Knowledge, Attitudes, and Perceptions towards Microbial Larviciding in Malaria Vector Control, Lower Moshi Tanzania: A Mixed Methods Study

by

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Duke Kunshan University and Duke University

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Keith Dear

Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in the Global Health Program Graduate School of Duke University

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ABSTRACT

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Abstract

**Background:** Malaria remains a significant threat to public health in many countries, especially in Sub-Saharan Africa. To address this preventable health problem, there is need to evaluate the existing practices and identify new prevention methods. Integrated vector management approaches that include microbial larviciding are effective in the fight against malaria. The need to explore the applicability of microbial larviciding in malaria endemic areas is critical. This study assessed community knowledge, perceptions, attitudes, and acceptability of microbial larviciding as a malaria control strategy in Lower Moshi, Tanzania.

**Methods:** A cross-sectional, mixed methods study was conducted in Chekereni and Mabogini villages in Lower Moshi Tanzania. The two villages were purposively selected because most of the community members in these villages cultivate rice and researchers had good rapport with the community members. 100 interviewer-administered questionnaires were conducted in households. In addition, 4 in-depth interviews with key informants including health workers and agricultural experts, and 2 focus group discussions were conducted in the two villages.

**Results:** 60% of survey respondents reported they had knowledge or experience with larviciding. Most (96%) mentioned they had knowledge of chemical larviciding, while only 4% had knowledge of microbial larviciding. Nearly every respondent (97%) was willing to use fertilizer with larvicides in their rice fields after being informed about larviciding. Almost all (97%) reported willingness to inform and encourage other
community members to use microbial larviciding in their rice fields. Similarly, many of
the respondents (56%) were positive that microbial larviciding would significantly help
in reducing malaria cases. Concerns about applicability of microbial larviciding were
reported by survey respondents, focus group discussion participants and in-depth
interview respondents.

**Conclusion:** This study provides evidence that the community in Lower Moshi,
despite having little knowledge and some concerns, is positive about and willing to be
engaged in microbial larviciding to reduce the mosquito population in the area and
consequently to reduce malaria cases in the community. The future applicability of
microbial larviciding with rice farmers in Lower Moshi Tanzania as a component of an
integrated vector management strategy would require educating and sensitizing the
community and creating incentives so that farmers can afford the fertilizers with
larvicides.
Dedication

This thesis is dedicated to the people of Chekereni and Mabogini villages in Lower Moshi district for their participation in this study and to all those who work tirelessly to resolve the daunting problems that malaria causes around the world, particularly in sub-Saharan Africa.
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Finally, I would like to acknowledge the support of my family throughout the study period.
1. Introduction

The era of Millennium Development Goals (MDGs) saw considerable progress in the global fight against malaria. According to the World Malaria Report in 2015, malaria incidence and mortality rates decreased globally by 37% and 60%, respectively (WHO, 2015b). To mark the beginning of the Sustainable Development Goals (SDGs) era, WHO in 2016 launched the Global Technical Strategy for Malaria Elimination by 2030. The strategy is founded on 5 core principles including innovation in malaria control tools (WHO, 2016b). The strategy aims at reducing malaria incidence and deaths by 90% and eliminating it in about 35 countries across the world.

However, malaria remains a paramount threat to human health in many countries where it is endemic, despite ongoing research and control efforts by several partnering actors, including in-country ministries of health and national malaria control programs, international organizations, foreign aid institutions, non-governmental organizations (NGOs), and research institutions. In 2014, the World Health Organization (WHO) estimated that there were 214 million cases of malaria across the world which resulted in 438,000 deaths (WHO, 2015a). The report also indicated that 90% of these deaths occurred in Africa. Children under the age of 15 years have been said to be the most vulnerable population for malaria infection with about 306,000 of the total deaths occurring among children in this age bracket (WHO, 2015a). Pregnant women also face great risk with about 125 million pregnant women in sub-Saharan Africa exposed to malaria vectors in 2011 (Murray et al., 2012). Malaria has not only been associated with poverty but has also been regarded as a paramount hindrance to economic development.
and a cause of poverty. Despite being preventable and treatable, malaria continues to cause significant morbidity and mortality, especially in resource-deficient nations in Sub-Saharan Africa, Latin America, and Asia. The emergence of drug-resistant malaria infection, as well as pesticide resistant malaria vectors in Asia and elsewhere across the world, poses an even greater threat to global health (Ashley et al., 2014).

In 2012, the Ministry of Health in Tanzania rolled out a 5-year strategic plan to reduce the threat of malaria (PMI, 2014). The strategic plan focused on four main approaches to reducing the problem. The plan addressed case management, vector control, prevention among pregnant women and preparedness in epidemic cases. Overall, there has been significant improvement in malaria management, but the inadequacy of finance, community education or engagement and human resources continues to hinder the fight against malaria in Tanzania (Mboera et al., 2014). In East Africa, Tanzania remains relatively high in malaria prevalence. According to the WHO annual World Malaria Report (WHO, 2015a), Tanzania had approximately 30,000 malaria related deaths and over 7 million confirmed cases in 2015. These statistics indicate that despite the decreased malaria related deaths, many people are still at risk of contracting malaria and hence there is a need to reevaluate effectiveness of strategies that have been used in the control and prevention of malaria (Kramer et al., 2014).

Complicating the effort to eradicate malaria is the interplay between malaria and food production. Many countries in sub-Saharan Africa have seen their populations outstrip food production (Ijumba, Mosha, & Lindsay, 2002). For this reason, many countries in Africa, including Tanzania, have increased efforts to improve crop
production. One of the problems that Tanzania encounters is insufficient precipitation across most of the arable land, which calls for irrigation to improve crop production (Ijumba et al., 2002). Irrigation has had significant positive results in increasing crop yields, as well as ensuring continuous crop production throughout the year without having to depend on the amount of annual rainfall. However, in addition to the positive impact in improving the livelihoods of communities, there have been concerns that in many tropical countries irrigation has also had negative consequences. One concern is that irrigation may escalate health risks of communities living in such regions by providing breeding grounds for disease vectors such as mosquitos (Ijumba et al., 2002). However, in the Lower Moshi area, villages actively involved in rice farming were found to have lower incidences of malaria compared with non-irrigated villages due to better socio-economic conditions of rice farmers (Ijumba et al., 2002).

Large-scale irrigation is a relatively new method in rice production. In the 1980s, rice was predominantly produced on farmland that had sufficient amounts of rainfall (Veco East Africa, 2015). However, in recent years, rice production in irrigation schemes has made Tanzania the second largest rice producer in eastern Africa after Madagascar. The advent of irrigation to expand rice production in Tanzania has provided ideal breeding sites for the malaria vector most common in Africa, the Anopheles gambiae. According to Ijumba (2002) irrigation schemes can result in portentous numbers of mosquitoes, which increases the malaria risk significantly (Ijumba et al., 2002). In Lower Moshi, Tanzania, where communities predominantly engage in rice farming in irrigated rice fields, low to moderate transmission of malaria occurs throughout the year (Kweka
et al., 2011). Vector control strategies such as indoor residual spraying (IRS) and insecticide treated nets (ITNs) are commonly used vector control methods and might produce better results when supplemented with microbial larviciding (Kramer et al., 2014). Community based control strategies such as use of microbial larviciding by rice farmers can be cost effective and significantly reduce malaria vectors around rice fields. However, its applicability might be influenced by community knowledge, attitudes, and perceptions towards microbial larviciding. This study aims to explore the knowledge, attitudes and perceptions that may influence acceptability of microbial larviciding among community members in Lower Moshi Tanzania.

1.1 Microbial Larviciding

Focusing on optimization of resources and improving efficacy, cost effectiveness, ecological soundness and sustainability of malaria vector control approaches, the WHO has recommended integrated vector management (IVM) (WHO, 2016a). This approach focuses on overcoming the challenge that limits the effectiveness of using single conventional vector control methods. The operational strategy focuses on policy making, multisector collaborations, integration of chemical and non-chemical vector control methods, evidence-based decision making and the provision of adequate human resources in healthcare and research (WHO, 2016a).

