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Effectiveness of commonly used insecticides in controlling key vegetable pests in peri-urban areas of Dar Es Salaam, Tanzania

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Abstract

Vegetable growers in peri-urban centres of Dar es Salaam use various types of insecticides to control vegetable pests. However, some farmers recently complained of the ineffectiveness of some of the currently traded insecticides such that worries on possible resistance by target pests or rampancy of counterfeit pesticides in the market had become a growing concern by scientists. The present study was undertaken to determine the most grown vegetable and the commonly used insecticides upon which the effectiveness of the later was tested against major pests. Chinese cabbage, *Brassica rapa* subsp. *pekinensis* and eggplant, *Solanum melongena* were the main vegetable grown hence used for experiments at Malolo Center in in Dar es Salaam, Tanzania. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and four treatments applied at three-week interval. The insecticides tested were: Duduba 450EC (Cypermethrin 10% + Chlorpyrifos 35%), Septer (Imidacloprid 200 g/l) and Ninja 5EC (Lambdacyhalothrin 50 g/l) alongside with a control (unsprayed). The results showed that Duduba 450 EC applied at the rate of 2 ml/l of water, Septer at the rate of 1 ml/l of water, and Ninja 5EC at the rate of 2.5 ml/l of water, caused significant reduction in larval population of *P. xylostella*. Equal protection against hairy caterpillars on leaves of *B. rapa* and *S. melongena* was recorded. Obtained yield of Chinese cabbage was 8.6 t ha^{-1}, 6.7 t ha^{-1} and 4.6 t ha^{-1} from plots treated with Duduba 450EC, Septer and Ninja 5EC respectively. The recorded eggplant yield (fruits) was 6.7 t ha^{-1}, 5.9 t ha^{-1} and 5.7 t ha^{-1} in plots treated with Septer, Duduba 450EC and Ninja 5EC respectively. The study recommended the use of Duduba 450EC and Septer for effective control of *P. xylostella* on *B. rapa* and hairy caterpillar on *S. melongena*.

Keywords: Caterpillars, Diamondback moths, Insecticide effectiveness, Pest control, Vegetables

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Introduction

Vegetables are important components of daily diets in Tanzania, and an important income-generating activity for smallholder farmers in urban centers and rural areas (Kanda et al., 2014). The delicate nature of vegetables makes them vulnerable to insect pests which often require intervention by growers through various control measures. Despite the diverse options for pest control that exists, vegetable growers in Tanzania rely heavily on commercial inputs particularly pesticides as was observed in Benin and Ghana (Coulibaly et al., 2008). Several types of agricultural pesticides are used by farmers to control diverse vegetable crop pests. However, suspected malpractices by farmers in using insecticides have sometimes portrayed that some insecticides are ineffective against major vegetable pests.

Nevertheless, there has been scanty information on whether the limited efficacy is caused by the farmers' poor insecticides application techniques or the insecticides' ineffectiveness. As observed by other researchers in Togo (Mondédji et al., 2014) synthetic insecticides are the most available pesticides on the markets in Tanzania and consequently, the most accessible to farmers but inadequately used. In spite of the excessive amounts of pesticides used on vegetables, significant crop losses are often reported by farmers which suggest a reduced sensitivity in some vegetable's pests against the applied insecticides. The Diamond back moth, *Plutella xylostella* L. (Lepidoptera: Plutellidae), a common pest of brassica vegetable is one among the reported insensitive pest to the applied insecticides.

Available data in Tanzania suggest that insect pests can cause more than 50% of crop losses in Chinese cabbage, *Brassica rapa* subsp. *pekinensis* despite the various groups of synthetic insecticides applied (Ahmad et al., 2009). Likewise, Hairy caterpillars can cause more than 45% of crop losses in Eggplant, *Solanum melongena* crop treated with various groups of synthetic insecticides (Srinivasan, 2009). This study aimed at assessing the field effectiveness of commonly used insecticides in vegetable production in urban and peri-urban areas of Dar es Salaam to establish facts upon which suitable recommendations in managing the respective pests would be made.

Materials and Methods

Survey on vegetable production and pest management

Field survey using structured questionnaire was undertaken to document insecticides commonly used by growers to control vegetable pests in Kinondoni District in Dar es Salaam. A total of 120 vegetable growers were interviewed. Data were collected through a farm-based survey on face to face interviews with farmers during farm activities which included physical inspections of the crops. Criteria for respondents' selection were; if leafy vegetables were being grown, if insecticides were used, and ease of accessibility of the field location. The commonly used insecticides (identified by trade or common name) to control pest infestation and minimize crop losses on vegetable were later identified with the Tropical Pesticides Research Institute (TPRI) database (a country's authority on pesticides registration). The choice of the vegetables and three commonly used insecticides (that were later used in the experiments) was based on the most frequent scores after the mentioned vegetables and insecticides were ranked from most to the least grown and used.

