

Evaluation of Traditional and Modernized Pest Control Methods Used by Smallholder Farmers in Malawi

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ABSTRACT

In order to compare the environmental performance of the existing pest control methods used by Malawian smallholder farmers a study was conducted to assess the environmental performance of two pest control methods used in cultivation of tomatoes (traditional pest control method vs. modernized pest control method). The study was conducted in two gardens, a farm using traditional pest control methods (Tikondwe Freedom Gardens) and another farm using modernized pest control techniques (Mgwirizano Farm Produce Club). The soil and tomato samples were analyzed, by liquid chromatography–mass spectrometry (LC–MS) with electrospray ionization (ESI) in positive mode. The results revealed the presence of pesticide residues at various concentration levels both in the soil and tomato samples. The concentrations of pesticide residues regarding the Mgwirizano Farm Produce Club Gardens were; for tomatoes, Dimethoate (1.2 - 3 ppm), L-Cyhalothrin, (0.2-3 ppm) Cypermethrin (< 0.03 ppm) Mancozeb (2-4 ppm) Chlorothalonil (0.02- 3ppm) while for soil samples, Dimethoate (<0.01 ppm), L-Cyhalothrin (<0.01ppm), Cypermethrin (<0.01ppm), Mancozeb (0.3-1ppm) and Chlorothalonil (0.02- 2ppm). For comparison purposes tomato and soil samples collected from the field that uses traditional pest control methods (Tikondwe freedom farm) were also analyzed for pesticides residues and had the following outcome, the tomatoes had Dimethoate (< 0.01 ppm), L-Cyhalothrin, (0.01 ppm) Cypermethrin (< 0.01 ppm) Mancozeb (<0.01ppm) Chlorothalonil (<0.01 ppm) while the soil samples had concentrations of Dimethoate (0.03 ppm), L-Cyhalothrin (<0.01ppm), Cypermethrin (0.02ppm), Mancozeb (0.01ppm) and Chlorothalonil (0.01ppm). Furthermore, the study collected more information on health effects of pest management methodologies through Interviews with farmers, farm workers and health practitioners in rural areas where horticultural crops such as tomatoes are mostly cultivated using farm inputs, particularly pesticides.

Keywords: Smallholder, pesticide residues,
Traditional methods, modernized methods.

INTRODUCTION

Agriculture is the most important sector of Malawi's economy. It is the primary source of livelihoods for large number of households in Malawi where majority of them manage their own farms as farm operators with extremely small farm size¹. It is estimated that up to 84% Malawians realize their livelihoods directly from agriculture, a vital land use, which contributes over 90% to the country's export earnings, about 39% of the country's Gross

Domestic Product and accounts for 85% of total employment². The performance of Malawi's economy is closely associated with the performance of the agriculture sector which is essentially rain fed. Consequently, successful agricultural development is a precondition for successful development. In order to realize maximum production, the Malawian agricultural sector has adopted the extensive use of agro-chemicals, fertilizers and improved seed³. This excessive use of chemicals is and continues to put agriculture at a risk of contaminating the soil

and reducing food quality⁴. Pesticide use in tomato farms is intensive especially in the rainy season. A plant retains only half of this applied spray as the leaf creates a non-wetting interface for the pesticide. The remaining pesticide runs off and contaminates soil and water and affects terrestrial and aquatic life⁵.

Tomato (*Lycopersicon esculentum* Mill.) is a commercially important crop throughout the world both for the fresh vegetable market and the processed food industries. Tomato's local name in Malawi *matimati* and it is the most commonly bought vegetable in Malawi with 13 % of the surveyed population using it for consumption⁶. Tomatoes are major fresh market crop and grown in wide range of climates. The tolerance of pest and diseases on tomatoes is often very low, and this is one of the reasons why most farmers find means to control pests and diseases in tomatoes whether the vegetable is grown for home consumption or sale. In most parts of Malawi, the majority of the farmers are predominantly using synthetic pesticides to control weeds, pest and disease. Countable small-scale tomato growers like those at *Tikondwe* freedom gardens solely still use traditional control methods and occasionally botanical pesticides to control and prevent crop damage from pests and diseases. So far, farmers' perception of vegetable pests and how they control pests are not yet fully understood. Farmers in Malawi control pests and diseases in tomatoes using both traditional and modern pest control techniques. Recently, there has been intensification of agriculture and increasing usage of pesticides¹⁴. Pesticide use in Malawi is based on manufacturer's recommendations but sadly due to high illiteracy levels among the smallholder farmers, most of them use pesticides without full understanding of their impact on human health and the environment.

