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Environmental and Health Impacts of Pesticide Use Practice in Vegetable Production in Karatu and Arumeru Districts, Tanzania.

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Declaration

I, Tesfaye Ayano-Negawo declare that this thesis is a result of my research investigations and findings. Sources of information other than my own have been acknowledged and a reference list has been appended. This work has not been previously submitted to any other university for award of any type of academic degree.

Signature………………………………..
Date……………………………………..

Dedication

To

Farmers and laborers in Oromia, Ethiopia who have been working without health insurance and safety equipment during spray, weeding and harvesting. They have been working with hand to mouth payment since the establishment of floriculture companies in the areas. The farmers and laborers have been exposed to pesticides that risked their health and environmental resources.

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List of Acronyms

ACN	Acetonitrile
CEC	Commission of European Countries
EEC	European Economic Community
EFSA	European Food Safety Authority
EIQ	Environmental Impact Quotient
EU	European Union
EUROEM	European Predictive Operator Model
EXTOXNET	Extension Toxicology Network
FAO	Food and Agricultural Organization of the United Nations
GC-MS	Gas Chromatography-Mass Spectrometry
HODECT	Horticultural Development Council of Tanzania
LC-MS	Liquid Chromatography –Mass Spectrometry
LD50	Lethal Dose, 50%
LOQ	Limit of Quantification
MRL	Maximum Residue Level
MRM	Multiple Reaction Monitoring
NCBI	National Center for Biotechnology Information
NIBIO	Norwegian Institute of Bio-economy Research
QuEChERS	Quick, Easy, Cheap, Effective, Rugged and Safe
PSA	Primary-secondary amine
WHO	World Health Organization

Table of Contents

List of Tables

List of Figures

Abstract

Vegetable production is an important part of local economic growth and export earnings in Tanzania. The government of Tanzania is encouraging vegetable products due to favorable condition and increasing demands. Vegetables serve as a quick income source and important diet components for small-scale farmers. However, pests have become a major constraint to this economically important sector. Consequently, farmers utilized different pesticides to control pests in onion and tomato crops. However, pesticides have negative effects on the health of farmers, workers, consumer and environments. To evaluate the impacts of pesticides on farmers, workers, consumers and environment, the study was conducted in Arumeru and Karatu Districts of Northern Tanzania. Survey was carried out in both districts on 107 onion and 125 tomato-producing farmers belonging to eight tribes and three different religions during the years of 2013. In addition, 30 different crop-producing farmers were also involved in face-face interview during the year 2014. To analyze pesticide residues, onion and tomato samples were collected. The samples were analyzed at department of biotechnology and Plant Health Division in NIBIO, Ås, Norway. The two instrument used for pesticides residue analysis were GC-MS and LC-MS. The impacts of pesticides on consumers, workers and environment were evaluated using EIQ formula. Both onion and tomato farmers applied different pesticides to control pests. Insecticides were applied predominantly due to high prevalence of insect pests. For example, 88% and 100% of the farmers applied insecticides before and after emergence of onion seedlings respectively. The majority of farmers used carbosulfan and profenofos insecticides in onion production. Profenofos and abamectin insecticides had the highest and lowest EIQ values respectively both in onion and tomato production. Farmers used more fungicides in tomato than that of onion. Fungicide, mancozeb had the highest EIQ index on consumers and workers. About 30%, 69% of farmers applied fungicides and insecticides in tomato farms during pre-emergence. Mancozeb had more than six times load of on the health of workers and consumers than metalaxyl applied at similar rate. All farmers agreed that use of pesticides is risky for their health. This is because of entrance of pesticides in their body via inhalation, skin openings, and residues in consumed vegetables. Almost all interviewed farmers experienced headache, burning sensation of skin, eyes, and weakness after spraying. Despite that more than 60% of farmers strongly disagreed on the notion of limiting pesticides use to produce crop. Pesticides residues were detected both in onion and tomato samples. About 84% of residues were above EU MRLs values due to greater amount of carbosulfan (62%) detected in onion samples. However, in tomato out of 24 residues only three residues remain above EU MRLs. Safe application technique and equipment were lacking in the study area. Providing farmers and workers with information and knowledge regarding pesticide choice, safe pesticides storage and disposal facilities, and protective equipment can increase safety level of farmers and workers. Further, investing more on sustainable public health services and environmental friendly pest control methods could be a policy option for Tanzanians.

1. Introduction

Horticulture is an important part of local economic growth and export earnings in Tanzania. The sector is growing at 6-10% rate annually (HODECT, 2010). Small-scale farmers mainly play a pivotal role in horticultural growth (HODECT, 2010; Mhango, Swando, & Magesa, 2014). There is an increasing demand for fresh vegetables in urban areas. Vegetable production is becoming an important sector for economic development and food security in the country (Lynch, 1999). Vegetables play a major role in consumers diet by contributing important nutrients, fibers and vitamins (Yu, Qiang, Liu, Wang, & Wang, 2016). Farmers prefer vegetables than other crops due to their more quick maturing ability and nutritional values (HODECT, 2010; Mhango et al., 2014). Hence, the government of Tanzania is promoting vegetable production. Vegetable producers in Tanzania face several production constraints. Among the constraints, pests are the major in Northern parts of Tanzania. The term pests refer to any unwanted living organism that present a threat to vegetables (EPA, 2004). The main pests in Northern Tanzania are insects, fungi and weeds. Insects are key pests in onion and tomato production (Mhango et al., 2014; Ngowi, Mbisea, Ijania, London, & Ajayic, 2007). Since insects are the major problem in onion and tomato production, farmers predominantly apply insecticides. For example, according to Ngowi et al. (2007), about 59%, 29% and 10% of farmers in the Northern part of Tanzania used insecticides, fungicides and herbicides, respectively.

Pesticides are chemicals used to prevent, kill, repel or mitigate any form of life declared a pest in agricultural production systems. Pesticides have great contribution in food security by reducing the yield loss from pest damage. However, for some pesticides their detrimental effect outweighs the positive ones. They have an immense potential to risk human health and to contaminate environment (WHO, 1990). Pesticides are a mixture of the active and inert ingredients. The active ingredients are those that do the damage to the pest. Some pesticides have more impacts on the health of consumers and environments than others due to their active ingredients, mode of action, formulation types and biodegradability status (Levitan, 1997, 2000; Mhango et al., 2014). Indiscriminant use of pesticides to produce food has been an increasing concern due to their negative impacts on human health, food safety, water quality, plants, animals and beneficial microorganisms (Kovach, Petzoldt, Degnil, & Tette, 1992; Ngowi, Maeda, & Partanen, 2001; Stenrød, Heggen, Bolli, & Eklo, 2008). Plant Protection Act in Tanzania gives a legal mandate to register and distribute pesticides in Tanzania. Licensed retailers involved in distributing different pesticide formulation (Lekei, Ngowi, & London, 2014a). In some Latin American countries, approval of pesticides and other pest control means carried out based on their efficacy, human safety and environmental compatibility and comply with the culture and norms of the community(Rodríguez & Niemeyer, 2005). Agricultural extension services focus on promoting the use of pesticides to easily control pests in crops without emphasizing their impacts on health of workers, consumers and environment (Ngowi et al., 2007). As a result, acute pesticide poisoning has become a common health problem (Lekei, Ngowi, & London, 2014b). Small-scale farmers in Tanzania are more vulnerable to pesticide poisoning due to limited knowledge about pesticides and safe application techniques (Lekei et al., 2014a; Lekei et al., 2014b; Randhawa, Anjum, Ahmed, & Randhawa, 2007). Application method that gives low exposure are, seed treatment in approved facilities, fumigation, mist blowers, granular application, tunnel spraying(Spikkerud, Haraldsen, Abdellaue, & Holmen, 2005). The pesticide application methods that give high exposure are: knapsack (mist), tractor mounted mist, and manual pressure sprayers. The later application method is most common with small-scale farmers in developing countries (Spikkerud, Haraldsen, Abdellaue, & Holmen, 2005).

The most toxic pesticides in Tanzania were organophosphate groups such as chlorpyrifos and profenofos. Organophosphate contributed for 64% and 62 % of poison cases reported in retrospective and prospective studies respectively (Lekei et al., 2014b). Applying dangerous pesticides at high dose and frequency increases pesticides residues in consumable vegetable products(Sæthre, Komlan, Svendsen, Holen, & Godonou, 2013). Most vegetables consumed raw or with a limited processing which can serve as a path for pesticide residue transfer to human body (Yu et al., 2016). Further, limited information about malignant and benign pesticides, unsafe pesticide application techniques and lack of pesticides residue monitoring policy, risk health of workers, consumers and the environment (Lekei et al., 2014a; Lekei et al., 2014b; Ngowi, 2003). Thus, monitoring residues in vegetables enables us to assess potential risks of pesticides to health of consumers and to provide information on applied chemical products to control pest in crop production. Reducing use of toxic pesticides and encouraging more benign pest control options could significantly minimize negative impacts (Levitan, 1997). Therefore, this thesis work aims to evaluate impacts of various pesticides used in onion and tomato production on the health of farmworkers, consumers and ecological resources.

1.1. Pesticide residues

Pesticides residue is any foreign substance found in the samples of onion and tomato as a result of application of different insecticides, fungicides and herbicides during crops production season (FAO, 1992). Food items imported from developing countries contained pesticide residues above maximum residue levels (MRLs) with about 5.7% during the year of 2013 (EFSA, 2015). "Maximum residue level for pesticide is the highest quantity of pesticide residue legally tolerated by consumers in food commodities. It is based on Good Agricultural Practice data"(CEC, 2007). MRLs is expressed (mg/kg) as a combination of a specific crop (onion and tomato) and specific pesticide(Sæthre et al., 2013). In the report of European Food Safety Authority during 2012, food items that were imported from developing countries contained above MRLs were about 7.5%. This indicated that the rate at which pesticide residues in imported food from developing countries is declining(EFSA, 2015). The reason for residues in food imported from developing countries includes use of banned pesticides in EU for instance; endosulfan or pesticides not approved in EU, high environmental contaminants for instance mercury in wild fungi, natural background level in soil and post harvest processing. Wide pattern of pesticide residues were detected in samples strawberry, tomato, and peaches from developed countries. Peaches samples from Spain, Italy, and Greece contained more chlorpyrifos residue above MRLs (EFSA, 2015). According to CEC (2007), the percentage of multiples residues have increased from 1997-2005 in the analyzed samples of both imported and products of European countries. The most frequently detected residues in the year 2005, on fruits and vegetables were mainly fungicides and on cereals were insecticides(CEC, 2007).

1.2. Pesticide impact assessment tools

The environmental impact assessment tools ("risk indicators") measures or estimates the changes in the environment as a result of human action. The action could be application of pesticides to control pests. Risk indicators complies various methods in order to assess pesticide impacts(Levitan, 1997). For instance, simulating environmental effects using different models, sampling, monitoring, and identifying long-term changes in species diversity. Besides, the models assess data obtained from surveying, observation, interview, and participatory action (Levitan, 1997). Pesticide impact assessment tools are developed to meet at least three different objectives: (1) to serve farmers as a decision-making tool to choose pest control options and evaluate their impacts, (2) to serve as a research and policy tools in government, research institutions, academia, and industry (Levitan, 1997, 2000; Padovani, Trevisan, & Capri, 2004), (3) to serve as an “ecological-labeling” system in order to influence market and behavior of consumers(Levitan, 1997, 2000).

The two main factors used in pesticide risk indicators are: behavioral or “input factors” and impact or “output factors”(Levitan, 1997, 2000). Behavioral factors can be described by personal interview, survey, observation and farm assessment, tools and evaluating techniques of pesticide use and pest management systems. Impact variables explained by pesticide test for example single species toxicity test (LD_{50}) measuring amounts of pesticides residue in food, soil, water, biota and sometimes in the air (Levitan, 1997).

Inappropriate application of pesticides can affect environment, human health, and damages ecosystem biodiversity and contaminate water. They also reduce productivity of soils due to their persistence nature in soil. The persistence nature of pesticide can also affect beneficial microorganisms, fauna and flora in the soil (Levitan, 2000; Stenrød et al., 2008; WHO, 1990).

Application of pesticides particularly on large scale in agricultural food production contributes for climate change by depleting ozone layer. A depleted ozone layer can expose people for skin cancer and other diseases. For example, use of methyl bromide as a pesticide in a larger quantity for a long period of time contributed for major ozone depletion (Levitan, 2000; Padovani et al., 2004). Applications of pesticides also affect health of applicators and consumers. Because pesticides enter human body through inhalation, skin contact, food chain and drinking water. Farmers who frequently apply pesticides are more exposed than those who don´t apply. Because, pesticides poison human internal organs, burn skin and damages eyes when workers and farmers exposed without or with limited care. The hazardous potential of pesticides varies according to their nature. The majority of the farmers in Tanzania have limited knowledge to differentiate various pesticides for example organophosphorus from organochlorines pesticide groups (Ngowi et al., 2001; WHO, 1990). Assessing the risk associated with applying pesticides for crop production demands different analytical tools and models. Hence, the Environmental Impact Quotient (EIQ) and EIQ Field

Use Rating models developed by Kovach et al. (1992) used to assess the load of pesticides on the environment, biota and farmworkers and as a decision support system(Levitan, 1997).

There are various environmental and health risk indicator models. The so far developed pesticide risk indicators vary with purposes. For example, the purposes are to support farmers, extension workers, policy makers, and food industry. They not only vary with purpose but also vary with scale. The scales were pesticide, crop, farm, regional, and national. The variation among risk indicators further observed due to compartment differences. The compartments were ground water, surface water, soil and air. The difference among the models also observed owing to pesticides effect on human health, aquatic organisms, soil organisms, bioaccumulation, and bees. Methods by which the risk indicating model developed made them vary. For instance, relative scoring ranking and risk ratios. Pesticide chemical properties like active ingredient, dosage and formulated product and application factors, environmental conditions make risk-indicating models different from one another (Reus et al., 2002). For example, applying pesticide closer to water bodies increased score of risks to aquatic organisms. But a soil rich with organic carbon decreased contamination of ground water. Higher soil temperature facilitated degradation of pesticides and hence reduced risks to soil organisms(Reus et al., 2002).

Each risk indicator has its merit and demerit in measuring risks of pesticide on environment and human health (Reus et al., 2002). Some of the indicators developed to support farmers' decision to choose pesticides having minimum environmental and human health risk. Most pesticide risk indicators were developed as a tool for farmers at farm level (Reus et al., 2002). For example, EIQ was developed to evaluate pesticide impacts on ecological components, farm workers and consumers based on scoring factors. The model mainly focused on toxicity of the chemical and the environmental factors exposure potential to pesticide (Kovach et al., 1992). The EIQ reduces environmental impact of pesticide to a single index value. The single value may not explain the environmental impacts in a detail but by comparing the impact values of different pesticides, it is possible to choose pesticides with a minimum load. Calculating and ranking the index values of pesticide impacts are the two final steps in EIQ model. The composite values of the model ranges from 6.7 to 167.7. The values classify into categories based on threshold criteria. The categories of pesticide according to EIQ model can be formed based on numerical or percentile scores (Levitan, 1997). In order to apply EIQ at farm level, farm workers needs to multiply EIQ with percent of active ingredient and application rate to calculate EIQ Field Use Rating. Therefore, it is possible to compare the impacts of various pest management options by employing EIQ Field Use Rating method. However, the model is more focused on terrestrial environment compared to aqueous environment. Apart from fish, the toxicity of pesticides on other aqueous species like algae was not considered by EIQ (Kovach et al., 1992). The EIQ model does not indicate or measure the actual pesticide risks to consumers, workers and ecological components. The model does not take into account specific routes for exposure and uptake. It generalizes potential risks based on toxicological data, chemical and physical properties of the pesticide. Effects of pesticides on different environmental parameters into summarized into a single figure. These might be the drawback of the EIQ model. Though the model lacks accuracy and specificity to the actual situation on the field, it is simple to use as an impact assessment tool (FAO, 2008).