Field experiments

Field experiments were conducted for two seasons (during 2016 and repeated in 2017) at Malolo Agricultural Centre (Mabwepande ward) in Kinondoni District in Dar es Salaam to test the effectiveness of three commonly used insecticides in vegetable production. A randomized complete block design with three replications and four treatments applied at three weeks interval was used. A total of twelve plots measuring 9.2 m^2 (2.3 m x 4.0 m each) for *B. rapa* and twelve plots measuring 21.6 m^2 (3.6 m x 6.0 m each) for *S. melongena* spaced at 2 m apart between the plots were used. *Brassica rapa* and *S. melongena* seedlings were initially established in an insect proof screen house for five weeks, after which they were transplanted to the open field on raised beds. The beds were enriched with chicken manure at the rate of 15 tonnes ha^{-1}, two weeks before transplanting. Top dressings with compound fertilizer (NPK 15:15:15) was done at four weeks after transplanting at a rate of 12 g per plant.

Four treatments inclusive of three insecticides; Duduba 450 EC (Cypermethrin 10% + Chlorpyrifos 35%) applied at recommended rate of 2 ml/L, Septer 200SC (Imidacloprid 200 g/L) at the rate of 1 ml/L, and Ninja 5EC (Lambdacyhalothrin 50 g/L) at the rate of 2.5 ml/L and the negative control (water applied as the control treatment) were used. The treatments were applied in three rounds of spray at an average of two to three weeks intervals in *B. rapa* starting nine days after transplanting. JACTO = HD400 Knapsack sprayer (Jacto inc., Tulatin, OR, USA) fitted with a hollow cone nozzle was used. Insecticide spray was applied whenever necessary after scouting to establish the number of pests on the crop. Following insecticide spray, the pest population was monitored after one, three, five and seven days to monitor the residual effect of the applied insecticides.

Assessment of insect pests

Scouting for pest numbers and assessment of inflicted injuries were done a day before spraying as pre-treatment counting of the larvae. Post treatment count was recorded at one, three, five and seven days after each spraying. Five plants were randomly selected and tagged in each plot (excluding border rows) for assessment of the pest population. Pest assessment on experimental plots were made from top, middle to bottom leaves during the early morning hours (at most before 09:00 am) every after three days. The number of larvae from each tagged plant was counted with the aid of hand lens 50 mm diameter and 10x magnification (Thomas Scientific) and mean number per plant was calculated. Assessment of insects was done by visual examination of the entire plants as described by Lal (1998) (Fig. 1). First spraying was done nine days after transplanting followed by second spray at 21 days interval on *B. rapa* to allow subsequent population build-up in the experimental plots. One spray was made on *S. melongena* about 21 days after transplanting.

Fig. 1 Visual inspection of vegetables for insect pests' infestation on *S. melongena* and *B. rapa*

Data collection

Collected data included the insecticide used including date and time of spraying, numbers of insect pests counted before and after each spray, *S. melongena* fruits yield and *B. rapa* marketable leaf yield and fruits harvested. The marketable leaves were graded based on pests' damage assessment by consumers that leave with no damage holes or few small sized holes were regarded suitable for sell while the excessively damaged with plenty of holes were qualified as non-marketable. Same criteria were used for egg plants. Number and the weight of obtained yield data from each treatment were converted into tonnes per hectare.

Data analysis

Data from the field survey were coded and analysed using the Statistical Package for Social science (SPSS 16.0) computer software. Descriptive statistics such as means, frequencies and percentage were computed. The collected data on insects count were tested for normality using SPSS statistical package upon which conformity to the normal distribution suggested no need for transformation. Data for insect count were subjected to the analysis of variance (ANOVA) and mean separation tested at $P<0.05$ by using Duncan's multiple range tests in GenStat statistical package (14^{th} edition, VSN international). Data on the percentage reduction in the population of insect pests over untreated check in different treatments were computed using the modified Abbot's formula (Fleming & Retnakaran, 1985) as presented below:

$$\%\ \text{reduction in population} = \left[1 - \left(\frac{\text{Post treatment population in treatment}}{\text{Pre treatment}} \times \frac{\text{Pre-treatment population in check}}{\text{Post treatment}}\right)\right] \times 100$$

Economic data collection and analysis

The monetary expenses on all field operations including land hiring, cultivation, seed purchase, weeding, procurement of insecticides, labour to spray until harvesting were recorded. The harvested yield was graded into two categories of marketable and non-marketable ones. Non-marketable grade of yields was discarded while the marketable ones weighed (Kg) to obtain the yield weight per plot. The cost and yield data were converted to hectare as standard unit of measurement. The obtained yield was multiplied to the retail market price to obtain the value of attainable revenue. The costs related to each of insecticides used were computed with reference to the values obtained from the control plots. A financial benefit cost analysis (BCA) was used to estimate the costs involved and benefits accrued in the management of insect pests in *B. rapa* and *S. melongena* crops.

