East Africa Vegetable IPM IL Annual Report
October 1, 2016 – September 30, 2017

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Background
The East Africa Vegetable Crop IPM Innovation Lab works in Feed-the-Future areas of Ethiopia, Kenya, and Tanzania to build the capacity of local institutions to implement effective IPM research and locally-adapted technology transfer programs to reduce losses attributed to pests while reducing use of synthetic pesticides. Our intent is to improve crop productivity and enhance incomes for growers while reducing environmental impacts of crop production in the region.

This report is for activities for the Fiscal Year 2017. Progress reports are arranged by country.

Location - TANZANIA
Morogoro Region: Morogoro Rural and Mvomero districts; Iringa Region: Iringa and Kilolo districts. Villages: Mlali, Peco-Misegese, Msufini, Malolo, Lumuma, Ulaya-Kibaoni, Kibwaya, Mikese station, Sinyaulime, Ruaha Mbuyuni, Iyai, Kihesa-mgagao, Mangalali, Nzihi and Kiponzero). These are villages in Feed-the-Future areas where we have not previously worked.

Description
Tanzania is about 4-times the size of Texas, with a population of 51 million people. According to the Food and Agricultural Organization, 15.7 million Tanzanians were food insecure in 2013.

Nearly 11 million Tanzanians living in Feed the Future target regions, 28.2% in poverty. Agriculture accounts for 31.1% of annual GDP growth. Production of vegetable crops provides employment and income, for especially for the rural population. Vegetables also form a significant part of quality nutrition, although per capita consumption of vegetables is 20-50% of the daily recommended level. Population growth and rapid urbanization have increased the demand for commercially-produced vegetables, and producers are under pressure to intensify or increase the area for production. Most vegetables are produced in 0.25-ha fields; even those that specialize in vegetable production, the area is 0.5 to 1.0 ha. Labor is mostly supplied by the household, but is also hired on casual basis. Production relies mostly on rain to provide the majority of water requirements. Vegetable production producers have a great need for independent information on pests and appropriate control measures, instead of the current dependence on "agro-dealers." Major pests that are of economic importance in vegetables production include: viruses for tomato, brassicas, cucurbits, and beans. In many cases farmers cannot distinguish virus infestation from other crop disorders, so they apply multiple applications of ineffective control measures. Other important pests of tomato include *Tuta absoluta*, nematodes, soil borne seedling diseases, and bacterial wilt. Onions are adversely affected by thrips, purple blotch, and downy mildew.

Collaborators
<u>At Sokonie University of Agriculture</u> (SUA), Morogoro, Tanzania: Drs. Amon P. Maerere, Delphina P. Mamiro, Maulid W. Mwatawala, Hellen Kanyagha, R.O. Majubwa, Gratian M. Rwegasira, Kallunde P. Sibuga, Hosea D. Mtui, Elias Mgembe.

<u>At Mikocheni Agricultural Research Institute</u> (MARI), Dar es Salaam, Tanzani: Dr. Peter Sseruwagi, Dr. Joseph Ndunguru, Malidhia Njelekela

Activities at Sokonie University of Agriculture

Project Objective 1 – Conduct participatory needs assessments to identify priority pests, current pest management practices, availability of alternative IPM technologies, and constraints to IPM adoption by farmers, including policy and regulatory constraints

***Activity 1*:** Vegetable Production Baseline and Impact Assessment Surveys

Activity leaders: Dr. Samwel J. Kabote (SUA), G. Norton (VT), C. Rakowski (OSU), Amon Maerere (SUA) with assistance from Menale Kassie of ICIPE and the Grains IPM IL project.

Site of activity*:* Morogoro (Morogoro Rural and Mvomero districts) and Iringa (Iringa and Kilolo districts), in 15 Villages (Mlali, Peco-Misegese, Msufini, Malolo, Lumuma, Ulaya-Kibaoni, Kibwaya, Mikese station, Sinyaulime, Ruaha Mbuyuni, Iyai, Kihesa-mgagao, Mangalali, Nzihi and Kiponzero). These are villages in Feed-the-Future areas where neither SUA nor OSU have previously worked.

Cooperators: A total of 428 people participated: Farmers 404 (122 female, 282 male), Local Governments Extension Agents 14 (5 female, 9 male), Technicians from collaborating NGOs 3: TAHA (1 male, 1 female) and MVIWATA (1 female), SUA researchers 7 (5 male, 2 female).

***Summary of Results**:*
Baseline survey to identify priority pests, pest management practices, knowledge of IPM was conducted in the two project target regions of Morogoro and Iringa, involving 5 districts and three villages in each district. The 15 villages surveyed had a total of 12,958 households and a population of 53,636 (27,903 female, 25,733 male).

Data were collected on vegetable growers' levels of income and income sources, land, labor and input used in vegetable production, vegetable varieties and marketing information, output, management experience, knowledge about Integrated Pest Management (IPM), pests and control practices, pesticides handling and storage, and technology adoption. A sample size of 404 vegetable growers was involved in the survey where 27% were females. A brief summary of results is given below.

The mean age of vegetable growers was 40 years. About 80% of the respondents had completed primary school level education.

Percent use of various farm inputs by farmers for four vegetable crops in Tanzania.

Farm inputs	Tomato (n=209)	Cucurbits (n=9)	Cabbage (n=45)	Onion (n=141)
Hired labor	73	44	73	86
Inorganic fertilizer	94	33	100	100
Farm manure	14	11	11	4
Compost	1	0	0	1
Mulch	9	11	7	4
Staking	10	0	0	0
Irrigation	75	44	18	97
Pesticides	97	100	100	100

Most important arthropod pests:

Vegetable crop	**Anthropod pest**	**% of respondents**
Tomato	Tomato leaf miner	88
	Aphids	50
Onion	Thrips	44
	Aphids	22
Cabbage	Aphids	63
	Cutworm	21
Cucurbits	Beetles	35
	Cucumber moth	35

Important vegetable diseases:
Tomato blights (early and late blights) were mentioned as the most common diseases followed by tomato leaf rust and bacterial wilt. Blights were the most important as well in onion, cabbage

and cucurbits. In onion blights were followed by purple blotch, leaf spot and powdery mildew, while in cabbage it was the cabbage head rot.

Pest management techniques:
The arthropod pests and diseases were commonly managed through chemical control methods across the four vegetable crops. Generally, the frequencies of spray were high, more so in watermelon and tomato than in cabbage or onion.

Number of times farmers sprayed vegetables in the previous season (% respondents)				
Sprays per season	**Tomato (n=209)**	**Watermelon (n=9)**	**Cabbage (n=45)**	**Onion (n=141)**
0	1.0	0.0	0.0	0.0
1	1.0	0.0	0.0	2.8
2	0.0	0.0	28.9	19.1
3	9.1	22.2	42.2	17.0
4-5	24.9	11.1	20.0	16.3
6-10	22.5	22.2	2.2	34.0
>10	41.6	44.4	6.7	10.6

Vegetable markets:

Location	**Tomato**	**Onion**	**Cabbage**	**Cucurbits**
Farm gate	70.3	95.7	91.1	77.8
Road side	7.2	1.4	4.4	4.4
Local market	35.9	5.3	6.7	6.7

Conclusions: Most vegetable growers in the new study areas are individuals with at least a primary school level of education. Besides seeds, the most important vegetable production inputs used by farmers are synthetic fertilizers and pesticides. Tomato growers reported a wide range of insect pests compared to the growers of other vegetable crops. The most important insect pest of tomato was the tomato leaf miner (*Tuta absoluta*) followed by aphids (*Aphis gossypii*) and Red spider mites (*Tetranicus urticae*), With respect to diseases, blights (early and late blights) were the most important in all the four vegetable crops. Farmers' knowledge on diseases was generally more limited compared to insect pests and weeds. Chemical pest management was the commonest practice across all crops. Overall, most of these vegetable growers, with whom we have not worked previously, had little knowledge of IPM practices. Hence the frequency of spray using synthetic pesticides was very high. This suggests that pest management is causing an increase in production costs and that produce are being harvested and sold with high pesticide residue levels.

The vegetable growers sold their harvests mainly at farm gate. Some tomato, cabbage, and onion growers sold at a local market and at a road side. The important buyers at a farm gate and road side were middlemen coming from different regions.

For the areas of Tanzania ***where OSU and the IPM-IL has not previously worked***, the baseline survey included 404 farmers, 23% female and 77% male. Farms had an average of 4.3 acres, and tomatoes, onion, and cabbage were their main vegetable crops. Only about 12% of farmers had heard of IPM.

Participant metrics: 428 people participated in this field survey as follows:
122 female farmers
282 male farmers
5 female Extension Agents
9 male Extension agents
2 female field technicians
1 male field technicians
2 female researchers
5 male researchers

Project Objective 3**:** Test prototype management technologies, evaluate their potential yield and environmental benefits in on-station or on-farm trials with grower groups, and work with local partners to develop and implement training in the use of technologies that prove cost effective.

Activity 1: On-station experiment on tomato and cucumber grafting for management of bacterial, fungal and nematode root diseases.

Leaders of the activity: Dr. Elias R. Mgembe and Dr. Delphina P. Mamiro

Objectives*:*

1. To search, procure, and propagate potential rootstocks for use in grafting of tomato and cucurbits.
2. To assess grafting compatibility between selected rootstocks and common tomato and cucurbits varieties grown by small-scale farmers in Tanzania.
3. To determine the susceptibility of the rootstock to soil borne pathogens.
4. To determine plant growth, fruit yield and fruit quality attributes of tomato and cucurbits varieties grafted on different rootstocks

Treatments evaluated:

- Control 1: Non grafted tomato and cucumber plants of selected susceptible commercial varieties
- Control 2: Non grafted Solanaceae and Cucurbitaceae rootstocks
- Solanaceae rootstocks for tomato grafting: Sodom apple (*Solanum incanum*), "Shelter RZ F1", "Rampart RZ F1" and "MT 56"
- Cucurbitaceae rootstocks for Cucumber grafting: Luffa gourd (*Luffa aegyptica*), Calabash gourds (*Cucumisficifolius, C. metuliferus* and *Legenaria vulgaris*)

Summary of Results:
Seeds of solanaceae rootstocks included "Shelter RZ F1", "Rampart RZ F1""MT 56" and Soda apple (*Solanum incanum*). The first two varieties are known to have resistance to bacterial and fusarium wilts. Nematodes were procured from Rijk Zwaan Seed Company in Arusha. The other

rootstock seeds were obtained from the existing stocks at SUA. Tomato variety “Nowara” was used as a source of scion.

Seeds of the rootstocks and scion were sown in polybags containing well decomposed compost. The rootstock seeds were sown one week earlier before the scion. A total of 705 seedlings were raised out of which 252 seedlings were grafted. This lower number of grafted seedlings was brought about by the differences in diameter of rootstock and scion during grafting. The rootstock "Shelter" was thicker than the scion which made grafting difficult. On the overall, there was very poor grafting success attributed to the prevailing dry and hot weather which could have made healing difficult.

Preliminary observations showed that for the rootstocks and scion varieties used, seedlings should be of the same age; i.e., the rootstock and scion seeds must be sown at the same time to avoid existence differences in stem diameter between the two during grafting.

Luffa gourd (*Luffa aegyptica*), Calabash gourds (*Cucumis ficifolius, C. metuliferus* and *Legenaria vulgaris*) were collected locally for use as rootstocks for Cucumber. Data collection is ongoing.

Participant metrics: 9 people participated in this on-station experiment;
2 male farm workers
1 male agricultural officer
2 male field technicians
1 female researcher
3 male researchers

Activity 2**:** On-station and on-farm participatory research evaluation of onion varieties for resistance to white grub, thrips, and the purple blotch disease.

Leader of the activity**:** Dr. Hosea D. Mtui

Objectives*:*

1. To train farmers in five villages in IPM technologies for onion production.
2. To assess the susceptibility of the available onion varieties to white grub, thrips, and purple blotch disease
3. To assess yield and quality attributes of the major onion varieties commonly grown by farmers in Morogoro and Iringa regions

Site of activity: Morogoro: Sokoine University of Agriculture (SUA) Horticulture Unit (On station), Lumuma,Ulaya-Kibaoni and Malolo B, Ruaha Mbuyuni and Malangali villages (on-farm).

Cooperators*:* Farmers: 115 (33 female 82 male), Extension Agents: 5 (1 female 4 male), Collaboration NGOs (TAHA and MVIWATA) 2 Technicians and SUA researchers 5 (2 female 3 male)

***Treatments*:**
(i) Control: Variety "Red Bombay" the currently most popular and cultivated variety
(ii) Four open-pollinated varieties (Tajirika, Lumuma Super, Red Creole, and Meru Super)
(iii) Two hybrid F1 varieties (Jambar and Russet)
The experiment was laid in CRBD in all locations. The on-station trial was established at the SUA Hort Farm and the treatments were replicated 18 times. On-farm participatory trials were variably replicated: Lumuma (5), Ulaya- Kibaoni (6) and Malolo B (4), Ruaha Mbuyuni (3) and Malangali (4), depending on the available land area and the best fit for the trial. Seedlings were transplanted at a spacing of 20 cm × 15 cm. The on station trial was established under drip irrigation system with plot a size of 1 m × 7 m, while the field trials were established on furrow irrigated land with a plot size of 2.5 m × 5 m.