1.3. Objectives

- To assess farmer's perception about pesticide usage, handling and health risk
- To determine and compare environmental load of different pesticides used in onion and tomato production in Karatu and Arumeru Districts.
- To evaluate impacts of pesticides on the health of farmworkers, consumers and ecology in the study areas
- To determine the pesticide residue in onion and tomato samples

2. Materials and Methods

2.1. Description of study area

The study was conducted in Northern Tanzania. The study area was located in Arusha Administrative Region, Karatu and Arumeru Districts. Arumeru District was located on North East of Arusha Town and Karatu was located on the West side of the town. Arumeru District is found on the out skirt of Arusha Town. Mount Meru (figure 4) also found in this district which influences local climate by cooling the temperature (Kahimba, Mutabazi, Tumbo, Masuki, & Mbungu, 2014). Karatu District was found at a distance of 150km from Arusha Town with altitudinal range of 100 to 1900 masl. The district is classified as arable, pasture, forest, bush, tree cover and lake Eyasi(Owenya, Mariki, Kienzle, Friedrich, & Kassam, 2011). From Arumeru District, Ngare Nanyuki Ward and from Karatu District, Mangola Ward was chosen for survey and onion and tomato samples collection. The samples of onion and tomato were collected from farm sites indicated by figure 3.

Figure 1. Map of Tanzania
Source: Google Earth 2016

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Figure 2. Map of Arusha Region
Source: Google Earth 2016

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Figure 3. Location of the study area
Source: Google Earth 2016

Figure 4. Mount Meru
Photo credit: Ole Martin Eklo

2.2. Data collection methods

There are two main factors used in pesticide risk indicators. The data were collected based on these two factors. The first factors are behavioral (input factors) which described by personal interview, survey, observation and farm assessment, tools and evaluating techniques of pesticide use and pest management systems. The second factors are impact (output factors). Impact factors are described by impact variables. These impact variables explained by pesticide test for example single species toxicity test (LD_{50}) measuring amounts of pesticides residue in food, soil, water, biota and sometimes in the air (Levitan, 1997, 2000).

2.2.1. Pesticide-related socio-economic and biographic data collection

Semi-structured questionnaire was designed to collect survey data. After selecting randomly vegetable-producing households, from each districts (Karatu and Arumeru) face-to-face interview and farm assessment was conducted. The survey was carried out on 107 onion farmers and 125 tomato farmers in the years of 2013. Besides, 30 farmers who produce different crops in addition to onion and tomato were interviewed in 2014. Farm assessment was conducted by direct observation and surveying the type of pesticides used by farmers, dose per acre, formulation type, equipment used, spray mechanisms, and family members involved in mixing and spraying. Furthermore, data related to frequency of application, pesticides choice, disposal mechanisms of pesticides, other pests control methods, pesticides storage systems and storage places were collected from farmers or their family member, who had direct involvement with pesticide application, weeding, and crop harvesting. Survey participants were asked about their family size, sources of income, labor division, farm size, educational background, pesticides application methods, care during and after pesticide application, health treatment facilities and other relevant information.

2.2.2. Onion and tomato sample collection for pesticide residue analysis

Sixteen farms of onion and tomato were selected for sampling. From Mangola Ward of Karatu District five samples of onion and from Ngare Nanyuki Ward of Arumeru District eleven samples of tomato were collected (figure 5). The samples of onion and tomato were gathered according to EEC (2000) when matured and became ready for harvest. The sample size for field was 2 kg and for laboratory 1 kg (EEC, 2000). The samples of onion and tomato

collected from Arumeru and Karatu districts in Tanzania were analyzed. The sampling parts of the plants were bulb, leaf of onion and fruit of tomato. The collected samples were stored under cool and dark condition within 24 hours before homogenization. To reduce the size of onion, the sample was cut into two parts and one part was used for homogenization. But for tomato, after removing stems the whole samples were homogenized. During homogenization, two containers of 100 ml were filled and marked with sample code. A blender was used to homogenize the samples, and the homogenized sample was stored in a freezer at -18 °C.
During transporting the samples from Tanzania to Norway, the samples were kept in a cooler.

Figure 5. Samples of onion and tomato
Photo credit: Ole Martin Eklo

2.2.3. Pesticide residue analysis procedure

Sample analysis was conducted at "NIBIO", Biotechnology and Plant Health Division. To analyze the samples, two accredited multi methods (M86 &M93) were used. The homogenized samples was extracted according to "Quick, Easy, Cheap, Effective, Rugged and Safe (QuEChERS) procedure using acetonitrile (ACN) (Anastassiades, Mastovska, & Lehotay, 2003; Brondi, de Macedo, Vicente, & Nogueira, 2011). Magnesium sulfate ($MgSO_4$), sodium chloride (NaCl), and buffering citrate salts were mixed thoroughly and centrifuged for phase separation. Step 1: A 10-g (±0.05g) amount of the homogenized each sample of onion and tomato was placed in a 50-mL centrifuge tube. 100 µL of the appropriate spiking solution was added. The sample was vortexed for 1 min, and then 10 mL of acetonitrile (ACN) were added. The sample was shaken vigorously for 1 min, and then 4 g of $MgSO_4$ and 1 g of NaCl were added. The sample was vortexed for 1 min. A 50-µL amount of internal standard solution was added, and then the sample was centrifuged for 5 min at 5000 revolutions per minutes (rpm)(Usher & Majors, 2012).

Step 2: The aliquot of the organic phase was cleaned up by dispersive solid phase. Dispersive solid-phase extraction (SPE) step that involves further cleanup using various combinations of salts and porous sorbents to remove interfering substances. The use of primary-secondary amine (PSA) as a porous sorbents removes a variety of matrix compounds that are co-extracted in Step 1 (Usher & Majors, 2012).

A. QuEChERS extraction procedure, step 1

Add 10 g homogenized onion and tomato samples separately into 50 mL centrifuge tube

⇓

Spike and vortex the sample for 1 minute

⇓

Add 10 mL ACN

⇓

Add 4g $MgSO_4$ and 1g NaCl

⇓

Add 50 µL internal standard and vortex for 30 seconds

⇓

Centrifuge for 5 minutes at 5000 rpm

Figure 6. QuEChERS extraction procedure, step 1 for general fruits and vegetables

Adapted from: Usher and Majors (2012).

B. **QuEChERS extraction procedure, step 2**

Add 1 mL upper layer in 1.5 mL centrifuge tube with 50 mg PSA and 150 mg $MgSO_4$

⇓

Vortex for 30 seconds

⇓

Centrifuge for 5 minutes

⇓

Add 0.5 mL into sample vial

⇓

Inject 1.5 µL into GC/MS

Figure 7. QuEChERS extraction procedure, step 2 for general fruits and vegetables
Adapted from: Usher and Majors (2012)

The final extract was made ready for analysis using Gas Chromatography–Mass Spectrometry (GC-MS) and Liquid Chromatography-Mass Spectrometry (LC-MS) instruments.

A. GC-MS analysis, multi method number 93 (M.93)

Agilent 7890 GC equipment with a 700 MS/MS detector and a multimode injector was used for the analysis. The column HP-5MS, 15 m X 0.25 mm X 0.25 µm and helium were applied as carrier gas. The equipment was programmed from 60 °C (1min.) at the rate of 55 °C/ min to 150 °C (0 min), then 6.6 °C/min to 200 °C (0 min), and 17.6 °C/min to 310 °C (4.56 min). Injections (5 µL) was made using solvent at 50 °C for 0.48 min, then 720 °C/min to 280 °C (21.022 min). The temperature of MS detector was adjusted at 230 °C (ion source) and 150 °C for both quadruples. The detector ran in Multiple Reaction Monitoring (MRM) mode, El+.

B. LC-MS analysis, multi method number 86 (M.86)

The analysis was carried out using Agilent 1200 LC by connecting it to Agilent 6410B MS/MS-detector. The detector ran in MRM mode, ES+. The column was an eclipse Plus C18, 100 mm x 2.1 mm x 1.8 µm. The mobile phase was methanol with 5 mm ammonium formate + 0.01 % formic acid. The mobile phase was applied in gradient mode and the total run time was 32 minutes. The injection volume was 2 µL, and the flow rate was 0.3 mL/min at a column temperature of 50 °C.

2.2.4. Pesticide impact analysis

Environmental Impact Quotient (EIQ)(Kovach et al., 1992) was used to analyze the impacts of pesticides on consumers, workers and ecological components. To analyze the values of EIQ, application rate per acre, active ingredient name and quantity were summarized. Each pesticides formulation having the same dose was put together. Reference, field use rating, consumers, workers and ecological componenets EIQ were calculated separately using Cornell University EIQ Calculator. (http://www.nysipm.cornell.edu/EIQCalc/input.php). EIQ values of pre-emergence and post emergence application of pesticides were calculated separately. After analyzing the values of EIQ for each active ingredient, pesticide formulation applied at same dose, they were summarized and ranked. Those pesticides having highest values of EIQ ranked first and those having lowest values set at the last. Besides, all pesticides used by individual farmer were added and summarized as a composite EIQ values.

Field Use Rating EIQ values were used to compare the impact of different pesticides formulation used to control pests in onion and tomato crops. Toxicity of active ingredients in each formulation and their effects on environmental components was evaluated and grouped into three categories. The categories are low toxicity, medium toxicity and high toxicity. These three categories related to one, three and five scales. The coefficient used in EIQ equation values individual factor based on a one to five scales. Factors having high impact multiplied by five and medium impact multiplied by three and those with low impact by one. Environmental impact of pesticide is equal to toxicity times exposure(Kovach et al., 1992).

2.2.4.1. EIQ formula (Kovach et al., 1992)

A. Applicator exposure + picker exposure

Farm worker risk determined as the sum of applicator exposure (DT*5) and picker exposure (DT*P) times chronic toxicity. Chronic toxicity (C) is the long-term effect of pesticide.

Applicator exposure is calculated as dermal toxicity (DT) times five. To calculate picker exposure, multiply DT with plant surface half-life potential (P). Plant surface half-life potential refers to the time required for one half of the pesticide chemical to break down on plant surfaces(Kovach et al., 1992).

C[(DT * 5) + (DT* P)]……………………………………………………… *(Eq. 1)*

B. **Consumer exposure potential**

To determine consumers' exposure potential, multiply chronic toxicity (C) by average residue potential in soil (S) and plant surfaces (P) with systemic potential rating of pesticide (SY) plus the potential ground water effect (L). Systemic potential rating of pesticide is the ability of pesticide to be absorbed by plant systems. Potential ground water effect (L) was considered under consumers' exposure potential because it is related to human health. Consumers have a possibility to drink contaminated water from wells, rivers and lakes. The health effects of pesticide were calculated based on the result obtained from tests conducted on small mammals such as rats, mice, rabbits and dogs. Farm workers and consumers in EIQ model represented mammals' exposure to pesticide(Kovach et al., 1992).

[C* ((S+P)/2)) *SY) + (L)] ………………………………………………… *(Eq. 2)*

C. Ecological components exposure

Ecological components of EIQ model comprised of fish (F), birds (D), bees (Z) and beneficial arthropods (B). The model calculates effects on both aquatic and terrestrial. To calculate impacts of pesticides on aquatic system, multiply chemical toxicity to fish rate (F) with surface runoff potential (R) of specific pesticide. Surface run potential takes into account the half-life of the pesticide on surface water. To determine the impacts of pesticides on birds, multiply toxicity rate to birds (D) with average half-life on plant and soil surfaces times three. The impacts of pesticides on bees calculated as toxicity rating to bee (Z) times half-life on plant surfaces (P) times three. The effect of pesticides on beneficial arthropods (B) is determined by pesticide rating to beneficial natural enemies times the half-life on plant surfaces times five. Arthropods are not transient like birds and bees; hence their exposure potential greater. This accounted to multiply the risks by scale of five (Kovach et al., 1992).

[(F* R) + (D *((S+P)/2)) *3) + (Z*P*3) + (B*P*5)]……….........................*(Eq.3)*

Reference EIQ= (Eq. 1+ Eq. 2 + Eq. 3)/3 (Kovach et al., 1992)

Field Use Rating EIQ is used to compare the impacts of pesticides at field level. To calculate Field Use Rating, it requires percent active ingredient, dose and how frequent the pesticides applied. To calculate Field Use Rating EIQ, multiply reference EIQ for a specific pesticide with percent active ingredient and with rate per acre(Kovach et al., 1992).

EIQ Field Use Rating: EIQ * % active ingredient (AI) * rate (R) (Kovach et al., 1992)

2.2.5. Limitation of the study

Pesticides project team members at `NIBIO´ surveyed and collected pesticide samples in Karatu and Arumeru Districts of Tanzania. The role of the researcher was to organize, collected data, analyze the data and thesis writing. Lack of involvement in collecting data and field observation by the researcher is a limitation to this research. To make the research more comprehensive and sound, the researcher has incorporated both primary and secondary data.

3. Results

3.1. Pesticide application practice effects on health of farmers and environment

The household survey was conducted on farmers of eight different tribes having three different religions. Among the interviewed farmers, 26% of them were females having primary education. Farmers who completed secondary school were only 34%. The household members of each farmer ranged from single person in the house to 10 persons. The minimum size of their farm was a quarter of an acre and the maximum size was four acres. The size of the farms didn´t corresponds with the numbers of persons in the households. The famers having nine household members had only 0.75 acres while the famers with four household members had four acres.

Farming was considered as a livelihood for farmers living in Arumeru and Karatu Districts of Tanzania. They produced vegetables and cereal crops besides animal husbandry. All the interviewed farmers engaged in producing vegetables. Among the vegetables, tomato and onion were the dominant crops. Farmers produced onion and tomato for own use and at the same time supplied to the markets. Farmers considered pesticide use as economically important pest control options. All famers involved in the survey used pesticides in onion and tomato production. Pesticides were applied to control protects pests like insects, fungi, weeds in onion and tomato crops. Although pesticides are important, almost all farmers agreed that pesticides uses caused negative health effect. But only 22% of the surveyed farmers aware that all pesticides have no the same negative health effect. All interviewed farmers agreed that pesticides use were dangerous. They experienced that pesticide residue drifts enter body via inhalation and skin openings. Further, the onion and tomato-producing farmers explained that, during spraying pesticides residues remain in the air. Farmers believed that when people are breathing, the residues enter body through inhalation. Almost all famers observed that the residues of the pesticides remain in the soil and water bodies. Furthermore, about 90% of onion and tomato producers believed that pesticides residues remain in the fruits while all producers agreed that they remain in vegetables too.

Before using the pesticides, almost all farmers read manufacturer notifications but some farmer didn´t apply the notification into practices. All agreed that proper knowledge and information about pesticides and their use is necessary. Besides, 60% of the onion and tomato producers strongly agreed that pesticides uses have minimal health effect when they are used with precaution. All farmers believed that pesticides are important for good crop production. Because of that, more than 60% of the famers strongly disagreed with the notion of limiting the use of pesticides to produce crops.

The application method for pesticides to control pest in both onion and tomato were manual spraying. Farmworkers applied pesticides within one to four weeks after emergence of onion and tomato. Though farmers were aware about the negative impacts of pesticide, less than one percent of them used gloves and goggles to protect themselves during spraying. Almost no farmworker used head cover in order to apply pesticides safely. The farmers applied pesticides in very unsafe way because no single farmer used oral mask, few workers put on special boots on their feet during spraying. Worst of all, 65%, 48%, and 26% of the farmers and workers responded that they drink, eat, and smoke during pesticide application, respectively.

Figure 8. Pesticide spray practice in onion farms without any protective equipment in Northern part of Tanzania.
Photo credit: Ole Martin Eklo

Some farmers store pesticides in their own living house. After applying pesticides, 83% of the farmworkers disposed the extra pesticide solution into lakes, irrigation canals. Almost all surveyed farmers washed their containers in near by water bodies (rivers, lakes and irrigation canals). Nearly all farmworkers experienced headache, burning sensation of skin, eyes and weakness after application of pesticides. The eyes of the worker who applied pesticides dropped tears during and after application of pesticides. Besides, almost all farmworkers experienced skin itching, irritation, chest pain and dizziness after spraying. Furthermore, some farmworkers had experienced vomiting and diarrhea after spraying pesticides.