Results

Types of commonly used pesticides by farmers

Vegetable growers in Kinondoni district were using different types of insecticides to control different pests although some farmers admitted to the tendency of mixing more than one insecticide before spraying. Insecticide used belongs to five major groups namely; organochlorines, organophosphates, pyrethroids, carbamates and mercury based. Some were solely insecticides while some were a blend of insecticides and acaricides while some were fungicides. All used insecticides were identified by either trade name or common name (Table 1). The only fungicide found in use was Ridofarm 72WP (2.3%) meant for the control of fungal diseases on vegetables. Insecticides were being applied without adequate knowledge of pest ecology, economic injury levels and the recommended pests to be controlled. Other information not adhered to by vegetable growers were the recommended dosages (application rate), method of application, pre harvest interval and use of protective measures. Major troublesome pests on important vegetables viz. *B. rapa* and *S. melongena* respectively were *Plutella xylostella* and unidentified hairy caterpillar (Fig. 2).

Table 1 Common pesticides used by vegetable farmers in Kinondoni district (n = 120)

Trade Name	Active ingredient	Chemical group	Proportion (%)
Duduba 450EC	Cypermethrin 10% + chlorpyrifos 35%	PY + OP	47.1
Supaclop	Imidacloprid 200 g/l	Neonicotinoids	9.9
Ninja 5EC	Lambda cyhalothrin 50 g/l	PY	8.4
Abanil	Abamectin 18 g/l	OC	8.4
Tanzacron	Profenofos 720 g/l	Neonicotinoids	8.3
Karate 5EC	Lambdacyhalothrin 50 g/l	PY	7.1
Attakan C	Imidacloprid 350 g/l	OC	5.5
Ridofarm 72WP	Mancozeb 640 g/Kg + Metalaxyl 80 g/kg	C + HG	2.4
Dume 40Ec	Dimethoate 400 g/l	OP	2.3

Agromectin	Abamectin 18g/l	OC	0.6

OP = Organophosphorus compounds; PY = Pyrethroids; OC = Organochlorine compounds; C = Carbamates; HG = Mercury compound

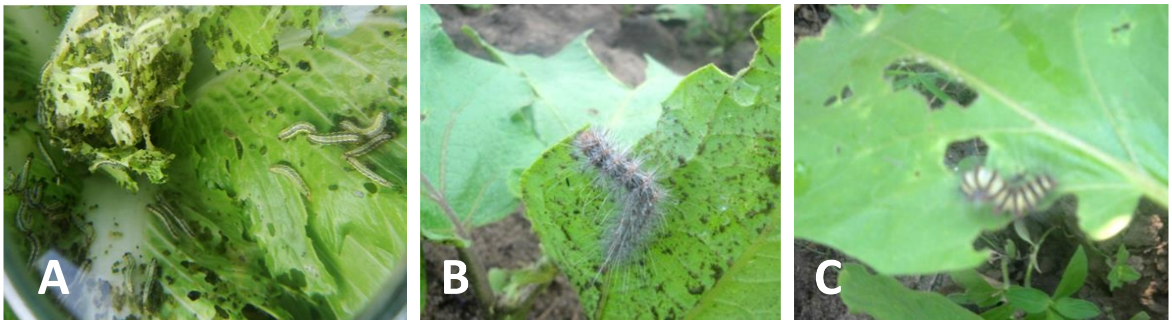

Fig. 2 Key pests of vegetable crops in Kinondoni: A, *Plutella xylostella* larvae on *Brassica rapa*; B &C, Hairy defoliator caterpillars on *Solanum melongena*.

Efficacy of insecticides on *P. xylostella* in *B. rapa* after first spray

Pests scouting data one day after spraying Duduba 45EC recorded total (100%) reduction of *P. xylostella* larvae population. Imidacloprid 200 g/l accounted for 86% reduction while Lambdacyhalothrin 50 g/l contributed to 50% reduction of the larvae population. The control plot had limited effect on *P. xylostella* hence a population of 7.27 larvae per plant was recorded. Consecutive records for third, fifth and seventh days were as presented (Table 2). All insecticides had an extended residual effect beyond one week.