Microbial larviciding can be a significant component of an IVM strategy, but it has not been extensively utilized in malaria control (Imbahale, Githeko, Mukabana, & Takken, 2012). This method could be potentially more effective in irrigation settings as it
incorporates the use of an anti-larval agent on the irrigated land. Unlike insecticides which kill most microorganisms, microbial larviciding selectively eliminates the mosquito larvae without harming other microorganisms important to soil health (Geissbühler et al., 2009). Currently, the most effective and preferred microbial agents in mosquito larviciding are *Bacillus sphaericus* (Bs) and *Bacillus thuringiensis* (Bti) (Walker & Lynch, 2007). The use of these microbial agents in larval source management to control malaria has been highlighted through evidence in a Cochrane Review Report and has been shown to be an important component of integrated vector management (IVM) in malaria endemic areas (Tusting et al., 2013).

In 2012, the WHO advised the scientific community that larviciding should be considered as an effective vector control strategy in sub-Saharan Africa, especially in areas where the breeding sites are “few, fixed and findable” (Maheu-Giroux & Castro, 2013). Rice plots are a fixed breeding ground appropriate for the application of microbial larvicides. Thus, a larviciding intervention would significantly reduce the cost of malaria control (Maheu-Giroux & Castro, 2014) and would be sustainable as long as rice is grown under irrigation in the region. The WHO acknowledged that larviciding can be an effective vector control method in urban and peri-urban areas in sub-Saharan Africa (WHO, 2013). Few studies have been conducted to investigate the effectiveness of larviciding in vector control (Maheu-Giroux & Castro, 2013), limiting its applicability. However, the fact that microbial larviciding can be applied in a few fixed locations makes it only applicable as a complement to other vector control strategies rather than as the primary control measure. In particular, control of mosquito larvae in Lower
Moshi can potentially be effective because of the location and nature of the breeding sites (Lowassa et al., 2012). Studies that were conducted in Kenyan highlands and in some urban areas in Tanzania provide evidence of significant reduction of the vector when larviciding was used (Maheu-Giroux & Castro, 2013), (Mboera et al., 2014).

The rationale for using larviciding in malaria control in malaria endemic areas is manifold. These areas are often characterized by the presence of large human populations that are clustered in small areas and therefore reaching the breeding grounds is much easier. For instance, it is much easier to control the mosquito larvae in rice fields because the focus will be centralized around the irrigation schemes. Studies have also indicated that *A. gambiae* demonstrates exophagic behavior although the vector is principally endophagic (Govella et al., 2009). This means that there still exists substantial risk of infection outside the house, a situation not addressable by either Indoor Residual Spraying (IRS) or Insecticide Treated Bed Nets (ITNs). Intensification of such adaptational characteristics by the vector could mean more bites and more malaria even with the heightened use of the previously effective and most commonly used strategies. For this reason, larviciding could prove to be a more useful part of the arsenal in the fight against malaria even with increased exophagic behavior of the *A. gambiae* (Maheu-Giroux & Castro, 2013). Similarly, there has been increased insecticide resistance in Africa and elsewhere across the world which has continued to render IRS and ITNs less effective (Mahande, Dusfour, Matias, & Kweka, 2012). Augmenting these strategies with larviciding where appropriate could be more desirable and more effective in the control of malaria vectors. With the current aim of eliminating malaria in sub-Saharan...
Africa, use of insecticides alone may not achieve this goal. Maheu-Giroux & Castro argued that larviciding as part of Integrated Vector Management (IVM) could prevent malaria transmission and effectively aid in eliminating the disease when used in combination with other strategies (Maheu-Giroux & Castro, 2014).

1.2 Applicability of Microbial Larviciding

1.2.1 Safety

The consideration of microbial larviciding in malaria control intervention is a novel approach in controlling and containment of malaria in Africa if used in conjunction with the widely-used IRS and ITNs. This is because of the varied advantages this strategy contains. First, the two bacteria species that are currently used in microbial larviciding (i.e. *Bti* and *Bs*) have been shown to be environmentally safe and non-toxic to other non-target organisms (Mboera et al., 2014). This is particularly important whenever the community is to be involved in a control strategy as the safety of the people, their animals and the environment comes first and will undoubtedly inform acceptance of the vector control measure.

1.2.2 Cost-effectiveness

Microbial larviciding has been shown to be cost-effective compared to other malaria control interventions (Rahman, Lesser, Mboera, & Kramer, 2016). A study conducted in Kenya estimated that the cost of using microbial larvicides in protecting populations from malaria is less than $1 per person per year (Fillinger & Lindsay, 2006). Another study conducted in Dar es Salaam, Tanzania evaluated the cost effectiveness of
larviciding in malarial control in urban areas and recommended that malaria control programs consider larviciding as a part of an IVM approach, especially in malaria endemic regions, due to its high cost effectiveness (Maheu-Giroux & Castro, 2014).

1.2.3 Intervention Comparisons

Studies have strongly linked the effectiveness of other malaria control interventions, such as adherence to use of ITNs, with human behavior (Singh, Musa, Singh, & Ebere, 2014). In this regard, larviciding solves this problem as its effectiveness is less influenced by human behavior and is independent of vector avoidance mechanisms.

The vector ecology in Lower Moshi, Tanzania provides a good setting for the applicability of this IVM strategy in the control of malaria. The rice fields provide breeding grounds for mosquitos, and larviciding could effectively help in controlling malaria significantly in this region. Allowing farmers to use fertilizers mixed with microbial larvicides in their fields could help in the control of malaria. This project will seek to evaluate the community acceptance, concerns and challenges that would influence the applicability of this novel approach in malaria control in Lower Moshi, rural Tanzania.

1.3 Conceptual Framework

People’s perceptions about the strategies that have been applied in the fight against malaria significantly influence the implementation and applicability of strategies on a wider scale. This means that the acceptability and sustainability of microbial
larviciding is significantly dependent on the people’s attitudes, perceptions, and knowledge. Understanding the people’s concerns before the implementation of the intervention is important to reshape the implementation plan to fit the community and ensure acceptability and future sustainability.

**Figure 1:** Factors that influence acceptability of microbial larviciding

The figure above shows the relationship that exists between dependent and independent variables in this study. Acceptability of microbial larviciding could be associated with demographic characteristics such as gender, age, education level, and occupation, among others. We expected that the cost of larviciding would be a major
factor influencing community acceptance and willingness to participate in the proposed microbial larviciding program. Though it might be easier for those who are knowledgeable about larviciding to accept it, those without experience or knowledge might not be ready to accept it, especially because of the cost implication and the uncertainties that they may perceive. Acceptability of microbial larviciding could also be associated with knowledge level about malaria as well as attitudes and perceptions towards microbial larviciding.

Although some studies have contradicted the finding that knowledge about a preventive method leads to improvement in practice, we expected that more knowledgeable people would be more likely to accept and put into practice such methods (Singh et al., 2014). As shown in a study conducted in Ghana, how the community perceives an intervention is a critical determinant of its acceptance (Meñaca et al., 2014).
2. Methodology

2.1 Study Design

This was a mixed methods study that incorporated both qualitative and quantitative data collection approaches. Objectives were realized through in-depth interviews, focus group discussions (FGDs) and a cross-sectional, household survey. In-depth interviews were conducted among different stakeholders, including agricultural experts and community health workers, while the focus group discussions and the survey involved community members in two selected villages in Lower Moshi, Tanzania. The study was conducted in an 8-week period, from June to mid-August. The data collection was conducted within the months of July and early August.