In the cropping season of onions, farmers in Arumeru and Karatu Districts applied pesticides before sowing, before the onion seedlings emerged, after they have emerged and after harvest. For insect control, growers sprayed insecticide pre sowing, pre-emergence and post-emergence; for fungi control, they sprayed fungicide; for weed control, they sprayed herbicides. Less than one percent of onion-producing farmers applied pesticides before sowing and after harvesting onion. Farmers applied insecticides in both pre sowing and post harvest of onion. About 39% and 38% of the farmers applied pesticides before and after emergence of onion seedlings respectively. During pre-emergence of onion, 88%, 9% and 3% of insecticides, herbicides and fungicides were applied, respectively. The majority of the farmers used insecticides during pre emergence of onion. All farmers (100%) used only insecticides after onion emerged from the soil.

Tomato producing farmers in the Arumeru and Karatu Districts of Tanzania applied various pesticides as a pest control means. During cropping season of tomato, the famers applied pesticides at different times and frequencies. Tomato farmers use more pesticides in quantity and kinds than that of onion farmers. The frequency of application varied among the tomato-producing farmers than that of onion. About 18% of the farmers applied pesticides four times during growing season of onion. While about 49%, 23%, 10% of the farmers applied two, three and once for a growing season of onion. About 3% of the farmers applied six and five times. About 18%, 20%, 48%, 11% of the tomato farmers applied pesticides four, three, two and once respectively during growing season of the crop. Most of the farmers sprayed pesticides two times during the cropping seasons. Among tomato producers, about 2% of the farmers applied pesticides before they sow seed of tomato into soil. All pesticides used before sowing were insecticides. About 47% of the farmers applied pesticides of different categories before the emergence of tomato seed. The farmers used more fungicides (30%)

during pre emergence in tomato than that of onion. About 1% of the farmers used herbicides to control weeds in tomato and 69% of them used insecticides for pre emergence application. About 44% of the farmers applied pesticides as a form of post emergence of tomato. Among post emergence applicators, 41% applied fungicides and 59% sprayed insecticides. About eight percent of the farmers used pesticides as a post harvest treatment of tomato out of these, 14%, 86% were fungicides and insecticides respectively.

3.2. Pesticides residues analysis in onion and tomato samples

Pesticide residues were detected in both onion and tomato. Five different pesticides residues were detected in five samples of onion. In all analyzed samples of onion, carbofuran was detected. About 84% of detected pesticides residues in onion were more than EU maximum residue levels (MRLs). Carbofuran constitutes about 62% of the residues, which were greater than EU MRLs in onion samples. The quantity of pesticides residues detected in onion samples ranges from 0.014mg/kg (lambda-cyhalothrin) to 1 mg/kg (chlorpyrifos). The maximum amount of pesticides residue in onion was chlorpyrifos (1mg/kg). While the minimum level of pesticides residue was lambda-cyhalothrin (0.014mg/kg) (Tables 1 & 2). The other detected residues in the samples of onion were carbofuran, cypermethrin, and lambda-cyhalothrin. All the pesticide residues detected in onion samples were insecticides, which corresponds with post-emergence application of pesticides (Table 2).

In eleven tomato samples, 24 pesticide residues were detected. Out of 24 residues, only three of them were above EU MRLs level. The maximum amount of pesticide residue detected in tomato samples was profenofos (1.3mg/kg). The minimum amount of detected residue in tomato was endosulfan sulfat (0.007mg/kg).

The dominant pesticide residues in terms of quantity were chlorpyrifos and profenofos in onion and tomato respectively. In tomato, the detected residues included cypermethrin, endosulfan, chlorpyrifos, deltamathrin, lambdacyhalothrin, metalaxyl, acetamiprid, and triadimenol. The last three-pesticide residues were categorized under fungicide while the rest were insecticide.

Table 1 Quantity of detected pesticides residue in onion samples ❖

			M86		M93			
Sample	Sample ID	Samples	Active ingredient	Quantity (mg/kg)	Active ingredient	Quantity (mg/kg)	Category	EU MRLs (mg/kg)
1	364-1	Leaf	Carbofuran	0.25	_	_	Insecticide	0.002*
			Carbofuran-3- hydroxy	0.11	_	_	Insecticide	0.002*
2	364-2	Leaf	Carbofuran	0.062		_	Insecticide	0.002*
			Carbofuran-3- hydroxy	0.042	_	_	Insecticide	0.002*
3	364-6	Bulb	Carbofuran	0.024	_	_	Insecticide	0.002*
			Profenofos	0.069			Insecticide	0.02
3					Cypermethrin	0.54	Insecticide	0.1
					Chloripyrifos	1.0	Insecticide	0.2
					Lambdacyhalothrin	0.014	Insecticide	0.2
4	364-8	Bulb	Carbofuran	0.35	_		Insecticide	0.002*
			Carbofuran-3- hydroxy	0.48	_		Insecticide	0.002*
			Profenofos	0.017	_		Insecticide	0.02
5	364-9	Bulb	Carbofuran	0.051	_	_	Insecticide	0.002*

- Limitation of Determination (LOD) MRLs is not yet in force.

Source: Maximum Residue Level (MRL) database: www.secure.pesticide.gov.uk/MRLs

❖ Unpublished data

Table 2. Quantity of detected pesticides residue in tomato samples □

			M86		M93			
Sample	Sample ID	Samples	Active ingredient	Amount (mg/kg)	Active ingredient	Amount (mg/kg)	Category	EU MRLs (mg/kg)
1	364-11	Fruit	_	_	Chloripyrifos	0.18	Insecticide	0.5
			_	_	Cypermethrin	0.099	Insecticide	0.5
2	364-14	Fruit	_	_	Cypermethrin	0.024	Insecticide	0.5
			_	_	Endosulfan alfa	0.017	Insecticide	0.05*
			_	_	Endosulfan beta	0.027	Insecticide	0.05*
			_	_	Endosulfan sulfat	0.007	Insecticide	0.05*
			_	_	Chloripyrifos	0.097	Insecticide	0.5
3	364-15	Fruit	_	_	Deltamathrin	0.025	Insecticide	0.3
4	364-23	Fruit	_	_	Lambdacyhalothrin	0.8	Insecticide	0.1
5	364-24	Fruit	Triadimenol	0.036	_	_	Fungicide	1.0
					Chloripyrifos	0.61	Insecticide	0.5
					Cypermethrin	0.5	Insecticide	0.5
6	364-31	Fruit	Profenofos	1.3	_	_	Insecticide	0.05*
			Triadimenol	0.086	_	_	Fungicide	
7	364-32	Fruit	_	_	Lambdacyhalothrin	0.06	Insecticide	0.1
8	364-35	Fruit	Profenofos	0.022	_		Insecticide	0.05*
10	364-43	Fruit			Cypermethrin	0.064	Insecticide	0.5
			_	_	Chloripyrifos	0.22	Insecticide	0.5
			_	_	Lambdacyhalothrin	0.11	Insecticide	0.1
					Metalaxyl	0.031	Fungicide	0.2
11	364-44	Fruit	Acetamiprid	0.014	-		Insecticide	0.2
			_	_	Chloripyrifos	0.13	Insecticide	0.5
			Triadimenol	0.013			Fungicide	1.0
			_		Cypermethrin	0.01	Insecticide	0.5

- Limitation of Determination (LOD) MRLs is not yet in force. ❖ Unpublished data

3.3. Evaluating impacts of pesticides on the health of farmworkers, consumers and ecology using environmental impact quotient (EIQ)

To compare the EIQ values of different pesticide formulations ranking was done for similar application rate. Among applied pesticides, profenofos had the highest EIQ values for field use rating, ecology, workers and consumers. At the application rate (0.24L/acre), the EIQ values were the higher than that of other pesticides. For example, comparing the EIQ values of profenofos at rate (0.24L/acre) with that of abamectin whose application rate (1500g/acre), the EIQ index values of the former was by far greater than that of the later. Both profenofos and abamectin were insecticides. Thus, use of abamectin at relatively highest rate seemed to be preferable for the health of workers, consumers and the environment based on the index value of EIQ. Even, use of lambda- cyhalothrin insecticide applied at 0.32L/acre showed lower load on the environment than that of profenofos applied at the rate of 0.24L/acre. Particularly, profenofos showed highest impact on the ecological componenets than on consumers and workers. Mancozeb affected more health of consumers and workers compared to ecological resources (Tables 3 and 4). Next to profenofos, chlorpyrifos, carbosulfan insecticides had higher EIQ values.

Onion farmers used both granular and liquid formulation pesticides. Based on EIQ values, granular pesticides showed a higher value than liquid formulation. For example, field use rating EIQ value of granular profenofos was 75.6, while liquid formulation was 72.5 (Table 3). Abamectin, lambda-cyhalothrin had lower EIQ values for environmental componenets, consumer and workers. On the contrary, at every rate of application, insecticide profenofos showed the highest EIQ indexes for environment and health of people.

Table 3. Pre-emergence uses of pesticides against pests in onion farms and ranking EIQ values from highest to the lowest

Active ingredient name	Active ingredient quantity	Category	Dose/acre	EIQ values				Ranking
				Consumers	Workers	Ecology	Field Use Rating	
Profenofos	720 g/L	Insecticide	0.32L	1.5	3.9	81.5	29	1
Chlorpyrifos	480 g/L	Insecticide	0.32L	0.6	1.9	23.6	8.7	2
Carbosulfan	250 g/L	Insecticide	0.32L	1.4	1.2	21.4	8	3
Lambdacyhalothrin	50 g/L	Insecticide	0.32L	0.1	0.7	3.7	1.5	4
Profenofos	720 g/L	Insecticide	0.4L	1.9	4.9	101.9	36.2	1
Carbosulfan	250 g/L	Insecticide	0.4L	1.8	1.5	26.8	10	2
Chlorpyrifos	480 g/L	Insecticide	0.48L	1	2.9	35.1	13.1	1
Carbosulfan	250 g/L	Insecticide	0.48L	2.1	1.7	32.1	12	2
Oxyfluorfen	240 g/L	Herbicide	0.48L	1.7	2.9	20.1	8.2	3
Profenofos	720 g/L	Insecticide	800g	3.9	10.3	212.6	75.6	1
Profenofos	720 g/L	Insecticide	0.8L	3.7	9.9	203.8	72.5	2
Mancozeb	800 g/kg	Fungicide	800g	11.5	28.6	68.8	36.3	3
Carbosulfan	250 g/L	Insecticide	0.8L	3.5	2.9	53.6	20	4
Abamectin	20 g/L	Insecticide	800g	0.1	0.5	3	1.2	5
Abamectin	18 g/L	Insecticide	0.8L	0.1	0.4	2.6	1.1	6

Table 4. Post emergence uses of pesticides against pests in onion farms and ranking from highest to the lowest EIQ values

Active ingredient name	Active ingredient quantity	Category	Dose/acre	EIQ values				Ranking
				Consumers	Workers	Ecology	Field Use Rating	
Profenofos	720 g/L	Insecticide	0.32L	1.5	3.9	81.5	29	1
Carbosulfan	250 g/L	Insecticide	0.32L	1.4	1.2	21.4	8	2
Lambdacyhalothrin	50 g/L	Insecticide	0.32L	0.1	0.7	3.7	1.5	3
Profenofos	720 g/L	Insecticide	0.4L	1.9	4.9	101.9	36.2	1
Carbosulfan	250 g/L	Insecticide	0.4L	1.8	1.5	26.8	10	2
Profenofos	720 g/L	Insecticide	0.48L	2.2	5.9	122.3	43.5	1
Chlorpyrifos	480 g/L	Insecticide	0.48L	1.0	2.9	35.3	13.1	2
Carbosulfan	250 g/L	Insecticide	0.48l	2.1	1.7	32.1	12	3
Profenofos	720 g/L	Insecticide	0.8L	3.7	9.9	203.8	72.5	1
Chlorpyrifos	480 g/L	Insecticide	0.8L	1.6	4.9	58.9	21.8	2
Carbosulfan	250 g/L	Insecticide	0.8L	3.5	2.9	53.6	20	3

Insecticides used in tomato production were, abamectin, carbosulfan, chlorpyrifos, cypermethrin, endosulfan, lambda-cyhalothrin, profenofos. While fungicides used were mencozeb and metalaxyl. From highest impact to lowest or zero impact on the health of people and environment, we can rank (from one to eight) as profenofos, mancozeb, endosulfan, chlorpyrifos, cypermethrin, lambda-cyhalothrin, metalaxyl and abamectin based on their EIQ values (Table 6).

Among pesticides applied to tomato, abamectin, metalaxyl and lambda-cyhalothrin had least effect on the people and environment. While profenofos, mancozeb, endosulfan, carboulfan had the highest value of EIQ ranking from first to fourth respectively (Table 6). At relatively high rate of application (1.5L/acre), chlorpyrifos showed closer EIQ value (110.4) on ecological resources compared to mancozeeb (123.7). The EIQ value of chlorpyrifos was lower than that of endosulfan and carbosulfan (figure 9 &10).

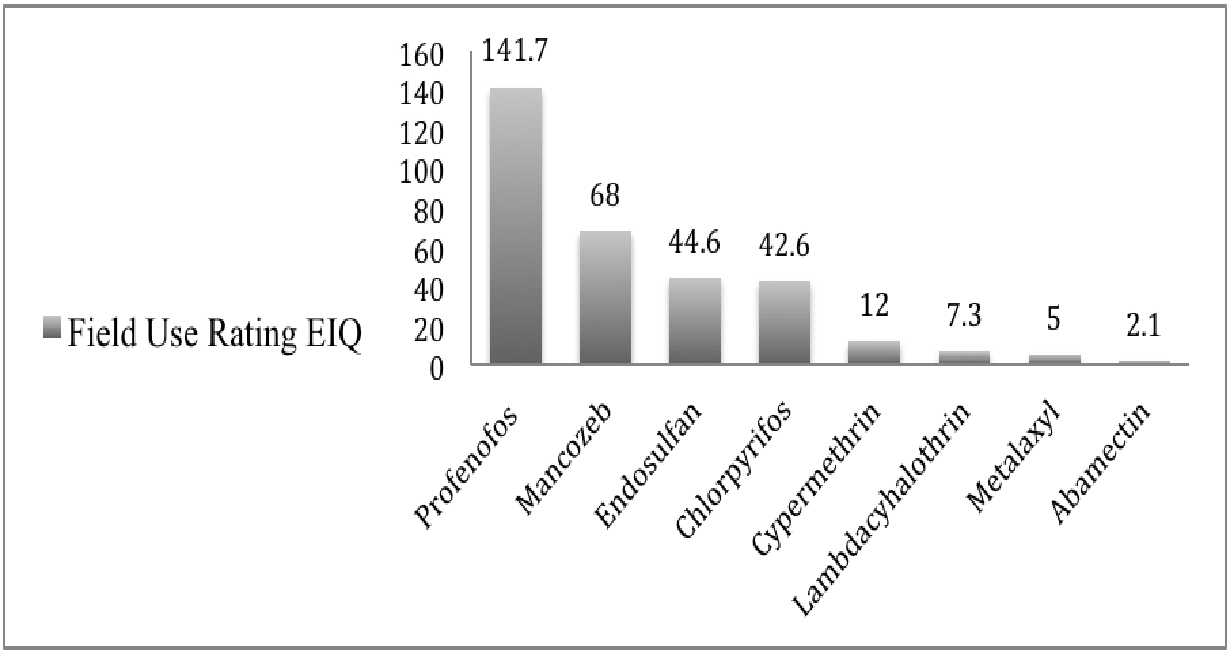

Figure 9. Field use rating EIQ values of pesticides applied in pre-emergence tomato at the rate of 1500g/acre