Table 2 Mean number of *P. xylostella* per plant and percent mortality after first spray at various intervals on *B. rapa*

Treatment	Dosage (l/ha)	Average number of *P. xylostella* larvae / Plant DBS	1DAS	3DAS	5DAS	7DAS	% reduction of larva population *P. xylostella* 1DAS	3DAS	5DAS	7DAS	Mean
Duduba 450EC	1.0	5.07[a]	0.00[a]	0.00[a]	0.00[a]	0.00[a]	100	100	100	100	100
Septer 200SC	0.3	5.13[a]	0.73[a]	0.00[a]	0.00[a]	0.00[a]	86	100	100	100	96.5
Ninja 5EC	0.3	5.80[a]	2.53[b]	0.47[a]	0.00[a]	0.00[a]	58	93	100	100	87.75
Control	0.0	7.07[a]	7.27[c]	8.47[b]	8.00[b]	10.6[b]	-	-	-	-	-
P-value		0.27	<.001	<.001	<.001	<.001					
SE(±)		0.71	0.67	0.59	0.47	0.31					
CV %		21.2	31.3	45.4	40.9	20					

DBS = Days before spray; DAS = Days after sprays; Mean values followed by the same letters in a column are not significantly different at (P≤ 0.05)

Sustained efficacy of insecticides after second and third round of spray

Observation made one day after the second and third spray round indicated that the plots treated with Cypermethrin 10% + Chlorpyrifos 35% and Imidacloprid 200 g/l registered 100 % reduction of *P. xylostella* larvae population followed by Lambdacyhalothrin 50 g/l with 48% (mean count 4.2 larvae/plant) while untreated control had 14.6 larvae per plant. Three day after spraying, chlorpyrifos 10 % EC + cypermethrin 35 % EC and imidacloprid 200 g/l maintained 100 % reduction of *P. xylostella* larvae while Lambdacyhalothrin 50 g/l recorded an increase in mortality to 94 % (0.4 larvae per plant). Larvae count in control treatment increased to 15.73 larvae per plant. Five days after spray all three insecticides had caused 100 % larval mortality but pest counts in untreated control recorded an average of 18.0 larvae per plant. Similar results were maintained at seven days after second round of pesticide application with minor changes in control plots where 17.87 larvae per plant was recorded. Similar trends were recorded after the third round of insecticides application as detailed (Table 3).

Efficacy of applied insecticides against Hairy caterpillars on *S. melongena*

One day after application of insecticides, it was observed that all the treatments were found significantly superior to untreated control in reducing hairy caterpillar. However, statistically significant differences were recorded among them (Table 4). The maximum reduction of 59 % (0.607 caterpillar per plant) was recorded in plots treated with Cypermethrin10%+Chlorpyrifos 35% followed by 47 % (0.73 caterpillar per plant) in Lambdacyhalothrin 50 g/l treated plots and the least was 44 % (0.93 caterpillar per plant) reduction in Imidacloprid 200g/l treated plots all with reference to control plots that recorded 1.53 caterpillars per plant. Subsequent assessments three days after insecticide spray revealed similar effectiveness between Cypermethrin10%+Chlorpyrifos 35% and Imidacloprid 200 g/l with hairy caterpillar population reduction and 73% and 74 % respectively. Lambdacyhalothrin 50 g/l still had the lowest reduction in numbers at 65 %. The trend was maintained among the applied insecticides after five and seven days with 86 %, 84 % and 76% as well as 93 %, 87 % and 80% respectively. Maximum mean count of hairy caterpillar population was 1.8 caterpillars per plant in the control plots.

Table 3 Mean number of *P. xylostella* per plant and percent mortality after 2nd and 3rd spray at various intervals on *B. rapa*

2nd spray round	Average number of *P. xylostella* larvae / Plant						% reduction larva population *P. xylostella*				
	Dose (l/ha)	DBS	1DAS	3DAS	5DAS	7DAS	1DAS	3DAS	5DAS	7DAS	MEAN
Duduba 450EC	1	2.33a	0.00a	0.00a	0.00a	0.00a	100	100	100	100	100
Septer 200SC	0.3	3.00a	0.00a	0.00a	0.00a	0.00a	100	100	100	100	100
Ninja 5EC	0.3	7.60b	4.20b	0.40a	0.00a	0.00a	48	94	100	100	85.5
Control		13.87c	14.60c	15.73b	18.00b	17.87b	-	-	-	-	-
P-value		<.001	<.001	<.001	<.001	<.001					
SE(±)		0.903	0.874	0.758	0.929	0.754					
CV %		23.3	32.2	32.5	29.2	17.2					
3rd spray round											
Duduba 450EC	1	1.73a	0.00a	0.00a	0.00a	0.00a	100	100	100	100	100
Septer 200SC	0.3	2.80a	1.33b	0.33a	0.00a	0.00a	33	84	100	100	79.25
Ninja 5EC	0.3	3.27a	1.80b	0.73a	0.27a	0.47a	23	71	90	79	65.75
Control		14.47b	10.33c	11.07b	12.40b	9.87b	-	-	-	-	-
P-value		<.001	<.001	<.001	<.001	<.001					
SE(±)		0.574	0.252	0.265	0.307	0.936					
CV %		17.9	12.3	15.1	16.8	26.6					

DBS = Days before spray; DAS = Days after sprays; DBM = Diamondback moth; Means followed by the same letters in column are not significantly different (P≤ 0.05).