Summary of Results
A preliminary survey was conducted in Morogoro, Iringa, and Arusha regions to gather information on available onion varieties marketed by Vegetable Seeds Suppliers. Major seed companies contacted were Kibo Seeds, East West Seeds, Africasia, Seminis, EA Seeds and Balton (T) Limited. A total of 6 varieties were found to be currently supplied on the market by the seed companies. The varieties included Russet, Tajirika, Red Creole, Meru Super, Red Bombay and Jambar. Seeds of these varieties were procured directly from the suppliers. A 7^{th} variety, Lumuma Super was found to be locally produced by farmers under the Quality Declared Seeds (QDS) program. Seeds for the variety was procured from Lumuma village in Kilosa district Morogoro region.

The experiment is ongoing. The same plots were used during the training under Objective 2 Activity 1. Preliminary observations suggest that the locally produced varieties are out-performing the hybrids in terms of resistance to thrips. Harvest will begin in mid-October and extend through November, depending on variety.

Participant metrics

Village	**Participant category**	**Participants**		**Total**
		Female	**Male**	
Lumuma	Farmers	6	15	21
	Extension agents	-	1	1
RuahaMbuyuni	Farmers	25	5	30
	Extension agents	-	1	1
	Other organizations - MVIWATA	-	1	1
Mangalali	Farmers	8	14	22
	Extension agents	1	-	1
UlayaKibaoni	Farmers	9	13	22
	Extension agents	-	1	1
	Other organizations –TAHA	-	1	1
Malolo B	Farmers	5	15	20
	Extension agents	-	1	1
SUA Researchers		2	3	5
Total		**54**	**68**	**127**

Participant metrics*:* 122 (+ 5 researchers) participated in this participatory on-farm experiment as follows:
4 male extension agents
84 male farmers
33 female farmers
1 female extension agent
2 female researchers
3 male researchers

Conclusion*:* There is a narrow range of commercial varieties in Tanzania. Most varieties are distributed to farmers without prior multi-locational trials to ascertain their ecological adaptability and resistance to major pests. Early results are highlighting differences in the variety resistance to pests, which are expected to influence potential yields under different farmers and on-station based growth environments. Results will enable selection and recommendation to farmers in the respective locations the most suitable variety for production.

Activity 3: Laboratory and field experiments to assess the effectiveness of recipes for bio-slurry, and bio-pesticides (*Trichoderma, Bacillus*, etc.) to get consistent products/recipes for control of root diseases as transplant treatment for tomato and cucumber.

Leader of the activity**:** Prof. Delphina P. Mamiro

Objective: To evaluate the effectiveness of IPM tactics (e.g. bio-slurry, neem cake, marigold, *Trichoderma* spp., and *Bacillus* spp.) to for management of root diseases and root-knot nematode infection in tomato and cucumber.

The study consists of two components:
(i) Laboratory experiment to identify the beneficial microorganisms present in bio-slurry (cattle waste after bio-gas production) for use in vegetable pests management; and
(ii) Field experiment to determine the effect of bio-pesticides (bio-slurry, neem cake, marigold and microbes (*Trichoderma* spp.)) on nematode management in tomato and cucumber.

Site of activity: Morogoro, on-station –SUA Horticulture Unit.

Cooperators*:* Undergraduate students, Laboratory and Field technicians and researchers. Dr. Yasinta Nzogela, nematologist, assisted with nematode assessment.

(i) Laboratory experiment: to identify the beneficial microorganisms present in bio-slurry (cattle waste after bio-gas production) for use in vegetable pests management.

Treatments:
Two samples of bio-slurry collected from Mkambarani and Bigwa villages in Morogoro district were cultured on potato dextrose agar and nutrient agar. The treatments were replicated five times and sterile distilled water was included as a control.

Summary of Results
A number of microorganisms which grew from the cultures were identified as follows:
• Bacterial colonies which contained *Bacillus* spp., *Bacillus subtillis*, *Corynebacterium* spp., *Pseudomonas* spp. and *Streptococcus* spp.

•Fungal growths contained *Aspergillus* spp., *Penicillium* spp., *Cladosporium* spp., *Rhizopus* spp. and *Absidia* spp.

Conclusions: The bio-slurry contains beneficial microorganisms such as *B. subtilis* which has the ability to reduce soil-borne diseases.

(ii) Field experiment to determine the effect of bio-pesticides (bio-slurry, neem cake, marigold and microbes (*Trichoderma* spp.)) on nematode management in tomato and cucumber

Treatments:
Tomato and cucumber experiment was established with the following treatments:
(i) Control: Tomato variety Cal-J and cucumber variety Ashley not treated with any of the bio-pesticides
(ii) Trichoderma spp. applied at transplanting
(iii) Neem cake applied at transplanting
(iv) Bio-slurry drenched two days before planting/transplanting
(v) Intercropping with marigold (Tagetes spp.)

Before establishing tomato and cucumber trials, 10 soil samples (15-25 cm depth) weighing 1 kg each were collected randomly from 1.5 acre-plot for plant parasitic nematodes analysis assisted by IITA participant, Dr. Danny Coyne. Soil sampling and analysis for plant parasitic nematodes was repeated 5 weeks after planting tomato and cucumber experiments. Soils samples were randomly collected around the plots to avoid crop destruction.

Summary of Results
Roots were collected for plant parasitic nematodes. Free living and parasitic nematode types were observed and counted as presented in the table below.

	Nematode count per 500 cc soil	
Nematode type	Week 1	Week 5
Free-living	179	193
Parasitic	11	33

We found that root knot nematode infestation was significantly affected by the bio pesticides used. There was highly significant ($p < 0.0001$) effect of the treatments on the nematodes infective stage (J2/10g of roots) and Root galling index for both cucumber and tomato.

The effect of bio-pesticides on cucumber and tomato nematode infestation

Crop	**Variable**	**Source of variation**	**df**	**F value**	**p-value**	**LSD**	**Std dev**
Tomato	J2/10g	Treatment	4	45.55	p<0.0001	154	446
	Root galling index	Treatment	4	26.23	p<0.0001	1.47	1.792

Cucumber	J2/10g	Treatment	4	7.69	*p*<0.0001	251	172.1
	Root galling index	Treatment	4	23.55	*p*<0.0001	0.6	1.177

The findings indicated that neem cake and *Trichoderma* had significant effects on reduction of the infective nematode stage (J2/10 g) of tomato. Marigold effect was similar ($p \leq 0.05$) to the control on reduction of infective nematodes. However, marigold and neem cake significantly reduced root galling compared to the control. The findings revealed that bio-slurry significantly increased both J2/10g of roots and root galling index. Neem cake had significant effect on reducing J2/10g of root and galling index in cucumber. Although *Trichoderma* had a significant effect in reducing root galling of cucumber, it had no significant effect ($p \leq 0.05$) on reducing nematode infestation.

Participant metrics:
7 people participated in this on-farm experiment
2 undergraduate students (1 female and 1 male)
2 female laboratory technologist
1 male agricultural field officer
1 female researcher
1 male researcher

Conclusion**:** Neem cake was the most effective bio-pesticide for control of nematodes in tomato and cucumber. The Season II experiment (ongoing) will provide more insights on the effectiveness of the tested treatments.

Activity 4: On-station and on-farm evaluation of cabbage pests and their management of the diamond back moth.

Leader of the activity: Prof. Delphina P. Mamiro

(a) On station inventory of cabbage pests

Objective: To establish a list of major insects and diseases of cabbages in Morogoro.

Treatments*:*
(i) Farmers practice = DAP 30g per plant at transplanting, then Urea 30 g per plant 21 days after transplanting (DAT) and then 30 g per plant 52 DAT.
(ii) Basal organic (cow dung) fertilizer at transplanting applied at 2-4 liters per meter; then CAN 60 g per 16 liter of water at 1, 3 and 5DAT followed by 10, 15, 20 and 15 g per plant of Urea and Muriate of Potash (1:1, 2:1, 1:1) at 7, 14, 21 and 30 DAT respectively.
(iii) DAP 320 Kg/ha at transplanting; Urea: Muriate of Potash 175:0, Kg/ha, 150:150 Kg/ha, 150:100 Kg/ha at 7, 14 and 28 DAT respectively. The on-station experiment was established in complete randomized design with three treatments and three replications. Spacing 0.6 m x 0.5 m in a 4 m wide and 6 m long plot.

Summary of results

Diamond back moth (*Plutella xylostella)* and cabbage webworm (*Hellula undalis*) were rated as the most important pests of cabbage in Morogoro, regardless of the fertilizer regimes. Grasshoppers and aphids were second in importance, particularly under high N fertilizer application rates. Diseases were not observed in to be important constraint to cabbage production at the site during the season.

Conclusions: Diamond back moth and cabbage webworm were the main insect pests recorded in cabbage followed by Aphids spp. Pest pressure was generally higher in the farmer practice, with high nitrogen fertility. IPM approaches will have to take into consideration the fertilization practices of the crop.

Activity 5: Laboratory Experiment to evaluate efficacy of crude plant extracts for the management of the tomato leaf miner.

Leaders of the activity: Prof. A.P. Maerere and M. W. Mwatawala.

Objective: To determine the effectiveness and the lethal dose of *Commiphora swynnertonii, Synadenium glaucescens* and *Alliumsativum ethanolicextracts* in controlling *T. absoluta* in tomatoes at egg and larval stages.

Treatments :

(i) Control 1: Synthetic insecticide BELT®SC 480 Flubendiamide

(ii) Control 2: Sterile distilled water (SDW) containing 0.1% Tween® 20

(iii) Crude extracts from root bark of *Synadenium glaucensens* (Euphorbiaceae) at three different concentrations of 2%, 4% and 8% v/v

(iv) Crude extracts from Garlic *Allium sativum* (Alliaceae) bulbs at different concentrations of 2%, 4% and 8% v/v

(v) Resin of *Commiphora swynnertonii* (Burseraceae) at different concentrations of 2%, 4% and 8% v/v

***Summary of Results*:**

The plant extracts caused significantly different mortality rates to egg and larvae of *T. absoluta* after 5 days of treatment in comparison to the control. Commiphora was the only extract that showed potential to be used as a control agent against eggs, with 0% hatchability recorded. Synadenium resulted in the lowest *T. absoluta* egg mortality, as hatchability was 96.6%. Commiphora extracts showed the highest effects on *T. absoluta* second instar larvae while Synadenium extracts exhibited the least effect. Commiphora resulted in the highest second instar larval mortality of 100%.

***Conclusion*:** Results suggest some potential for Commiphora extract to be incorporated into integrated pest management strategies for the control of *T. absoluta*. We are conducting further studies with refined extract to determine if can be developed into a practical product for managing this insect.

Activity 6: Suppressing populations of tomato leaf miner (*Tuta absoluta*) in the agro-ecological zones of Morogoro.

Leader of the activity: Prof. Maulid W. Mwatawala

(a) *Title of activity:* Spatial and temporal abundance of tomato leafminer (*Tuta absoluta* Meyrick) (Lepidoptera: Gelechidae) along the Uluguru Mountains in Morogoro, Tanzania.

***Objective*:** Assess the population of Tomato leaf miner along the Uluguru Mountains using delta traps loaded with para-pheromone.

Sites of activity: Tanzania, Morogoro region, Mlali (570 m asl), Langali (1133 m asl) and Nyandira (1584 m asl) villages.

Summary of Results

T. absoluta moth trapped varied significantly between the locations ($P < 0.001$) and ($P < 0.016$) for the 1st and 2nd growing season respectively. Population between weeks after transplanting for the 1st growing season was not statistically significant ($P > 0.07$), compared to that of the 2nd growing season which was statistically significant ($P < 0.028$). The 2nd growing season had the lowest moth population but showed more significant difference to that of the 1st growing season.

Conclusions: The population of the moth was present throughout the two growing seasons and the three locations. Trapped Tomato leafminer (*Tuta absoluta*) (Meyrick) populations occurring in Langali (1133 m above sea level) and Nyandira (1584 m) was higher due to favorable climatic conditions, favoring the moth spread and the year-round presence of numerous vegetables that act as suitable alternative hosts for the moth. The alternative hosts facilitated completion of *T. absoluta* life cycle in the absence of tomato plants.

(b) Title of activity: Management of tomato leaf miner (*Tuta absoluta*) (Meyrick) (Lepidoptera: Gelechidae) in Morogoro, Tanzania.

***Objective*:** Evaluate selected control measures and establish the host preference for tomato leaf miner (*Tuta absoluta*) (Meyrick) in Morogoro, Tanzania.

***Sites of activity*:** Mlali (570m asl), Morogoro Municipality (490m) and Dakawa (287m asl) in Morogoro.

Treatments: Antario (Russell IPM), Biotrine (Russell IPM), Wiltigo, and Control.

Results

Host plants collected for this study were crops readily available in close proximity to the tomato cultivation sites. The number of *T. absoluta* moths emerged from the collected host samples varied significantly between the host plants ($P<0.001$) and with a LSD of 9.5. During the survey tomato was observed to be the most preferred host plant of *T. absoluta* in the two locations. No significant difference was observed between the number of emerged moths in Amaranthus and

African eggplant, compared to tomato and eggplant which had had significantly different numbers of emerged moths.

There was in the 1st growing season a significant difference (P <0.049) between the applied treatments. Wiltigo had lower mean population compared to the other control measures. For the 2nd growing season there was no significant difference (P >0.3) between the applied treatments in Dakawa and Morogoro Municipality.

Conclusion: In order to conduct and implement a control strategy for *T. absoluta*, factors such as alternative hosts should be considered. This is because the moth has a wide range of plants that can facilitate the completion of its life cycle.

Participants metrics*:* 20 people participated in this on farm experiment.
1 male lab technician
2 female farmers
14 male farmers
2 male field officers
1 female field officer
1 male graduate student
1 male researcher

Activity 8*:* On-station and on-farm evaluation of fertilizer rates on insect pests and diseases of water melon.