2.2 Setting and Study Population

As can be seen in Figure 2, the study was conducted in Lower Moshi, Tanzania in two villages covered by the Lower Moshi Irrigators Association (LOMIA), i.e. Chekereni and Mabogini. Moshi district lies in Kilimanjaro province, the northeastern part of Tanzania. This is an area of low transmission of malaria with prevalence rate of less than 5% (Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC), [Tanzania Mainland], Ministry of Health (MoH) [Zanzibar], National Bureau of Statistics (NBS), Office of the Chief Government Statistician (OCGS), and ICF International, 2016). Despite the low level of transmission, this area was deemed appropriate for the study because rice farming sustains mosquito breeding and transmission of malaria throughout the year.
The general population involved in this study included household members for the survey and focus group discussion and agricultural and human health experts for the in-depth interviews. These two villages depend on water from nearby rivers and commonly use the traditional flooding method in their rice paddies in an irrigation scheme started in 1978 by Japan International Cooperation Agency (JICA). Most people in the study area are rice farmers, although they alternatively grow corn using the same irrigation water. The two villages have about 417 Ha of land under irrigation for rice farming (Veco East Africa, 2015).
2.3 Sample Size, Sampling, and Eligibility

Study subjects were sampled from the two study villages in Lower Moshi, Chekereni and Mabogini, where rice irrigation is done. Subjects for the in-depth interviews were sampled purposively, i.e. key informants (two health workers and two agricultural extension officers from both villages). Participants of focus group discussions were randomly selected from a list of community members available at the village leader’s office. Eligibility criteria for FGDs participants included: 1) Adult (aged 18 or above) community members; 2) Residents of respective villages; 3) Fluency in Swahili; and 4) Willingness and ability to provide consent. Exclusion criteria eliminated individuals who had not been residents in either village for a period of more than 1 year, were unable to speak in Swahili or were unable to provide authentic consent. Residency was determined through self-reporting and confirmation from the village and community leaders.

The households for the survey were randomly sampled from a list of household registers available at the village leaders’ offices. Interviewers administered 50 questionnaires in each village. If eligible respondents were absent at the time of the visit, follow ups were conducted to a maximum of three times among identified households. If there was no one in the household eligible to answer the questionnaire, replacement households were selected randomly.
2.4 Data Collection Tools

2.4.1 In-depth Interviews (IDIs)

In-depth interviews were conducted among agricultural and human health experts in selected villages in Lower Moshi. The interviews were guided by themes that explained the objectives as outlined in the interview guide. The interview guide included the following domains: 1) Malaria risk in the community; 2) Malaria vector control strategies used in the community; 3) Community understanding, attitudes, and perceptions of microbial larviciding; and 4) Factors that underlie use of different malaria vector control strategies. The main theme here was underlying perceptions and attitudes towards microbial larviciding as a part of the IVM strategy by the community. Several questions were set to guide the interview, although other relevant questions were asked to probe more deeply.

2.4.2 Focus Group Discussions (FGDs)

The discussions were guided by a semi-structured discussion guide in line with the set objectives. The investigators sought to unravel underlying attitudes and perceptions of the people in terms of decision making and the choice of vector control strategies. The discussion also aimed at identifying the concerns and challenges that may face the research team in implementation of the project. Two focus group discussions were conducted; one discussion was facilitated in each village. The composition of participants in each group was approximately balanced. In Chekereni, there were four male and five female participants (total 9 participants). Seven were
farmers, one was teacher and another was village leader in the group. The ages of participants ranged from 25-60 years. In Mabogini village, the composition was also approximately balanced with five male participants and six females (Total 11 participants). Their age ranged from 25-55 years. Most participants (8/11) were farmers, but two of the participants were self-employed and one was a village leader.

2.4.3 Survey

The survey questionnaire contained three sections that sought to gather basic demographic information of respondents, knowledge of malaria vector control strategies, including microbial larviciding, and attitudes and concerns towards acceptability of microbial larviciding. The questions were adapted from a previous study conducted in Mvomero, Tanzania in 2014 on community knowledge, attitudes and acceptance of larviciding for malaria control (Kramer et al., 2014).

2.5 Procedures

The study progressed in two stages. First, a cross-sectional survey was conducted to collect quantitative information on the knowledge, attitudes, and perceptions of the people in Lower Moshi towards malaria vector control and the acceptability and sustainability of microbial larviciding as a complementary strategy in malaria vector control. A questionnaire was administered in 100 households in the two villages with the help of a local village guide. The Principle Investigator together with research assistants (RAs) from Kilimanjaro Christian Medical Center (KCMC) administered questionnaires to sampled households. RAs were experienced in
conducting interviews and were knowledgeable about ethics in research. Before going to the field, the Principle Investigator familiarized the RAs with the project, objectives of the study and data collection tools. The team rehearsed together to ensure that the questions were asked in uniformity across the research team. The team was assisted in locating households by community leaders and a village guide. GPS locations of the surveyed households were also marked for later mapping of the surveyed area. The Principle Investigator had the responsibility of overseeing the whole process to ensure that ethical concerns and quality of data were not compromised.

Secondly, FGDs and in-depth interviews were conducted in selected villages among community members and other stakeholders as defined in the sampling plan. To analyze the people’s understanding regarding the topic, FGDs were conducted among community members (including rice farmers). The subjects were screened for eligibility. Written consent was obtained from participants in the survey and in-depth interviews and by word of mouth for participants of the FGDs. The Principle Investigator gave a briefing on the nature of the proposed malaria vector control intervention to ensure that the members in each discussion understood the discussion topic. The FGDs were moderated by a local research assistant who understood the dialect of the local people. At the end of the FGDs, a small amount of incentive (US$ 2) was provided to each participant to cover transport or lunch. The proceedings were audio recorded and notes were taken.

Four in-depth interviews, each lasting for about 45 minutes, were conducted with two agricultural experts and two health workers from the two villages. Notes were
taken during the interviews. The Principle Investigator was responsible for conducting the in-depth interviews and taking notes. The survey, FGDs and IDIs were all conducted in Kiswahili.

2.6 Measures

Both qualitative and quantitative measurements were used to measure the outcome. This triangulation of data augmented well to provide enough data to deduce conclusions. The interview questions addressed relevant issues and sought to answer the research questions and satisfy specific objectives. Each subset of interview questions or discussion topics in FGDs addressed a specific study objective. The questions attempted to measure the acceptability of microbial larviciding among the community members, and the concerns and general perceptions towards the proposed intervention. To seek more understanding of the same, FGDs served the purpose of uncovering attitudes and expected challenges that could be faced in implementing this intervention with the community. Similarly, structured questions for participants of the in-depth interviews tried to uncover concerns that would be of interest to the researchers in realizing their objectives and the overall success of the project. Combining the survey data with qualitative data was important in drawing conclusions of the overall study.

2.6 Variables

The dependent variables were larviciding knowledge, willingness of community members to use microbial larviciding in their rice farms and the willingness to pay for the larviciding fertilizer. Independent variables, as explained in the conceptual
framework, were demographic characteristics, knowledge about malaria and perceived attitudes and perceptions towards microbial larviciding.

2.7 Ethical Considerations

To protect the rights of human participants, the study received Institutional Review Board (IRB) approval from the Duke Kunshan University IRB, National Health Research Ethics Review Committee (Nat-REC) and Kilimanjaro Christian Medical University College IRB. Being an exploratory study seeking to understand community attitudes, perceptions, and concerns in regard to microbial larviciding, little or no harm to the study participants was expected. To mitigate risk of personal information being disclosed, confidentiality of the participants in the FGDs, in-depth interviews and survey respondents was maintained through a variety of mechanisms. Participants in the FGDs were asked to strictly observe confidentiality of the proceedings during the discussion. They were also advised to respect the opinions of every participant to avoid conflicts. They were advised to allow each participant to freely express their opinions. Confidentiality of the in-depth interview participants and survey respondents was addressed by giving them unique identifications number without names or other identifying details. The data was kept safely and identifiable data was only accessible to the Principal Investigator and RA administering the questionnaire. Consent was sought whenever audio recording or pictures were taken.
2.8 Data Collection and Analysis

The Principle Investigator took the lead in collection of data from the in-depth interviews, FGDs and survey. With consent from the participants, the proceedings of the interview were audio recorded. Translating and transcribing of the recordings and entry of data was done by the Principle Investigator. The transcribed data was coded to capture different themes that emerged during the study.