Table 4 Mean number of hairy caterpillar per plant and percent mortality after first spray at various intervals on *S. melongena*

Treatment	Dose (l/ha)	Average no. of caterpillar larvae per plant					% reduction in caterpillar population				
		DBS	1DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS	5 DAS	7 DAS	Mean
Duduba 450EC	1	1.47a	0.67a	0.47a	0.27a	0.13a	59	73	86	93	**78**
Septer 200SC	0.3	1.53a	0.93ab	0.47a	0.33a	0.27a	44	74	84	87	**72**
Ninja 5EC	0.3	1.27a	0.73a	0.53a	0.40a	0.33a	47	65	76	80	**67**
Control		1.4a	1.53b	1.67b	1.87b	1.80b	-	-	-	-	
P-value		0.823	0.049	0.002	0.003	0.003					
SE(±)		0.207	0.180	0.189	0.199	0.196					
CV %		21.6	18.2	19.5	20.1	18.2					

DBS = Days before spray; DAS= Days after sprays; Means followed by the same letters in a column are not significantly different at (P≤ 0.05).

Insecticides contribution to marketable yield

The use of insecticides on *B. rapa* in the present study indicated significant increase in yield compared to the control plots which were used as checks (Table 5). Highest marketable leaves yield was recorded in plots treated with Cypermethrin10% + Chlorpyrifos 35% (8.6 t ha^{-1}) closely followed by a crop treated with Imidacloprid 200 g/l (6.7 t ha^{-1}). The yield obtained from plots treated with Lambdacyhalothrin 50 g/l was comparatively low (4.6 t ha^{-1}). Lowest yield was realised from untreated (control) plots (2.5 t ha^{-1}). In *Solanum melongena*, the highest yield was obtained from Imidacloprid treated crop (6.7 t ha^{-1}) followed closely by Lambdacyhalothrin 50 g/l treated plots with 5.9 t ha^{-1} marketable yield (Table 7). Conversely, the observed efficacy in controlling hairy caterpillars by using Cypermethrin10% + Chlorpyrifos 35% was not reflected on yield (5.7 t ha^{-1}). This was nearly similar to what was obtained (5.9 t ha^{-1}) when Lambdacyhalothrin 50 g/l was used. As expected, the untreated (control) plots recorded the lowest yield (5.2 t ha^{-1}).

Table 5 Marketable yield of *B. rapa* and *S. melongena* at harvest

B. rapa	Dosage (L/ha)	Yield(Kg/plot)	Yield (t/ha)
Duduba 450EC	1	7.9a	8.6
Septer 200SC	0.3	6.3b	6.7
Ninja 5 EC	0.3	4.2c	4.6
Control	-	2.3d	2.5
Grand mean		5.2	5.6
P-value		<.001	
SE(±)		0.236	
CV		6.5	
S. melongena			
Duduba 450EC	1	12.3a	5.6
Septer 200SC	0.3	14.4a	6.7
Ninja 5 EC	0.3	12.7a	5.9
Control	-	11.3a	5.2
Grand mean		12.65	5.85
P-value		0.583	
SE(±)		1.1	
CV		19.9	

Means followed by the same letter in a column are not significantly different ($P \leq 0.05$).

Cost economics

Cost economics of different insecticides applied on *Brassica rapa* against *P. xylostella* and other pests revealed that Cypermethrin 10% + Chlorpyrifos 35% and Imidacloprid 200 g/l gave net profit of Tshs 1 315 000 and 846 000, respectively (Table 6). The lowest net profit was obtained from Lambdacyhalothrin 50 g/l which recorded only Tshs. 321 000. The results on benefit-cost ratio revealed that highest benefit cost ratio was obtained from Cypermethrin 10% + Chlorpyrifos 35%treatment which recorded 6.3:1. This was followed by Imidacloprid 200 g/l which recorded Benefit-Cost (B/C) ratio of 4:1 and the lowest B/C ratio was 1.6:1 which was recorded on Lambdacyhalothrin 50 g/l treatment on the crop. In *Solanum melongena* crop, the cost economics of different insecticides used revealed that Imidacloprid 200 g/L and Lambdacyhalothrin 50 g/l gave net profits of Tshs. 232 000 and 72 000, respectively. The lowest net profit was obtained from Cypermethrin 10% + Chlorpyrifos 35% which recorded only Tshs 10 000. The results on benefit cost ratio suggested that highest benefit was obtained from Imidacloprid 200 g/l treatment at 3.4:1. This was followed by 1.1:1 of Lambdacyhalothrin 50 g/l and the lowest 0.1:1 of Cypermethrin 10% + Chlorpyrifos 35% treatment on *S. melongena* crop.