Leader of the activity: Prof. D.P. Mamiro

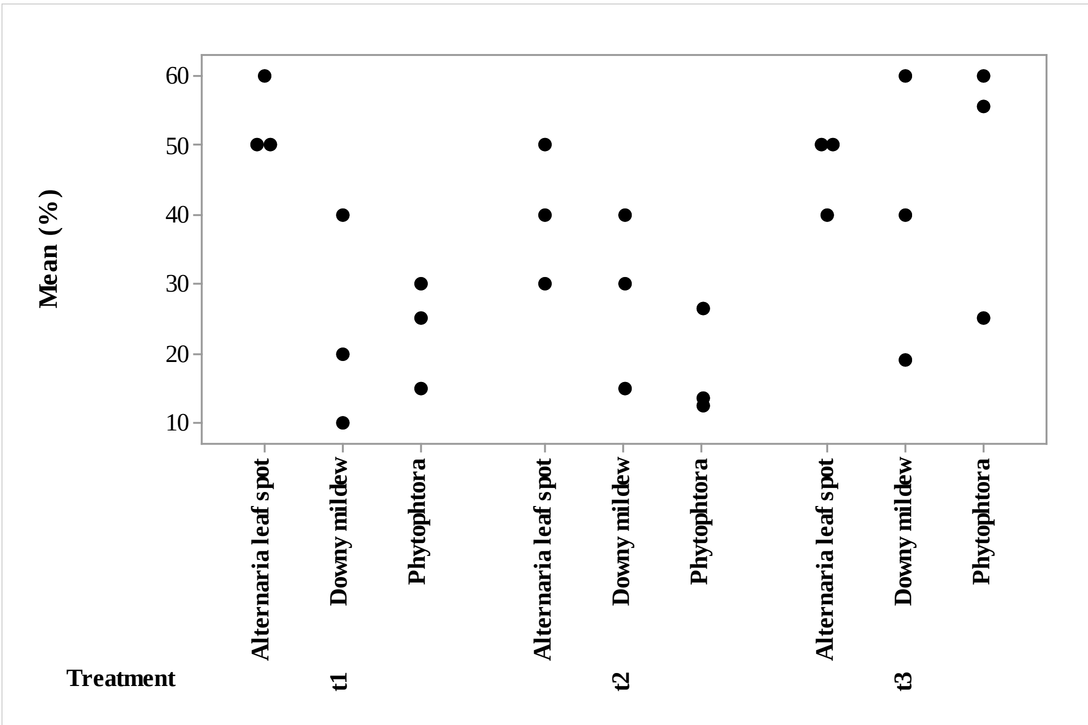
Treatments :
T1 = NPK at rates of 244.4N, 73.6P and 75K Kg/ha respectively
T2 = NPK at rates of 353.2N, 126P and 519.4K Kg/ha respectively
T3 = NPK at rates of 292N, 0P and 0K Kg/ha respectively

The on-station experiment was established in complete randomized design with three treatments and three replications. Spacing 1.5 m x 0.5 m in a 8 m wide and 7 m long plot.

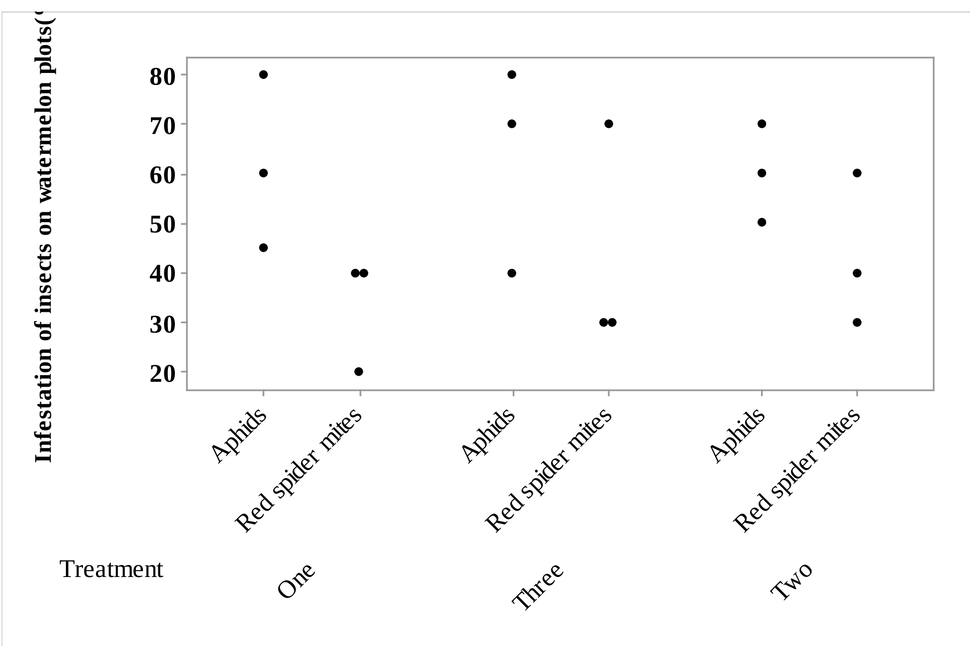
Summary of Results
Variation of water melon pests across the treatments (+ std dev).

Treatments	**Altenaria leaf spot**	**Downy mildew**	**Phytophthora**	**Aphids**	**Red spider mites**
T1	53.3(5.77)	23.3(15.27)	22.4 (1.43)	61.6 (10.1)	33.0 (6.67)
T2	40.0(10.0)	28.4(12.58)	16.56 (1.47)	60.0 (12.0)	43.0 (13.3)
T3	46.6(5.6)	39.6(20.5)	43.65 (1.62)	63.3 (5.77)	43.0 (8.82)
Df	2	2	2	2	2
F value	2.4	0.776	4.147	0.03	0.33
p value	0.0171	0.501	0.079	0.971	0.729

Tukey's HSD value	13.3	16	4.7	1.7	10



Disease distribution by individual values



Insect pest distribution by individual values

Conclusions: The treatments had no significant impacts on pest occurrences. However, distribution of individual pest values showed requirements for management of these pests. The distribution of disease data (Phythopthora and downy mildew) show reduced infection rates (30% >) on a majority of experimental units across the treatments.

Activities at Mikocheni Agricultural Research Institute

Activity 1**:** Conduct biological and socio baseline surveys on vegetable viruses and vectors in Tanzania.

Activity Leaders: Peter Sseruwagi, Joseph Ndunguru, Malidhia Njelekela, Namsifu Nyiti, Deogratius Mark

Brief Description: A study was conducted to assess farmers' knowledge of vegetable viral diseases and their management in major vegetable production areas of Tanzania including Morogoro and Iringa districts. Interviews were conducted using structured questionnaires to gather production and disease management data from the farmers. The data were analyzed in SPSS software. The baseline surveys of vegetable viral diseases and the associated insect vectors were conducted in five major vegetable growing regions of Tanzania including: Southern zone (Iringa, Mbeya, Rukwa, Ruvuma, Mtwara and Lindi), Eastern zone (Morogoro), Western zone (Kigoma), Central zone (Tabora, Dodoma and Singida) and Lake zone (Bukoba and Mwanza). At least 125 viruses and 46 insect samples (whitefly, aphids, leaf hoppers, thrips, beetles and caterpillars) were collected from 40 smallholder vegetable (tomato, cabbage, Chinese cabbage, kale, green pepper, onions, African egg plants, squash/pumpkins) fields. The virus samples were stored at -80ºC in the laboratory at MARI. The insect samples were kept in ethanol at room temperature. Questionnaires on socio-economics were administered to 24 smallholder vegetable farmers to assess the knowledge of virus diseases and insect vectors.

The socio-economic data were used to assess farmers' knowledge of vegetable virus diseases and their management in Tanzania. The demography of the respondents is presented below A draft manuscript is under development and is currently with the co-authors for review.

Demographic characteristics of the respondents

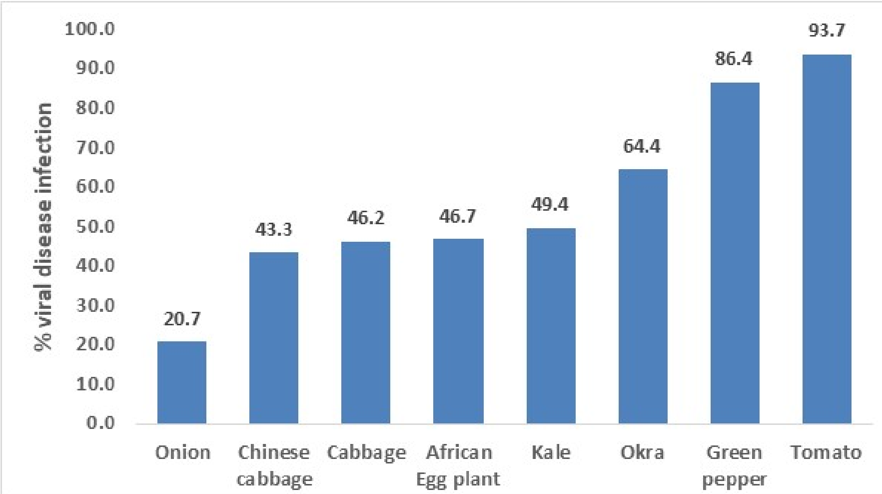
Gender	**Frequency**	**Percentage**
Male	17	70.8
Female	7	29.2
Total	**24**	**100**
Education		
Primary male	15	62.5
Primary female	7	29.2
Secondary male	2	8.3
Secondary female	0	0
Total	**24**	**100**

Age group (years)		
Below 16 years	60	44.78
Between 16 and 60	68	50.75
Above 60	6	4.48
Total	**134**	**100**
Size of land owned (acres)		
<1	2	8.3
>1<5	21	87.5
>5	1	4.2
Total	**24**	**100**
Years farmer grown vegetables		
<1	8	25
>1<5	18	56.25
>15	6	18.75
Total	**32**	**100**
Occupation		
Farmers	24	100
Teachers	0	0
Others	0	0
Total	**24**	**100**

Summary of Results:
Results indicate that disease and insect pests (62%) were the main constrains in vegetable production. The farmers produced their own nurseries and seedlings, irrigation and manure application (29%). About 75% of the farmers recognized diseases by symptom description, but were unable to tell what the causal pathogens were. Additionally, majority of farmers (88%) complained about serious damage due to viral diseases, especially in tomato and peppers. About 67% of the farmers used own knowledge to manage pests and diseases. Furthermore, chemical pesticides were used the most (13%) compared to phyto-sanitation methods. About 54% of the claimed to use protective gear, although this was not evident during the field visits, probably due to visiting outside the spraying periods. There was poor disposal of chemical containers (38%), and most farmers (54%) lacked knowledge of the importance of proper disposal of the chemical containers, risking contamination of the environment and water sources for human consumption.

Activity 2: Conduct a field assessment of vegetable viruses and vectors in Tanzania.

The surveys were conducted three major vegetable producing regions including: Morogoro, Iringa and Lake Victoria (Bukoba and Mwanza). Viral disease incidence ranged from 20% to 93.7% on the vegetable crops assessed in the smallholder farmers' fields. The viral diseases were highest on okra, green pepper and tomato with 64.4%, 86.4% and 93.7% incidence (see figure below).



Incidence of viral disease infections on vegetable crops in Tanzania

<u>Virus identification and sequencing</u>
Plant virus samples were subjected to PCR and rolling circle amplification (RCA) to detect and sequence the DNA viruses. Sequences were obtained and are currently awaiting analysis at MARI, Tanzania. In addition to morphological keys, mitochondrial cytochrome oxidase I (mtCOI) DNA will be used to study the identity and diversity of the insect vectors.

***Outputs*:**
- Disease occurrence and distribution maps developed.
- Farmers' awareness and management of vegetables viral diseases and insect vectors established.
- Genetic diversity of viruses and associated insect vectors affecting vegetables in Tanzania established.
- Sequence used to design more efficient diagnostic primers for detection and identification of vegetable viruses.

Activity 3: Evaluation of IPM packages and agronomic practices for management of vegetable viruses and vectors.

***Activity Leaders*:** Peter Sseruwagi, Joseph Ndunguru, Malidhia Njelekela, Damiani Kalekayo

***Objective*:** To conduct on-station and on-farm validation of vegetable viral diseases IPM technologies/practices.

Brief description of tasks
Characteristics of the trial locations, Bagamoyo, Tanzania

Location	Ecology	Type of farmer/s
Chambezi	• Isolated from vegetable crops • Surrounded by Cassava and bushes • Sandy-loam soil	On-station trial site for MARI
Kerege	• Vegetable demonstration farm • Sandy soil	Smallholder model farmer

Zinga	• Surrounded by vegetables and bushes within a residential area • Loam soil	Smallholder vegetable farmers' group
Matega	• Surrounded by vegetable fields in a valley • Clay-loam	Smallholder vegetable farmer – individual

Treatments

Treatments	**Name**	**Active ingredient**	**Mode of action**	**Target**
1. Chemical insecticides	DELTAPAZ 25 EC	Deltamethrin 2.5%	Contact	Aphids Whiteflies Thrips Mealy bugs Caterpillars
2. Natural (Botanical) insecticide	NIMBECIDINE (NEEM OIL)	Azadrachtin	- Anti-feedant - Repellent - Insect growth regulator - Sterilant	Aphids Thrips Whiteflies Mealy bugs Caterpillars Leafhoppers Cutworms Bollworms Nematodes
3. Plastic mulch	N/A	N/A	Insect repellant	Insects
4. Control	No treatment	No treatment	No treatment	N/A

Design: Randomized complete block design (RCBD)
Replications: 4 (1 on-station and 3 on-farm)
No. of plots: 2 varieties x 4 treatments = 8
Spacing: 60cm x 60cm
Plant population per plot: 90 plants

Good Agricultural Practices (GAP)

1. Healthy seedling production

Healthy seedlings were produced with an upcoming commercial vegetable seedling producer, Mr. Joseph Mbuji. The project guided Mr. Mbuji on setting new insect proof screenhouses in Kerege, Bagamoyo near the IPM trials for close monitoring of the quality and health of the seedlings.