The traces of pesticides and herbicides, during pesticide application, weeding, pruning, harvesting and during storage and consumption of food may lead into acute and/or chronic exposures, with adverse health effects further posing danger to human health and environmental quality¹⁵. In spite of the frequent worldwide studies on the environmental performance of various pest control methods and on the host plant and the soil environment in order to promote appropriate pest control methods that

can minimize the negative impacts and enhance environmental performance^{16,17}. However, in Malawi there are very few comprehensive studies to evaluate the pest control methods used by smallholder farmers, for instance, there have been studies on experimentation of developments of integrated control methods for tomatoes red spider mite (*tetranychus evansi*) but this study and some other studies that have been done by Malawian scholars have focused at the chemical evaluation of the methods used on the environment and health impacts associated with each of the methods used (traditional methods vs. modernized methods) forming the basis of the study. Hence the main objective of the research was to evaluate pest control methods used by tomato growers with respect to residue levels in tomatoes and the soil. The specific objectives were to determine pesticide residues on tomatoes and in the soils and further assess the health and environmental impacts related to the pest control method used.

MATERIALS AND METHODS

Study areas and pest control methods

Two gardens all located in the central region of Malawi (Salima and Dowa) were sampled and used for the study. The selected gardens for the study solely used either traditional or modernized pest control methods. The sampled fields were: *Tikondwe* Freedom Gardens from Dowa district and *Mgwirizano* Farm Produce Club from Salima district. *Tikondwe* Freedom Garden was chosen because it is among the few farms in the central region that practices complete permaculture farming system using traditional pest control methods. Specifically, the tomato cultivation at *Tikondwe* freedom garden is practiced through a mixed cropping system, polyculture, which is a form of permaculture, including trees and other crops. This helps in reducing the availability of pest and diseases, the cultivation of many crops on the same piece of land results in increased diversity. The increased diversity reduces the scale and intensity of pest and diseases in tomatoes. Decrease in the incidence of diseases, makes pesticide use less necessary. This is why the farmers treat the tomatoes only once or twice a month. Meanwhile, *Mgwirizano* farm produce club farm, is a modernized garden with a monoculture system executing the growing of a single crop or

plant species over a wide area and for a large number of consecutive years. Monocultures can lead to the quicker spread of pests and diseases, where a uniform crop is susceptible to a pathogen. The spreading of the pests and diseases at a large scale promotes the intense use of chemicals and pesticides in order to protect the crop yields from getting destroyed¹⁴.

Pest management

It was noted that pest treatment in *Tikondwe* freedom gardens (traditional pest control methods) were done twice a month or thrice depending on the diversity of pests especially in rainy periods of the year, while during the dry period the treatment is just once a week and mostly in form of mulching, whereas at *Mgwirizano* farm produce club farm (modernized pest control methods) pest treatment was administered once every other week up to the harvesting period. This was due to the higher occurrence of pests and diseases throughout the growing period.

Soil sampling

Soil samples were collected from the study areas by proper soil sampling methods⁷. The soils from the different sample points was made into a composite sample. To obtain a representative sample of soil from each block, the following procedure was used: soil samples from cultivated soils were generally taken down to tillage depth up to 20 cm – 40 cm using an urger and soil samples for uncultivated soil was taken down to a depth of 20 cm using an urger⁸. Walking down each selected block in a zig-zag fashion collecting 40-50 equal sized cores or slices (at least 2cm wide) per block and covering as much of the area as possible. Thirty subsoil samples were collected. The subsamples were placed in a plastic bucket and thoroughly mixed. 25 soil samples were collected from each of the farms and a composite sample was made for each of the farms separately. The composite sample was made to ensure that the soil collected was truly representative of each location. The composite sample was then air-dried, grounded and sieved through a mesh with a grain size of 2 mm. The samples were packed in air tight plastic bags and transported ice preserved to Malawi Bureau of Standards (MBS) laboratory for pesticides residue analysis.

Tomato fruit sampling

The tomato fruits were picked systematically from each ridge. Distance of 5 meters apart, this was done to ensure that the samples collected were a representative of the field. More than 75 grams of the tomatoes was collected and taken to MBS laboratory for pesticides residue analysis. Samples were collected during the rainy period from *Mgwirizano* farm produce club garden that uses modernized pest control methods and the other set of samples were also collected during the same rainy period from *Tikondwe* freedom garden that uses traditional pest control methods.

Chemical analysis

The work was analyzed, by liquid chromatography–mass spectrometry (LC–MS) with electrospray ionization (ESI) in positive mode. The chromatographic and the MS parameters of the studied compounds were enhanced in order to develop selectivity and sensitivity. The separation was carried out in a C18 column using as mobile phase methanol (MeOH) with 0.01% acetic acid with a flow of 0.2 mL/min in gradient mode. The molecular ion was selected for the quantification in selective ion monitoring (SIM) mode. A solid-phase extraction (SPE) method with HLB Oasis cartridges was applied to allow pre-concentration of the target analytes from water samples. However, extraction of the compounds from soil samples was carried out by sonication using liquid–solid extraction with methanol/water. In addition, a clean-up step by *acetone* extraction and *florisil* cleanup was necessary for both the samples^{19;20;21&22}.