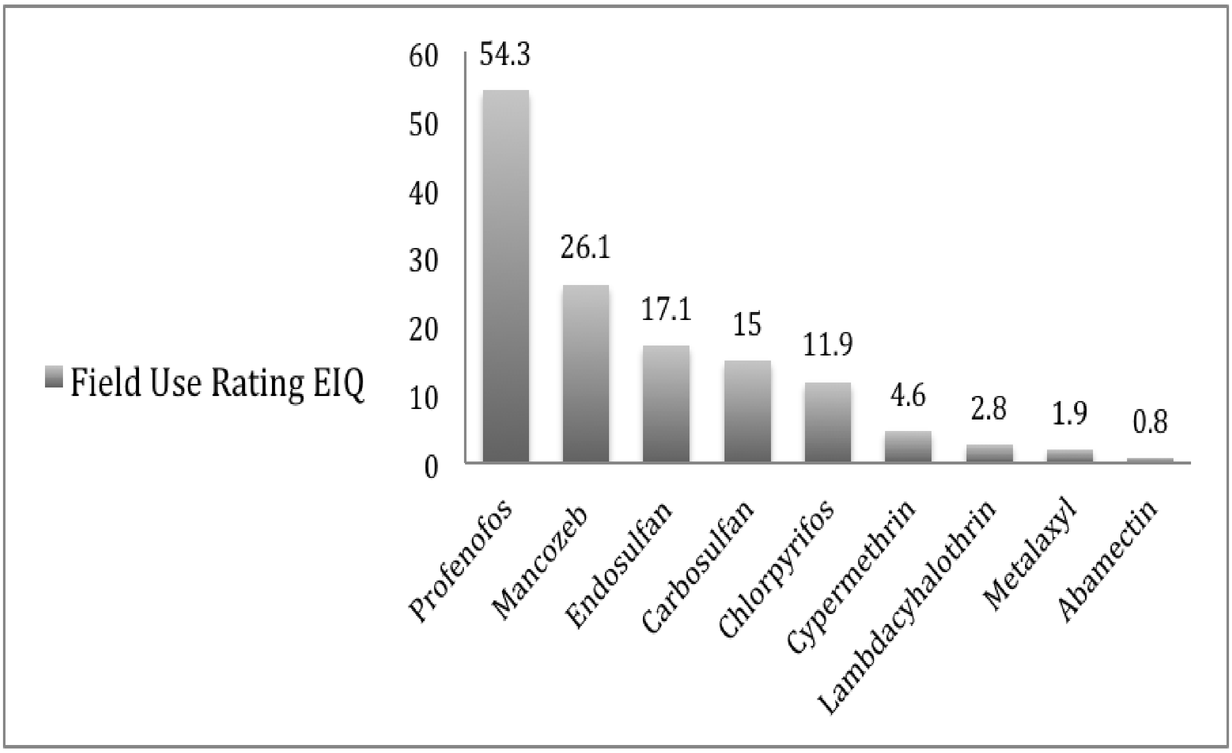

Figure 10. Field use rating EIQ values of pesticides applied in post-emergence tomato at the rate of 0.6L/acre.

Figure 11. Pictures of pesticides used to control pests in onion and tomato crops
Photo credit: Ole Martin Eklo

Table 5. Pre-emergence use of pesticides against pests in tomato farms

Active ingredient name	Active ingredient quantity	Category	Dose/acre	EIQ values				Ranking
				Consumers	Workers	Ecology	Field Use Rating	
Endosulfan	350 g/L	Insecticide	0.75L	3.1	15	46.1	21.4	1
Carbosulfan	250 g/L	Insecticide	0.75L	3.3	2.7	50.2	18.8	2
Abamectin	20 g/L	Insecticide	0.75L	0.1	0.4	2.7	1.1	3
Profenofos	500 g/L	Insecticide	0.9L	2.9	7.7	159.2	56.6	1
Mancozeb	800 g/kg	Fungicide	0.9L	12.4	30.8	74.2	39.1	2
Endosulfan	350 g/L	Insecticide	0.9L	3.7	18.0	55.4	25.7	3
Chlorpyrifos	480 g/L	Insecticide	0.9L	1.8	5.5	66.2	24.5	4
Carbosulfan	250 g/L	Insecticide	0.9L	4.0	3.3	60.3	22.5	5
Profenofos	720 g/L	Insecticide	1500g	7.3	19.3	398.7	141.7	1
Mancozeb	800 g/kg	Fungicide	1500g	21.5	53.6	129.1	68.0	2
Endosulfan	350 g/L	Insecticide	1500g	6.4	31.3	96.2	44.6	3
Chlorpyrifos	480 g/L	Insecticide	1500g	3.2	9.5	115.2	42.6	4
Cypermethrin	10%	Insecticide	1500g	2.0	4.6	29.5	12.0	5
Lambdacyhalothrin	50 g/L	Insecticide	1500g	0.6	3.4	17.9	7.3	6
Metalaxyl	80 g/kg	Fungicide	1500g	3.2	2.1	9.8	5.0	7
Abamectin	18 g/L	Insecticide	1500g	0.2	0.8	5.1	2.1	8

Table 6. Post-emergence uses of pesticides against pests in tomato farms

Active ingredient name	Active ingredient quantity	Category	Dose/acre	EIQ values				Rankings
				Consumers	Workers	Ecology	Field Use Rating	
Profenofos	720 g/L	Insecticide	0.3L	1.4	3.7	76.4	27.2	1
Mancozeb	800 g/kg	Fungicide	0.3L	4.1	10.3	24.7	13.0	2
Mancozeb	640 g/kg	Fungicide	0.3L	3.3	8.2	19.8	10.4	3
Chlorpyrifos	480 g/L	Insecticide	0.3L	0.6	1.8	22.1	8.2	4
Lambdacyhalothrin	50 g/L	Insecticide	0.3L	0.1	0.7	3.4	1.4	5
Metalaxyl	80 g/kg	Fungicide	0.3L	0.6	0.4	1.9	1.0	6
Abamectin	20 g/L	Insecticide	0.3L	0	0.2	1.1	0.4	7
Profenofos	720 g/L	Insecticide	0.6L	2.8	7.4	152.9	54.3	1
Mancozeb	800 g/kg	Fungicide	0.6L	8.2	20.5	49.5	26.1	2
Endosulfan	35%	Insecticide	0.6L	2.4	12	36.9	17.1	3
Carbosulfan	250 g/L	Insecticide	0.6L	2.6	2.2	40.2	15.0	4
Chlorpyrifos	35%	Insecticide	0.6L	0.9	2.7	32.2	11.9	5
Cypermethrin	10%	Insecticide	0.6L	0.7	1.7	11.3	4.6	6
Lambdacyhalothrin	50 g/L	Insecticide	0.6L	0.2	1.3	6.9	2.8	7
Metalaxyl	80 g/kg	Fungicide	0.6L	1.2	0.8	3.7	1.9	8
Abamectin	18 g/L	Insecticide	0.6L	0.1	0.3	2.0	0.8	9

3.4. Evaluating impacts of pesticides used by individual farmer using composite EIQ values

The impacts of pesticides on the environment, health of workers and consumers could increase due to application rate, active ingredients and nature of pesticides (granular vs liquid formulation). High active ingredient and high application rate greatly affected consumers, workers and ecological resources. For example, profenofos having active ingredient (720g/kg) and mancozeb (800g/kg) had the highest field use rating EIQ value than other pesticides at application rate of 1500g/acre (figure 10). However, low active ingredient content (cypermethrin, 10%) applied at (0.3L/acre) rate resulted in a lower field use rating EIQ (2.3) (appendix 2.7). Carbosulfan (250g/L) with the dose (3L/acre) resulted in high composite ecological resources EIQ value (401.8) (appendix 2.1).

Abamectin was one of the insecticides used to control insects in tomato and onion. It had zero EIQ value for consumers, which applied at, 0.3L/acre and 1.1 EIQ value for ecological components (appendix 2.2). The same application rate (0.6L/acre) for lambda-cyhalothrin (ID no. 78) and profenofos (ID no. 79) resulted in 13.8 and 305.8 composite values of EIQ for ecological components respectively (appendix 2.3).

Applying lambda-cyhalothrin two times at the rate of 0.32L/acre in a growing season of onion resulted in a minimum EIQ value of field use rating compared to other pesticides (Table 7 & appendix 1.1 ID no. 7). Applying pesticides, which had high environmental load even at relatively lower dose, could increase the impacts both on environment and people. For example, applying profenofos two times and chlorpyrifos once at 0.32L/acre increased the EIQ values (appendix 1.4 ID no. 36). Applying carbosulfan at 0.32L/acre three times during the growing season of onion and two times at 0.48L/acre resulted almost the same EIQ values (Table 7 & appendix 1.2 ID no. 12 &14). Farmer with ID number 15 (Table 7 & appendix 1.2) applied carbosulfan four times during growing season of onion at different rates showed the highest EIQ values for consumers (48.5), workers (40.1), ecological components (736.6) and field use rate (275).

Table 7. Composite EIQ values for individual onion farmer

ID no.	Active ingredient (a.i.)	a.i. quantity	Dose/acre	Application	Consumers	Workers	Ecological	Field Use Rating
7	Lambda-cyhalothrin	50 g/L	0,32L	Premergence	0.1	0.7	3.7	1.5
	Lambda-cyhalothrin	50 g/L	0,32L	Postemergence	0.1	0.7	3.7	1.5
					0.2	1.4	7.4	3
12	Carbosulfan	250 g/L	0.48L	Preemergence	2.1	1.7	32.1	12
	Carbosulfan	250 g/L	0.48L	Postemergence	2.1	1.7	32.1	12
					4.2	3.4	64.2	24
14	Carbosulfan	250 g/L	0.32L	Preemergence	1.4	1.2	21.4	8
	Carbosulfan	250 g/L	0.32L	Postemergence	1.4	1.2	21.4	8
	Carbosulfan	250 g/L	0.32L	Postemergence	1.4	1.2	21.4	8
					4.2	3.6	64.2	24
101	Abamectin	20g/L	800g	Preemergence	11.5	28.6	68.8	36.3
	Mancozeb	800g/kg	800g	Preemergence	0.1	0.5	3	1.2
					11.6	29.1	71.8	37.5
64	Profenofos	720 g/L	0.48L	Preemergence	2.2	5.9	122.3	43.5
	Profenofos	720 g/L	0.48L	Preemergence	2.2	5.9	122.3	43.5
	Profenofos	720 g/L	0.48L	Postemergence	2.2	5.9	122.3	43.5
	Profenofos	720 g/L	0.48L	Postemergence	2.2	5.9	122.3	43.5
					8.8	23.6	489.2	174
15	Carbosulfan	250 g/L	3.2L	Preemergence	14.1	11.7	214.3	80
	Carbosulfan	250 g/L	3.2L	Preemergence	14.1	11.7	214.3	80
	Carbosulfan	250 g/L	3L	Postemergenece	13.2	10.9	200.9	75
	Carbosulfan	250 g/L	1.6L	Postemergenece	7.1	5.8	107.1	40
					48.5	40.1	736.6	275

Tomato producing farmers used different pesticides with various combinations and doses. The index values of field use rating rages from 2.1 to 419.4. Composite values of EIQ indicate the impacts of pesticides on consumers, workers and ecological resources. The lowest composite EIQ value was observed among farmers who applied abamectin pesticide alone or in combination with others. The farmers who applied abamectin once in the growing season of tomato, showed very low EIQ value (appendix 2.2 ID no. 75, 76, 86 &95). On the contrary, applying mancozeb and chlorpyrifos at frequency of two and once respectively in a growing season of tomato showed high composite value of EIQ (appendix 2.6 ID no. 99). Combined use of pesticide at relatively high dose per acre indicated high EIQ value. For example, applying chlorpyrifos at pre emergence, mancozeb and endosulfan during post emergence of tomato at (3000g/acre) increased the composite value of EIQ so high (appendix 2.9 ID no. 113). Furthermore, use of profenofos and mancozeb at the same time to control insects and fungi was the most dangerous practice of pesticide application. For example, farmer whose ID number 118 (Table 8) sprayed both profenofos and mancozeb before and after emergence of tomato at 1500g/acre dose resulted in the highest composite value of EIQ. Applying lambda-cyhalothrin at the rate of 0.6L/acre with two frequencies during tomato production showed lower EIQ values (Table 8; appendix 2.3 ID no.79). Endosulfan contributed greater EIQ value in tomato production applied once and twice (appendix 2.7 no.97 &105).

Table 8. Composite EIQ values for individual tomato farmer

ID no.	Active ingredient (a.i.)	a.i. quantity	Dose/acre	Application	Consumers	Workers	Ecological	Field Use Rating
86	Abamectin	20 g/L	0.3L	Preemergence	0	0.2	1.1	0.4
	Abamectin	20 g/L	0.3L	Postemergence	0	0.2	1.1	0.4
					0	0.4	2.2	0.8
75	Abamectin	18g/L	1500g	Presowing	0.2	0.8	5.1	2.1
76	Abamectin	20 g/L	1500g	Preemergence	0.3	0.9	5.7	2.3
79	Lambdacyhalothrin	50 g/L	0.6L	Preemergence	0.2	1.3	6.9	2.8
	Lambdacyhalothrin	50 g/L	0.6L	Postemergence	0.2	1.3	6.9	2.8
					0.4	2.6	13.8	5.6
104	Mancozeb	640 g/kg	1500g	Preemergence	17.2	42.9	103.3	54.4
	Metalaxyl	80 g/kg	1500g	Preemergence	3.2	2.1	9.8	5
	Abamectin	18 g/L	1500g	Preemergence	0.2	0.8	5.1	2.1
	Abamectin	18 g/L	1500g	Postemergence	0.2	0.8	5.1	2.1
					20.8	46.6	123.3	63.6
89	Abamectin	20 g/L	0.3L	Preemergence	0	0.2	1.1	0.4
	Mancozeb	800 g/kg	1.5L	Postemergence	20.6	51.4	123.7	65.2
	Chlorpyrifos	480 g/L	1.5L	Postemergence	3	9.1	110.4	40.9
	Chlorpyrifos	480 g/L	0.6L	Postharvest	1.2	3.7	44.2	16.3
	Endosulfan	35%	0.6L	Postharvest	2.4	12	36.9	17.1
					27.2	76.4	316.3	139.9
118	Mancozeb	800 g/kg	1500g	Postemergence	21.5	53.6	129.1	68
	Profenofos	720 g/L	1500g	Postemergence	7.3	19.3	398.7	141.7
	Mancozeb	800 g/kg	1500g	Preemergence	21.5	53.6	129.1	68
	Profenofos	720 g/L	1500g	Preemergence	7.3	19.3	398,7	141.7
					57.6	145.8	1055.6	419.4

4. Discussion

The discussion part includes farmers' biographic background, knowledge about pesticide handling and risks, safety precaution and farmers' health, pesticide residues in onion and tomato. In the last part, we will discuss about the types of pesticides used and their impacts on consumers, farmworkers and environmental components.

The literacy level of female and male famers is different in Arumeru and Karatu Districts of Tanzania. Female farmworkers have less literacy level than male farmworkers. Among survey participants, 26 % are female farmworkers who attended primary school. More than 34% of male farmworkers have completed secondary school. Illiteracy level of the farmworkers may be one of the contributing factors for the high environment load of pesticides in the Arumeru and Karatu Districts of Northern Tanzania. However, some researchers argued that having knowledge about pesticides and their impacts on peoples´ health might not adequately avert poisoning problem of pesticides (Brisbois, 2016; Galt, 2013).

There is a difference in family size and farm size among survey participants. The member of a household ranges 1-10 persons. The size of the farms is not proportional to the family size of a household. The larger the family size the lower the farm size per person. For instance, a household of nine people has three quarter of an acre while a household of four members has four acres that is 0.083-acre/person and 1acre/ person, respectively.