Analysis of collected data was done by the Principle Investigator using NVivo software for qualitative data and Stata (Version 14) for the quantitative data. For the IDIs and FGDs data, the investigator looked for emerging themes using the NVivo software while descriptive statistics and associations between independent and dependent variables from quantitative data were derived using the Stata software. Internal validity was determined by comparing the two sets of data, i.e. quantitative and qualitative data. Analysis of the merged data helped the investigator to draw generalizable conclusions on acceptability, attitudes, and perceptions of the community towards microbial larviciding in mosquito vector control as well as to explain associations that emerged.
3. Results

This chapter details the results obtained from analysis of quantitative and qualitative data. The analysis of data looked into understanding the community knowledge, attitudes and perceptions towards microbial larviciding. We also focus on understanding the acceptability of microbial larviciding as well as the concerns that the community might have regarding accepting use of a fertilizer with microbial larvicides in their rice farms and their willingness to pay for the fertilizer.

3.1 Quantitative Results

Socio-demographic characteristics of respondents

Table 1 shows demographic characteristics of household survey respondents. One hundred household interviews were conducted in two villages. As shown in the table, most the respondents were women (56%). The respondent mean age was 47.4 years with the modal age group falling between the ages of 51-61 years. It is important to note that 44% of households had under-five years of age children who are more vulnerable to malaria than other age groups. Thirty percent of the respondents were below the age of 40 years and about 18% were aged above 62 years. Most of the respondents had some education or had completed primary-level education (67%). Only about 20% of the respondents had some or had completed secondary or higher level of education. About 6% of the respondents had informal or no education. The majority (52%) of families had between four to six household members. The household size was inclusive of extended family and non-family members. The largest household size had
ten people and the smallest had one person. The most common economic activity was
crop farming (50%), followed by mixed farming where respondents reported keeping
animals in addition to growing crops (35%). About 8% of the people were self-employed
and about five people reported being unemployed or engaging in no economic activity.
Table 1: Demographic characteristics

Summary of Socio-demographic Characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>n</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex of household head</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>44</td>
<td>44.00</td>
</tr>
<tr>
<td>Female</td>
<td>56</td>
<td>56.00</td>
</tr>
<tr>
<td><strong>Age of respondent</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 - 28</td>
<td>11</td>
<td>11.00</td>
</tr>
<tr>
<td>29 - 39</td>
<td>19</td>
<td>19.00</td>
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<tr>
<td>40 - 50</td>
<td>25</td>
<td>25.00</td>
</tr>
<tr>
<td>51 - 61</td>
<td>27</td>
<td>27.00</td>
</tr>
<tr>
<td>62+</td>
<td>18</td>
<td>18.00</td>
</tr>
<tr>
<td><em>Mean Age = 47.4 Years, SD= 14.1</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Household with under 5</strong></td>
<td>44</td>
<td>44.00</td>
</tr>
<tr>
<td><strong>Education level of respondent</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>6</td>
<td>6.06</td>
</tr>
<tr>
<td>Informal</td>
<td>6</td>
<td>6.06</td>
</tr>
<tr>
<td>Primary</td>
<td>67</td>
<td>67.68</td>
</tr>
<tr>
<td>Secondary</td>
<td>17</td>
<td>17.17</td>
</tr>
<tr>
<td>Post-Secondary</td>
<td>3</td>
<td>3.03</td>
</tr>
<tr>
<td><strong>Number of household members</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 - 3</td>
<td>21</td>
<td>21.00</td>
</tr>
<tr>
<td>4 - 6</td>
<td>52</td>
<td>52.00</td>
</tr>
<tr>
<td>7 - 9</td>
<td>24</td>
<td>24.00</td>
</tr>
<tr>
<td>10+</td>
<td>3</td>
<td>3.00</td>
</tr>
<tr>
<td><strong>Occupation of household head</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crop Farming</td>
<td>50</td>
<td>49.50</td>
</tr>
<tr>
<td>Pastoralism</td>
<td>2</td>
<td>1.98</td>
</tr>
<tr>
<td>Mixed Farming</td>
<td>35</td>
<td>34.65</td>
</tr>
<tr>
<td>Employed</td>
<td>1</td>
<td>0.99</td>
</tr>
<tr>
<td>Self-employed</td>
<td>8</td>
<td>7.92</td>
</tr>
<tr>
<td>Unemployed</td>
<td>5</td>
<td>4.95</td>
</tr>
</tbody>
</table>

Table 2 describes respondents’ knowledge about different malaria control methods and their practice. As shown in the table, knowledge and use of insecticide treated nets (ITNs) were common among the respondents (99% and 96% respectively).
Most respondents (97%) also understood the importance of clearing grass and bushes around their homes in reducing hiding places of mosquitoes. This method was also widely practiced by many respondents (85%). Regarding other strategies, there seemed to be a gap between knowledge and practice. Draining of stagnant water was common knowledge in many respondents as a method of mosquito population control but was not as commonly practiced. Despite a large proportion of respondents (93%) knowing that larviciding is important in mosquito control and reducing malaria, only about 28% practiced this method.

**Table 2: Community knowledge and use of different malaria control methods**

<table>
<thead>
<tr>
<th>Method</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITNs</td>
<td>93 (94)</td>
<td>98.94</td>
</tr>
<tr>
<td>Insecticide coil</td>
<td>59 (93)</td>
<td>63.44</td>
</tr>
<tr>
<td>Insecticide spraying</td>
<td>84 (92)</td>
<td>91.30</td>
</tr>
<tr>
<td>Draining stagnant water</td>
<td>87 (92)</td>
<td>94.57</td>
</tr>
<tr>
<td>Clearing grass/bushes</td>
<td>90 (93)</td>
<td>96.77</td>
</tr>
<tr>
<td>Mosquito repellant</td>
<td>74 (92)</td>
<td>80.43</td>
</tr>
<tr>
<td>Antimalarial drugs</td>
<td>60 (92)</td>
<td>65.22</td>
</tr>
<tr>
<td>Larviciding</td>
<td>82 (93)</td>
<td>88.17</td>
</tr>
</tbody>
</table>

Table 3 shows the reported understanding of mosquito breeding sites within the community. As shown, majority (88.3 %) of the respondents had knowledge that mosquito breeding occurs in stagnant water. However, one person reported that mosquitoes breed in trees and another one reported that they breed in bushes. 3 people did not know where mosquitoes breed.
Table 3: Knowledge of mosquito breeding sites

<table>
<thead>
<tr>
<th>Reported Breeding site</th>
<th>n = 94</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bushes</td>
<td>1</td>
<td>1.06</td>
</tr>
<tr>
<td>Trees</td>
<td>1</td>
<td>1.06</td>
</tr>
<tr>
<td>Stagnant water</td>
<td>83</td>
<td>88.30</td>
</tr>
<tr>
<td>Inside house</td>
<td>5</td>
<td>5.32</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>1.06</td>
</tr>
<tr>
<td>Don’t know</td>
<td>3</td>
<td>3.19</td>
</tr>
</tbody>
</table>

Reported understanding of mosquito breeding control in the rice paddies is shown in table 4. Participants had knowledge of various approaches that they thought could reduce breeding. About 53% reported spraying of insecticides as one of the ways community could reduce mosquito breeding while 18% and 15% reported intermittent irrigation and microbial larviciding, respectively, as other methods that could help reduce mosquito breeding in rice paddies.

Table 4: Reported mosquito breeding control methods in rice paddies

<table>
<thead>
<tr>
<th>Method</th>
<th>n = 92</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent irrigation</td>
<td>17</td>
<td>18.48</td>
</tr>
<tr>
<td>Clearing grass/bushes</td>
<td>3</td>
<td>3.26</td>
</tr>
<tr>
<td>Spraying insecticides</td>
<td>49</td>
<td>53.26</td>
</tr>
<tr>
<td>Microbial larviciding</td>
<td>14</td>
<td>15.22</td>
</tr>
<tr>
<td>Don’t know</td>
<td>9</td>
<td>9.78</td>
</tr>
</tbody>
</table>

Table 5 illustrates respondents’ knowledge about larviciding. Sixty percent reported they had knowledge or experience with larviciding. Most of them (96%)
mentioned they had knowledge of chemical larviciding, while only 4% had knowledge of microbial larviciding. After information about microbial larviciding was provided by the interviewer, 70% of the respondents said they would prefer to use microbial larviciding in preference to chemical larviciding. Nearly every respondent (97%) was willing to use fertilizer with larvicides in their rice fields after being informed about larviciding. Almost all (97%) said they would be willing to inform and encourage other community members to use microbial larviciding in their rice fields.