Health effects of the pest management methodologies

In order to acquire data on the health effects on the pest management method used. Interviews with farmers and farm workers in rural areas where horticultural crops such as tomatoes are mostly cultivated using farm inputs, particularly pesticides were conducted. A questionnaire consisting of structured, semi-structured and unstructured items was designed and administered to the farmers. Through face-to-face interviews and discussions with farm owners and farm workers.

RESULTS AND DISCUSSION

The concentrations of the pesticides residues obtained on tomatoes and soils are given in Tables 1 and 2, respectively. In reference to table 1, tomato samples grown under traditional pest control methods from *Tikondwe* freedom garden was found to contain a considerably less amount of pesticides residues than tomatoes grown under modernized pest control methods. Pesticide residues in tomatoes from the farm using traditional pest control methods were less than 0.01 ppm, that is, there was negligible or no pesticides residues. The small levels of pesticides residues on tomatoes from the farm using traditional pest control methods could have been because of the botanical pesticides used which might contain some of the chemical compounds similar to those of the pesticides detected as residues or because of the synthetic pesticides from neighboring fields which might have been transferred through wind.

The presence of pesticide residue levels on tomatoes taken from *Mgwirizano* farm produce club garden which uses modernized pest control

methods had readings of pesticide residues which were found in notable amounts as compared to the tomatoes from *Tikondwe* freedom garden, this is the case because *Mgwirizano* farm produce club uses synthetic chemicals and pesticides for pest control. Some of the applied chemical and pesticides have a long half-life as compared to others, for instance, *Cypermethrin* was detected at lower levels unlike *Dimethoate*, *L-Cyhalothrin*, *Mancozeb* and *Chlorothalonil*. Lower residues of *Cypermethrin* on tomato surface might also be as a result of wind blowing it away from the tomatoes or faster degradation¹⁷. It may also reflect the effect of wind spraying as it is estimated that up to 90% of the pesticides never reach the intended targets [9]. The pesticides residues pose a great threat to beneficial organism and human beings as they can be ingested by non-targeted organisms (insects).

In reference to table 2, soils sampled from the garden that uses traditional pest control methods had results that were unexpected since *Tikondwe* freedom farm being a permaculture farm does not use any of these synthetic pesticides or chemicals. It is important to note that *Dimethoate* and *Cypermethrin*

Table 1: Concentrations of Pesticides Residues on Tomatoes

Pesticides	Traditional pest control methods-	Modernized pest control methods-
	Tikondwe Freedom garden	Mgwirizano farm produce
Pesticides Residues (ppm)		
L-Cyhalothrin	<0.01	0.2-3
Cypermethrin	<0.01	< 0.03
Dimethoate	<0.01	1.2 – 3
Mancozeb	<0.01	2-4
Chlorothalonil	<0.01	0.02- 3

Table 2: Concentrations of Pesticides Residues in Soils

Pesticides	Traditional pest control methods-	Modernized pest control methods-
	Tikondwe Freedom garden	Mgwirizano farm produce
Pesticides Residues (ppm)		
L-Cyhalothrin	<0.01	<0.01
Cypermethrin	0.02	<0.01
Dimethoate	0.03	<0.01
Mancozeb	<0.01	0.3-1
Chlorothalonil	<0.01	0.02- 2

were detected as 0.03ppm and 0.02ppm respectively although there is no use of synthetic pesticides that could have contributed to the detection of the pesticides residues. The availability of *Dimethoate* and *Cyberthrin* could be attributed to a number of factors such as run off and natural availability of naturally occurring compounds similar to those of the pesticides detected. There are high chances that the available pesticide residues were from the upland gardens that uses modernized pest control measures and were later carried and deposited in *Tikondwe* freedom farm by the runoff water. *Tikondwe* freedom farm is in the low land area in the valley which makes the garden more susceptible to the incoming polluted waters from the upper catchment areas since the rain water passes through the garden before they get deposited into the river that passes through the garden. The run-off water and winds may have carried pesticides residues from upland gardens which uses synthetic pesticides since gardens are an open system and thus, tracing the sources of these residues may not be easy. Since permaculture promotes diversity of plants the garden is likely to have different kind of plants that may release those chemical compounds similar to those of the pesticides residues detected¹⁰.

