open field and greenhouse farmers

A. COMPLIANCE WITH PESTICIDE USE STANDARDS

Table 3.3 shows results for the total number of tomato farmers per site and the farmers who were interviewed. Results in Table 3.3 show that Tomatoes in Mwea Irrigation Scheme are mainly grown in Gathingiri, Tebere and Nyangati wards.

Name of 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
Total	403	201

Table 3.3: Number of tomato farmers and those interviewed per site

Results from interviews indicated that 58% of the farmers who grew tomatoes on open field farms had not been trained on safe use of pesticides as compared to 42% who had been trained. Table 3.4 shows that the farmers were mainly trained by Ministry of Agriculture Livestock and Fisheries (MALF).

Characteristic	Open field farms		Greenhouses	
	Frequency (n=196)	% of Farmers	Frequency (n=5)	% of Farmers
Source of knowledge on pest and disease identification and control Self Self and Neighbour Self and Agricultural extension officer Agricultural Extension officer Agricultural Extension officer, plant clinic Neighbour KALRO and KEPHIS, Horticultural Development Authority	42 73 28 0 0 12 30 11	21.4 37.2 14.3 0 0 6.1 15.3 5.6	1 0 0 3 1 0 0 0	20 0 0 60 20 0 0 0
Who advises on type or rate of pesticide to spray Self Self, Neighbour and friend Extension officer Self and Agro-dealer Self and Extension officer Self, Neighbour, Extension officer Agro-dealer KALRO and KEPHIS Horticultural Development Authority	41 25 23 15 14 11 11 40 16	20.9 12.8 11.7 7.7 7.1 5.6 5.6 20.4 8.2	1 0 3 0 1 0 0 0 0	20 0 60 0 20 0 0 0 0

Table 3.4: Knowledge source on pest and disease identification and control in open field and greenhouse farms

Other organisations and agencies which trained the farmers were Kenya Agricultural and Livestock Research Organisation (KALRO), Agro-chemicals Association of Kenya (AAK), Pest Control and Product Board (PCPB), Kenya Plant Health Inspectorate Services (KEPHIS), Kenya Horticultural Exporters, Bayer, Bayer and Sigenta Companies among others. However, 60% of the farmers who grew tomatoes in greenhouses had not received any training on safe use of pesticides while 40% had been trained by MALF, AAK and Amiran Company (Table 3.4).

Results from interviews show that 77%of the farmers who grow tomatoes on the open field farms identified pests and diseases before deciding on the pesticide to purchase for control while 23% purchased the pesticides without identifying the pests and diseases.

The farmers mainly combined the neighbour's and their own knowledge to identify and control pests and diseases (Table 3.4) whereas greenhouse farmers mainly depended on the agricultural extension officers. Other institutions that advised farmers on pest and disease identification and control included; Researchers from KALRO and KEPHIS, and the Horticultural Development Authority (Table 3.4).

Farmers who did not identify pests or diseases claimed they knew common pests or diseases to be controlled from the many years of experience and that they preferred to prevent attack rather than to wait for the infestation time.

B. TYPES AND RATES OF PESTICIDES APPLIED IN OPEN FIELD AND GREENHOUSE FARMS

The results from interviews showed that 57 different trade names of pesticides were applied on tomatoes on open field farms. Forty (40) of these pesticides (69%) were applied at higher rates than those recommended by the manufacturers. Ten of these pesticides were applied by farmers who had been trained and 30 were applied by farmers who had not been trained on safe use of pesticides.

Table 3.4 shows that 16 out of 20 pesticides farmers mainly used on tomatoes on open field farms were applied at significantly higher rates than recommended by the manufacturers. The insecticides that were applied at higher rates were; coragen (Chlor-antraniliprole), duduthrin (lambda-cyhalothrin), bestox (alpha-cypermethrin) and belt (flubendiamide). Farmers applied coragen at a mean rate of 8.1040±0.2122 ml and duduthrin at 24.6154±1.8719 ml which were significantly (p<0.001) higher than the specified rate of 5 and 10mls respectively. Their T- test analysis gave df=124, t=14.6308, p<0.001 and df=51, t=7.8079, p<0.001 respectively (Table 3.4).