Mr. Joseph Mbuji is a commercial vegetable seedling farmer with a good knowledge of seedling and vegetable production. He was a participant in the 'Seedling Health Management Workshop', conducted at SUA, February 2017. He uses an insect-proof screen house that provides 50% shade net to reduce the effect of sunshine and heat. Seedlings were produced in peat moss and plastic seedling trays from Balton Tanzania Ltd, a private company that deals in horticultural products. He used raised wooden platforms to keep the seedlings away from soil contamination and for easy management. Two tomato varieties were planted: Kipato and Victory, which are popular varieties selected with guidance of farmers. For brassicas (Chinese Cabbage), they selected Michihili and Fahari F1. Other GAP included: weeding, spacing, staking and pruning. All plots were managed uniformly with GAP practices: proper spacing, staking and timely weeding and pruning.

Data were collected on the IPM trials as follows:
Weekly assessments for 8 (tomato) and 3 (Chinese cabbage) weeks for 2 months (June to August, 2017). Parameters measured:
Plant height (cm)
Viral disease severity (scale 1-5, Hahn et al., 1980)
Viral disease symptom description (mosaic, leaf curl etc)
Insect types
No of insects
Fruit development
Yield assessment
No of fruits per plot
Weight and number of marketable fruits per plot
Weight and number of non-marketable fruits per plot
Total number and weight of fruits harvested per plot

Field data will be analyzed by using ANOVA, a process that is ongoing. Virus identification and characterization is being conducted in the lab using leaf samples collected for confirmation of virus species. Laboratory sequence data will be analyzed using Geneous software.

Location- KENYA

Description

Kenya, with a population of 46 million, has a temperate and tropical climate with two rainy seasons that are increasingly unreliable. In Feed the Future areas, over 58% of people live in poverty, with 21% of children under 5 suffering from stunting. The Kenya Agricultural Research Institute estimates that 10 million Kenyans are food insecure. Climate change is expected to further increase the levels of pest damage as rainfall patterns become more erratic and temperatures rise. Pest management in vegetable crops is by repeated use of synthetic pesticides, leading to early resistance development and loss of potential natural enemies. The major specific constraints in vegetable production are pest and disease infestations, poor post-harvest handling leading to huge losses, excessive chemical pesticide use leading to exceedances of maximum residue levels (MRLs) hence rejection in export markets. Vegetable production, marketing, and consumption offer many benefits for Kenyans. Population pressure, migration to urban areas, and dwindling arable land sizes are increasing challenges. Our effort has focused on a Feed the Future area in Tharaka-Nithi County, where access to irrigation has recently been made available. Early attempts by farmers to exploit this resource led to crops with significant disease, land degradation, and other problems associated with their approach. While vegetable production for local and export market, are poised for expansion, in Tharaka –Nithi County, production will be governed in part by small holder farmers' abilities to minimize crop stress through a coordinated, efficient, and data based approach.

Collaborators

Drs. Jesca Mbaka, Beth Ndungu, Charity Gathambiri, Caeser Kambo, Sylvia Kuria, Samson N. Kihara, S.J.N. Muriuki, Kenya Agricultural and Livestock Research Organization, KALRO
George A. Odingo, Mulinge Mukumbu, Stephen New, KAVES
Henry Wainwright, Patrick Mathenge, Real IPM
Danny Coyne, Luara Cortada-Gonzalez, IITA-Nairobi

Participants:
Dr. Geofrey Gathungu, Chuka University
Prof. Sheila Okoth, University of Nairobi
Rosemary Muthomi, Meru Greens Horticulture
David Mokaya, Agriculture Department, Tharaka Nithi
Hellen Kanyua, Agriculture Department, Tharaka Nithi
Anne Weveti, Agriculture Department, Tharaka Nithi
Samuel Rugendo, Agriculture, Livestock and Fisheries Department, Tharaka Nithi,
Jasper Njue, Agriculture Department Tharaka Nithi
Jotham Burundi, Agriculture Department, Tharaka Nithi

Achievements

Activities at Kenya Agricultural and Livestock Research Organization (KALRO)

Project Objective 1 – Conduct participatory needs assessments to identify priority pests, current pest management practices, availability of alternative IPM technologies, and constraints to IPM adoption by farmers, including policy and regulatory constraints.

***Activity 1*:** Vegetable Production Baseline and Impact Assessment Surveys

We conducted two baseline surveys:
Activity 1.A., led by Dr. Beth Ndungu, focused specifically on the farmers in an irrigation scheme area of Tharaka Nthi County with whom KALRO is working. This is a Feed the Future area that is new to KALRO and the project.
Activity 1.B., , led by Dr. George Norton, focused on tomato, cabbage, and French beans crops in the counties of Nyeri, Tharaka Nithi, Nakuru and Bomet.

Activity 1. A.
Participatory Identification of Pest Constraints in Selected Vegetable Crops and Farmer Management Practices in Tharaka-Nithi County, Kenya

Activity Leaders: Ndungu B., Mbaka J., Wepukulu S., Kihara S., Muriuki S., Gathambiri C., Kambo C., Kuria S., Ndegwa A. and Farray R.

Introduction
Vegetables represent an important cash crop for small-scale growers and the crops are associated with increased rural incomes, living standards, nutrition, and employment.
In addition to reduced crop productivity and increased costs of production, vegetable crop pests are a threat to food safety that lead to lower incomes, nutrition, and access to purchased food, medical care, and education. Crop losses of up to 100 % have been reported depending on the production system. A baseline socioeconomic survey was conducted among tomato, French bean and cabbage farmers in Tharaka Nthi County, Kenya to assess farmers' knowledge of pests and non-conventional pest management practices. This is a Feed-the-Future area that we have not work in previously.

Methods
Data were collected using a structured questionnaire administered by face to face interview with 108 farmers randomly selected from four farming groups. Color pictures of vegetable pests were used as visual aids for identification of pests and diseases. Descriptive data were analysed using the SPSS program.

Results
Socio-demographic characteristics of the farmers
The results revealed that a typical household had an average of six members and the mean age of the respondents was 57 years for the head of the household and 43 for the spouse. About 82% of the household heads had attained primary and secondary school education, 10% tertiary and 7% had no formal education. For the spouses 71% had primary and secondary school education, 8% had tertiary education and 22% had no formal education.
The sources of household income included crops, livestock, business and salary among others. A majority (73%) of the households were distributed in the first three income quartiles with an

annual earning of below KES 30,000 to KES 120,000. Only about 27% of the households had an annual income of more than KES 120,000 (about $1,160).

Table 1: Household income quartiles

Income quartile	Mean annual household income (KES)	Percentage households
Lowest (1st) quartile	< 30,000	19.1
2nd quartile	30,001 to 60,000	25.3
3rd quartile	60,001 to 120,000	28.8
4th quartile	120,001 to 240,000	16.3
Highest (5th) quartile	> 240,000	10.5
(KES 1000 ~ $10)		

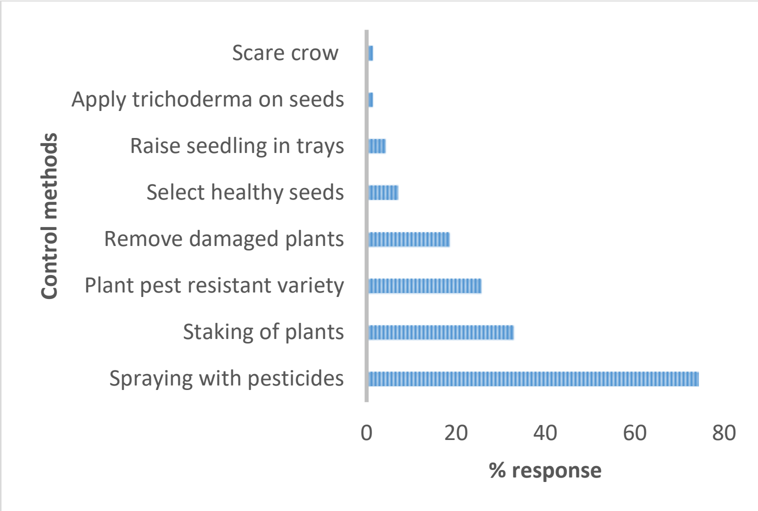
Vegetable production practices

The average farm sizes were 2.5 acres with an average acreage of less than half an acre for French bean and cabbage, and about half an acre for tomato. Important tomato varieties grown by the farmers were “Onyx” produced by 40% of the respondents, “Kilele” (24%) and “Riogrande” (18%). For cabbage, farmers mainly grew “Sugar loaf” variety (40%), while for French bean the most important variety was “Sagana” grown by about half of the producers.

Reported vegetable pests and their management

Various pests and diseases of economic importance were identified under each target crops. The most serious diseases in tomatoes were bacterial wilt, which was mentioned by 71% of the respondents, followed by leaf blights (52%) and nematodes 30%. The most common tomato pests were white flies according to 70% of the interviewed farmers, leaf miners (64%), spider mites (52%), and *Tuta absoluta* (36%). Black rot was mentioned as a key cabbage disease by 70% of the respondents while diamond back moth and Aphids were important arthropod pest according to 68% and 60% of the interviewed farmers respectively. Important French bean diseases were rust (57%), angular leaf spot (47%) and anthracnose (33%) while pod borer, thrips, bean fly and mites were identified by most farmers as main arthropod pests by 55%, 51%, 49% and 43% of the respondents, respectively.

A majority of the farmers (86%) used pesticides to manage vegetable pests, with tomato farmers applying pesticides about 17 times per growing season at a cost of about KES 21,000 (~$203) per acre. The French farmers applied pesticides about 12 times per season and spent an average of KES 14,000 while for cabbage, farmers sprayed their crop about eight times spending an average of KES 5000 for one acre every season. Farmers used a range of non-chemical pest control methods including staking in tomatoes (43%), pest resistant varieties, and removal of damaged plants.

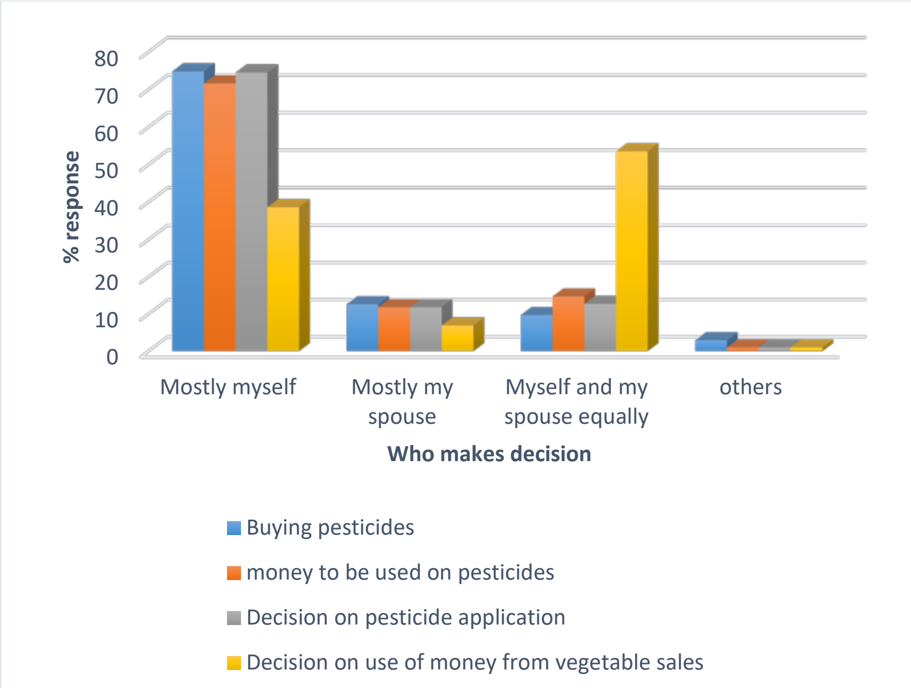


Non-chemical pest control methods

Reasons for use of non-pesticides were less exposure to associated health risk, lower cost of non-chemical pest control methods than conventional pesticides, and little contamination to the environment

Training on IPM
Farmers were asked whether they had received any training on IPM. About 40% of the farmers had heard of IPM while over 60% had not received any training related to IPM. Main sources of farmer training on IPM were Ministry of Agriculture Livestock and Fisheries (MoALF) and other agriculture based institutions.

Gender and IPM
This study sought to find out the division of roles on crop protection activities in the study area and this was largely a male domain. More than 60% of the interviewed heads of households applied pesticides on their crops while about 21% of the labor was provided by hired male laborers. The decision making pattern on buying and application of pesticides as well as use of income from vegetable sales between husbands and their wives was also dominated by the husbands (figure (1).



Decision making pattern

Heads of households were the ones who mainly purchased pesticides (75%), made main decisions on amount of money to be spent on pesticides (72%) and when to apply pesticides (61%). Decisions on how to spend money from the sale of the vegetables was, however, shared by head and their spouses (54%) with only 39% of the household heads claiming to solely decide on how to use money from vegetable sales.