Farmers in Arumeru and Karatu Districts in Northern part of Tanzania produce vegetables, onion, and tomato and cereal crops besides animal husbandry. In Arumeru Districts, farmers produces vegetables and coffee in addition to other crops (Lekei et al., 2014a). Producers prevent and control pests during growing season of onion and tomato using different types of pesticides at different frequency without considering their negative impacts on environments and health of workers and consumers. The frequencies of pesticide application in the area ranges from one to six times during growing and harvesting season. The study of Ngowi et al. (2007) showed that farmers used pesticides frequently during growing period of vegetables without considering their negative impacts on environments and health of workers and consumers. Accordingly, more than 50% of the farmers applied about five times during the growing season based on types of crops they produce (Ngowi et al. (2007). Most farmers applied pesticides to control pests in onion and tomato production every week or every two weeks using manual knapsack sprayers and similar application frequency and technique were reported in Zimbabwe (Sibanda, Dobson, Cooper, Manyangarirwa, & Chiimba, 2000). Men and boys involved in spraying duties while women and children engaged in weeding practices.

Safe pesticides application techniques and equipment were lacking in Arumeru and Karatu Districts of Tanzania (figure 8). Majority of farmers didn´t use equipment to protect their eyes, body, hand, head and foot from pesticide contacts. Very few farmers used gloves, masks or goggles in Tanzania. In Zimbabwe, according to study conducted by Sibanda et al. in (2000), almost no farmer or worker used such protective equipment during spraying, mixing and preparing pesticides. Exposure to pesticides can be intensified by frequency, duration and unsafe method of application and lack of protective equipment during spray and preparation(García-García et al., 2016)**.** The earlier study conducted in Northern parts of Tanzania showed that vegetable producing farmers had limited knowledge about the kind of pesticides they use, and they were not informed about safety precaution techniques and tools (Lekei et al., 2014a; Ngowi et al., 2007). Almost all farmworkers said that they had experienced headache, burning sensation of skin, eyes and weakness after application of pesticides. The eyes of the worker who applied pesticides dropped tears during and after application of pesticides. Besides, almost all farmers, workers experienced skin itching, irritation, chest pain and dizziness after spraying. Furthermore, some farmers, workers had experienced vomiting and diarrhea after spraying pesticides.

Lack of information about the toxic effect of pesticides, lack of protective tools, and limited knowledge about the use and handling of pesticides were mentioned as a main factor for the aforementioned sicknesses. Growers also have their own reason for not using the protective tools. For example, some farmers in Costa Rica believed that use of protective tools during spraying consumes time of spray. Hence, workers and farmers risked their health by avoiding safety tools in order to save spray times(Brisbois, 2016). Despite having quite good knowledge about the danger of pesticide, some workers and farmers in both developing and developed countries don´t use protective tools and measures during spraying and mixing (Brisbois, 2016; Galt, 2013). Farmers relied on their own experience in choosing types of pesticides and application techniques (Ngowi, 2003). The use of protective tools by workers and farmers are shaped by information, individual worker and farmer, political economy, cultural and climate constraints (Brisbois, 2016; Galt, 2013). The other reason for limited or lack of protective tools during spraying and mixing in developing countries is lack of information, non-inclusive pesticide promotion, and environmental constraints. For example, unfavorable climate conditions, hot and humid particularly in tropical countries like that of Tanzania makes use of protective tools unbearable (Galt, 2013). Besides, lack of information about pesticide choice led farmers to believe that use of different types of pesticides better control pests. But proper knowledge and information about the fate of pesticide residues in crop production is also important to assess their impact and support to make choice (Randhawa et al., 2007). The safety of workers, consumers and ecological components can be improved if information and knowledge about pesticide choice, safe pesticide storage, application techniques introduced into small-scale vegetable farming communities in developing countries like Zimbabwe and Tanzania (Sibanda et al., 2000). In addition to introducing benign pesticide choosing knowledge and safe application techniques, promoting integrated pest control and prevention strategy can be an effective approach to reduce pesticide load on the health of people. For example, combing cultural, biological and rational pesticides use to prevent and control pests in vegetable and other crop production (Eklo, Henriksen, & Rafoss, 2003; Rodríguez & Niemeyer, 2005).

Farmers and workers in Arumeru and Karatu Districts were not informed well about the impact of storing pesticides in their living houses. The majority of the farmers (81%) in Arumeru District, according to the study of Lekei et al. (2014a), store pesticides and equipment used to spray at living home. But keeping pesticides and used containers at home led to acute and chronic health effects(Ngowi, 2003). Farmer’s didn´t benefited from the knowledge they had about pesticide practice to safe guard themselves using safety measures. Hence, knowledge about pesticides and safety measures didn´t relate in Tanzania. Long term and extensive application of pesticides by farmers and workers creates potential hazards to their health, consumers and to ecological resources(García-García et al., 2016)**.**

Pesticide risk is the quotient of hazard and exposure. According to the European Predictive Operator Model (EUROEM), to calculate internal exposure of farmers and workers to pesticide, it was used formulation type, application equipment type, treated area (crop type and size of farm), dose, active ingredient quantity, protective equipment during operation, percent absorbed during preparation and application of pesticides, body weight of applicators as determining factors(Vercruysse & Steurbaut, 2002). The risk indicator for farmers is the quotient of internal exposure and acceptable farmers exposure level(Vercruysse & Steurbaut, 2002). Farmers and workers expose to pesticides by greater magnitude due to their occupation's duty. They expose to different chemical pesticides mainly during mixing, loading, carrying, spraying, washing equipment (García-García et al., 2016). Farmers expose to pesticides not only during spraying, mixing and handling but also during harvesting and postharvest processing. Pesticide residues remain on the outer part of sprayed crops and during harvesting and processing farmers get contacts with foliage of the crops. Particularly, farmers who harvest and process without necessary protective equipment, dermal exposure during repeated contacts, could be the likely exposure route. Hence, as the application rate of pesticides and the degree of contacts increase, exposure also increases. Consequently, as exposure increases, the risks of pesticides also rises(Vercruysse & Steurbaut, 2002). Inhalation of pesticide drifts during spraying through dermal and oral openings were common in the area. Besides, health personnel in the Northern part of Tanzania were not trained well to diagnose symptoms related to pesticides exposure (Ngowi et al., 2001). Agricultural extension services that supposed to increase knowledge of farmers about pesticides were limited in the area. Rather extension services had focused only on boosting use of pesticides to easily control pests in crops without emphasizing the negative impacts of pesticides use on environment and health of workers and consumers(Ngowi et al., 2007). As a result, small-scale farmers in Tanzania became more vulnerable to pesticide poisoning. Acute pesticide poisoning has become a common health problems in the pesticides using farmers(Lekei et al., 2014b). The study of Ngowi et al. (2007) showed that 68% of the farmers in the study area had felt sick after routinely applying pesticide using manual spray technique. But the health treatment facilities for the farmworkers before, during and after application of pesticides was very limited in the districts(Ngowi et al., 2001).

Misuse of pesticides to control pest poisons health of workers and farmers and the environment (Brisbois, 2016; Galt, 2013; García-García et al., 2016; Sinha, Vasudev, & Rao, 2012). Therefore, reforming safe pesticides use policy and improving diagnosis facilities for pesticide users was suggested(Ngowi et al., 2007). Safe use of pesticides is the decision and responsibility of individual farmer and worker(Galt, 2013). This is because, exposure of farmworkers to pesticides with high concentration can lead to cancer, birth defects, miscarriages, endocrine system malfunction that govern sexual and mental development. It can further suppress human immune system(Galt, 2013). For example, unsafe use of pesticides in Costa Rica led to stomach cancer and killed those were highly exposed family members and workers who didn´t use protective tools during mixing and spraying(Galt, 2013). Pesticides can be applied using different methods, treating seed, applying in granule forms, pouring pesticides on a plant, and spraying. Farmers should choose the method that can have minimum impact on their health and environment(Vercruysse & Steurbaut, 2002). But, exposure of farmers applying pesticides using seed treatment, granules, and pouring to a plant considered minimum due to limited pesticides residue remain on crops. In developing countries like Tanzania, exposure to aquatic organisms may increase, because farmers wash pesticides in the surrounding water bodies after spraying. However, it is possible to reduce aquatic organisms' exposure to pesticides by avoiding washing pesticides equipment in water bodies. Producing crops like vegetables in greenhouse, pesticide application using seed treatment, granules and dipping plants into pesticides can reduce aquatic organisms exposure to pesticide poisoning(Vercruysse & Steurbaut, 2002). Though seed treatment, using granules and dipping a plant into pesticides can increase impacts on soil organisms it can decrease impacts on bees, birds, workers and aquatic organisms(Vercruysse & Steurbaut, 2002). In the Northern parts of Tanzania, farmers use more of insecticides due to the high prevalence of insects in both onion and tomato. Study in Cameroon also showed that farmers used more insecticides in vegetable production than herbicides and fungicides(Matthews, Wiles, & Baleguel, 2003). The second and third most used pesticides in Arumeru and Karatu District are fungicides and herbicides respectively. The earlier study of Ngowi et al. (2007) also reported similar results. In onion production, the farmers used less herbicide than that of tomato farmers. This is because the household members of each farmers particularly women and children weed in the field of onion instead of using herbicides (Ngowi et al., 2007). Farmers in Zimbabwe also used manual weeding as to control weeds in vegetable production(Sibanda et al., 2000).

Farmers use some fungicides dominantly compared to others. For example, they use mainly mancozeb fungicide. However, long term use of mancozeb fungicide, can risk farmworkers to the development of cancers (EXTOXNET, 1993; Ngowi et al., 2007; Novikova, Litvinenko, Boikova, Yaroshenko, & Kalko, 2003). Besides, it has a potential to cause goiter, birth defects in humans and cancer in animals (EXTOXNET, 1993). The major route whereby workers can expose themselves to mancozeb is through skin openings and inhalation. However, it has low short toxicity on mammals. Even though, mancozeb can cause goiter, birth defects and cancer in animals. Its breakdown product can cause cancer in humans(Blasco, Font, & Picó, 2004). It is slightly toxic to birds but toxic to fish. It is highly toxic to warm water fishes. Mancozeb is harmful to wildlife but not to honey bees. It is unstable in biological system, in the presence of oxygen, moisture and under cooking vegetables. Its rapid degradation behaviors lowers the impacts on the environment compared to profenofos (EXTOXNET, 1993; López-Fernández et al., 2015). Insecticides like carbofuran is risky and can cause acute health effects. However, farmers in the study area accepted illness caused by pesticides exposure as a normal phenomena and very few farmers visited health centers(Ngowi et al., 2007). Some farmers in Northern Tanzania and Zimbabwe apply Endosulfan, the most persistent pesticides in soil and bio-organisms and it was banned in European countries(Sibanda et al., 2000). Farmers also use insecticide abamectin in the area. Abamectin is highly toxic to aquatic organisms and bees. Nevertheless it doesn´t accumulate or persist in fish. Rapid degrading behavior of the insecticide reduces negative impacts on bees. It is relatively non-toxic to birds and doesn´t easily absorbed into human skin. Using abamectin as insecticide has an advantage for farmers who spray it without protective equipment because it doesn't easily be absorbed into human skin (EXTOXNET, 1994). It has also low toxicity to non-target beneficial arthropods. Relative to other pesticides, abamectin considered to be safe to people and environment. It degrades easily on plant surfaces when exposed to light. Soil microorganisms in the soil also easily degrade abamectin (Lasota & Dybas, 1990).

Pesticides remain as residue in the vegetables due to their non-biodegradability nature when exposed to light and microorganisms. For example, pesticides, like chlorpyrifos, cypermethrin, endosulfan, and lambda-cyhalothrin remain in the vegetables as residues. High concentration of residues in the food can risk the health of consumers(Sæthre et al., 2013). Besides, frequent use of pesticides in creates resistant insects. Further more, presence of pesticides residues in crop products limited export quantity and foreign earnings(Rodríguez & Niemeyer, 2005). Hence, the amount of residue should be lower than maximum residue limit (MRL). In order to get minimum amount of pesticides residue in the vegetable food, farmers or producers need to focus on pesticides that can easily degrade by sunlight and microbial organisms in the soil. For example, abamectin, according to the value of EIQ and sample analyzed for onion and tomato had the lowest impact on consumers due to its degradability nature. Abamectin is safe to people and environment relative to other pesticides due to its low toxicity(Lasota & Dybas, 1990). On the contrary, profenofos doesn´t degrade easily on expose to light and soil microorganisms. Although it metabolizes rapidly in alkaline condition(NCBI, 2015). Profenofos is one of the organophosphrus insecticides used to control insects in vegetables and fruits. During heating of profenofos, it emits toxic substances, sulfur oxide, phosphorus oxide, hydrogen bromide and chloride. It may be fatal if it is swallowed or absorbed through skin. Thus, workers need to avoid skin contact. It is non-carcinogenic to humans. Nevertheless, causes nausea, dizziness, confusion and at high rate of exposure resulted in respiratory paralysis and death. It is risky to fish and can kill them on a larger scale (Abassa, Reponena, Jalonenb, & Pelkonena, 2007; NCBI, 2015). The kind of pesticides, amount applied, and frequency of application, mode of action and chemical properties of pesticides determines the amount residues in our food. If the amount of pesticides residue in our food commodity is higher than that of MRLs, it can affect the health of consumers negatively(Sæthre et al., 2013). In Northern Tanzania, 11 pesticides residues out of 13 residues in onion production were above the MRLs. For tomato, out of 24 residues only three were above MRLs. Farmers apply higher insecticides than fungicides at post emergence of tomato seedlings. Among detected pesticides residues in tomato samples, about 17% and 83% of them were fungicides and insecticides respectively.

Pesticide residue in individual sample of tomato was more than that of onion (Tables 1 &2). The pesticide residue in onion samples, which surpassed by far beyond the MRLs (0.002mg/kg) level, was carbofuran (0.48mg/kg). The amount of labda-cyhalothrin (0.014mg/kg) was minimal compared to MRLs (0.1mg/kg). Carbofuran dominates residues in the onion samples It may affect the health of onion consumers more than other pesticides due to its quantity. According the study in Benin, West Africa, pesticides residue in the vegetables above analytical Limit of Quantification (LOQ) were 22% out of 92 samples (Sæthre et al., 2013). The residue of profenofos in different vegetable samples collected 1987-1989 in Thailand was 0.11mg/kg. The study conducted Egypt in 1995 revealed that profenofos residue in tomato samples ranged from 0.04-2mg/kg (Thapinta & Hudak, 2000). Workers expose to profenofos through dermal contact during spraying and preparation. The Codex maximum residue limit of profenofos for different crop samples ranged from 0.05 to 2mg/kg. The residue of profenofos in tomato samples from Egypt was higher in tomato than in other vegetables (Radwan, Abu-Elamayem, Shiboob, & Abdel-Aal, 2005). The study in Pakistan by Randhawa et al. (2007), showed that chlorpyrifos residue exceeded MRL value on vegetables collected from farmers field. The research carried out in Thailand on 117 samples of Chinese kale reported that 29% of analyzed pesticides residues were greater than MRLs values. Chinese kale widely consumed by Asia countries (Wanwimolruk, Kanchanamayoon, Kamonrat, & Prachayasittikul, 2015). However, washing and other post harvest processing of vegetables can reduce the amount of profenofos residue in vegetables. For instance, frying of vegetables reduced 98% of profenofos contents in vegetables. Washing using soap and acetic acid solutions removed 100% of profenofos residue in vegetables (Radwan et al., 2005). Washing by running water reduced the profenofos residues in Chinese kale by 55% (Wanwimolruk et al., 2015). Further, washing by clean water reduced chlopyrifos residues by 30% in spinach, 30% in potato, and 25% in cauliflower and 10% in tomato (Randhawa et al., 2007).