Active ingredient (ai)	Trade name	Target pest species	WHO class	Farmers' applied rate (ml/g in 20L water)	Manufacturer's rate in 20L water	T- test		
						t	df	p
Chlorantra-niliprole	Coragen	Insectside	IV	8.1040±0.2122	5	14.6308	124	<0.001
Abamectin	Dynamec	Insecticide	II	12.7083±0.7185	10	3.7695	71	<0.001
Mancozeb	Oshothane	Fungicide	III	51.6714±1.1241	50	1.4868	69	>0.05
Lambda-cyhalothrin	Duduthrin	Insecticide	II	24.6154±1.8719	10	7.8079	51	<0.001
Alphamethrin	Tata alpha	Insecticide	II	14.6000±1.3079	10	3.5172	44	0.001
Chlopyrifos	Ranger	Insecticide	II	28.3333±1.4385	40	8.1103	38	<0.001
Abamectin	Deacarid	Insecticide	II	12.6389±0.7839	7	7.1932	35	<0.001
Metalaxyl-M+Mancozeb	Ridomil	Fungicide	IV	50.3226±1.8828	40	5.4826	30	<0.001
Imidacloprid+Betacyfluthrin	Thunder	Insecticide	II	15.3704±1.7073	10	3.1455	26	<0.01
Abamectin	Abamite	Miticide	II	16.2000±1.7146	20	2.2162	24	<0.05
Alpha-cypermethrin	Bestox	Insecticide	II	23.5000±2.5675	10	5.2580	19	<0.001
Propineb	Antracol	Fungicide	III	53.8235±1.5770	60	3.9165	16	<0.01
Flubendiamide	Belt	Insecticide	III	8.2143±0.5759	4	7.3180	13	<0.001
Alpha-cypermethrin	Alfatox	Insecticide	IV	11.1538±0.6081	5	10.1193	12	<0.001
Xymoxanil+mancozeb	Mistress	Fungicide	II	47.8571±1.5473	30	11.5411	13	<0.001
Propineb+xymoxanil	Milraz	Fungicide	II	50.0000±1.6013	40	6.2450	12	<0.001
Thiamethoxam	Actara	Insecticide	IV	9.7500±0.5522	10	0.4527	11	>0.05
Emamectin benzoate	Prove	Insecticide	III	12.0000±1.3143	10	1.5218	10	>0.05
Acetamiprod	Twigaace	Insecticide	II	20.4286±3.4424	10	3.0294	6	<0.05
Permethrin	Ambush	Insecticide	II	7.2000±0.7717	8	1.0366	9	>0.05

P values show < = less than > = greater than

Table 3.4: Types and rates of 20 pesticides mainly applied on tomatoes in open field farms

Likewise, Bestox was applied at a rate of 23.5000±2.5675 ml and belt at (8.2143±0.5759 ml) which were significantly (p<0.001) higher than the manufacturers' recommended rates of 10mls and 4 mls with T- test values of df=19, t=5.2580, p<0.001) and df=13, t=7.3180, p<0.001 respectively in 20 litres of water. Some fungicides such as mistress (xymoxanil+mancozeb) and ridomil (metalaxyl-M+ mancozeb) were applied at higher rates than those recommended by the manufacturers. Mistress was applied at a mean rate of 47.8571±1.5473 g that was significantly (p<0.001) above the recommended rate of 30g, the T-test obtained was df = 13, t=11.5411, p<0.001, while ridomil was at 50.3226±1.8828g, that was significantly (p<0.001) above the manufacturers' rate of 40g and gave T-test value of df=30, t=5.4826, p<0.001.

Results in Table 3.5 show the farmers applied only 12 pesticides on tomatoes in greenhouse farms. The results show that all the pesticides were applied at higher rates than is recommended. However, 3 pesticides out of the 12 were applied at rates that were significantly above the manufacturers' specified rates. These were; insecticides coragen (Chlorantraniliprole) and evisect (thiocyclam), and a fungicide ridomil (metalaxyl-M+mancozeb).