Table 5: Knowledge attitudes/perceptions towards larviciding

<table>
<thead>
<tr>
<th>Variable</th>
<th>n</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge/experience with larviciding</td>
<td>56 (90)</td>
<td>60.22%</td>
</tr>
<tr>
<td>Familiarity with larviciding methods</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>52</td>
<td>96.30%</td>
</tr>
<tr>
<td>Microbial</td>
<td>2</td>
<td>3.70%</td>
</tr>
<tr>
<td>Larviciding method preference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemical</td>
<td>16</td>
<td>29.63%</td>
</tr>
<tr>
<td>Microbial</td>
<td>38</td>
<td>70.37%</td>
</tr>
<tr>
<td>Willingness to use microbial larviciding</td>
<td>72 (73)</td>
<td>97.30%</td>
</tr>
<tr>
<td>Willingness to encourage other community members to adopt microbial larviciding</td>
<td>89 (91)</td>
<td>96.74%</td>
</tr>
</tbody>
</table>

In response to the question about the likelihood that microbial larviciding would help in reducing malaria cases, a majority (56%) thought it was “very likely” and 37% of the respondents thought that microbial larviciding would “likely” reduce malaria.

---

1 The interviewer explained to respondent about microbial larviciding in regards to the concept, how microbial larvicides work and how the proposed study would be introduced to rice farmers in fertilizers. This information was provided to all the respondents regardless of whether they reported knowledge about larviciding or not.
infections (See Figure 3). Only 4% of the respondents thought that microbial larviciding was “very unlikely” to reduce malaria cases in the community (See Figure 3).

**Figure 3:** Reported likelihood of microbial larviciding in reducing malaria cases

Respondents had varied concerns regarding the usage of microbial larviciding as shown in Figure 4. Safety was a major concern to many respondents (40%). They mentioned that before they could apply microbial larvicides in their farms, they would be concerned about their personal and the safety of their animals as well as their crops. Another concern which 23% of respondents mentioned was cost. They were concerned that the fertilizer with larvicides might be costlier than the fertilizers they commonly use in their farms. Thirteen percent of respondents were concerned about the effectiveness of the fertilizer with larvicides regarding their crop yields. Only 7% of respondents said they had no concerns with using the fertilizer with larvicides in their farms.
As shown in Figure 5, respondents reported how much they would be willing to pay for a 50kg bag of fertilizer with larvicides. The mean price reported was TSh 35489.45 (1 US$~2000). As expected, many of the respondents were willing to pay a lower cost than what they currently pay\(^2\) to purchase usual fertilizers for their crops. There are, however, a few who expressed a willingness to pay a higher price for the larviciding fertilizer because of the added advantage that they perceived would come with the larviciding fertilizer.

\(^2\) The reported market price for 50 Kg bag of fertilizer without larvicides was Tsh 45000
Figure 5: Household willingness to pay for a 50Kg bag of fertilizer with microbial larvicides

Table 6: Logistic regression of determiners of larviciding knowledge

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR</th>
<th>95% CI</th>
<th>z</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>1.65</td>
<td>0.55–4.91</td>
<td>0.90</td>
<td>0.368</td>
</tr>
<tr>
<td>Number of people in household</td>
<td>0.93</td>
<td>0.74–1.18</td>
<td>-0.58</td>
<td>0.565</td>
</tr>
<tr>
<td>Respondents grow crops (rice)</td>
<td>4.46</td>
<td>1.55–12.85</td>
<td>2.77</td>
<td>0.006***</td>
</tr>
<tr>
<td>Primary level education</td>
<td>0.71</td>
<td>0.16–3.21</td>
<td>-0.44</td>
<td>0.66</td>
</tr>
<tr>
<td>Secondary and higher education level</td>
<td>0.13</td>
<td>0.02–1.04</td>
<td>-1.92</td>
<td>0.055</td>
</tr>
<tr>
<td>Age</td>
<td>0.95</td>
<td>0.91–0.99</td>
<td>-2.50</td>
<td>0.012***</td>
</tr>
</tbody>
</table>

Table 4 shows the results of a logistic regression model that we used to determine variables that were associated with knowledge of larviciding among the
respondents. The overall model had a p-value of 0.0013 and a pseudo $R^2$ of 0.1813. Thus, the model was statistically significant and explained about 18% of the observed variation in the dependent variable. From the results, growing crops (rice) was seen to be a positive predictor of knowledge of larviciding with an OR of 4.46 compared to those who did not grow crops. Age was a negative predictor of knowledge of larviciding. For every unit increase in age, there is an expected 5% decrease in odds of having knowledge of larviciding. Other predictor variables in the model had no statistical significance at the 95% confidence level.

Table 7: Linear regression model of determiners of willingness to pay for fertilizer with microbial larvicides

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>95% CI</th>
<th>t</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>-1516.543</td>
<td>-7389.451 – 4356.365</td>
<td>-0.43</td>
<td>0.668</td>
</tr>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of people in household</td>
<td>1028.864</td>
<td>-257.209 – 2314.936</td>
<td>1.33</td>
<td>0.187</td>
</tr>
<tr>
<td>Respondents grow crops (rice)</td>
<td>4822.818</td>
<td>-3333.247 – 12978.88</td>
<td>0.99</td>
<td>0.328</td>
</tr>
<tr>
<td>Has knowledge on larviciding</td>
<td>7149.38</td>
<td>1212.028 – 13086.73</td>
<td>2.01</td>
<td>0.049***</td>
</tr>
<tr>
<td>Secondary and higher education level</td>
<td>1494.886</td>
<td>-5290.411 – 8280.182</td>
<td>0.37</td>
<td>0.715</td>
</tr>
<tr>
<td>Age</td>
<td>-126.9988</td>
<td>-342.1363 – 88.13871</td>
<td>-0.98</td>
<td>0.328</td>
</tr>
<tr>
<td>Household has children (5 and below years old)</td>
<td>1028.864</td>
<td>-257.2087 – 2314.936</td>
<td>1.33</td>
<td>0.187</td>
</tr>
</tbody>
</table>

Table 5 shows the results of a regression model that we used to determine factors associated with willingness to pay for fertilizer with larvicides. The model was not statistically significant at 95% confidence level (p-value of 0.1725 and F statistic of 1.53).
R² of the model was 0.1342, thus, the model statistically explained about 13% variation observed in willingness to pay for fertilizer with microbial larvicides among the survey respondents. As shown in the table, the willingness to pay for fertilizer was significantly influenced by knowledge on larviciding (p-value 0.049). Having knowledge on larviciding increased willingness to pay for fertilizer with larvicides by Tshs 7149.38 compared to people without knowledge on larviciding while holding other variables constant. Other variables were not statistically significant at 95% confidence level. However, these results were inconclusive as the association noted could have occurred by chance (p-value > 0.05).

3.2 Qualitative Data

3.2.1 In-depth Interviews Results

A total of four in-depth interviews were conducted. In each village, one agricultural expert and one human health expert were purposively selected to participate. They all understood well the risk factors of malaria in this community. They identified rice farming as a risk factor for malaria by acknowledging the fact that stagnant water that stays for long in the rice plots is a rich breeding ground for mosquitoes. One agricultural expert stated that, “although the cases of malaria has gone down over the years, stagnant water in the rice plots and in the trenches supplying water to the plots harbor mosquito larvae and support the breeding of mosquitoes.” Another participant working in a community health center pointed out that the rice farming poses a big risk
of malaria infections especially where people are predominantly rice farmers. They concurred that rice farming increases the risk of malaria in the village.