Table 6 Cost economics as influenced by different insecticides on *B. rapa and S. melongena*

B. rapa	Dosage (l/ha)	Yield (kg/ha)	Increase in yield over control (kg/ha)	*Value of increased yield (Tshs/ha)	Cost of treatment (Tshs/ha)	Benefit due to treatment (Tshs/ha)	Cost benefit ratio
Duduba 450EC	1	8600	6100	1 525 000	210 000	1315 000	1:6.3
Septer 200 SC	0.3	6700	4200	1 050 000	204 000	846 000	1:4.1
Ninja 5EC	0.3	4600	2100	525 000	204 000	321 000	1:1.6
Control	-	2500	-	-	-	-	-
S. melongena							
Duduba 450EC	1	5600	400	80 000	70 000	10 000	1:0.1
Septer 200 SC	0.3	6700	1500	300 000	68 000	232 000	1:3.4
Ninja 5EC	0.3	5900	700	140 000	68 000	72 000	1:1.1
Control	-	5200		-	-	-	-

**Price of *B. rapa* green leaves during the season was Tsh.200 per kg and price of *S. melongena* fruits during the season was Tsh. 250 per kg; Tsh 1.00 = US$ 0.0004 (US$ 1.00 = Tshs 2320.00)

Discussion

Obtained results indicated a great diversity of vegetable grown Kinondoni district. It was established that vegetable production is one among major source of livelihood for the youths and women (Coulibaly et al., 2008). Chinese cabbage, Spinach, Amaranths, eggplant and okra were the most significant crop species considering the area under the crop in proportion to other cultivated crops. Early maturity of vegetables, high demand and assured quick return to investment were among the critical reasons for biased engagement in vegetables production. Similar finding has been reported (Kanda et al., 2014) that early maturity and being vital source of income are among reasons for farmers in urban and peri-urban areas to engage in vegetable production.

Attacks by insect pest were the most significant constraint identified by most vegetables' growers. Similar observations and concerns on vegetable production were reported by other workers in Ghana (Avicor et al., 2011) and Togo (Mondédji et al., 2014). *Plutella xylostella* was identified as the most problematic pests in production of *Brassica rapa* while other pests were of limited significance. The sporadic nature of occurrence and persistence of the pest has forced farmers to continually depend on insecticide as a lone strategy against the pest. A serious injury inflicted by *P. xylostella* that translates to significant damages makes production of *B. rapa* and insecticides application inseparable. Consequently, the excessive use of synthetic insecticides on *B. rapa* would lead to reduced susceptibility of the targeted insects' pests to the insecticides used against them prompting development of resistance against insecticide. Part of the interesting finding in this study was that farmers tend to capitalize on a single type of insecticides provided that it has proven to work best. Generally farmers are reluctant to change from using the insecticides they know better. It has been documented that when a population of insects is continuously exposed to one type insecticide, its sensitivity to that particular molecules decreases, because of the selection of individuals with resistant genes against the compound (Shono and Scott, 2003). The fact that *P. xylostella* was identified as a major pest in this study put vegetable production at stake because it has been reported for its great capacity to develop resistance to several classes of insecticides (Tsukahara et al., 2003; Nakasuji et al., 2006). Although the insecticides used by farmers in the current study belong to various classes ranging from organophosphates to synthetic pyrethroids, they are not used in recommended rotations that would adequately overcome the possibility of developing resistance. Pyrethroids are preferred to other insecticides due to their affordability and quick knock down effect on pests. Similar preference of Pyrethroids was also reported in West Africa, particularly Ghana as the most liked insecticide class by farmers (Obeng-Ofori and Ankrah, 2002). Surprisingly, insecticides of the organo-chlorine class were still being used on vegetable crops despite the ban by international authorities. As it was rare to find such insecticides in registered agro-shops the source was suspected to be from old un-destroyed stocks which continue to circulate illegally in the country.

The majority of insecticides used by vegetable growers ranged from high to moderately hazardous compounds according to the WHO Hazard Classes. Such acts by farmers were not unusual. PAN UK (2007) and Coulibaly et al. (2008) reported that farmers' crop protection practices are based on the intensive use of hazardous pesticides throughout most of vegetable farms in West Africa especially in Togo. The practice would constitute a factor worsening not only the farmers and consumers intoxication but also the environmental pollution. The effectiveness of a particular insecticide varies greatly from one field to another depending on previous insecticide use, pestiferous insect species and level of tolerance to insecticide classes (Mulrooney & Elmore, 2000).