Active ingredient (ai)	Trade name	Target pest species	WHO class	Farmers' rate in 20L water)	Manufacturer rate in 20L water	T- test		
						t	df	p
Flubendiamide	Belt	Insecticide	III	4.6667±0.3333	4	2.0000	2	>0.05
Chlorantra-niliprole	Coragen	Insecticide	IV	12.500±1.4434	5	5.1962	3	<0.05
Abamectin	Dynamec	Insecticide	II	16.6667±1.6667	10	2.0000	2	>0.05
Thiocyclam	Evisect	Insecticide	III	25.0000±2.8868	10	5.1962	3	0.01
Copper hydroxide	Funguran	Fungicide	II	55.0000±5.0000	50	1.0000	1	>0.05
Lambda-cyhalothrin	Karate	Insecticide	II	22.5000±2.5000	10	5.0000	1	>0.05
Flubendiamide	Merit	Insecticide	III	12.5000±2.5000	10	1.0000	1	>0.05
Mancozeb	Oshothane	Fungicide	III	55.0000±5.0000	50	1.0000	1	>0.05
Metalaxyl-M+Mancozeb	Ridomil	Fungicide	IV	48.3333±1.6667	40	5.0000	2	<0.05
Imidacloprid+Betacyfluthrin	Thunder	Insecticide	II	17.5000±2.5000	10	3.0000	1	>0.05
Thiamethoxam	Actara	Insecticide	IV	15.0000±0.5000	10	1.0000	1	>0.05
Carbendazim	Goldazim	Fungicide	III	65.0000±5.0000	50	3.0000	1	>0.05

P values show < = less than > = greater than

Table 3.5: Rates of all pesticides applied on tomatoes in greenhouse farms

The manufacturers' specified rate for coragen (Chlorantraniliprole) is 5ml and evisect (chloranthraniliprole) is 10 ml in 20 litres of water. Farmers applied coragen at a mean rate of 12.500±1.4434 ml and evisect at 25.0000 ± 2.8868 ml, which was significantly (p<0.05, p=0.01 respectively) above the manufacturers' specified rates of 5 and 10ml respectively in 20 litres of water, giving T- test values of df=3, t=5.1962, p<0.05 and df=3, t=5.1962, p=0.01 respectively. Similarly, a fungicide ridomil applied at a rate of 48.3333±1.6667g was significantly (p<0.05) above the recommended rate of 40g, giving T-test values of df=2, t=5.0000, p<0.05 (Table 5).

C. PRE-HARVEST INTERVALS (DAYS) OF PESTICIDES APPLIED IN OPEN FIELD FARMS AND GREENHOUSES

Pre-Harvest Intervals **(**PHI) in days for 30 (53%) of the 57 pesticides applied on tomatoes in open field farms were less than the manufacturer's specified values. Farmers harvested tomatoes sprayed with these pesticides earlier than the manufacturer's specified duration (Table 3.6).

From the 20 pesticides farmers mainly applied on tomatoes in open field farms (Table 3.6) eleven (11) pesticides had PHI values in days that were significantly (p<0.001, p<0.01) less than the recommended values (Table 3.6). Farmers harvested tomatoes sprayed with these pesticides before the specified withholding period. Such pesticides were ranger (Chlorpyrifos) and actara (Thiamethoxam). Tomatoes sprayed with ranger were harvested after 5.0513±0.2292 days, with T-test values of df = 38, t = 69.5646, p<0.001, was significantly (p<0.001) below the recommended interval of 21 days.