Meanwhile, soil samples from the garden that uses modernized pest control methods had detected, *L-Cyhalothrin*, *Cypermethrin* and *dimethoate* of less than 0.01 ppm pesticide residue levels. This could mean that the applied pesticides were ingested by the intended targets (insects) and the non-targeted ones¹³. Plants break pesticides down relatively quickly reducing their residual life¹¹. It can also be due to the fact that the applied pesticides may have degraded right there on the sprayed surface of the tomatoes and less amount was washed into the soils by rainwater or irrigated waters. This could explain why the detected amount is negligible with readings close to almost zero. It could also have been as a result of the pesticides degrading in the soil at a faster rate aided by other chemicals conditions existing in the soil^{13,15}.

Health impacts related to the choice of the pest control method used

The overall analysis of the interviews results showed that most farmers from *Mgwirizano* farm produce club raised several complaints on how

the spraying of pesticides causes severe irritation of the skin especially when it is sprayed direct on the skin. They also complained of migraine headaches and the respiratory problems that occur soon after administering the pesticides in their gardens. The said health problems are normally treated with antibiotics from the nearest hospital but no solution has been provided to the continued contamination of soil through leaching and run off.

The data collected from the farmers was later confirmed by medical personnel at nearby Health Center, a hospital which is located close to the farm. The information showed that most of the patients around that area visit the hospital with diseases such as malaria, diarrhea and cases relating to allergies (people complaining of irritation of the skin). Even though it is hard to related the diseases to pesticides poisoning but it was evident to the doctors that most of the vomiting and irritations were due to the inappropriate use of pesticides and vapor inhalation of these chemicals through the air blast application. Inhalation of higher levels of the contaminated water may cause other serious health problems. Unlike organochlorine pesticides, Ops (organophosphorus) such as *dimethoate* do not persist in the environment having a small half-life ranging from 10 - 48 days¹² as it has been noted in the results obtained from the laboratory, the detected amount was negligible with readings close to zero <0.01ppm. Instead, their problem lies in their health effects on humans and other organisms. So far there are many medical reports from other countries confirming the presence of pesticide residues in food, human beings and the environment. Less data is there in Malawi because the nation has no health database and there are insufficient and outdated technologies to help researchers follow up such cases. Meanwhile at *Tikondwe* freedom farm the story was different, the laborers did not complain of any Health related impacts caused by the use of the traditional pesticides.

Environmental impacts related to the usage of the pest control method used

The use of synthetic pesticides and chemicals in crop protection is very damaging to the environment when poorly used¹⁸. Crop losses may be inevitable, but continuous usage of insecticides can lead to several environmental complications.

Several pests have developed insecticide resistance, degradation of natural enemies, secondary pest outbreaks, Occurrence of toxic residues in crops, soils and food products have increased enormously having chemical residues finding their way to the aquatic systems or getting accumulated in the plant products with an estimate of 50% of the pesticides that are applied to the crops reaching the soil. In addition to killing the pests and diseases that are the target of a particular treatment, pesticides can also reduce populations of insects and other arthropods that are economically desirable such as those that prey on unwanted insects, such as spiders, which are desirable predators in many agricultural systems because of their appetite for insects that would otherwise be agricultural pests. For example, the farmers at *Mgwirizano* farm produce club during the interviews reported that they observed that treating tomato with modernized pesticides such as *cypermethrin* caused a decrease in the number of spiders and an increase in the number of plant hoppers, a pest insect. Because of the “resurgence” of the pest plant hopper, yields in the *cypermethrin*-treated tomato were lower as compared to the traditional treated tomatoes. *Cypermethrin* can also have sub lethal effects on the pollinators (bees).

The farmers at *Mgwirizano* farm produce club had made observations that spraying of various pesticides and herbicides in their gardens during the flowering period of tomato was also causing bee losses. Residues on leaf surfaces tend to be toxic for more than 3 days following treatment killing at least 25 percent of bees tested¹³. In reference to the situation at *Mgwirizano*, Moyo (2014) discussions how the heavy use of pesticides injures the non-targeted flora and fauna causing the deaths of creatures such as birds and fish that are influenced by accumulation of pesticides in their bodies, and

these are just some of the ecological effects posed by pesticides on the environment.

In conclusion, heavy use of pesticides create hazard both on soil and crop quality. The study reviewed that for gardens that use modernized pest control methods, not all chemicals used to kill the targeted organism breakdown some of it is carried by wind, water, soil (as it has been discovered in our research, the soil had pesticides residues) and kills non targeted organisms. Pesticides kill pests, but their overuse harm farmers, consumers and the effects of pesticide residue spray also drift on fauna and flora. For instance, data collected through questionnaire interviews reviewed that farmers at *Mgwirizano* farm produce club complained of prolonged coughing, irritations, vomiting upon usage. The research study concludes that traditional pest control method achieve best environmental performance than the use of modernized pest control method since with traditional pest control practices there is no application of synthetic chemicals and pesticides that leave residues on the tomatoes, soils and the ecosystem.

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