Conclusion

This study recommended the need for researchers to develop crop specific IPM packages for target crops and train farmers on proper pests and disease identification and IPM management strategies and their benefits. The study prioritized tomato bacterial wilt and *Tuta absoluta*, cabbage black rot, diamond-back moth and French bean for future research in developing, validating and disseminating technologies for their integrated management.

Activity 1. B. Baseline Socioeconomic Survey of of Nyeri, Tharaka Nithi, Nakuru and Bomet Counties.

***Activity Leaders*:** G. Norton (VT), C. Rakowski (OSU), Jesca Mbaka, and Beth Ndungu (KALRO), with assistance from Menale Kassie of ICIPE and the Grains IPM IL project.

For Kenya, data from the baseline survey (403 farmers) conducted in the previous year were cleaned, formatted, and summarized in tables. The data include priority pests, pest management practices, knowledge of IPM, extent of current vegetable IPM adoption, who the adopters are (low or high-income farmers, male or female), and why they adopt or do not. The crops include tomato, cabbage, and French beans for the counties of Nyeri, Tharaka Nithi, Nakuru and Bomet.

The data were analyzed in an MS thesis to assess factors affecting adoption of IPM practices and current pesticide use.

The Kenya Baseline survey included 206 male and 197 female respondents, with a mean of 3.3 acres of land (.33 acres of tomato, .53 of cabbage, .51 of beans, 1.11 of chili peppers, and .47 of onions). Most (257) farmers sold their vegetables to traders (25% of them were consumed at home) and most farmers used irrigation. Fifty percent of tomato farmers feel they have a high severity pest insects and diseases, and that diseases/viruses cause the most damage (especially bacterial wilt and bacterial canker). The two most common non-pesticide means they use to manage those problems are staking the plants and removing damaged plants. The main reason they use a non-pesticide practice is to save costs. They apply pesticides an average of 7.9 times and spend 7.9 days spraying and 5.6 days weeding.

Roughly half of cabbage producers felt that the severity of insects and diseases was low with 45% saying that insects/worms were their major type of pest and 51.6 % saying that diseases were their main pest problem. Black rot was their worst disease. Removing damaged plants was their main non-pesticide practice used to manage insect and disease problems. Cost considerations was the main reason they gave for using non-pesticide practices rather than pesticides. They applied pesticides 4.5 times, spent one day spraying and 10 days weeding.

Similar numbers of French bean producers felt that their insect/worm severity was low (27.7%), medium (31.9), or high (36.2), and 44.7% felt that their disease pressure was medium (a fourth low and a fourth high). Rust and blight were their worst diseases and white flies their worst insect pest. They applied pesticides an average of 7.1 times and spent 13 person days weeding. Removing damages plants was their most utilized non-pesticide pest management practice. Cost compared to pesticides was the reason the most important reason for using a non-pesticide practice.

Analysis of the for Kenya data found that experience in vegetable cultivation, wealth, and being a member of a farm or community organization have a positive impact on IPM adoption and distance to town a negative impact. Male farmers were more likely to adopt resistant varieties, but for some practices, such as staking tomatoes, adoption was reduced by lack of credit or off–farm income. For all three vegetables, greater distance from town and lower insect and disease stress reduced pesticide applications.

Project Objective 3: Evaluate prototype IPM Technologies in on-station and on-farm trials.

Activity 1 – On-farm participatory field trials.

Activity Leaders: Jesca Mbaka, Caeser Kambo, Sylvia Kuria, Samson N. Kihara, and S.J.N. Muriuki.

The sixty-nine farmer group members participated in the on-farm validation of Trichoderma and a bio-fertilizer for management of bacterial wilt of tomato. Preliminary results showed that Trichoderma reduced wilt incidence by 40%. Azadirachtin (Nimbecidine EC), Bacillus thuringiensis (Halt 5WP), pyrethrum + garlic (Pyegar 35.7 EC) and petroleum spray (DC-Tron) suppressed leaf-miner populations and reduced Tuta absoluta damage in tomatoes. Cabbage variety "Queen F1" and tomato variety "Kilele F1," resistant to black rot and bacterial wilt, respectively, were introduced to and adopted by farmers. Preliminary results indicate that Trichoderma reduced nematode damage in French beans despite the heavy galling by the nematodes.

The participatory research model is operating effectively in Kenya, perhaps because farmers are willing to organize and are somewhat educated in concerns about pesticides. The goal for next year will be to double this number. We are considering ways to expand that might involve farmer-to-farmer training.

Trial 1: Validation of biopesticides in the management of Diamondback moth (*Plutella xyllostella*) in cabbage and kale.

Scientist: SJN Muriuki

Treatments

1. Biopower –A formulation based on *Beauveria bassiana*
2. Neemraj Super 3000- A formulation based on Azadirachtin
3. Dipel 2X- A formulation based on *Bacillus* thuringiensis
4. Tomato/Kale intercrop at the ratio of 1:2
5. Untreated control/Negative control

Results

Infestation by DBM occurred very lightly and late in the season consequently data collection was carried out only once before the crop was abandoned. Sparse infestation by aphids was also noticed but these were adequately managed by hoverflies and parasitic wasps.

Next steps

Another experiment has been planted and hopefully better results will be generated.

Trial 2: Validation of *Trichoderma* strains and Plantmate biofertilizer effects in the management of Bacterial wilt (*Ralstonia solanacearum*) and Root Knot Nematodes (*Meloidogyn*e spp.) in Tomato (*Solanum lycopersicum*).

Scientist: Sylvia Kuria

Treatments**:**

1. Triunum (*Trichoderma harzianum*)
2. REAL Trichoderma (*Trichoderma asperellum*)
3. Combination of *T. hazianum* and *T.asperellum*
4. Plantmate Biofertilizer
5. Untreated control

Results

Season one failed due to seed impurity while the second season planting was delayed due to poor seed germination caused by very low temperatures at Nthambo where the nursery was set. The seeds were then sowed at Mbwiru-Mwanjati where it is warmer and now the tomatoes have been transplanted and data collection will start as soon as wilting starts.

Trial 3**:** Validation of selected biopesticides for management of *Tuta absoluta*, serpentine leaf miner (*Liriomyza trifolii*) and other arthropod pests of tomato

Scientist: Caesor Kambo

Treatments
1. Pyrethrin+Garlic extract (Pyegar)
2. *Bacillus thuringiensis* (Halt 5 WP)
3. Refined base oil (98.8%) (DC-TRON)
4. Azdirachtin (Nimbecidine EC)
5. Control (water spray)

Results
Nimbecidine EC (*Azadirachtin),* Halt 5 WP (*Bacillus thuringiensis(kurstaki)* and DC-Tron Plus (*Refined base Oil 98.8%)* had relative low number of leaves showing Tuta damage as compared to the plots treated with Pyegar and the untreated control plots. DC Tron plus had significantly few number of fruits damaged by the *Tuta absoluta*, followed by Nimbecidine and Halt 5 WP with 0.0, 0.3 and 1.0 damaged fruits per plant respectively as compared to Pyegar 35.7 EC and untreated control plots with each having 5.0 damaged fruits per plant.

Trial 4: Validation of T*richoderma* and *Bacillus* strains for management of black rot and soft rot of cabbage.

Scientist: Jesca Mbaka

Treatments
1. *Trichoderma harzianum* (Triunum)
2. *Bacillus thuringiensis* (Halt 5 WP)
3. *Trichoderma asperellum* (REAL Trichoderma)
4. *Bacillus subtilis* (REAL Bacillus)
5. Control (spray or drench with water only)

Results
There was no incidence of black rot in any of the treatments. The cabbage variety Queen F1 was resistant to bacterial wilt. However, at the end of the season, there was 50 % infection by soft rot. The trial will be repeated with focus on soft rot and treatments will be applied as soil drench at transplanting.

Trial 5**:** Validation of three biopesticides for management of foliar diseases and nematodes in French beans.

Scientist: Samson Kihara

Treatments

1. *Trichoderma asperellum* (Real Trichoderma)
2. Azdirachtin (Nimbecidine EC)
3. *Paecilomyces lilacinus* (Bionematone)
4. Control (Foliar spray with water only)

Results

Bionematone treated plots had the lowest root galling index of 2 compared to the control with 7. Real Trichoderma treatment gave the highest percentage of dry matter, 50%, while the rest of the treatments had almost equal amounts ranging from 30% to 34%. Plots treated with Real Trichoderma produced the highest pod yield of over 46 kg, followed by Bionematone which had 37 kg, Nimbecidine with 30 kg, while control had lowest, 21kg. Pod yield and % biomass (dry matter) performance followed the same pattern. Although Real Trichoderma treatments had more galling than Bionematon, they had the highest yield and % biomass.

Location - ETHIOPIA
Description
Ethiopia, with a population of about 100 million, has an economy that depends on agriculture, which accounts for 41 percent of gross domestic product and 90 percent of exports. Ethiopia has one of the fastest-growing economies in Africa. However, challenges persist, including plot sizes too small to maximize economies of scale, low crop yields, lack of access to credit and land tenure constraints, limited use of improved seeds and fertilizers, and weak connections between farms and markets. Only 6% of cultivated land is currently under irrigation, which is exacerbated by drought conditions. About 27% of people in Feed the Future areas are in poverty, and childhood stunting is estimated at over 47%. The East Africa IPM-IL project is working in the Rift Valley, a large area that dissects the whole country. It holds intensive production of horticultural crops at different levels from small-holders to industrial scale farms. There is significant potential for intensification and expansion due to proximity and access to research and markets. It is also becoming a hotbed for pest problems, and for the widespread misuse and abuse of pesticides. About 90% of farms in the valley grow onion or tomato, and 40-50% grow cabbage or chili pepper. There is a wide range in the level of knowledge and use of pest management. Small holders and contract growers are typified by year-round production with irrigation; they produce mainly for the local market, but some export to neighboring countries. Farmers recognize the main pests and diseases, and management depends mainly on use of a few pesticides at high rates and frequencies with little awareness of pesticide safety or regulation.

Collaborators at Hawassa University:
Dr. Ferdu Azerefegne, Leader, Entomologist, and co-PI
Dr. Yibrah Beyene, Entomologist
Dr. Alemayehu Chala, Plant Pathologist

Achievements

Project Objective 1 – Conduct participatory needs assessments to identify priority pests, current pest management practices, availability of alternative IPM technologies, and constraints to IPM adoption by farmers, including policy and regulatory constraints.

Activity 1**:** Vegetable Production Baseline and Impact Assessment Survey

For Ethiopia, the baseline survey was conducted in January and the data were then cleaned and summarized in tables. The data include priority pests, pest management practices, knowledge of IPM, extent of current vegetable IPM adoption, who the adopters are (low or high-income farmers, male or female), and why they adopt or do not. The crops include tomato and cabbage and the survey was conducted in the Oromiya region.

The Ethiopia baseline survey included 288 male and 11 female respondents, with a mean of 3 acres of land (0.63 acres of tomato and 0.31 of cabbage). Most farmers sold their vegetables to traders with very little home consumption. Seventy percent of tomato farmers feel they have a high severity of insect pests and 54% a high severity of diseases. Leaf miners were their most severe insect pest of tomato. The diseases that cause the most damage were bacterial canker, bacterial wilt and leaf blight. The two most common non-pesticide means they use to manage those problems are removing damaged plants and healthy seeds/seed treatments. The main reasons they use a non-pesticide practice is to save costs and effectiveness. They apply pesticides an average of 17 times and spend 61 days spraying.

Forty-three percent of cabbage producers felt that the severity of insects and diseases was medium or high with 49% saying that diamondback moth was their worst pest and 38% saying it was bacterial soft rot. Removing damaged plants was their main non-pesticide practice used to manage insect and disease problems. Cost considerations was the main reason they gave for using non-pesticide practices rather than pesticides. They applied pesticides 10 times, spent 14 days spraying and 25 days weeding. The data are still being analyzed.

Activities Coordinated by Hawassa University

Establishing link with the main actors of Vegetable IPM in the Rift Valley of Ethiopia. Ethiopian participants established contact with the main government office working on horticulture cops in the central rift valley of Ethiopia and Southern Ethiopia. The main offices collaborating are the three plant Health clinics (Ziway, Hawassa, and Arbaminch); the Irrigation Authority, Batu; and the Adami Tulu Woreda Bureau of Agriculture and Natural Resources.

Vegetable producers are not organized like other partnering countries or like cereal and other farming systems in Ethiopia. Vegetable growers in this area will only give land for such demonstrations if they are paid well. Therefore, we work with progressive growers who can serve as agents of change. Two farms (Ato Kassahun Seifus and Wasihun Abebe) have cooperated. Both farms have irrigation facilities and grow various vegetables including onions, cabbage, pepper, tomato, eggplant and cucumber. They are willing to implement some of the options of pest management, including the use of healthy seedlings, monitoring of pests, and delayed pesticide use based on monitoring. The two farms produced onion with only one and two sprays for thrips. The yield of the plots will be harvested in mid-October in presence of the trainee farmers.