When talking about commonly used malaria control strategies, it was clear from the respondents that insecticide treated nets were common among the residents of the village. Among the reasons given for why ITNs were common was low cost (they are often given freely by the government or non-governmental organization). However, both a retired health professional and one of the agricultural experts mentioned that sometimes cost of the ITNs is an issue, especially when the government stops the program to provide the nets. A respondent also stated that this method is not very effective because some people do not like ITNs. “They say the nets are suffocating”, one agricultural expert reported. Another agricultural expert mentioned that people also commonly use Ngao (insecticide) to spray and kill mosquitoes inside the house. Another agricultural expert mentioned that use of insecticides in the rice plots sometimes kills mosquito larvae. He also said that some villages use crop rotation, which helps in reducing breeding of mosquitoes.

Regarding the response of the community to microbial larviciding, the interview subjects were positive that the community would embrace the program. The retired health professional mentioned that with education, the community would be ready to embrace the program. One agricultural expert predicted, “The community will welcome microbial larviciding when they see the practical applicability of microbial larviciding.” One human health expert stated that it would be important for researchers to educate the farmers on the safety and effectiveness of the program. One agricultural expert
mentioned that it would be important to lower the cost of the fertilizer. He suggested that a lower price than the cost of commonly used fertilizer (TShs 50,000 or US$ 25) would encourage the farmers to use it. He also said that researchers might consider using sample plots to show the effectiveness and safety of the fertilizer with larvicides. It was suggested that the farmers will need to be assured of availability of the fertilizer. One agricultural expert asserted that working with other partners who have interest in the rice farms, including the buyers of the rice, would be important in addressing the issues together.

**3.2.2 Focus Group Discussion Results**

Using Nvivo to analyze the data obtained from FGDs, four major themes were identified. These included:

1. **Knowledge on malaria and vector control**
2. **Effectiveness and shortcomings of various malaria vector control strategies used in the community**
3. **Concerns regarding applicability of microbial larviciding**
4. **Community uptake of microbial larviciding in malaria vector control**

Although there were slight differences between the results obtained from the two villages, the major themes identified were the same.

**Knowledge on malaria and vector control**

Most participants in both villages had a clear understanding of malaria as a disease that is transmitted by mosquitoes. From the analysis, many participants could
associate malaria infections with mosquito bites. Regarding the fatality of malaria, especially among vulnerable groups, i.e. pregnant women, and children below the age of five years, it was evident that very few made such associations. However, one participant from Chekereni mentioned that sometimes malaria could cause death. In this regard, it might be important for more community education to emphasize the importance of pregnant women taking prophylactic treatment during pregnancy and families getting the children under five checked by physicians when they show fever or malaria like symptoms.

It was evident that most people understood and linked activities such as rice farming to risk factors of malaria. One participant said, “In this area, there are many people who grow rice and there is stagnant water for long time and in these fields, there are a lot of mosquitoes in the evening because they breed in the water. Also, the trenches that supply water to the rice plots support breeding of mosquitoes.” However, there was some evidence of misconceptions about where mosquitoes breed. Some people mentioned that mosquitoes breed in bushy live fences and dirty compounds.

Participants had a good understanding of malaria symptoms, and they also had knowledge of different ways that can be used to protect them from malaria. Some of the commonly used methods that resulted from the analysis included using mosquito treated bed nets, getting into the house early to avoid mosquito bites, closing doors and windows in the evening, using repellants, cleaning the environment, emptying cans, burning cow dung, and using mosquito coils.

*Effectiveness and shortcomings of various malaria vector control strategies*
The issue of efficacy and cost effectiveness of malaria control strategies was a common theme in the two villages. It was evident as mentioned by many participants that the community used treated bed nets more than any other method. This could be partly because the government and other NGOs have been successful in widely distributing free nets to the people as was reported by participants and IDIs respondents. One male participant commented “I think nets are effective and cheap to afford for many people. Most are usually offered freely in this area by some government bodies or other organizations. Some people do not however use the nets.” Other malaria control strategies mentioned by some participants were ineffective because of the cost, accessibility or sometimes because they had other contraindications to some people. For instance, some people commented that insecticide spraying inside the houses was expensive and could sometimes cause breathing problems to children. Similarly, insecticide coils were said to be unpopular as some people associated them with coughing or breathing problems.

Concerns regarding applicability of microbial larviciding

After being explained about the proposed microbial larviciding program through use of fertilizers by rice farmers, most participants commented that it would significantly help in control of mosquito breeding and reducing malaria cases. Most indicated that they had never heard about microbial larviciding before. Some mentioned that they had heard about chemical larviciding. One member said, “Mosquito population has been increasing. Controlling the breeding sites will be very effective in controlling the
vector.” As was expected, participants raised questions about its efficacy and safety, among other concerns. In both villages, participants agreed that before they could use the fertilizer with larvicides on their farms, they would need to be sure that the bacteria in the fertilizer would not cause any harm to them, their animals, or the plants. It was also clear that cost would be a concern because most people cannot afford high costs of fertilizers. However, one participant mentioned that as long as rice productivity is not affected, then cost will not be a problem. Regarding applicability, it emerged that there would be need for community education and advocacy through offering practical examples in demonstration plots.

Community uptake of microbial larviciding in malaria vector control

In the two villages, most people felt that community members, particularly rice farmers, would be willing to buy the fertilizer with larvicides when the concerns are addressed. From this analysis, participants expressed their desire to reduce the mosquito population, which would not only reduce malaria cases but will reduce the biting. Most people also expressed the feeling that the farmers’ willingness to use the fertilizer would be enhanced if cost of the fertilizer was slightly lower than the currently used fertilizers. One female participant asked, “How about the cost? I think many people will be very concerned about how much the fertilizer will retail at. I know many people use fertilizer but they are always complaining about the cost of the fertilizer so the cost of this new fertilizer will be a concern.” This was expected because most people might not be willing to pay more for something they have little knowledge or experience about, especially
when it comes to fertilizers. Most people in this community are small-scale farmers and therefore cost is a major concern. Offering them the fertilizer at a lower cost would incentivize them to buy and use it in their farms.
4. Discussion

The findings of this study suggest that most people in the two villages understood well about malaria in terms of its transmission, prevention measures and, more importantly, the risk associated with rice farming in the community. Despite their understanding that rice farming significantly contributes to increased mosquito breeding and heightened risk of malaria in the community, there was little knowledge on how they could effectively control mosquito breeding in the rice fields using non-chemical methods. This has also been documented by other studies conducted in rural Tanzania looking at the knowledge of larval source management (Mboera et al., 2014). While most members understood, and had knowledge of different mosquito control methods, most agreed that they do not practice them because of their various shortcomings.

As has been shown in other studies (Mboera et al., 2014), community knowledge of larviciding was generally low. Larviciding has remained a rare practice in malaria endemic areas in Tanzania, except in the capital city of Dar es Salaam (Geissbühler et al., 2009). Some studies (Maheu-Giroux & Castro, 2013) have been conducted in urban areas on larviciding to examine its efficacy and cost effectiveness, but only a few have considered working with rural communities, especially those that cultivate rice. Studies (Maheu-Giroux & Castro, 2013) (Rahman et al., 2016) have shown the cost effectiveness of microbial larviciding, but the intervention has not been put in practice in rural Tanzania or most other countries in sub-Saharan Africa where malaria is endemic.
The regression analysis showed that crop farming significantly associated with knowledge of larviciding. Rice farmers reported that they spray chemicals, which kill pests including mosquito larvae, which possibly explains why they are more knowledgeable about larviciding. This was also evident from interviews with agricultural experts in the community. Increased age appeared to be associated with lack of knowledge of larviciding. Younger people are likely to be taught in school different malaria control methods including larviciding, which might have enhanced their knowledge (The World Bank, 2009).