Farmers use different pesticides in onion production. The insecticides used were abamectin, carbonsulfan, chlorpyrifos, lambda-cyhalothrin and profenofos. The majority of the farmers use carbosulfan and profenofos to control insects in onion crop. To control weeds, farmers apply oxyfluorfen. To control fungi they apply mancozeb as fungicide during onion production. Tomato production in Northern Tanzania came out with higher EIQ values than that of onion production due to intensive and diverse use of pesticides in the former than the later. The study of Eklo et al. (2003) in Vietnam also indicated that tomato production resulted in highest EIQ load on the environment while cabbage production came out as the lowest EIQ. Lack of enough information and limited knowledge about malignant and benign pesticides in Arumeru and Karatu Districts caused farmers to choose pesticides that have high load on environment and health of farmworkers and consumers. Farmers considered pre sowing and pre emergence application of pesticides as relatively safe to the environment and consumers.

Mancozeb and profenofos pesticide have the highest EIQ values compared to other pesticides. Abamectin and lambda-cyhalothrin have lower EIQ values for consumer, environmental components and workers. The study of Lekei et al. (2014a) indicated that the most dangerous active ingredients ranked with their poisoning ability were mancozeb, profenofos, chlorpyrifos and endosulfan (Lekei et al., 2014a). Similar dose for mancozeb and metalaxyl (150g/acre) resulted in different impact on environment. Mancozeb had more than six times load on the health of people and environment than metalaxyl (Table 3). This could be due to higher quantity of active ingredient in mancozeb (640g/kg) than metalaxyl (80g/kg). Based on ranking pesticides, mancozeb had highest EIQ value for consumers and workers. Accounting for highest EIQ index, profeneofos could have higher impact on ecological components than other pesticides due to its highest EIQ value. Profenofos, application rate (1500g/acre) affected environmental resources like birds, fishes, bees and more than chlorpyrifos; even though chlorpyrifos applied at double rate (3000g/acre). Abamectin had the lowest EIQ load on ecological resources, and worker. It showed zero EIQ value on the consumer of tomato at the rate of 0.3L/acre (Table 3). Next to mancozeb, endosulfan has higher load on workers more than other pesticides applied at the rate of 0.6L/acre. Endosulfan can be risky to consumer and farmworkers of tomato than carbosulfan applied at the rate of 0.75L/acre based on EIQ values (Table 3). Carbosulfan, inseticide showed more impact on ecological resources than herbicide, oxyfluorfen as per EIQ value; although they indicate comparatively equivalent impact on worker and consumers according to EIQ values (Table 5). Mancozeb and endosulfan have higher impact on worker and applicators than other pesticides applied in tomato (Table 6). Comparing the environmental loads of granular profenofos applied at 800g/acre with liquid formulation carbosulfan applied at 3.2L/acre was almost similar (Table 3). Carbosulfan has higher load on consumers than chlorpyrifos at same rate of application (0.48L/acre) as per EIQ values.

Majority of the farmers used mancozeb and profenofos in combination with other pesticides. Combined use of abamectin with mancozeb to control insects and fungi had reduced the composite EIQ values; indicating reduced impacts on consumers and workers (Table 7 ID no.101). Similarly, combined use of abamectin and profenofos to control insects had reduced the loads on workers and consumers than applying Profenofos two times (Table 7, ID no. 118). Repeated spray of insecticide for example carbosulfan, three times during growing season of onion at the rate of 1.6L/acre increased the composite EIQ value, implying increased impact on the ecological resources, consumers and workers (Table 7 & appendix 1 ID no.2). The onion-producing farmer applied profenofos at the rate of (0.48L/acre) with frequency of four within a growing season (appendix 1.8 ID no.64). The presence of profenofos insecticide in combination with others increased EIQ values on ecological resources (Tables 6, 7 &8). Some authors claimed that combined use of two or more pesticides could cause more impact on ecological components (Jeyaratnam, 1985; Omari, 2014; Sibanda et al., 2000). Application practice of mixed pesticides formulation also increases the risk of poisoning among farmworkers by the highest level in developing countries(Jeyaratnam, 1985). Furthermore, wrong application time, rate, and lack of safety precaution techniques and equipment expose both aquatic and terrestrial ecology to a greater risk (Omari, 2014). Therefore, it important to implement pesticide-monitoring policy, improving health facilities related to pesticide poisoning, providing farmers and workers with timely information, devising ways to minimize exposure of workers and farmers could better handle pesticide problems (Brisbois, 2016).

5. Conclusion

Farming is the main livelihood for farmers in Northern parts of Tanzania. The majority of the farmers engaged in vegetable production. They produce onion and tomato both for local market and consumption. Pesticide use is one of economically important pest control options in the study area. However, all surveyed farmers agree that use of pesticides with limited or without safety precautions increases exposure risk. Lack of safe pesticide application techniques and tools risk health of farmers. Most of the farmers experience headache, burning sensation of skin, eyes, and chest pain, dizziness and weak body strength.

In the analyzed samples of onion and tomato, various types of pesticides residues detected. The majority of carbofuran, residue in the onion is greater than that of EU MRLs levels. Chlorpyrifos and lambda-cyhalothrin are the maximum and minimum quantities of pesticides residues in onion samples respectively. In tomato samples, the maximum and minimum residues amounts are profenofos and endosulfan sulfat respectively.

Most of the farmers in Northern Tanzania use pesticides that have high impact on the health of workers, consumers and environment. Both profenofos and mancozeb have the highest EIQ values while abamectin has the lowest EIQ value. Mancozeb shows the highest load on onion and tomato consumers. Profenofos has the highest load on environment components. Endosulfan is the highest consumers EIQ value next to mancozeb. Farmers and workers of onion and tomato should avoid the combined use of dangerous pesticides, profenofos and mancozeb to protect pests. Instead, it is preferable to combine mancozeb and profenofos pesticide with abamectin or avoid using them in order to minimize their impacts on health of consumers, worker, and environmental resources. Abamectin is one of the insecticides that have the lowest impact on environment, consumers, and workers.

In general, safety precaution techniques and equipment are lacking with the farmworkers of onion and tomato in Northern part of Tanzania. To improve safety of workers, consumers and ecological components, providing information and knowledge about pesticide choice, implementing safe pesticide storage and disposal, introducing safe technique of application and protective equipment are important. Onion and tomato producers strongly disagree with the notion of limiting the use of pesticides in crop production. Thus, the viable option to minimize the impacts of pesticides on the health of farmers, consumers and the environment is to use pesticides selectively.

Increasing the level of education particularly for female farmers and raising the awareness about pesticide impacts is recommended. Furthermore, introducing post harvest vegetable processing techniques to remove pesticide residues in consumable part of vegetable is advisable. Pesticide monitoring and control polices in the farming communities in Tanzania can also reduce long-term impact of pesticides on health of people and environmental components. Moreover, investing on public health services and environmental friendly pest control methods could be a policy option for Tanzanians.

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7. Appendices

Appendix 1. Composite EIQ for onion farmers

Id nr.	Trade name	Active ingridient	A.i quan.	Pesti. Cat.	Dose/acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
2	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1.6L	Preemergence	47.3	7.1	5.8	107.1	40
2	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1.6L	Preemergence	47.3	7.1	5.8	107.1	40
2	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1.6L	Postemergenece	47.3	7.1	5.8	107.1	40
Total (2)								21.3	17.4	321.3	120
3	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Preemergence	47.3	2.1	1.7	32.1	12
3	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1.6L	Preemergence	47.3	7.1	5.8	107.1	40
3	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1.6L	Postemergenece	47.3	7.1	5.8	107.1	40
Total (3)								16.3	13.3	246.3	92
Total (4)	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1L	Presowing	47.3	4.4	3.6	67	25
5	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Preemergence	47.3	1.4	1.2	21.4	8
5	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Postemergenece	47.3	1.4	1.2	21.4	8
Total (5)								2.8	2.4	42.8	16
Total(6)	Marshal 250	Carbosulfan	250 g/L	Insecticide	0.32L	Postemergenece	47.3	1.4	1.2	21.4	8

Appendix 1.1. Composite EIQ for onion farmers

Id nr.	Trade name	Active ingredient	A.i quan.	Pesti. Cat.	Dose/acre	Application	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
7	Karate 5EC	Lambdacyhalothrin	50 g/L	Insecticide	0,32L	Preemergence	44,2	0.1	0.7	3.7	1.5
7	Karate 5EC	Lambdacyhalothrin	50 g/L	Insecticide	0.32L	Postemergenece	44,2	0.1	0.7	3.7	1.5
Total (7)								0.2	1.4	7.4	3
8	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1L	Preemergence	47.3	4.4	3.6	67	25
8	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (8)								6.5	5.3	99.1	37
9	Galigan 240 EC	Oxyfluorfen	240 g/L	Herbicide	0.48L	Preemergence	33.8	1.7	2.9	20.1	8.2
9	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
9	Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
Total (9)								6	10.5	174.5	63.7
10	Galigan 240 EC and Oxyfen 240 EC	Oxyfluorfen	240 g/L	Herbicide	1.6L	Preemergence	33.8	5.7	9.7	66.9	27.4
10	Galigan 240 EC and Oxyfen 240 EC	Oxyfluorfen	240 g/L	Herbicide	1.6L	Preemergence	33.8	5.7	9.7	66.9	27.4
10	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (10)								13.5	21.1	165.9	66.8

Ref.= Reference; Con.=Consumers; Wor.=workers; F.U.EIQ= Field Use EIQ

Appendix 1.2. Composite EIQ for onion farmers

Id nr.	Trade name	Active ingridient	A.i quan.	Pesti. Cat.	Dose/ acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
11	Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.64L	Preemergence	59.5	3	7.9	163.1	58
11	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
11	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total(11)								7.2	11.3	227.3	82
12	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Preemergence	47.3	2.1	1.7	32.1	12
12	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (12)								4.2	3.4	64.2	24
14	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Preemergence	47.3	1.4	1.2	21.4	8
14	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Postemergenece	47.3	1.4	1.2	21.4	8
14	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Postemergenece	47.3	1.4	1.2	21.4	8
Total(14)								4.2	3.6	64.2	24
15	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	3.2L	Preemergence	47.3	14.1	11.7	214.3	80
15	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	3.2L	Preemergence	47.3	14.1	11.7	214.3	80
15	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	3L	Postemergenece	47.3	13.2	10.9	200.9	75
15	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1.6L	Postemergenece	47.3	7.1	5.8	107.1	40
Total(15)								48.5	40.1	736.6	275
20	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Preemergence	47.3	1.4	1.2	21.4	8
20	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.4L	Postemergenece	47.3	1.8	1.5	26.8	10
Total (20)								3.2	2.7	48.2	18

Appendix 1.3. Composite EIQ for onion farmers

Id nr.	Trade name	Active ingridient	A.i quan.	Pesti. Cat.	Dose/ac	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
21	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Preemergence	59.5	1.5	3.9	81.5	29
21	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (21)								3.6	5.6	113.6	41
24	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Preemergence	47.3	1.4	1.2	21.4	8
24	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (24)								3.5	2.9	53.5	20
25	Galigan 240 EC	Oxyfluorfen	240 g/L	Herbicide	0.48L	Preemergence	33.8	1.7	2.9	20.1	8.2
25	Marshal 250 EC	Carbosulfan	250 g/L	300cc/drum	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (25)								3.8	4.6	52.2	20.2
27	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Preemergence	47.3	2.1	1.7	32.1	12
27	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total(27)								4.2	3.4	64.2	24
28	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.40L	Preemergence	47.3	1.8	1.5	26.8	10
28	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Postemergenece	47.3	1.4	1.2	21.4	8
Total(28)								3.2	2.7	48.2	18
29	Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.64L	Preemergence	59.5	3	7.9	163.1	58
29	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Postemergenece	26.9	1	2.9	35.3	13.1
Total(29)								4	10.8	198.4	71.1

Appendix 1.4. Composite EIQ for onion farmers

Id nr.	Trade name	Active ingredient	A.i qu.	Pesti. Cat.	Dose/ac	Application	Ref. EIQ	Con.	Worke	Eco.	F.U. EIQ
30	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1.6L	Preemergence	47.3	7.1	5.8	107.1	40
30	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1.6L	Postemergenece	47.3	7.1	5.8	107.1	40
Total (30)								14.2	11.6	214.2	80
Total (31)	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
33	Galigan 240 EC	Oxyfluorfen	240 g/L	Herbicide	0.48L	Preemergence	33.8	1.7	2.9	20.1	8.2
33	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
33	Profecron 720 EC	Profenofos	720 g/L	300cc/drum	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
Total (33)								6	10.5	174.5	63.7
34	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Preemergence	47.3	2.1	1.7	32.1	12
34	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
34	Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
Total (34)								6.4	9.3	186.5	67.5
35	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.8L	Preemergence	47.3	3.5	2.9	53.6	20
35	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.8L	Postemergenece	47.3	3.5	2.9	53.6	20
Total (35)								7	5.8	107.2	40
36	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Preemergence	59.5	1.5	3.9	81.5	29
36	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.32L	Preemergence	26.9	0.6	1.9	23.6	8.7
36	Selecron 720 EC	Profenofos	720 g/l	Insecticide	0.32L	Postemergenece	59.5	1.5	3.9	81.5	29
Total (36)								*3.6*	*9.7*	*186.6*	*66.7*

Appendix 1.5. Composite EIQ for onion farmers

Id nr.	Trade name	Active ingredient	A.i qu.	Pesti. Cat.	Dose/ac	Application	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
37	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Preemergence	26.9	1	2.9	35.1	13.1
37	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
37	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Postemergenece	26.9	1	2.9	35.3	13.1
Total (37)								4.2	11.7	192.7	69.7
Total (38)	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
39	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Preemergence	26.9	1	2.9	35.3	13.1
39	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
39	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Postemergenece	26.9	1	2.9	35.3	13.1
Total (39)								4.1	7.5	102.7	38.2
40	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.4L	Preemergence	59.5	1.9	4.9	101.9	36.2
40	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.4L	Postemergenece	59.5	1.9	4.9	101.9	36.2
Total (40)								3.8	9.8	203.8	72.4
41	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
41	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Preemergence	47.3	2.1	1.7	32.1	12
41	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
41	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (41)								8.6	15.2	308.8	111
42	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
42	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
42	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Postemergenece	26.9	1	2.9	35.3	13.1
Total (42)								5.4	14.7	279.9	100.1

Appendix 1.6. Composite EIQ for onion farmers

Id nr.	Trade name	Active ingredient	A.i qu.	Pesti. Cat.	Dose/ac	Application	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
43	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Preemergence	47.3	2.1	1.7	32.1	12
43	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (43)								4.2	3.4	64.2	24
44	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
44	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Preemergence	26.9	1	2.9	35.3	13.1
44	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.8L	Postemergenece	59.5	3.7	9.9	203.8	72.5
44	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.8L	Postemergenece	26.9	1.6	4.9	58.9	21.8
Total (44)								8.5	23.6	420.3	150.9
45	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Preemergence	47.3	1.4	1.2	21.4	8
45	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.32L	Postemergenece	47.3	1.4	1.2	21.4	8
Total (45)								2.8	2.4	42.8	16
46	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.4L	Preemergence	47.3	0.8	1.5	26.8	10
46	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.4L	Postemergenece	47.3	1.8	1.5	26.8	10
Total (46)								2.6	3	53.6	20
47	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.64L	Preemergence	59.5	3	7.9	163.1	58
47	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.64L	Postemergenece	59.5	3	7.9	163.1	58
Total (47)								6	15.8	326.2	116
48	Selecron 720 EC	Profenofos	720 g/l	Insecticide	0.4l	Preemergence	59.5	1.9	4.9	101.9	36.2
48	Selecron 720 EC	Profenofos	720 g/l	Insecticide	0.4l	Postemergenece	59.5	1.9	4.9	101.9	36.2
Total (48)								3.8	9.8	203.8	72.4