Discussion was held with Mr. Taye Afaw, Head of the plant Health clinic and Mr. Alebel Nigussie, pest management expert, on pest issues and the need for farmer training. Together with the Mr. Abrham Walelign, Team leader crop protection in Admit Tulu Woreda Bureau of Agriculture and Natural resources, 103 small scale seedling producers (12 female 91 male) are selected and will have a training on Seed management (cleaning, seed treatment with synthetic chemical and Clorox solution,), seed bed management (types of seed beds, solarisation, protective covering, fertilization, use of manure etc.), safe use of pesticides, visit to reduced insecticide use to control onion thrips on onion. The plant Health clinic and the Adami Tulu Woreda Bureau of agriculture give services to over 4000 farmers in the area. In addition the Adami Tulu Woreda Bureau of Irrigation Authority on board and discussion were held with Mr. Jilo Gunta (Irrigation Horticulturist), Mr . Nura Tessa Agronomist) and Mr. Negash Head (crop Protection Expert). They are members and organizers of the training.

Contacts and Discussion was held with Mr. Taye Mamo (former head of the Hawassa Plant health Clinic and currently The southern Region Crop protection Expert) and Mr. Mululam Mersha (Head of The Arbaminch Plant Health Clinic). These two offices cater for more than

5000 vegetable producers, Currently, there is influx of vegetable growers from Meqi-Ziway area to Arbaminch because of some disagreements with locals. The experts in these offices will be part of the team to visit the two sites in Meki and transfer the technologies.

Raising Healthy Pepper Seedlings.

The main problem with peppers produced for green pods and dried chili powders, have been the pepper viruses. In the rift valley of the common and most prevalent one is the Ethiopian Pepper Mottle Virus (EPMV) transmitted by aphids. Use of healthy seedlings will give a head start so as to begin with plants that have reasonable chance to produce some yield, although they may succumb to the virus at later stages. Farmers commonly raise their own seedlings. Intensification and continuous production of vegetables in the Rift Valley aided movement of this viral disease from crop to crop. Small companies that sell seedlings have started; however, farmers still use seedlings from their own farm and small scale producers who charge less. An ongoing survey on health of seedlings by graduate student Kumsa Dida indicated that up to 30% of the peeper seedlings produced by local farmers show viral symptoms at planting.

Production of seedlings under net covering helps to reduce the risk of viral infection to seedlings. Small farmers with this simple technology can produce healthy seedlings for their own use and also can sell to fellow farmers. In a small test at Hawassa, the incidence of the EPMV was low because seedlings were raised in an area far from intensive pepper production and the nursery was protected from the surroundings by a 2-m high plastic wall. Peppers that were produced under the net cover were taller than those in other treatments, including those protected with insecticides. The farmers' practice of repeated spraying with insecticide to protect pepper seedlings from sucking insects has negative effects on their growth, and leaves of these seedlings show some phytotoxicity.

Virus symptoms on peeper seedlings raised under different treatments at planting.

	Pepper seedlings with virus symptoms (%)		Average height
	Hawassa	Meki	(cm)
Not protected	8	30	10.8
Net cover	0	6	21.3
Insecticide	4	18	13.3
Net cover + insecticide	0	2	20.1

Farmers spend about $500/ha to raise peppers in addition to the seed cost. A small trial showed that raising seedlings under a protective net covering was found to be as effective as insecticide applications; also growing seedlings far from production areas was found to be equally effective.

Effect of protective covering for virus disease transmission on pepper yield, Ziway, Central Rift Valley, Ethiopia

	Pod weight/plant (kg)
Net covering 80 days	2.2
Net covering 60 days	2.1
Net covering 40 days	1.7
Net covering 20 days	1.8
Insecticide	1.8
Unprotected	1.4

An 800-meter square area of onion was established to demonstrate monitoring and reduced insecticide application. Farmers in the area usually spray a minimum of eight times, mainly with Profenofos. The onions were planted in July, in the middle of the rainy season. Discussion was held with the owners (Mr. Kasshun and Mr. Wasihun) on crop protection, and with the field hands (Mr. Shelele Abu, Mr. Fekadu Geteye), on how to monitor thrips and the need spraying different insecticides in rotation. They abandoned the former schedule spraying and the onion was sprayed only two times. Some portion of the field was left without spraying for comparison purposes. The onions will be ready for harvest next week.

A study was conducted on seedlings purchased from small scale nursery producers. The seedlings were sorted in to healthy looking and symptomatic plants, which were discarded. The heathy looking plants were planted and protected from vectors for various durations. Those which were protected longer had better pod yield. Protection with insecticide was only slightly better than those unprotected. The study indicates that introduction of technologies like low tunnels can protect plants from insects that feed and transmit viral diseases. The study is a part of MSc thesis of Kumsa Dida.

***Tuta Absoluta* management studies.**

Tuta absulta has become the major threat on Tomato in Ethiopia. Farmers repeatedly spray the insecticide Coragen on weekly or less duration. It is known that the insect develops resistance if sprayed with an insecticide repeatedly and such reports are already coming for Coragen. Farmers in the Central Rift valley spray insecticides which they get from various sources, one of the sources being the cut flower industry. With the aim of increasing the spectrum of insecticides to be use in rotation as part of Tuta IPM, the efficacy of registered products from various sources. Tomato not protected with any of the test insecticides had high number of fruits damaged by Tuta larvae and the fruit yield was significantly lower. There was no significant variation yield among the insecticide treatments. All the tested insecticides gave better tomato yield and the number of infested fruits were low. A follow up study will start in November with rotation of insecticides.

New directions of research on Tuta absoluta.

The use of attractants in the management of Tuta will be evaluated in the November tomato field experiment. Three hundred lures of one of attractant has been secured and there is a possibility to include a second attractant.

Activities Coordinated by IITA-Nairobi

Project Objective 3: Evaluate prototype IPM Technologies in on-station and on-farm trials.

Activity 1 – Applied laboratory and field research.

***Activity Leaders*:** Danny Coyne, Luara Cortada-Gonzalez

***Research in progress*:**

1. Application Regime of *Trichoderma* spp and *Bacillus* spp for the control of root knot nematodes and bacterial wilt on tomatoes
2. Efficiency of antagonistic soil microbes on vegetable pests and diseases under different agronomic practices
3. Formulation, mass production and application of selected bio-insecticides against nematodes and agricultural pests. and of microbial bio-enhancers for at least 3 selected resistant varieties of tomato and pepper
4. Field and greenhouse trials at greenhouses, research sites at Hawassa and farmer's (vegetable growers) at Marako, Koka, Bishoftu, Zeway, Jimma, Wachamo, Hawassa.

Location – USA, KENYA, TANZANIA, ETHIOPIA

Projective Objective 3: IPM Communication for Diagnosis and Management

Activity 1- Development of an IPM Communication Network

***Site of activity*:** USA, Kenya, Tanzania, Ethiopia

***Activity leaders*:** Patrick Mathenge (Real IPM), Henry Wainwright (Real IPM), Amon P. Maerere (SUA), Peter Sseruwagi (MARI), Jesca Mbaka (KALRO), Ferdu Azerefegne (Hawassa Univ), and Robert L. Gilbertson (UC-Davis).

***Summary of Results*:** The Plant Health Network was designed to serve as an outlet for fast communications between main grant participants during workshop events, through the duration of the grant and beyond. The network uses the phone application WhatsApp because it functions the same way across multiple phone platforms and countries. Furthermore, in East Africa WhatsApp is the main text phone application system and many users are already familiar with this platform.

Currently, experts and extension educators from Kenya, Tanzania, and Ethiopia are included in the main group with 64% of participants being female.

The group has been active during workshops and has continued to engage throughout the duration of the project, and it has been a good outlet for the dissemination of information. Example of topics discussed include pest and disease identification, and management recommendations against plant diseases and insects. The Network allows for extension personnel and advanced farmers to send photos of symptoms of diseases, insects, and other disorders to a network of experts via WhatsApp to allow for rapid diagnosis. This approach has been successful, particularly as it provides a way for real-time diagnostics.

The metadata for the network resides with Real IPM and Ohio State University, who will jointly coordinate use of images and linkages among sub-groups that are being initiated in various village farming groups. The maximum number of participants in a group is 256, but members can form or join another group and therefore act as a bridge between groups. Members of the initial core group are taking the lead to form and join sub-groups to provide such linkage. Ideally, these would also provide links to value chain partners in the various countries.

As the participants have become more aware of its capabilities there have been more interactions not only from experts in the US but also from experts in the three countries collaborating in the project. We expect that in the future similar networks will be developed with farmers, where the extension educators connect with the farmers they interact with and establish the link with the main network. Denis Nyamu, from Kenya, an MS student of Entomology at Ohio State University will lead efforts to evaluate the impact of the connections established between the core Plant Health Network group and his farmer group at Mwea, Kenya (200+ farmers).

Two significant contributions of our Network to IPM capacity building in East Africa are:

1. The Plant Health Network greatly expands the IPM diagnosis and recommendation capacity of every village farming group that forms a linkage.
2. The Network is neutral with respect to gender, time, location, income, and social class. Our metrics so far show that women participate at least as frequently as men. Villages linked to the core network can communicate in any language.

Activity 2- Development of enhanced virus identification capacity.

***Site of activity*:** USA

***Activity leaders*:** Robert L. Gilbertson, Monica Macedo, Maria Rojas, UC-Davis.

***Summary of Results*:**
The aim of his activity is to introduce extension officers and crop consultants in East Africa to diagnostic methods that can allow them to identify the cause of virus diseases in the field. The long-term goal is to gain insight into the range of viruses infecting vegetables in East Africa that farmers are most likely encounter. During a diagnostic training event in 2016 we collected samples of plants with virus symptoms (e.g., mosaic and leaf curling and crumpling). Two excellent examples of virus symptoms were observed: 1) mosaic of Chinese cabbage and 2) mosaic/mottle and distortion of leaves of wild and cultivated cucurbits, which was the most common virus disease observed on our trip.

One of the methods that was introduced was the immunostrip technology, including a new general immunostrip for potyvirus detection that was brought to the workshop along with immunostrips for *Cucumber mosaic virus* (CMV), *Tobacco mosaic virus* and *Tomato spotted wilt virus* (TSWV). During the workshop, the Chinese cabbage samples were found to be positive for infection with a potyvirus and negative with the other immunostrips, consistent with the well-known disease turnip mosaic. However, the cucurbit virus samples were negative with all four immunostrips, even though the symptoms looked very much like those of a potyvirus. This allowed us to introduce the other technology, FTA cards, for squashing samples on filter paper to bring samples back to UC Davis for further diagnosis.

Samples of the Chinese cabbage and cucurbits were returned to UC Davis and RNA extracted and tested for potyvirus infection by RT-PCR with degenerate primers. For the Chinse cabbage samples, the samples were positive as expected (based on the immunostrip test) and sequence analysis of these samples confirmed that the virus in these samples was *Turnip mosaic virus* (TuMV) based on 97% sequence identify with previously characterized strains of the virus. However, when RNA was extracted from the cucurbit samples and tested for potyvirus infection by RT-PCR, the results were strongly positive. Furthermore, sequence analysis of these samples revealed that they were infected with two different potyviruses, and that these viruses appeared to be different from previously characterized potyviruses (<80% identity with the closest known potyviruses), with the closest related potyvirus was *Moroccan watermelon mosaic virus*. Thus, it appears that we have identified two new potyvirus species from Tanzania.

These results also suggested that the potyvirus immunostrips were either not able to detect all potyvirus species (like these new species) or that in some cases the immunostrip test result was weak. Subsequent tests with the potyvirus immunostrips and samples of cucurbits infected with potyviruses in California (mostly *Watermelon mosaic virus*) revealed that some samples (e.g., older leaves or plants) gave weak signals that would only be observed after >30-60 minutes (compared with the usual 10-15 minutes). Thus, through the work conducted with the IPM-IL we learned that when using the potyvirus immunostrips it is often necessary to wait longer for results, and that positive samples can be weaker than samples with other immunostrips. This has been very helpful for our own diagnostic testing in the United States (California).

Based on the results of the sequencing of the helper component proteinase (HC-Pro) and cylindrical inclusion (CI) genes of the cucurbit viruses from Tanzania, there may be two new species of potyvirus infecting cucurbits. Therefore, to further investigate with, we decided to determine the complete sequences of these two putative viruses. We first tested the hypothesis that these viruses would be mechanically transmissible. Indeed, inoculation of pumpkin plants (cv. ‘Big Max’) with samples of the putative two viruses results in development of mosaic/mottle, yellowing, and distortion, similar to symptoms observed in the field in Tanzania. Moreover, the symptoms of the putative two different viruses were different: isolate F4P1 induced very strong stunting, leaf distortion, crumpling and mosaic; whereas the other isolate F4P4 induced strong yellowing, mosaic and crumpling. These results are consistent with the presence of two distinct species of potyvirus.

Then, samples of each of the potyviruses was sap inoculated into pumpkin cv. Big Max plants and the two isolates (F4P4 and F4P1) were selected and used to generate the full-length clones of these potyviruses. The cloning strategy used was Gibson assembly, which it is based on the concomitant PCR amplification of the virus and the vector (binary vector, pTL-89) and with a combination of enzymes that allows for ligation of the full-length genome of the virus into the binary vector. The full-length clones were successful generated and the sequences determined. The complete sequence of the F4P4 isolate was obtained (~10,000 nucleotides), and most of the sequence of the F4P1 isolate has been completed (>8,000 nt). The most closely related potyvirus species to F4P4 isolate is *Moroccan watermelon mosaic virus* with ~76% of identity, and the partial sequence of F4P1 with the sequences of F4P4 and other potyviruses from Genbank was ~75%. The full sequence of F4P1 will be completed and agroinfectious clones of these two isolates and a host range assay will be performed. In addition, diagnostic tools (e.g., specific PCR primers will be developed for these viruses for future diagnostic work in East Africa.