Most people believed that larviciding would significantly help in the control of mosquitoes and consequently further reduce malaria incidence in this area. However, as other studies have indicated, many people expressed different concerns with microbial larviciding. As Rahman, et al. (2016) expressed, cost of larviciding could be a major challenge towards its implementation. Most rice farmers do small scale farming and are cost sensitive. Per the survey responses, those willing to buy fertilizer with larvicides mentioned that the cost needs to be lower than the cost of other fertilizers currently being used to incentivize its use. Another concern expressed by many people is the safety of the larvicides to plants, humans, and animals. Other studies conducted in Tanzania also found this as a major concern of study subjects (Mboera et al., 2014). Interestingly, FGD participants seemed relieved upon hearing that the strategy has been applied elsewhere and has been safe to the environment, people, and animals as well. Some people were, however, indifferent in terms of having any concerns, and they argued that they were sure the government would not allow an unsafe program to be
run. These concerns as expressed by the community present considerable challenges towards successful community uptake and use of microbial larvicides and would have to be addressed by any future intervention efforts.

Talking to agricultural and human health experts in the area regarding the community’s acceptability, all respondents were optimistic that the community would accept the program. They raised similar concerns that the community would be worried about applying microbial larvicides in their rice plots through fertilizers. Agricultural experts mentioned that the farmers would be concerned about the productivity of the rice when they apply the fertilizer with larvicides. It was apparent that before implementation, it would be important to have demonstration plots that the farmers could see and learn from about the productivity. It also emerged that working with other stakeholders in rice farming would positively influence the uptake of the program by the farmers.

It was evident from the health and agricultural professionals that community sensitization and education would be a major component that would drive the acceptability of the program by the community. Community sensitization is an important component of IVM strategies that involve community engagement in larval source management (Mukabana et al., 2006). They proposed working with the village leadership in educating the community on the importance of larval source management and use of microbial larvicides in the rice plots which are a major source of mosquito breeding ground. Most respondents mentioned that mosquitoes are a major nuisance
especially because of their bites. Therefore, an effective program like microbial larviciding would be welcome in as much as the community are sensitized about it.

As another study (Mboera et al., 2014) conducted in rural Tanzania found, the community generally expressed readiness to pay for the fertilizers with larvicides. Many respondents mentioned that they would be ready to pay for this kind of fertilizer, but it should be sold at a lower cost than that of the usual fertilizers applied in their farms. Some members, however, felt that since the fertilizer is doing much more than adding nutrients for their crops, it should be sold at a slightly higher price than the fertilizer that does not kill mosquito larvae. Other studies have correlated willingness to pay with wealth in Sudan (Onwujekwe, Malik, Mustafa, & Mnzava, 2005) as well as in Tanzania (Mboera et al., 2014). Although the readiness to pay for the fertilizer and the amount respondents thought would be a fair price for a bag of fertilizer with larvicides could be associated with several factors, this investigation was beyond the scope of this study.

From the analysis of FGDs, it was evident that the practice of some mosquito control methods remains low due to misconceptions and lack of enough knowledge on how to carry out some of the practices. Also, it was clear that some of the control methods are not readily available to the community. Analysis also showed that there would be need for community sensitization on microbial larviciding to eliminate the doubts and fears that some of the community members could have regarding safety and efficacy of this approach. FGDs also provided evidence on the willingness to pay for the larviciding fertilizer. As in the survey and IDIs, it was important to note that the cost
would be an important factor in determining community acceptability of microbial larviciding through fertilizers.

**4.1 Study Strengths**

The major strength of this study lies in its triangulation of both quantitative and qualitative data using mixed methods. This combination not only enriches the data but also provides room for verification of data. The qualitative data expanded the understanding of outcomes obtained from the survey data. Involving experts in IDIs allowed integration of expert views in understanding common themes that emerged and enhanced our knowledge about successful implementation. For instance, the results from our regression analysis determinants of larviciding knowledge showed that rice farmers had higher odds of having larviciding knowledge compared to people who were not rice farmers. From analysis of our IDI data, we discerned that rice farmers are educated and trained through agricultural seminars on ways that they could use to kill pests including mosquito larvae. Also, including people who are not rice farmers in the study helped minimize sampling bias that could be associated with selection of rice farmers only in focus group discussions and in the survey.

**4.2 Study Limitations**

Most of the information collected was self-reported and therefore could have been biased in several ways. First, responses to the question on how much they would be willing to pay could have been influenced by social desirability bias during the focus group and the surveys. Respondents could have mentioned a price that they thought the
interviewers wanted to hear. Secondly, the questions about willingness to use the intervention or encourage other community members to use the intervention could have been biased as well. Also, the study did not collect some important variables (i.e., wealth index) that could have helped in modeling to predict willingness to pay for the fertilizer with microbial larvicides.

Another limitation was the possible perception of fevers and similar febrile illnesses to be malaria. Malaria prevalence in this region is particularly low, but the people often refer to any fever as malaria (Ijumba et al., 2002). This might have influenced our finding and biased the results.

4.3 Conclusion

The community in Lower Moshi understood well that rice farming supports large mosquito populations, which are a nuisance to them. Despite their understanding, they are less knowledgeable on methods that they can use to control breeding of mosquitoes in the rice fields. ITNs are the most commonly used malaria control method in this community. While the community seemed to be aware of other methods, they expressed various shortcomings including cost, effectiveness and contraindications associated with use of insecticides and repellants.

This study also provides evidence that the community in Lower Moshi is positive about and willing to be engaged in microbial larviciding, an integrated vector management strategy to reduce mosquito population in the area. The attitude towards applicability of microbial larviciding is positive, but would be amplified through
community sensitization from leaders and other stakeholders in rice farming.

Incentivizing the cost of fertilizers with microbial larvicides would motivate rice farmers to use it in their plots. Therefore, malaria control programs in the region would have to consider cost before implementing the program. Similarly, studies on safety, efficacy on reducing mosquito population and effect on rice crops would be critical in providing evidence to the community to boost confidence and willingness to adopt microbial larviciding. As was mentioned by agricultural experts, such studies might be carried out in collaboration with an agricultural training center and other agriculture oriented stakeholders.

The limitation of insecticide use in mosquito control due to resistance in Tanzania indicates a need for policy makers to consider integrating other non-chemical mosquito control approaches. Overall, the future of applicability of microbial larviciding with rice farmers in Lower Moshi Tanzania as a component of IVM lies in the efforts put towards educating and sensitizing the community and creating incentives so that farmers can afford the fertilizers with larvicides and render the program sustainable.
Appendix A- Survey Questionnaire

MICROBIAL LARVICIDING IN MALARIA VECTOR CONTROL

Understanding Community Knowledge, Attitudes, Perceptions and Concerns related to
Microbial Larviciding as an Integrated Vector Management (IVM) Strategy in Malaria
Control

Household Survey – Mabogini, Lower Moshi, Tanzania
June- August 2016

Household ID: ……………………………
Date: ………………………………………
Name of the village ………………………

Introduction
My name is David Wainaina, Masters Student in Global Health at Duke Kunshan
University. Am working with Global Health Research Center (Duke Kunshan
University, China), Duke Global Health Institute (Duke University, USA) in
collaboration with Kilimanjaro Christian Medical University College. We are working to
collect information on how the community perceives use of bacteria to kill mosquito
larvae (microbial larviciding), as a malaria control intervention that we plan to
implement with rice farmers. This interview is a part of my data collection process and
will take only a short time. Thank you for choosing to be a part of this study.
I. Demographics

1. For each member of the household, record the following:

<table>
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<tr>
<th></th>
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<td>1 2 3 4 5 6 9</td>
<td>1 2 3 4 5 6 9</td>
<td>1 2 3 4 5 6 9</td>
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</tbody>
</table>

* Respondent
II. Community Understanding of Malaria and Prevention

*Malaria Knowledge*

2. Have you ever seen mosquitoes in this household?
   
   [1] Yes *(Proceed to next question)*
   
   [2] No *(Proceed to question 4)*
   
   [-9] Don’t know

3. According to your knowledge what do you think attracts mosquitoes around this household? *(Do not read answers, circle all that apply)*
   