Appendix 1.7. Composite EIQ for onion farmers

Id nr.	Trade name	Active ingredient	A.i qu.	Pesti. Cat.	Dose/ac	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
50	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.8L	Preemergence	59.5	3.7	9.9	203.8	72.5
50	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.8L	Postemergenece	59.5	3.7	9.9	203.8	72.5
Total (50)								7.4	19.8	407.6	145
51	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Preemergence	59.5	1.5	3.9	81.5	29
51	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.56L	Postemergenece	59.5	2.6	6.9	142.7	50.7
Total (51)								4.1	10.8	224.2	79.7
52	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Preemergence	59.5	1.5	3.9	81.5	29
52	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.56L	Postemergenece	59.5	2.6	6.9	142.7	50.7
Total (52)								4.1	10.8	224.2	79.7
53	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Preemergence	59.5	1.5	3.9	81.5	29
53	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.56L	Postemergenece	59.5	2.6	6.9	142.7	50.7
Total (53)								4.1	10.8	224.2	79.7
55	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
55	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
Total (55)								4.4	11.8	244.6	87
Total (56)	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Postemergenece	59.5	1.5	3.9	81.5	29
57	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
57	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
Total (57)								4.4	11.8	244.6	87
58	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.4L	Preemergence	47.3	1.8	1.5	26.8	10
58	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.4L	Postemergenece	47.3	1.8	1.5	26.8	10
Total (58)								3.6	3	53.6	20

Appendix 1.8 Composite EIQ for onion farmers

Id nr.	Trade name	A.I name	A.i qu.	Pesti. Cat.	Dose/ac	Applicaction	Ref.	Con.	Wor.	Eco.	F.U. EIQ
59	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Preemergence	47.3	2.1	1.7	32.1	12
59	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (59)								4.2	3.4	64.2	24
Total (61)	Galigan 240 EC	Oxyfluorfen	240 g/L	Herbicide	0.48L	Preemergence	33.8	1.7	2.9	20.1	8,2
62	Selecron 720 EC) and Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Postemergenece	59.5	1.5	3.9	81.5	29
62	Selecron 720 EC) and Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Postemergenece	59.5	1.5	3.9	81.5	29
62	Selecron 720 EC and Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Preemergence	59.5	1.5	3.9	81.5	29
62	Selecron 720 EC and Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.32L	Preemergence	59.5	1.5	3.9	81.5	29
Total (62)								6	15.6	326	116
63	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Preemergence	47.3	2.1	1.7	32.1	12
63	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.48L	Postemergenece	47.3	2.1	1.7	32.1	12
Total (63)								4.2	3.4	64.2	24
64	Selecron 720 EC and Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
64	Selecron 720 EC and Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
64	Selecron 720 EC and Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
64	Selecron 720 EC and Profecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59,5	2.2	5.9	122.3	43.5
Total (64)								8.8	23.6	489.2	174

Appendix 1.9. Composite EIQ for onion farmers

Id nr.	Trade name	A.I name	A.i qu.	Pesti. Cat.	Dose/ acre	Applicaction	Ref.	Con.	Wor.	Eco.	F.U. EIQ
65	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Preemergence	59.5	2.2	5.9	122.3	43.5
65	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Preemergence	26.9	1	2.9	35.3	13.1
65	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.48L	Postemergenece	59.5	2.2	5.9	122.3	43.5
65	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.48L	Postemergenece	26.9	1	2.9	35.3	13.1
Total (65)								6.4	17.6	315.2	113.2
89	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.24L	Preemergence	59.5	1.1	3	61.2	21.7
89	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.8L	Postemergenece	59.5	3.7	9.9	203.8	72.5
89	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.8L	Postharvest	59.5	3.7	9.9	203.8	72.5
Total (89)								8.5	22.8	468.8	166.7
100	Tanzacrone 72E	Profenofos	720 g/L	Insecticide	800g	Preemergence	59.5	3.9	10.3	212.6	75.6
100	Oshotane 80 WP	Mancozeb	800 g/kg	Fungicide	800g	Preemergence	25.7	11.5	28.6	68.8	36.3
Total (100)								15.4	38.9	281.4	111.9
101	Milthane Super	Mancozeb	800 g/kg	Fungicide	800g	Preemergence	25.7	11.5	28.6	68.8	36.3
101	Abamectin	abamectin	20 g/L	Insecticide	800g	Preemergence	34.7	0.1	0.5	3	1.2
Total (101)								11.6	29.1	71.8	37.5
118	Mocron	Profenofos	720 g/L	Insecticide	0.8L	Preemergence	59.5	3.7	9.9	203.8	72.5
118	Balton Abamectin	Abamectin	18 g/L	Insecticide	0.8L	Preemergence	34.7	0.1	0.4	2.6	1.1
Total (118)								3.8	10.3	206.4	73.6

Appendix 2: Composite EIQ for tomato farmers

Id nr.	Trade name	Active ingridient	A.i quan.	Pesti. Cat.	Dose/acre	Application	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
23	Galigan 240 EC	Oxyfluorfen	240 g/L	Herbicide	3L	Preemergence	33.8	10.7	18.3	125.5	51.5
23	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	1L	Postemergence	47.3	4.4	3.6	67	25
Total (23)								15.1	21.9	192.5	76.5
26	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.6L	Postemergence	47.3	2.6	2.2	40.2	15
26	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.6L	Preemergence	47.3	2.6	2.2	40.2	15
Total 1	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.6L	Preemergence	47.3	5.2	4.4	80.4	30
26	Duduba 450 EC	Cypermethrin	10%	Insecticide	0.6L	Preemergence	36.4	0.7	1.7	11.3	4.6
26	Duduba 450 EC	Chlorpyrifos	35%	Insecticide	0.6L	Preemergence	26.9	0.9	2.7	32.2	11.9
Total (26)								6.8	8.8	123.9	46.5
28	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.9L	Preemergence	47.3	4	3.3	60.3	22.5
28	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	0.75L	Presowing	47.3	3.3	2.7	50.2	18.8
Total (28)								7.3	6	110.5	41.3

Appendix 2.1. Composite EIQ for tomato farmers

Id nr.	Trade name	Active ingridient	A.i quan.	Pesti. Cat.	Dose/acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
Total (29)	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.6L	Preemergence	26.9	1.2	3.7	44.2	16.3
30	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	3L	Preemergence	47.3	13.2	10.9	200.9	75
30	Marshal 250 EC	Carbosulfan	250 g/L	Insecticide	3L	Postemergence	47.3	13.2	10.9	200.9	75
Total (30)								26.4	21.8	401.8	150
65	Ninja 5EC	Lambdacyhalothrin	50 g/L	Insecticide	0.6L	Postemergence	44.2	0.2	1.3	6.9	2.8
65	Duduba 450 EC	Cypermethrin	10%	Insecticide	0.6L	Postemergence	36.4	0.7	1.7	11.3	4.6
65	Duduba 450 EC	Chlorpyrifos	35%	Insecticide	0.6L	Postemergence	26.9	0.9	2.7	32.2	11.9
65	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
Total (65)								23.3	59.3	179.5	87.3
Total (66)	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.3L	Preemergence	25.7	4.1	10.3	24.7	13
67	Twigafhos 48EC	Chlorpyrifos	480 g/L	Insecticide	0.9L	Preemergence	26.9	1.8	5.5	66.2	24.5
67	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.15L	Postemergence	25.7	2.1	5.1	12.4	6.5
67	Twigafhos 48EC	Chlorpyrifos	480 g/L	Insecticide	0.09L	Postemergence	26.9	0.2	0.5	6.6	2.5
67	Twigafhos 48EC	Chlorpyrifos	480 g/L	Insecticide	0.9L	Postemergence	26.9	1.8	5.5	66.2	24.5
Total (67)								5.9	16.6	151.4	58

Appendix 2.2. Composite EIQ for tomato farmers

Id nr.	Trade name	Active ingridient	A.i quan.	Pesti. Cat.	Dose/acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
69 (Total)	Dursban	Chlorpyrifos	480 g/L	Insecticide	0,3L	Postemergence	26.9	0.6	1.8	22.1	8.2
71	Ivory M72	Mancozeb	640 g/kg	Fungicide	0,3L	Postemergence	25.7	3.3	8.2	19.8	10.4
71	Ivory M72	Metalaxyl	80 g/kg	Fungicide	0,3L	Postemergence	19.1	0.6	0.4	1.9	1
Total (71)								4.5	10.4	43.8	19.6
72 (total)	Milthane Super	Mancozeb	800 g/kg	Fungicide	0,3L	Preemergence	25.7	4.1	10.3	24.7	13
73	Milthane Super	Mancozeb	800 g/kg	Fungicide	0,6L	Preemergence	25.7	8.2	20.5	49.5	26.1
73	Abamectin	Abamectin	20 g/L	Insecticide	0,3L	Postemergence	34.7	0	0.2	1.1	0.4
73	Thionex 35EC	Endosulfan	350 g/L	Insecticide	0,3L	Postemergence	38.5	1.2	6	18.5	8.6
Total (73)								9.4	26.7	69.1	35.1
75 (Total)	Balton Abamectin	Abamectin	18 g/L	Insecticide	1500g	Presowing	34.7	0.2	0.8	5.1	2.1
76(Total)	Abamectin	Abamectin	20 g/L	Insecticide	1500g	Preemergence	34.7	0.3	0.9	5.7	2.3
77	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	0,9L	Preemergence	38.5	3.7	18	55.4	25.7
77	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	1500g	Postemergence	38.5	6.4	31.3	96.2	44.6
Total (77)								10.1	49.3	151.6	70.3

Appendix 2.3. Composite EIQ for tomato farmers

Id nr.	Trade name	Active ingridient	A.i quan.	Pesti. Cat.	Dose/acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
78	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.6L	Preemergence	59.5	2.8	7.4	152.9	54.3
78	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.6L	Postemergence	59.5	2.8	7.4	152.9	54.3
Total (78)								5.6	14.8	305.8	108.6
79	Karate 5EC	Lambdacyhalothrin	50 g/L	Insecticide	0.6L	Preemergence	44.2	0.2	1.3	6.9	2.8
79	Karate 5EC	Lambdacyhalothrin	50 g/L	Insecticide	0.6L	Postemergence	44.2	0.2	1.3	6.9	2.8
Total (79)								0.4	2.6	13.8	5.6
80	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.3L	Postemergence	25.7	4.1	10.3	24.7	13
80	Thionex 35EC	Endosulfan	350 g/L	Insecticide	0.3L	Postemergence	38.5	1.2	6	18.5	8.6
Total (80)								5.3	16.3	43.2	21.6
81(Total)	Oshotane 80WP	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
82	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
82	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Postemergence	34.7	0	0.2	1.1	0.4
Total (82)								21.5	53.8	130.2	68.4
83	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21,5	53,6	129,1	68
83	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	0.75L	Preemergence	38.5	3,1	15	46,1	21,4
Total (83)								24,6	68,6	175,2	89,4

Appendix 2.4. Composite EIQ for tomato farmers

Id nr.	Trade name	Active ingridient	A.i qu.	Pesti. Cat.	Dose/acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
84	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Preemergence	34.7	0	0.2	1.1	0.4
84	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.3L	Postemergence	59.5	1.4	3.7	76.4	27.2
Total (84)								1.4	3.9	77.5	27.6
85	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Preemergence	34.7	0	0.2	1.1	0.4
85	Oshotane 80WP	Mancozeb	800 g/kg	Fungicide	1.5L	Postemergence	25.7	20.6	51.4	123.7	65.2
Total (85)								20.6	51.6	124.8	65.6
86	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Preemergence	34.7	0	0.2	1.1	0.4
86	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Postemergence	34.7	0	0.2	1.1	0.4
Total (86)								0	0.4	2.2	0.8
88	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.45L	Preemergence	26.9	0.9	2.7	33.1	12.3
88	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.15L	Postemergence	26.9	0.3	0.9	11	4.1
88	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.45L	Postharvest	26.9	0.9	2.7	33.1	12.3
Total (88)								2.1	6.3	77.2	28.7
89	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Preemergence	34.7	0	0.2	1.1	0.4
89	Milthane Super	Mancozeb	800 g/kg	Fungicide	1.5L	Postemergence	25.7	20.6	51.4	123.7	65.2
89	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	1.5L	Postemergence	26.9	3	9.1	110.4	40.9
89	Dursban	Chlorpyrifos	480 g/L	Insecticide	0.6L	Postharvest	26.9	1.2	3.7	44.2	16.3
89	Fionex (35 EC)	Endosulfan	35%	Insecticide	0.6L	Postharvest	38.5	2.4	12	36.9	17.1
Total (89)								27.2	76.4	316.3	139.9

Appendix 2.5. Composite EIQ for tomato farmers

Id nr.	Trade name	Active ingridient	A.i qu.	Pesti. Cat.	Dose/acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
90	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Preemergence	34.7	0	0.2	1.1	0.4
90	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.9L	Postemergence	59.5	4.2	11.1	229.3	81.5
Total (90)								4.2	11.3	230.4	81.9
91	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Preemergence	34.7	0	0.2	1.1	0.4
91	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postharvest	25.7	21.5	53.6	129.1	68
91	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.9L	Postemergence	26.9	1.8	5.5	66.2	24.5
Total (91)								23.3	59.3	196.4	92.9
92	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.6L	Preemergence	26.9	1.2	3.7	44.2	16.3
92	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	1500g	Postemergence	26.9	3.2	9.5	115.2	42.6
92	Dursban	Chlorpyrifos	480 g/L	Insecticide	0.6L	Postharvest	26.9	1.2	3.7	44.2	16.3
Total (92)								5.6	16.9	203.6	75.2
93	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Presowing	34.7	0	0.2	1.1	0.4
93	Farmerzeb	Mancozeb	80%	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
93	Duduba 450 EC	Cypermethrin	10%	Insecticide	0.6L	Postharvest	36.4	0.7	1.7	11.3	4.6
93	Duduba 450 EC	Chlorpyrifos	35%	Insecticide	0.6L	Postharvest	26.9	0.9	2.7	32.2	11.9
Total (93)								23.1	58.2	173.7	84.9
94	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.6L	Preemergence	26.9	1.2	3.7	44.2	16.3
94	Farmerzeb	Mancozeb	80%	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
Total (94))								22.7	57.3	173.3	84.3
Total (95)	Abamectin	Abamectin	20 g/l	Insecticide	0.45L	Preemergence	34.7	0.1	0.3	1.6	0.7

Appendix 2.6. Composite EIQ for tomato farmers

Id nr.	Trade name	Active ingredient	A.i qu.	Pesti. Cat.	Dose/acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
96	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.3L	Preemergence	59.5	1.4	3.7	76.4	27.2
96	Ninja 5E	Lambdacyhalothrin	50 g/L	Insecticide	0.3L	Preemergence	44.2	0.2	0.7	3.4	1.4
96	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Postemergence	34.7	0	0.2	1.1	0.4
96	Ninja 5EC	Lambdacyhalothrin	50 g/L	Insecticide	0.3L	Postemergence	44.2	0.1	0.7	3.4	1.4
Total (96)								1.7	5.3	84.3	30.4
Total (97)	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	1500g	Preemergence	38.5	6.4	31.3	96.2	44.6
98	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.6L	Preemergence	26.9	1.2	3.7	44.2	16.3
98	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.6L	Postemergence	59.5	2.8	7.4	152.9	54.3
Total (98)								4	11.1	197.1	70.6
99	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
99	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	1500g	Preemergence	26.9	3.2	9.5	115.2	42.6
99	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
Total (99)								46.2	116.7	373.4	178.6
100	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Preemergence	34.7	0	0.2	1.1	0.4
100	Milthane Super/ Oshotane 80WP	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
Total (100)								21.5	53.8	130.2	68.4
101	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.6L	Preemergence	25,7	8,2	20,5	49,5	26,1
101	Ninja 5EC	Lambdacyhalothrin	50 g/L	Insecticide	0.6L	Preemergence	44,2	0,2	1,3	6,9	2,8
101	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.6L	Postemergence	25,7	8,2	20,5	49,5	26,1
	Ninja 5EC	Lambdacyhalothrin	50 g/l	Insecticide	0.6L	Postemergence	44,2	0,2	1,3	6,9	2,8
Total (101)								16,8	43,6	112,8	57,8