The decision to use *B. rapa* and *S. melongena* as experimental crops and attempt to test the commonly used insecticides was guided by the desire to establish whether failures in effective pest control was due to pest resistance of the insecticides or the misuse of insecticides by vegetable growers. During experimentation, the prime consideration in the control of key insect pest was damage thresholds, insect pest species in question and the appropriate type of insecticide that was used. Chlorpyrifos 10% + Cypermethrin 35% EC gave best results for the control of *P. xylostella* in *B. rapa* as was similarly reported (Adebayo et al., 2007) because it contained cypermethrin which is a contact insecticide with the immediate knock down effect and chlorpyrifos which is a systemic insecticide. Combination of the two insecticides increased potency to control insect pests. Imidacloprid 200 g/l and lambda cyhalothrin 50 g/l gave good results for the control of hairy caterpillar in eggplant and *P. xylostella* in Chinese cabbage. This could be due to their high knock down effect. Unfortunately, the rapid knock down severely affects the natural enemies that would have otherwise preyed on caterpillars and *P. xylostella* larvae reducing their populations.

Control of all major insect pests in the first spray gave similar results at threshold to subsequent spraying because of relatively low pest population that did not warrant significant difference among treatments. After insecticide application however, the unsprayed check had more damaged leaves and numbers of pests clearly signifying the impacts of sprayed insecticides on the target pests. The combined effectiveness of insecticide with multiple actions was obvious on the post-application counts of *P. xylostella and* hairy caterpillars' abundance. This is buttressed by the synergistic effect of Chlorpyrifos 10% + Cypermethrin 35% EC which is both systemic and contact poison. The trans-lamina properties and subsequent translocation of the insecticide delayed its degradation under field conditions, contributing to its high efficacy in controlling the two pests (Adebayo et al., 2007). This was main reasons for its better performance compared to Imidacloprid 200 g/l which has only a systemic mode of action and Lambdacyhalothrin 50 g/l with a contact mode of action. Studies of Boopathi et al. (2013) were in close conformity with the results of present study that Cypermethrin10% + Chlorpyrifos 35%, was the most effective insecticide. In the past, the best insecticide was reported to be the cypermethrin (Khan et al., 1993) and endosulfan (Rizvi et al., 1986), but in the present study chlorpyrifos 10% EC + cypermethrin 35% EC, proved to be the best insecticide. Varied effectiveness among insecticides has been reported (Mulrooney & Elmore, 2000).

The varied effectiveness of the tested insecticides may not only be born of their inherent characteristics but also the plants and pests to which they were applied. Wang and Liu, (2007) reported several factors which affect insecticides' efficacy inclusive of leaf surface characteristics, foliage growth, pathways through which the insecticides acts on pests, types and concentration of the additives, type of applicators, knowledge of person responsible for spraying, water used for mixing the insecticides, and environmental condition during and after application. This could be the reasons for delayed effectiveness of Imidacloprid 200 g/l and Lambdacyhalothrin 50 g/l on *P. xylostella*. Narrating about factors affecting insecticide efficacy, Liu et al. (2003) hinted that foliage growth do not only dilute non-systematic insecticides deposits on the leaf surface but also results in some insecticides free leaves playing refuges to pests which could also decrease the mean efficacy of the applied insecticides. Rainfall, temperature and sunlight intensity have also been reported to cause insecticides degradation under field conditions, but given the fact that all insecticides were applied under same condition, the effects of weather parameters was assumed to be uniform. Nevertheless, it should be noted that insecticides would succumb differently to the weather parameters depending on the composed chemical group.

The effect of spraying insecticides is often accounted on abilities to suppress pests and allow realization of expected yield from the crop. In the current study, the reduction in *B. rapa* and *S. melongena* yield was mostly related to *P. xylostella* larvae and hairy caterpillar infestation. The economic yield would not be realized without the application of insecticides. Chlorpyriphos 10% + Cypermethrin 35% EC and Imidacloprid resulted into highest marketable *B. rapa* leaves compared to the rest of treatments. The population of *P. xylostella* increased greatly during the vegetative stage as reported by other workers (Ahmad and Ansari, 2010, Kahuthia-Gathu, 2013, Sow et al., 2013) and caused substantial damage on marketable leaves. At vegetative stage imposing effective control measures is usually very necessary (Ahmad and Ansari, 2010). The findings in the present study where three different insecticides were applied confirm the importance of applying insecticides to control pests. Arguably, these results cannot be compared in absolute terms to any of the studies conducted so far as none that we came across in literature has used this combination of insecticides. However, the findings are in general agreement with those of Rahimgul and Sasya, (2016), Dotasara et al. (2017), Boopathi et al. (2013), Lal and Meena (2001) as well as Rao and Lal (2001) that the application of insecticides reduced the larval population of *P. xylostella* and hairy caterpillar to a considerable extent leading to increase in economic yield.