   [1] Dirty compound
   
   [2] Long grass and bushes
   
   
   [4] Rainfall
   
   [5] High temperatures
   
   [9] Other
   
   [-9] Do not know

4. Which of the following ways do you think will help reduce malaria?
   
   [1] Fencing the homestead
   
   [2] Growing trees around the homestead
   
   [3] Controlling mosquitoes
   
   [4] Using clean drinking water
   
   [5] Eating good food
   
   [9] Other
   
   [-9] Do not know

5. According to your knowledge where do mosquitoes breed?
   
   [1] Bushes
   
   [2] On trees
   
   [3] In stagnant water
   
   [4] Inside the house
   
   [9] Other
6. Do you think mosquitoes breed in the rice fields?
   [1] Yes
   [2] No *(Proceed to question 8)*

7. How do you think we can reduce mosquito breeding in the rice fields?
   [1] Practice intermittent irrigation
   [2] Clearing grass and bushes around the home
   [3] Spray insecticides in the rice fields
   [4] Use microbial larvicides
   [9] Other ______
   [-9] Don’t Know
### Malaria Prevention

8. How can the community reduce malaria cases?

<table>
<thead>
<tr>
<th>SN</th>
<th>Method <em>(Mentioned)</em></th>
<th>8a. Do you think this helps?</th>
<th>8b. Do you do this?</th>
<th>8c. Which of these methods do you think is most effective at preventing malaria?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Use a mosquito net</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Use mosquito insecticide coils</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Spray insecticides inside the house</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Drain stagnant water</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Clear grass and bushes around the home</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Mosquito repellants</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Take anti-malarial intermittently</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Clean the environment around the Home</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Kill mosquito larvae (Larviciding)</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>Other</td>
<td>1 2</td>
<td>1 2</td>
<td>1</td>
</tr>
</tbody>
</table>
III. Knowledge, Attitudes, Perceptions and Concerns Regarding Microbial Larviciding

A. Knowledge

9. Do you have any experience or knowledge about larviciding (killing of mosquito larvae)?

   [1] Yes
   [2] No (Proceed to question 12)

10. Which particular larviciding method are you familiar with?

    [1] Chemical larviciding (Using chemical substances to kill the larvae)
    [2] Microbial larviciding (Using bacteria to kill the larvae)

B. Attitudes

11. According to your understanding, which of these two methods would you prefer to use?

    [1] Chemical larviciding
    [2] Microbial larviciding

12. According to my description of microbial larviciding, would you be willing to use microbial larviciding in your farm as a method to control mosquito breeding and prevent malaria?

    [1] Yes
    [2] No

13. Would you encourage other members in this community to adopt this method as a means of malaria prevention strategy?

    [1] Yes
    [2] No

14. Why would you/would you not encourage another person from adopting microbial larviciding as a malaria control strategy?

   -----------------------------------------------------------------------------------------------------------------------------------
   -----------------------------------------------------------------------------------------------------------------------------------
   -----------------------------------------------------------------------------------------------------------------------------------
   -----------------------------------------------------------------------------------------------------------------------------------
   -----------------------------------------------------------------------------------------------------------------------------------
15. According to my description of microbial larviciding, how likely do you think it will be in reducing malaria infections in this community?

[1] Very unlikely
[2] Unlikely
[3] Likely
[4] Very likely
[-9] Do not know

C. **Concerns**

16. What would be your biggest concern regarding applicability of microbial larviciding?

[1] Cost
[2] Effectiveness
[3] Safety
[9] Other
[-9] Do not know

17. In terms of the farm routine, what concerns would you have in using the larvicides?

.......................................................... ..........................................................

.......................................................... ..........................................................

18. What amount per 50 kg bag of larviciding fertilizer would you be willing to spend?

......................................................... TSh
Appendix B- In-depth Interview Guide

Interview Guide for In-Depth Interviews of village leaders and community health workers)

**Topic:** Attitudes and Perceptions towards Microbial Larviciding in Malaria Vector Control in Lower Moshi Tanzania

**Interviewee** ..........................................................

**Date:** ...............................................................

**Introduction**

My name is *David Wainaina*, Masters Student in Global Health at Duke Kunshan University. Am working with Global Health Research Center (Duke Kunshan University, China), Duke Global Health Institute (Duke University, USA) in collaboration with Kilimanjaro Christian Medical University College. We are working to collect information on how the community perceives use of bacteria to kill mosquito larvae (microbial larviciding), as a malaria control intervention that we plan to implement with rice farmers. This interview is a part of my data collection process and will take only 45 minutes. Thank you for being a part of this study.

*General interviewee background*

**Key Domains:**

1. Malaria risk in the community
2. Malaria vector control Strategies used in the community and factors underlying their usage
3. Community understanding, attitudes and perceptions of microbial larviciding

**Questions**
Malaria risk in the community

i) Kindly tell me about your knowledge on malaria and related risks in this village
ii) What do you think are the risk factors associated with malaria in this village?
iii) Do you think rice farming in this area aggregates the risk of malaria in the village? Why?

Malaria vector control strategies used in the community

i) Which vector control strategies are commonly used in this community?
ii) Why do you think these strategies are commonly used?
iii) What are the preferred measures in this community? How these are implemented/provided/who pay or provide?
iv) Problems/dissatisfaction with the current measures?

Attitudes and perceptions towards microbial larviciding

i) According to my description of the malaria control measure (intervention), how do you think the community members will respond to it?
ii) What concerns do you think the community members may raise regarding microbial larviciding?
iii) What challenges do you think the researchers would experience in implementing this intervention?
iv) How should we address these challenges that you have just described?
Appendix C- Focus Group Discussion Guide

Focus Group Discussion Guide

Introduction

My name is David Wainaina, Masters Student in Global Health at Duke Kunshan University. Am working with Global Health Research Center (Duke Kunshan University, China) and Duke Global Health Institute (Duke University, USA) in collaboration with Kilimanjaro Christian Medical University College. We are working to collect information on how the community perceives use of bacteria to kill mosquito larvae, as a malaria control intervention that we plan to implement with rice farmers. This focus group discussion is a part of my data collection process and will take only 1 hrs. Thank you for being a part of this study.

Key Domains for the discussion

1. Understanding of malaria and related risk factors
   - What is malaria?
   - What causes malaria
   - How do people get sick of malaria?
   - Who can get sick of malaria?
   - In what ways can we avoid malaria?
   - What do you think makes people get malaria in this area (risk factors)?

2. Malaria control methods and their effectiveness in cost and efficiency
   - Does anyone use any malaria control methods?
   - Which methods of malaria control are practiced in this area?
   - Which methods of malaria control are the most commonly used and why do you think they are common?
   - Which of these methods do you think is most effective and why?

3. Malaria vector control methods
• Which methods of mosquito control or mosquito larva control do you use in this area?
• Which of these methods do you think is the best and why?
• Do you think there are other ways in which mosquitoes can be controlled more effectively?
• Do you think controlling mosquitoes can have any effect on malaria incidences in this area?

4. Microbial larviciding as a vector control method
• Has anyone heard about larviciding?
• How about microbial larviciding?

(Definition and explanation of microbial larviciding will be given)

• Do you think this method of mosquito control will help in reducing malaria in this area?
• Would you be willing to use this method on your farms? Why?
• Would you be willing to pay?

5. Acceptability and challenges towards implementation of microbial larviciding by rice farmers in the village.
• What concerns would you have in regard to microbial larviciding?
• Does safety of this mosquito control method to the environment, animals and people concern you?
• Do you think other members of the community would consider using this method? Why/Why not?
• What ways do you think microbial larviciding would be a challenge to you if you were to apply it?
• Would the cost be a concern for you if you considered to apply this method?
• Do you feel like you can trust this intervention?
• How much would you be willing to pay for this type of mosquito control strategy say for example in 1 acre of land (Write the figure down in the paper provided)

6. Does anyone have any other comments in regard to this issue before we end the discussion?

7. Closing remarks: Tea token issuance, reminding of confidentiality of the discussion contents and contact information for further information.
References


Ijumba, J. N., Mosha, F. W., & Lindsay, S. W. (2002). Malaria transmission risk variations derived from different agricultural practices in an irrigated area of northern Tanzania. Medical and Veterinary Entomology, 16(1), 28–38.