Capacity Building

At the vegetable industry level, we now have farmers trained to produce high quality vegetable transplants that resist/tolerate pests and diseases and require fewer pesticide applications. Some farmers have now specialized in seedling production, a market that will not soon be satisfied. With healthy seedlings and other IPM approaches, farmers in three Kenyan villages are now marketing together French beans and other vegetables that would probably qualify for organic certification. The connection of IPM as a management approach together with business management skills appears to be effective in changing the industry in the three villages. Farmers in Tanzania are moving in this direction, and this is where value chain partners (MnM, TAHA) can help to provide the business training. The marketing situation in Ethiopia is less organized, and there is no associated value chain partner working in vegetable crops. At the individual level, many farmers, extension officers, Ministry of Agriculture personnel, and others have received training in IPM technologies and pest/disease diagnosis. We have evidence that in many cases this is being translated into adoption of new practices in the field, which are expected to reduce pesticide use and result in higher quality vegetable crops. In many cases, the use of IPM has allowed farmers to reduce the number of pesticide applications, with considerable cost savings; the farmer groups in Kenya provide many examples of this. At the institutional level, we have expanded the capacity for IPM research and education in several ways. One is the common experience in participatory on-farm trials combined with training. In other words, it is not just the farmer who learned from these; researchers and their staff have learned how to test and demonstrate IPM technologies. The whatsapp network has helped to build IPM diagnosis capacity by providing regional and international connections to pest information. It has also been a way for experts to demonstrate how to diagnose and respond to pest/disease problems or other plant disorders. The network essentially provides growers and managers with direct access to extension experts. At the research institution level, the project is supporting advanced training for 12 students, who are expected to return to university, research institute, or ministry-level positions with new expertise, and understanding of IPM, and the kinds of personal connections that can help to continue the advancement of IPM at multiple levels of the vegetable crop value chain.

Lessons Learned

Good work is under way in all three countries, and they are focusing in different ways depending on their needs for IPM research and outreach capacity. The most important effort that is underway is the development of relationships among researchers and research groups within and among countries. This is critical for the future capacity of IPM in these countries. The Tanzania group has the most activity in developing new technologies, i.e. novel botanical extracts for tomato leaf-miner, anaerobic disinfestation for soil-borne pathogens, finding new disease-resistant rootstocks, identifying thrips tolerance/resistance in onion varieties. The intention is that successful technologies will be scaled up in the third year of the project. The Kenya group is more focused on outreach to new groups of farmers who have recently joined together for farming and marketing. They are using fairly established IPM technologies, and have been successful in getting farmers to adopt them. The emphasis for year three will be on expansion of this effort, along with continued work on some novel biological products. The Ethiopian group has taken the longest to get started. This is due to several factors: unfamiliarity with management of the funding approach, internal political issues that inhibited communication networks, and the fall armyworm crisis that pulled entomologists away from vegetable IPM efforts. Nevertheless, they have field work underway and three MS students engaged in research, and are planning to host the project's annual meeting in 2018.

On-farm participatory trials combined with training in technologies evaluated were very effective for advancing IPM approaches. Farmers training and hands-on experience in pest and disease diagnostics and some basic epidemiology can easily lead to a reduction in pesticide usage, more yield of high quality produce, and increased income. Part of the reason why farmers use so many pesticides is because the agro-chemical dealers are the advisor even though they are not trained on safe use or environmental impact of pesticides. Participatory on-farm research (by researchers and farmers) proved to be an effective approach to technology dissemination and adoption. Raising seedlings in germination trays with soil-less media such as peat moss and coco-peat produced healthy seedlings and plants that withstood pest pressure. Plant nutrition and water management remain problems to be investigated further. Through Whatsapp and email, seedling producers are working among themselves and with experts to resolve these issues.

Travels to the tomato-producing village of Mlali Tanzania, for example, revealed a marketing system where villages specialize in one crop to the near exclusion of other crops. This system favors the produce buyers and haulers. They know which villages to visit to purchase tomatoes, which for onion, eggplant, potatoes etc. This means there is little diversification at the entire village level. So if it is a bad year for tomatoes, the whole village (more or less) suffers, but the buyers can go to other regions where conditions were favorable. An individual farmer cannot easily go against this system by producing something novel, because they cannot produce a large enough quantity to attract buyers. The system is similar in Kenya, although the Chuka County farmers that KALRO is working with are better organized to produce and market together.

From the trainings, farmers are now able to identify pests and diseases such as bacterial wilt, nematodes, black rot, *Tuta absoluta*, phosphorous deficiency, and pith necrosis in tomato, diamond back moth, aphids and cabbage moth and its natural enemy the hover fly. They now know the importance of scouting prior to taking management steps. To reduce pesticide use, they know the cultural methods to use including pest exclusion, use of traps, and use of healthy seedlings, plant resistance, staking and trellising, hand pulling and spot spraying. When pesticides must be used, the farmers know that they have options to use biopesticides, such as Trichoderma, Nimbecidine, *Bacillus thuringiensis*, and oil sprays. There were reports by farmers that before the start of the training, one would observe a pest in one crop, such as tomatoes, and spray all the other crops due to the belief that spraying with synthetic pesticides needed to be a routine. Now they know this is not true. They have seen it is possible to raise a vegetable crop and complete a growth cycle without the need to spray any synthetic pesticide.

The situation in Ethiopia is different from other East African countries, due to cultural and historical and language factors as well as resource availability. Growers are not organized and resist organization. Group marketing for vegetables has been tried but failed, so the approach that works in Kenya will not work here. Often, those who farm the land do not own the land. They talked of 'telephone farmers' referring to the remote connection between landowner and those who actually grow the crop.

The fall armyworm crisis had a big impact on this project, drawing Ferdu and others away from vegetable IPM work to attend numerous meetings to address this issue. The infrastructure problems in Ethiopia cause periods without internet access, making communication difficult or slow and inhibiting interactions with students. Poor connectivity results in a different sort of cell phone culture here than elsewhere, with less dependence on this technology and less urgency for frequent connection. Also, Whatsapp is less widely used here, and Viber is preferred; we need to determine if connections can be merged.

Lessons learned about gender differences in IPM and vegetable farming
By: Cathy A. Rakowski, The Ohio State University

Conducting a thorough gender analysis of IPM issues and other aspects of vegetable farming in the three countries included in the project (Kenya, Ethiopia, Tanzania) requires either that

> 1) gender as a variable be included in the design of questions and in the analysis of data for each survey *and/or*
> 2) survey data be shared with other researchers for the purpose of conducting gender analyses.

Surveys in all three countries had been completed at the time of this writing. One was a baseline survey conducted in Tanzania by Dr. Amon Maerere several years ago. It was a random survey, which likely explains why only 26.7% of those surveyed were women farmers while 73.3% were men. The data are available for analysis in SPSS if funds become available to hire a student to produce the required tables.

A survey of farmers also was conducted in Ethiopia by ICIPE (International Center of Insect Physiology and Ecology). Three hundred farmers were interviewed, of which only 11 were women (3.66%). This likely was a random survey, but the small number of women farmers included means it will be impossible to evaluate gender differences among vegetable farmers in Ethiopia.

Data for Kenya include an original survey of 403 farmers conducted with funding from this project for the purpose of analyzing diverse aspects of vegetable farming, IPM issues, sources of inputs, and a range of other variables shed light on gender differences. MS student Muntasir Hasan conducted the survey under the guidance of Dr. George Norton. Every effort was made to include both women and men farmers by alternating the sex of farmers interviewed in the households sampled. As a result, 48.9% of farmers interviewed were women. Rakowski was given access to the data set and enough funding to hire an Ohio State University graduate student (Asanka Wijesinghe) to assist with technical aspects of data analyses and to produce required tables using STATA.

Examples of Gender Findings for Kenya
The following presents a brief analysis of some important gender differences identified by the Muntasir-Norton survey. Simple crosstabs were used for preliminary analyses.
The study included 206 men farmers and 197 women farmers. For the purpose of comparison, the following uses % *within* each gender group.

Age: Ages of farmers surveyed ranged from 20-81, with distribution across age groups very similar except for a slightly higher percent of men in upper age ranges and a slightly higher percent of women in lower age ranges.
Marital status: With respect to "marital status" (whether legalized or cohabitation), 92.7% of men farmers and 70% of women farmers indicated that they were "married." A larger percent of women farmers identified as widowed (21%) than men (3.4%). More women farmers also identified as single (6.6%) compared with men farmers (3.4%). Only 1 man and 5 women indicated being separated or divorced.
Agriculture as an occupation: Farmers were asked whether agriculture was their primary occupation or their secondary occupation. For over 76% of the men, it was their primary occupation and for 24% it was their secondary occupation. For 80% of the women, it was their primary occupation and for 20% it was their secondary occupation. Other primary occupations included having a business or a wage job for both men (23%) and women (19%). Over half of both men (54%) and women (56%) stated that they had only one occupation (farming).
The farming households surveyed ranged from 1-28 members for men and 2-15 members for women. However, 84% of men and 63% of women farmers lived in households with between 3-10 members. It is unclear whether or not some households include any unrelated individuals or if all are related. "Members" do children and extended family members who are adults.
Most farmers, both men and women, appear to have reasonable or easy access to the nearest extension office (5 or fewer kilometers) and to agricultural inputs.

Sizes of plots vary greatly (from .125 acres to 30,000 acres). On average, women's plots tend to be only slightly smaller than men's although a larger percentage of women than men have very small plots (under 1 acre). A few farmers (2 men and 3 women) have access to public land for farming. Few farmers rent land and more than half of all men (59.2%) and close to half of all women (44.7%) surveyed inherited their land. Both women and men live in households that own a significant number of livestock (ranging from 1 or 2 to 80+).

Membership in farmer groups and other community-based organizations is low. Only 28.6% of men and 39% of women are members of a community organization and 56% of men and 57% of women farmers are *not* members of a savings group. Men farmers and their spouses are slightly more likely than women farmers and their spouses to be members of a marketing cooperative, but the numbers are low.

Men farmers are more likely than women farmers to receive advice from an agricultural extension worker (73% vs 53%) or from a farmer field school (10% vs 5.6%). Both are highly likely to receive advice from radio shows (85% of men and 80% of women).
Both women and men surveyed grow tomatoes and cabbage but plot sizes are not large. Tomatoes are grown on plots that range from .01 acres to 4 acres and cabbage is grown on plots that range from .001 to 4 acres. Men in the survey are somewhat more likely than women to grow tomatoes (40% vs. 30%) and cabbage (46.6% vs. 44.1%).

The percent of household income from selling vegetables varies greatly for both men and women farmers. However, men's households and women's households are both highly likely to report that half or more of the household income comes from selling vegetables (25.07% for men's households, 23.5% for women's).

Both men and women farmers are equally likely to use irrigation systems (55% and 58% respectively) while women farmers are more likely to use cans or buckets to water vegetables (51.5%) than men (41%).

Both women and men farmers struggle with a variety of crop pests and diseases and they use a variety of pesticides and strategies (including weeding and IPM) to address these. Many reported that they adopted IPM methods primarily because it costs less. However, most men and women interviewed regarding the effectiveness of IPM did *not* believe that IPM was more effective than pesticides, nor did they believe that it was safer for family health, better for the environment, or that it protects beneficial insects. However, a majority also thought that pesticides have adverse effects on the environment (especially water pollution, kills pests' natural enemies, kills bees). The majority of farmers surveyed, both men and women, had not received training in IPM and the majority who did received training only once. A majority of both men and women farmers who use pesticides use protective boots and hats when applying them, but few use a mask or goggles.

It is not clear whether both sets of respondents—male and female—were the heads of their households or not. The focus was on selecting a farmer knowledgeable about farming in each household surveyed. Male respondents tended to state, when asked, that men were more likely to make decisions regarding pests and women respondents stated that either women or both genders were more likely to make decisions about what to do about pests. Women respondents also gave more credit to women than men did for some decisions (i.e., spending money on pest management) but more credit to men for applying pest management products. About 20% of the farmers indicated that both farmers (male and female) in a household shared in making decisions about important issues involving both farming and pest management. Most indicated that they chose to use pesticides based on the number of pests detected on the plants and/or the visibility of damage on plants. Problematically, both men and women farmers indicate high rates of illness among family members after applying pesticides.

Presentations and Publications

Sseruwagi, P., J. Ndunguru, M. Njelekela, and D. Kalekayo. 2017. Major Viral Diseases of Tomato and their Management in Tanzania. (Dalili za magonjwa makuu ya virusi vya nyanya na udhibiti wake Tanzania). A 4-page document in Kiswahili and English with images describing tomato viral diseases, causes, symptoms, spread, effects, and management. More than 100 copies were distributed to participants in training workshops and to farmers making inquiries on vegetable production at MARI.

Presentations in the 16th Workshop on Sustainable Horticultural Production in the Tropics Chuka University, 28th November to -2nd December 2016:

1. Kihara S. N., Mbaka J. N., Ndung'u B. W., Muriuki SJN., Kuria S.N., Kambo C.M., Wepukhulu S.B., Gathambiri. C.W. and Faraay R.N. Farmers' Knowledge of Vegetable Pests and Diseases and their Perceptions of Pesticide Use Practices in Tharaka-Nithi County, Kenya
2. Muriuki SJN, Mbaka JN, Kambo CM, Kihara SN, Kuria SN, Gathambiri CW Wepukhulu SB. Distribution and severity of insect pests in cabbages and kales in selected irrigation

schemes in Chuka, Tharaka-Nithi County
3. Mbaka J.N. (2016). Integrated Pest Management: Challenges to Adoption in Horticulture Production in Kenya.
4.Ndungu B., Mbaka J., Wepukulu S., Kihara S., Muriuki S., Gathambiri C., Kambo C., Kuria S., Ndegwa A. and Farray R. (2016). Participatory Identification of Pest Constraints in Selected Vegetable Crops and Farmer Management Practices in Tharaka-Nithi County, Kenya

In preparation: Ngugi, CN. Mbaka, JN., Wachira, PN. Okoth, S. and Muriuki, SJN. Evaluation of five entomopathogenic nematode isolates for their infectivity on *Tuta absoluta*. Abstract presented for a poster presentation in the forthcoming 17th Workshop on Sustainable Horticultural Production in the Tropics at Pwani University, Kilifi, Kenya, and 27th November to 1st December 2017.