Effective control of *P. xylostella* was achieved in the current study which suggests that the feared development of resistance against the commonly used insecticides is inexistent. Despite delayed action recorded in Imidacloprid and Lambdacyhalothrin effective control was likewise attained. Resistance to Cypemethrin reported by Phokela et al. (1990) was not observed due to the fact that it was used in combination with Chlorpyrifos. Workers on *P. xylostella* in Pakistan (Ahmad et al., 1995) reported that Chlorpyrifos was proved to be the best insecticide against the insect pests although it demonstrated moderate to high levels of resistance to cypermethrin and endosulfan. Thus, if used correctly as per manufacturers' recommendations (Sharma and Chawla, 1992) most insecticides may remain effective against *P. xylostella* and other important pests. Specifically for an insecticide, Duduba 450EC (Chlorpyrifos 10% + Cypermethrin 35% EC) much benefits are expected to be reaped from using it because it has been registered for multiple pests such as bollworm, thrips, shoot and fruit borer, beetles and others in various agricultural crops like cotton, okra, eggplant (TPRI, 2020). Its combined action makes it an insecticide to depend on if used as recommended. It acts as strong contact and systemic compound with no phototoxic effect (Rahman et al., 2015).

Controlling hairy caterpillars on *S. melongera* was the most challenging compared to *P. xylostella*. All tested insecticides had somewhat limited effectiveness as was hard to achieve 100% efficacy. Rahman et al. (2014) reported that only Cypermethrin 10 EC at 1 ml/l of water sprayed after observing 5% level of plants infestation can control caterpillar effectively and economically because Cypermethrin is a pyrethroids group of insecticide and it acts as a sodium channel modulator in the nervous system of the insect. As observed in the current study a combination of (Chlorpyriphos 10% + Cypermethrin 35% EC) was the most effective and economically viable insecticide to manage caterpillars in eggplant crop similar to the report by Sharma et al. (2012) and Srinivasan (2009) despite the low yield. The observation suggests that the recorded yield reduction cannot only be attributed to hairy caterpillars but also other factors mostly the physiology of the crop. Best performance of Cypermethrin in producing highest yield of eggplant has been reported by other researchers (Dutton et al., 2003) despite not being reflected in the present study. Imidacloprid was the second most effective in controlling the caterpillars but higher in yield as similarly observed by other workers (Jat and Pareek, 2001). Imidacloprid is one of a group of insecticides called neonicotinoids which work by interfering with an insects' nervous system. It acts as an agonist of the acetylcholine receptor and is known to have a very selective toxicity, which is attributable mostly to its higher affinity for the insect than for the vertebrate nicotinic acetylcholine receptor (Liu and Casida, 1993). Imidacloprid is extremely effective against various sucking and mining pests including Apple maggot, second generation codling moth, Oriental fruit moth, first generation spotted tentiform leaf miner, Leafhoppers, Aphids, Japanese beetle, Mullein bug, Second and third generation spotted tentiform leaf miner and so on (Liburd et al., 2003). Its excellent systemic properties and lasting action make it suitable for foliar treatments (Pfliiger and Schmuck, 1991). In this experiment we found that this insecticide was very much effective against lepidopteran insect mainly in Eggplant. Nevertheless, this was contrary to observation (Muthusamy et al., 2011) that imidacloprid was less toxic to hairy caterpillar. Of the tested insecticides, Lambdacyhalothrin 50 g/l was the least effective insecticide on hairy caterpillar. Despite its contact mode of action, it had a substantial impact against various sucking and mining insect pests due to its excellent knock down properties and lasting action.

Considering the costs and revenue obtained, the use of Cypermethrin 10% + Chlorpyrifos 35% to control *P. xylostella* on *B. rapa* recorded highest profit margin while Imidacloprid 200 g/l had the highest profit margin when used against hairy caterpillars on *S. melongena*. Lambdacyhalothrin 50 g/l gave the lowest profit when used against *P. xylostella* while Cypermethrin 10% + Chlorpyrifos 35% had the lowest profit when used against hairy caterpillars.

Conclusion

It was concluded that there are several insecticides used by vegetable growers but the most common ones were Duduba 450 EC (Cypermethrin10% + Chlorpyrifos 35%), Septer 200SC (Imidacloprid 200 g/l) and Ninja 5EC (Lambdacyhalothrin 50 g/l). Most of the used insecticides were effective against *P. xylostella* but Duduba 450 EC would make the best option for *B. rapa* growers. There was no sign of resistance by *P. xylostella* against used insecticides. Therefore, the perceived inefficacy of the insecticides is born of poor application techniques by farmers. Septer 200SC (Imidacloprid 200 g/l) performed better than other insecticide in controlling hairy caterpillars and produced the best yield. As such, it would make the best choice for *S. melongena* growers who are constrained by hairy caterpillars. Apart from vegetable growers being made aware of the best choice of insecticides based on the pest in question, they should be educated on the rational use of insecticides with emphasis on the recommended application technologies.

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