Active ingredient (ai)	Trade name	Target pest species	WHO class	Farmer PHI (days)	Manufacturer PHI (days)	T- test		
						t	df	p
Chlorantra-nilipole	Coragen	Insecticide	IV	2.2960±0.0672	3	10.4723	124	<0.001
Abamectin	Dynamec	Insecticide	II	5.3975±0.1563	3	15.1957	71	<0.001
Mancozeb	Oshothane	Fungicide	III	4.9714±0.1820	14	49.6147	69	<0.001
Lambda-cyhalothrin	Duduthrin	Insecticide	II	5.2500±0.1939	3	11.6015	51	<0.001
Alphamethrin	Tata alpha	Insecticide	II	5.0222±0.2281	3	8.8673	44	<0.001
Chlopyrifos	Ranger	Insecticide	II	5.0513±0.2293	21	69.5646	38	<0.001
Abamectin	Deacarid	Insecticide	II	5.1389±0.2849	7	6.5314	34	<0.001
Metalaxyl-M+ Mancozeb	Ridomil	Fungicide	IV	5.0000±0.2540	7	7.8740	30	<0.001
Imidacloprid+ Betacyfluthrin	Thunder	Insecticide	II	5.6296±0.2677	7	5.1193	26	<0.001
Abamectin	Abamite	Miticide	II	5.4440±0.2713	7	5.7502	24	<0.001
Alpha-cypermethrin	Bestox	Insecticide	II	5.0000±0.3153	3	6.3431	19	<0.001
Propineb	Antracol	Fungicide	III	4.6471±0.3829	4	1.6898	16	>0.05
Flubendiamide	Belt	Insecticide	III	5.2143±0.5047	3	4.3874	13	<0.001
Alpha-cypermethrin	Mistress	Fungicide	IV	5.5333±0.3065	10	14.5711	13	<0.001
Xymoxanil+ Mancozeb	Alfatox	Insecticide	II	5.7692±0.4260	7	2.8893	12	<0. 05
Propineb+ Xymoxanil	Milraz	Fungicide	II	5.5164±0.4463	7	3.1022	12	<0.01
Thiamethoxam	Actara	Insecticide	IV	6.1667±0.4741	14	16.5234	11	<0.001
Emamectin benzoate	Prove	Insecticide	III	5.2727±0.4283	7	4.0325	10	<0.01
Acetamiprod	Twigaace	Insecticide	II	5.0000±0.7559	3	2.6458	6	<0.05
Permethrin	Ambush	Insecticide	II	4.5000±0.3416	2	7.3193	9	<0.001

P values show < = less than > = greater than

Table 3.6: Pre- Harvest Intervals (days) of 20 pesticides mainly applied in open field farms

Also, farmers harvested tomatoes sprayed with actara after 6.1667±0.4741 days with T-test values of df=11, t=16.5234, p<0.001, which is significantly (p<0.001) below the recommended 14 days.

Results in Table 3.7 show that farmers harvested tomatoes sprayed with all pesticides in the greenhouse farms before the specified duration. However, out of the 12 pesticides applied, only 2 had PHI values that were significantly less than the manufacturer's specified values. These were insecticides coragen (chlorantraniliprole) and actara (thiamethoxam). The farmers harvested tomatoes sprayed with coragen after 2.2500±0.2500 days, which was significantly (p<0.001), with T-test value of df = 3, t = 19.0000, p<0.001, earlier than the specified 7 days while the farmers' PHI value for actara was 2.5000 ± 0.5000 days, with T-test value of df = 1, t = 23.0000, p<0.05, which was significantly (p<0.05) less than the specified 14 days (Table 3.7).

Active ingredient (ai)	Trade name	Target pest species	WHO class	Farmer PHI (days)	Manufacturer PHI (days)	T- test		
						t	df	p
Flubendiamide	Belt	Insecticide	III	2.6667 ± 0.3333	3	1.0000	2	>0.05
Chlorantra-niliprole	Coragen	Insecticide	IV	2.2500 ± 0.2500	7	19.0000	3	<0.001
Abamectin	Dynamec	Insecticide	II	2.3333±0.3333	3	2.0000	2	>0.05
Thiocyclam	Evisect	Insecticide	III	2.2500 ±0.2500	3	3.0000	3	>0.05
Copper hydroxide	Fungoran	Fungicide	II	2.5000±0.5000	7	9.0000	1	>0.05
Lambda-cyhalothrin	Karate	Insecticide	II	2.5000±0.5000	5	5.0000	1	>0.05
Flubendiamide	Merit	Insecticide	III	2.5000±0.5000	3	1.0000	1	>0.05
Mancozeb	Oshothane	Fungicide	III	4.0000±1.0000	14	10.0000	1	>0.05
Metalaxyl-M+ Mancozeb	Ridomil	Fungicide	IV	5.0000±1.1547	7	1.7321	2	>0.05
Imidacloprid + Betacyfluthrin	Thunder	Insecticide	II	2.5000±0.5000	7	9.0000	1	>0.05
Thiamethoxam	Actara	Insecticide	IV	2.5000±0.5000	14	23.0000	1	<0.05
Carbendazim	Golderzim	Fungicide	III	3.0000±1.0000	7	4.0000	1	>0.05