Human and Institutional Capacity Development
Short-term training

Country of Training	Date of Training Activity	Brief Purpose of Training	Who was Trained	Number Trained M	F	Total
Tanzania	Feb. 14-16, 2017	Seedling Health Workshop: 3-day practical demonstration of IPM technologies, e.g. seeds, soil, water, protection, biocontrols, fertility, & quality assessment, for seedling production.	Trainers, extension officers, educators, students, farmers, male and female entrepreneurs	49	14	63
Tanzania	Feb. 25-28, 2017	Virus vector identification and management.	Research assistants	2	1	3
Tanzania	April 5-8, 2017	On – farm training on onion IPM technologies: Principles of IPM; rationale of IPM, pests identification; damage and symptoms; IPM in onion – insect pests, diseases and weeds; seed selection; variety resistance, nursery establishment; transplanting; onion crop field management.	Farmers, extension officers	37	43	80
Tanzania	May 15-16, 2017	IPM methods for tomato and Chinese cabbage.	Farmers, extension officers	67	23	90
Tanzania	August 25-28, 2017	Vegetable seedling health and crops production IPM practices and GAP. Training included use of WhatsApp to inquire, share	Farmers, extension officers, local leaders at	42	32	74

		and communicate pest and disease problems.	Kerege, Bagamoyo			
Tanzania	May to August 2017	Hands-on training in vegetable viral disease IPM. Objectives: Understand cause, symptoms, spread, effect and control of viral diseases and insect vectors Viral disease IPM Good agricultural practices (GAP) for vegetable crops	Farmers Local leaders Extension officers Journalists from Kerege, Matega Zinga, and Chambezi	155	91	246
Kenya	June, 2017	IPM systems and Technologies (i.e., site selection, solarization, insect proof netting, pathogen-free seeds/seedlings, scouting, identification of main diseases, establishment of seedlings in sterile media in germination trays).	Farmers from Nthambo, Mbuiru-Mwanjati, and Mbogoni Farmer Groups, and extension officers	33	40	73
Kenya	August, 2017	Use of WhatsApp for disease diagnostics and IPM communication. Those with good smart-phones are participating in the network by sending images and questions.	Farmers from Nthambo, Mbuiru-Mwanjati, and Mbogoni Farmer Groups	30	39	69
Kenya	Nov 13-14 2016	To define solarisation and its application for management of soil borne pests, pathogens and weeds in the nursery bed	Farmers, extension officers	32	22	54
Kenya	Nov 13-14 2016	Use of resistant varieties tomato (Var. Kilele) and Cabbage (Var. Queen) for management of bacterial wilt and black rot respectively	Farmers, extension officers	32	22	54
Kenya	Nov 13-14 2016	Pest exclusion by use of insect proof netting in the nursery bed	Farmers, extension officers	32	22	54
Kenya	Jan. 18/2017	Identification and integrated management of Tomato pests and diseases	Farmers, extension officers	43	53	96
Kenya	Jan. 19 2017	Identification and integrated management of French bean pests and diseases	Farmers, extension officers	43	53	96
Kenya	Jan. 19 2017	Identification and integrated management of Brassica pests and diseases	Farmers, extension officers	48	59	107

Kenya	March 10-11 2017	Use of Trichoderma for management of seedling damping off, Fusarium wilt and seedling rots	Farmers, extension officers	18	27	45
Kenya	June 14 2017	Vegetable seedling health management	Farmers, extension officers	14	16	30
Kenya	June 29 2017	Use of Smart phone for disease Diagnostics	Farmers, extension officers	38	39	77
Kenya		Use of social media for pest diagnosis and information sharing	Farmers, extension officers	38	39	77
Kenya	July 12 2017	Use of lime to increase soil pH for phosphorous availability	Farmers, extension officers	9	13	22
Kenya	August 3 2017	Identification and management of nematodes in French beans	Farmers, extension officers	9	20	29
Kenya	Aug 3 2017	Use of biopesticides in vegetable production	Farmers, extension officers	34	35	69
Kenya	Aug 17, 2017	Propagation of seedlings in coco peat and germination trays	Farmers, extension officers	34	35	69
Kenya	Sept 5 2017	Use of lime to increase soil pH	Farmers, extension officers	9	13	22
Kenya	Sept 26-27	Use of Microsft Dynamics AX for Enterprise Resource Planning for use in procurement and accountability	Farmers, extension officers	18	11	29
Ethiopia	Oct. 3-5	Seed management, seed bed management, solarisation, protective covering, fertilization, safe use of pesticides, reduced insecticide use.	Farmers	91	12	103
TOTALS				957	774	1731

Long-term training

Name (first, last)	**Gender**	**University**	**Degree**	**Major**	**Program End Date (month/year)**	**Degree Granted (Y/N)**	**Home Country**

Hellen Kanyagha	Female	Ohio State University	PhD	Plant Pathology	December/2019		Tanzania
Ester Rehema Matendo	Female	SUA	MS	Entomology	December 2017		Tanzania
Peter A. Maerere	male	SUA	MS	Entomology	December 2017		Tanzania
Tumsifu Samwel	Male	SUA	MS	Plant Protection	December 2017		Tanzania
Happiness Christopher	Female	SUA	MS	Plant Protection	December 2017		Tanzania
Denis Nyamu	Male	Ohio State University	MS	Entomology	June/2019		Kenya
Cecilia Ngugi	Female	University of Nairobi	PhD	Entomology	June 2018		Kenya
Joshus Kinene	Male	Chuka University	MS	Entomology	December 2018		Kenya
Kumsa Did	Male	Hawassa University	MS	Entomology	December 2018		Ethiopia
Yosef Beriun	Male	Hawassa University	MS	Plant Pathology	December 2018		Ethiopia
Feyisa Bekele	Male	Hawassa University	MS	Weed Science	December 2018		Ethiopia
Muntasir Hasan	Male	Virginia Tech	M.S.	Agricultural Economics	August 2017	Yes	Bangladesh

Long-term training: Graduate student Muntasir Hasan helped to summarize and analyze the baseline survey for Kenya and completed his MS thesis. He was fully funded by the project and is currently in the job market.

Institutional Development

At the institutional level, we have expanded the capacity for IPM research and education at SUA, MARI, KALRO, and Hawassa University in several ways:

1 - The project is supporting advanced training for 12 students, who are expected to return to university, research institute, or ministry-level positions with new expertise, and understanding of IPM, and the kinds of personal connections that can help to continue the advancement of IPM at multiple levels of the vegetable crop value chain.

2 - We have linked country coordinators and organization leaders in directing participatory on-farm trials combined with training. In other words, it is not just the farmer who learned from these; researchers and their staff have learned how to test and demonstrate IPM technologies.

3 - The East Africa IPM Information Network using WhatsApp has helped to build IPM diagnosis capacity by providing regional and international connections to pest information. It has also been a way for experts to demonstrate how to diagnose and respond to pest/disease problems or other plant disorders. The network essentially provides growers and managers with direct access to extension experts regionally and internationally.

4 - Various physical facility projects have received some project support so that the project activities can be carried out. For example, a lath house was renovated at Chuka University for the

MS student's experimental work. A screen house and a high tunnel were renovated at KALRO-Kandara for the PhD student's research work. Supports for netting to protect seedlings were obtained for SUA student research studies.

Partners:
Kenya: Chuka University, University of Nairobi, ICIPE, KAVES, IITA.
Tanzania: TAHA, MnM, SEVIA, MVIWATA, A to Z Textiles, JEP Enterprises.
Ethiopia: AAU Koka, AAU Ziway, AAU Marako, Debre Markos University, Wachamo University, Jimma University

Innovation Transfer and Scaling Partnerships
We have made good connections with Mboga na Matunda (MnM) and TAHA in Tanzania, and they are the best possibilities for collaborations so far. We hope to join with them in training and demonstrations. In Kenya, we have made consultations and networked with the Kenya Agricultural Value Chain Enterprises (KAVES) for future work on grafting tomatoes, linking French bean farmers with the market and packaging dissemination print materials. In addition, colleagues at KALRO have connected with the Meru Greens Horticulture, a company involved in marketing French beans for canning and/or export.

Technologies ready to scale
1. Solarization of nursery beds
2. Use of insect-proof netting in a nursery bed
3. Use of plant resistance to manage pests and diseases
4. Establishment of seedlings in sterile medium in germination trays
5. Use of Trichoderma in seedling establishment
6. Hand pulling and spot spraying to reduce pesticide use.

Technologies Transferred
1. Solarization
2. Insect proof netting in nursery beds
3. Establishment of seedlings in germination trays
4. Trap crops
5. Scouting to inform decisions
6. Trichoderma in the management of nematodes of French beans
7. Rouging to control viral diseases
8. Spot spraying and rouging to control aphids in brassica
9. Superior varieties and plant resistance in the management of bacterial wilt of tomato
10. healthy seedlings
11. Mulching (organic materials and plastic)
12. Pests identification and scouting
13. Pesticide handling and application safety
14. Soil /media sterilization
15. Seed treatments
16. Crop/variety resistance
17. Crop rotation
18. Farm Record keeping

19. Chlorinated water for shelf life improvement
20. Protected culture (low and high tunnels)
21. Grafting for management of soil borne diseases
22. Plant extracts and microbial pesticides
23. Proper pesticide rotations
24. Fumigation
25. Neem oil (Nimbecidine)
26. Scouting
27. Weeding alternative hosts
28. Staking
29. Pruning
30. Proper plant spacing

Technologies Scaled

1. Scouting for pests and diseases to inform on whether to start management strategies
2. Rouging to reduce inoculum
3. Spot spraying to reduce pesticide use
4. Use of superior resistant varieties to exclude pests and diseases
5. Seed/seedling selection for inherent pest and disease resistance and site selection to reduce pest and disease incidence.

Future Directions

A comprehensive work plan for FY18 has been submitted for this project, with details of planned experiments, training events, and associated project activities. Our future direction will concentrate in these four areas:

1 – ***Diagnosis.*** Labs at UC-Davis and MARI are using modern molecular methods to enhance our ability to detect and identify viruses. They are working with collaborators in Ethiopia on what appears to be Ethiopian pepper mottle virus. This work will support future efforts to map virus outbreaks, spread, and prediction. This will include completion and the characterization of the two new cucurbit potyvirus species from Tanzania, including development of diagnostic tools (PCR primers), sequence comparisons with other potyviruses, generation of infectious clones and host range determination. Training will continue to give attention to diagnosis.

2 – ***IPM Technology development and scaling***. Some early-stage laboratory work is being conducted to develop new technologies that have potential to replace synthetic pesticides for pest and disease management. Other technologies are – or soon will be - moved to the field for testing and verification. Some plant-based products being tested at SUA show promise against *Tuta absoluta*, for example, and some interesting toxin proteins from entomopathogenic nematodes are being isolated and identified in work at KALRO. The intention is to move these as far along as possible and to seek other sources of funding if they continue to show promise. We will continue to scale innovations based on established technologies, such as improved rootstocks for grafting, resistant varieties, insecticide-impregnated netting, neem-based products, and new isolates of Trichoderma and other biocontrol organisms. To move established IPM technologies out to farmers, we will continue to conduct participatory on-farm demonstrations in villages in Feed the Future areas all countries. These are combined with relevant training to educate farmers

on IPM technologies as well as the use of the diagnostic network. The training and demonstrations will include participation of local agency personnel. We will expand healthy seedling production capabilities through business planning for current producers and adding additional seedling producers in each country to meet current demand for healthy seedlings.

3 – ***IPM Communication***. The East Africa IPM Plant Health Network using WhatsApp will be expanded to village farmer groups. We have already initiated this effort in Kenya through work with Real IPM in the villages that KALRO is focusing on. These will serve as models for other farmer groups. Our plan is to train representatives from these groups as trainers for other farmer groups and to establish linkages among groups that will be linked to the core diagnostic group. IPM communication will also be expanded by pushing out SMS messages to farmers regarding IPM technologies. As part of IPM communication, cooperators and their students plan to prepare manuscripts for publication, including four from Kenya and one from the USA in a special issue of the journal Crop Protection. We will continue to build the project web site at Real IPM and the one under construction at Ohio State (http://u.osu.edu/cardina.2/) .

4 – ***IPM Training***. In conjunction with the project's annual meeting in Ethiopia in 2018, we will conduct a training event focusing on tomato and onion IPM packages, from seed selection and seedling production through to harvest and market. The goal will be to demonstrate all possible IPM technologies that can be used along the entire crop cycle. Locally-conducted training events in Kenya and Tanzania will focus on the connection between diagnosis and management – i.e. how to guide farmers in the choice of IPM technologies. This is a missing piece in adoption of appropriate IPM-based responses to pest, disease, weed, and nematode problems. These local trainings will be conducted in villages where participatory on-farm trials are conducted. At the advanced level, we will of course continue to support the PhD and MS students engaged in the project.