Appendix 2.7. Composite EIQ for tomato farmers

Id nr.	Trade name	Active ingredient	A.i qu.	Pesti. Cat.	Dose/acre	Applicaction	Ref. EIQ	Con.	Wor.	Eco.	F.U. EIQ
102	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.3L	Preemergence	59.5	1.4	3.7	76.4	27.2
102	Duduba 450EC	Cypermethrin	10%	Insecticide	0.3L	Preemergence	36.4	0.4	0.9	5.7	2.3
102	Duduba 450EC	Chlorpyrifos	35%	Insecticide	0.3L	Preemergence	26.9	0.4	1.3	16.1	6
102	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.3L	Postemergence	59.5	1.4	3.7	76.4	27.2
Total (102)								3.6	9.6	174.6	62.7
103	Abamectin	Abamectin	20 g/L	Insecticide	0.75L	Preemergence	34.7	0.1	0.4	2.7	1.1
103	Supercron 50 % EC	Profenofos	50%	Insecticide	0.9L	Postemergence	59.5	2.9	7.7	159.2	56.6
Total (103)								3	8.1	161.9	57.7
104	Ebony M72	Mancozeb	640 g/kg	Fungicide	1500g	Preemergence	25.7	17.2	42.9	103.3	54.4
104	Ebony M72	Metalaxyl	80 g/kg	Fungicide	1500g	Preemergence	19.1	3.2	2.1	9.8	5
104	Balton Abamectin	Abamectin	18 g/L	Insecticide	1500g	Preemergence	34.7	0.2	0.8	5.1	2.1
104	Balton Abamectin	Abamectin	18 g/L	Insecticide	1500g	Postemergence	34.7	0.2	0.8	5.1	2.1
Total (104)								20.8	46.6	123.3	63.6
105	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	0.9L	Preemergence	38.5	3.7	18	55.4	25.7
105	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	0.9L	Postemergence	38.5	3.7	18	55.4	25.7
Total (105)								28.2	82.6	234.1	115
106	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
106	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
Total (106)								43	107.2	258.2	136

Appendix 2.8. Composite EIQ for tomato farmers

Id nr.	Trade name	A.I name	A.i qu.	Pesti. Cat.	Dose/ac	Applicaction	Ref.	Con.	Wor.	Eco.	F.U. EIQ
107	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.9L	Preemergence	26.9	1.8	5.5	66.2	24.5
107	Mupacron 50EC	Profenofos	500 g/L	Insecticide	0.9L	Preemergence	59.5	2.9	7.7	159.2	56.6
107	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	0.9L	Postemergence	38.5	3.7	18	55.4	25.7
Total (107)								8.4	31.2	280.8	106.8
108	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.9L	Preemergence	25.7	12.4	30.8	74.2	39.1
108	Thionex 35EC	Endosulfan	350 g/L	Insecticide	0.9L	Preemergence	38.5	3.7	18	55.4	25.7
108	Balton Abamectin	Abamectin	18 g/L	Insecticide	0.6L	Postemergence	34.7	0.1	0.3	2	0.8
Total (108)								16.2	49.1	131.6	65.6
109	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
109	Duduba 450 EC	Cypermethrin	10%	Insecticide	1500g	Preemergence	36.4	2	4.6	29.5	12
109	Duduba 450 EC	Chlorpyrifors	35%	Insecticide	1500g	Preemergence	26.9	2.3	6.9	84	31.1
109	Abamectin	Abamectin	20 g/L	Insecticide	0.75L	Postemergence	34.7	0.1	0.4	2.7	1.1
Total (109)								25.9	65.5	245.3	112.2
110	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.9L	Preemergence	25.7	12.4	30.8	74.2	39.1
110	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.9L	Preemergence	59.5	4.2	11.1	229.3	81.5
110	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.9L	Postemergence	59.5	4.2	11.1	229.3	81.5
110	Milthane super	Mancozeb	800 g/kg	Fungicide	0.9L	Postemergence	25.7	12.4	30.4	74.2	39.1
Total (110)								33.2	83.4	607	241.2
111	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0.6L	Preemergence	26.9	1.2	3.7	44.2	16.3
111	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
Total (111)								22.7	57.3	173.3	84.3

Appendix 2.9. Composite EIQ for tomato farmers

Id nr.	Trade name	A.I name	A.i qu.	Pesti. Cat.	Dose/ac	Application	Ref.	Con.	Wor.	Eco.	F.U. EIQ
112	Selecron 720 EC	Prophenofos	720 g/l	Insecticide	0.9L	Preemergence	59.5	4.2	11.1	229.3	81.5
112	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.3L	Postemergence	25.7	4.1	10.3	24.7	13
112	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Postemergence	34.7	0	0.2	1.1	0.4
Total (112)								8.3	21.6	255.1	94.9
113	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	3000g	Preemergence	26.9	6.3	19	230.3	85.2
113	Milthane Super	Mancozeb	800 g/kg	Fungicide	3000g	Postemergence	25.7	43	107.1	258.2	136.1
113	Thionex 35EC	Endosulfan	350 g/L	Insecticide	3000g	Postemergence	38.5	12.7	62,5	192.5	89.2
Total (113)								62	188.6	681	310.5
114	Abamectin	Abamectin	20 g/L	Insecticide	0.3L	Preemergence	34.7	0	0.2	1.1	0.4
114	Milthane Super	Mancozeb	800 g/kg	Fungicide	0.6L	Postemergence	25.7	8.2	20.5	49.5	26.1
114	Victory 72WP/ Ridomil Gold 68WG	Mancozeb	640 g/kg	Fungicide	0.6L	Postemergence	25.7	6.6	16.4	39.6	20.9
114	Victory 72WP/ Ridomil Gold 68WG	Mancozeb	640g/kg	Fungicide	0.6L	Postemergence	25.7	6.6	16.4	39.6	20.9
114	Victory 72WP	Metalaxyl	80 g/kg	Fungicide	0.6L	Postemergence	19.1	1.2	0.8	3.7	1.9
114	Ridomil Gold 68WG	Metalaxyl-M	40 g/kg	Fungicide	0.6L	Postemergence	19.1	0.6	0.4	1.9	1
Total (114)								23.2	54.7	135.4	71.2

Appendix 2.10. Composite EIQ for tomato farmers

Id nr.	Trade name	A.I name	A.i qu.	Pesti. Cat.	Dose/ac	Applicaction	Ref.	Con.	Wor.	Eco.	F.U. EIQ
115	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
115	Ninja 5EC	Lambdacyhalothrin	50 g/L	Insecticide	1500g	Preemergence	44.2	0.6	3.4	17.9	7,3
115	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
115	Ninja 5EC	Lambdacyhalothrin	50 g/L	Insecticide	1500g	Postemergence	44.2	0.6	3.4	17.9	7.3
Total (115)								44.2	114	294	150.6
116	Abamectin	Abamectin	20 g/L	Insecticide	0,3L	Postemergence	34.7	0	0.2	1.1	0.4
116	Dursban 450 4E	Chlorpyrifos	480 g/L	Insecticide	0,3L	Postemergence	26.9	0.6	1.8	22.1	8.1
116	Milthane Super	Mancozeb	800 g/kg	Fungicide	0,6l	Preemergence	25.7	8.2	20.5	49.5	26.1
116	Dursban 4E	Chlorpyrifos	480 g/L	Insecticide	0,6L	Preemergence	26.9	1.2	3.7	44.2	16.3
Total (116)								10	26.2	116.9	50.9
117	Milthane Super	Mancozeb	800 g/kg	Fungicide	0,3L	Postemergence	25.7	4.1	10.3	24.7	13
117	Dursban 4E	Chlorpyrifors	480 g/L	Insecticide	0,6L	Preemergence	26.9	1.2	3.7	44.2	16.3
Total (117)								5.3	14	68.9	29.3
118	Milthane	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
118	Selecron 720 EC	Profenofos	720 g/L	Insecticide	1500g	Postemergence	59.5	7.3	19.3	398.7	141.7
118	Milthane	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
118	Selecron 720 EC	Profenofos	720 g/L	Insecticide	1500g	Preemergence	59.5	7.3	19.3	398,7	141.7
Total (118)								57.6	145.8	1055.6	419.4
119	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
119	Milthane Super/Oshotane 80WP	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
Total (119)								43	107.2	258.2	136

Appendix 2.11. Composite EIQ for tomato farmers

Id nr.	Trade name	A.I name	A.i qu.	Pesti. Cat.	Dose/ac	Applicaction	Ref.	Con.	Wor.	Eco.	F.U. EIQ
120	Duduba 450 EC	Cypermethrin	10%	Insecticide	0.9L	Postemergence	36.4	1.1	2.6	17	6.9
120	Duduba 450 EC	Chlorpyrifos	35%	Insecticide	0.9L	Postemergence	26.9	1.3	4	48.3	17.9
120	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	0.9L	Preemergence	38.5	3.7	18	55.4	25.7
Total (120)								6.1	24.6	120.7	50.5
121	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
121	Duduba 450 EC	Cypermethrin	10%	Insecticide	0.6L	Preemergence	36.4	0.7	1.7	11.3	4.6
121	Duduba 450 EC	Chlorpyrifos	35%	Insecticide	0.6L	Preemergence	26.9	0.9	2.7	32.2	11.9
Total (121)								23.1	58	172.6	84.5
122	Ninja 5EC	Lambdacyhalothrin	50 g/L	Insecticide	1.5L	Postemergence	44.2	0.5	3.3	17.2	7
122	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
Total (122)								22	56.9	146.3	75
123	Milthane Super	Mancozeb	800 g/kg	Fungicide	3L	Postemergence	25.7	41.2	102.7	247.5	130.5
123	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.3L	Preemergence	59.5	1.4	3.7	76.4	27.2
Total(123)								42.6	106.4	323.9	157.7
124	Victory 72WP	Mancozeb	640 g/kg	Fungicide	150g	Preemergence	25.7	1.7	4.3	10.3	5.4
124	Victory 72WP	Metalaxyl	80 g/kg	Fungicide	150g	Preemergence	19.1	0.3	0.2	1	0.5
Total (124)								2	4.5	11.3	5.9

Appendix 2.12. Composite EIQ for tomato farmers

Id nr.	Trade name	A.I name	A.i qu.	Pesti. Cat.	Dose/ac	Application	Ref.	Con.	Wor.	Eco.	F.U. EIQ
125	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	1.2L	Postemergence	38.5	4.9	24	73.8	34.2
125	Victory 72WP	Mancozeb	640 g/kg	Fungicide	150g	Preemergence	25.7	1.7	4.3	10.3	5.4
125	Victory 72WP	Metalaxyl	80 g/kg	Fungicide	150g	Preemergence	19.1	0.3	0.2	1	0.5
Total (125)								6.9	28.5	85.1	40.1
126	Ivory	Mancozeb	640 g/kg	Fungicide	0.6L	Postemergence	25.7	6.6	16.4	39.6	20.9
126	Ivory 72	Metalaxyl	80 g/kg	Fungicide	0.6L	Postemergence	19.1	1.2	0.8	3.7	1.9
126	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	0.6L	Preemergence	38.5	2.4	12	36.9	17.1
Total(126)								10.2	29.2	80.2	39.9
127	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Postemergence	25.7	21.5	53.6	129.1	68
127	Thionex 35 EC	Endosulfan	350 g/L	Insecticide	0.6L	Preemergence	38.5	2.4	12	36.9	17.1
Total(127)								23.9	65.6	166	85.1
128	Milthane Super	Mancozeb	800 g/kg	Fungicide	1.5L	Postemergence	25.7	20.6	51.4	123.7	65.2
128	Milthane Super	Mancozeb	800 g/kg	Fungicide	1500g	Preemergence	25.7	21.5	53.6	129.1	68
Total(128)								42.1	105	252.8	133.2
129	Ninja 5EC	Lambdacyhalothrin	50 g/L	Insecticide	0.6L	Postemergence	44.2	0.2	1.3	6.9	2.8
129	Selecron 720 EC	Profenofos	720 g/L	Insecticide	0.45L	Preemergence	59.5	2.1	5.5	114.7	40.8
Total(129)								2.3	6.8	121.6	43.6

Appendix 3. Survey Questionnaires and Codes

Variable name	Code/value
Hamlet	Mentioned, not coded
Village	Mentioned, not coded
Ward	Mentioned, not coded
Division	Mentioned, not coded
District	Mentioned, not coded
Date	Date
Questionnaire number	Number
MORATANZ ID	Mentioned, not coded
Sex	Female=1, male=2
Age in years	Number
Tribe	Mentioned, not coded
Occupation	Farmer=1, Farmer plus=2
Religion	Mentioned, not coded
Education level	Never to school=0, primary education=1, secondary education=2
Position in Family	Father=1, other than father=2
Economic activity	Farming=1, farming plus=2
Number of people in h/hold	Number
Number of below 18 in h/hold	Number
Farm size in acres	Number
Crops for own use	Mentioned, not coded
Crops for sale	Mentioned, not coded
Pesticides cause negative h/effects?	No=0, Yes=1
Pesticides have same h/effects	no=0, Yes=1
Pesticides dangerous to use?	no=0, Yes=1

Pesticides enter body via inhalation?	No=0, Yes=1
Pesticides enter the body via skin?	No=0, Yes=1
Pesticides enter body via mouth?	No=0, Yes=1
Pesticides residues in air?	No=0, Yes=1
Pesticides residues remain in soil?	No=0, Yes=1
Pesticides residues are found in water?	No=0, Yes=1
Pesticides residues found in fruits?	No=0, Yes=1
Pesticides residues found in vegetables?	No=0, Yes=1
Read manufacturer notification?	No=0, Yes=1
Respect to manufacturer notification?	No=0, Yes=1
Proper knowledge is necessary when using pesticides	Strongly disagree=0, agree=1, strongly agree=2
There are minimal health risks for pesticides use	Strongly disagree=0, agree=1, strongly agree=2
Pesticides be used with precaution	Strongly disagree=0, agree=1, strongly agree=2
Pesticides use is important for good crops	Strongly disagree=0, agree=1, strongly agree=2
Pesticide use be limited	Strongly disagree=0, agree=1, strongly agree=2
Date for planting/sowing	Date
Pesticide used before sowing	No=0, Yes=1
Pesticides used before emergence	No=0, Yes=1
Pesticide used after emergence	Mentioned, not coded
Active ingredient of the pesticide used after emergence	Mentioned, not coded
Pesticide dose applied after emergence	Mentioned, not coded
Method applied for administering the pesticide after emergence	Spraying
Date of administering pesticide after emergence (weeks)	Number
Date for harvesting (after how many days)	At least 90 days
Pesticide used after harvesting	No=0, Yes=1
Did you wear gloves to protect yourself in last 3 months?	No=0, Yes=1
Did you wear goggles to protect yourself in last 3 months?	No=0, Yes=1
Did you wear something to protect your head in last 3 months?	No=0, Yes=1

Did you wear oral/nose mask to protect yourself in last 3 months?	No=0, Yes=1
Did you wear special boots to protect yourself in last 3 months?	No=0, Yes=1
Did you wear overall to protect yourself in last 3 months?	No=0, Yes=1
Did you smoke during pesticide application in last 3 months?	No=0, Yes=1
Did you eat during pesticide application in last 3 months?	No=0, Yes=1
Did you drink during pesticide application in last 3 months?	No=0, Yes=1
Did you chew during pesticide application in last 3 months?	No=0, Yes=1
Where do you store pesticides?	Agrochemical store=1, in living house=2, in the bush=3, in animal house=4
Where do you dispose empty pesticide containers?	Sell to others, throw away on farm=1, throw away on farm=2, burn on farm=3, bury in ground on farm=4
Where do you dispose remnants after application?	On field, throw in rivers, lakes or irrigation canals=1, throw away in town or village garbage=2, bury in the ground on farm=3, I keep for next use because it is so expensive=4
Where do you wash the spraying containers?	In rivers, lakes, or irrigation canals=1, wipe with piece of cloth or paper and throw it away=2, at home using tap or bucket water=3

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