P values show < = less than > = greater than

Table 3.7: Pre- Harvest Intervals (days) of all pesticides applied in greenhouse farms

IV. DISCUSSION

Training on safe use of pesticides is important as it gives the pesticide users knowledge on appropriate and effective use when controlling specific pests and diseases. Information obtained from the farmers using a questionnaire indicated that most (58%) of the farmers in Mwea Irrigation Scheme had not received any training on safe use of pesticides, which may have contributed to non-compliance to laid down standards. Untrained farmers are likely to ignore the manufacturers' instructions on the pesticide label (Botwe *et al.*, 2012). Farmers mainly consulted each other which could be attributed to misuse and over use of the pesticides, some of which were toxic WHO Class II.

A. IDENTIFICATION AND CONTROL OF PESTS AND DISEASES

Some farmers who grew tomatoes on open field farms and in greenhouses did not identify pests and diseases before purchasing the pesticide to use. It is important for farmers to identify the pests and diseases that have attacked the crop or consult agricultural officers as this will help them purchase the right pesticide intended for controlling the specific pests or diseases (Sarah, 2015). Scouting of the crop before deciding on control measures helps to detect the pest or disease at early stages of infestation and also to quantify the severity within the farm. This way, the farmer will be able to decide on which control measures to take when the thresholds of the pest or disease are still low (Osborne, 2018).

B. RATES OF PESTICIDES APPLIED ON TOMATOES

Efficacy trials are conducted before a pesticide is registered and released for use (EPA, 2012) to determine an application rate that is effective in controlling the intended pests or diseases (FAO, 2014) as well as leaving residues on the crop that are within the EU/ Codex recommended Maximum Residue Levels (MRLs) at harvesting time. Many farmers in Mwea Irrigation Scheme did not adhere to the rate specified by manufacturers. All pesticides applied on tomatoes in greenhouse farms and 67% applied on open field farms were applied at higher rates than those specified by manufacturers. Farmers claimed that pesticides from some companies were less effective and this compelled them to spray higher rates and others said they used higher rates to re-spray when the specified rates were not effective to control the pests or diseases.

Some farmers intentionally sprayed higher rates to knock down the pests and diseases faster. Musebe *et al.* (2014) reported similar results that tomatoes in Tanzania were contaminated with pesticides at the time of consumption due to application of higher rates than specified. Application of higher rates may lead to accumulation of pesticide residue levels that might remain undegraded in the crop at harvesting and consumption time (Kariathi *et al.*, 2016). Consumption of crops with pesticide residue levels higher than the EU/ Codex permitted levels has been reported to have negative effects on the consumers; health (Vladi, *et al.*, 2014; Ye, *et al.*, 2016).

C. PRE-HARVEST INTERVAL

Harvesting of tomatoes earlier than the specified PHI was a common practice by farmers both in open fields and in greenhouses. Harvesting earlier than the specified withholding period has been attributed to detection of pesticide residue levels in tomatoes from production to the consumer, which is a health risk to the consumer (NPIC, 2018). The PHI, which is clearly indicated on the pesticide labels of the pesticide packages, allows for the degradation of pesticides in the plant or on the surface to metabolites that are safer, or levels that are within the EU/ Codex permitted limits. The sun, rain and temperatures may affect how quickly degradation happens (NPIC, 2018). The crop harvested before the stated PHI values may be contaminated with pesticide residues at the time of harvesting or consumption, which may cause negative health effects to the consumers especially on daily basis.

V. CONCLUSION

There is a major problem of tomato pests and disease infestation in Mwea Irrigation Scheme and therefore farmers heavily rely on pesticides to control them for higher and a profitable harvest. Whereas the recommended rate and PHI are clearly indicated on the pesticide packages, many farmers (both on the open field and greenhouse farms) did not comply with pesticide use standards specified by the manufacturers but apply higher rates and harvest tomatoes earlier than is recommended. This was mainly due to lack of training on safe use of pesticides and negligence.

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