Feed the Future: Innovation Lab for Integrated Pest Management Trip Report

Country(s) Visited: Ethiopia

Dates of Travel: 3-8 July 2017

Travelers' Names and Affiliations: Lorraine Strathie, Agricultural Research Council – Plant Protection Research Institute, South Africa

Purpose of Trip: To participate in the IPM Innovation Lab Workshop on Management of Parthenium in East Africa, give presentations on biological control, provide training on the biocontrol agents, provide insect agent, visit mass-rearing facilities and field release sites.

Sites Visited: Ambo University, Addis Ababa, Wollenchiti, Koka

Description of Activities/Observations:

Date	Itinerary
3 July 2017	Travelled from Pietermaritzburg, South Africa via Johannesburg, to Addis Ababa, Ethiopia.
4 July	Visited Guder Campus, Ambo University with Dr Mersie to view parthenium biocontrol mass-rearing facility and transfer *Listronotus setosipennis* supplementary culture from ARC-PPRI, South Africa for mass-rearing. Discussed technical aspects. Visited field release sites (*Z. bicolorata* and *L. setosipennis*) at Guder Hospital. Returned to Addis Ababa.
5 July	IPM Innovation Lab Parthenium Project Workshop in Addis Ababa, with oral presentations from Ethiopia, Uganda, South Africa, and Israel on progress and planning for Parthenium Project objectives. Meeting concluded at 5:30 pm.
6 July	Visited Guder campus, Ambo University parthenium mass-rearing facility with workshop participants. Met with President Tadessa Kenea of Ambo University. Viewed release sites (*Z. bicolorata* and *L. setosipennis*) at Guder Hospital compound. Returned to Addis Ababa.
7 July	Visited the parthenium biocontrol mass-rearing facility at Wollenchiti near Adama with workshop participants. Visited field release sites (*Z. bicolorata* and *L. setosipennis*) at Koka. Returned to Addis Ababa.
8 July	Travelled from Addis Ababa to Pietermaritzburg, South Africa via Johannesburg.

***Listronotus setosipennis*:**

A supplementary culture of 500 *L. setosipennis* adults was supplied to the Guder campus, Ambo University mass-rearing facility from the ARC-PPRI, South Africa laboratory culture (transferred on 4 July 2017), to supplement the existing culture (700 adults) at the facility and expand genetic diversity for mass-rearing.

Workshop:

Fifteen participants, representing the USA, Ethiopia, Uganda, Israel and South Africa attended the IPM Innovation Lab workshop on the Management of *Parthenium hysterophorus* in East Africa, held at Nexus Hotel, Addis Ababa on 5 July 2017. Partners from Tanzania were unfortunately unable to participate. The meeting discussed progress achieved on the project objectives, technical aspects, and planned project activities for the following financial year.

[Dr Fayad] IPM Innovation Lab improves practices for small-scale farmers, currently through eight projects in Africa and Asia. Different components of IPM packages that are developed by the projects are suitable for different sites. Examples of IPM packages include the use of *Trichoderma* mixed with seedling and coconut pith; eggplant grafting on rootstock; Fall Army Worm pheromone; biopesticides (neem); control of invasive species e.g. parasitoid *Acerophagus papaya* for control of Papaya mealybug *Paracoccus marginatus*; control of tomato yellow leaf curl virus using three-month host-free period.

Ethiopia:

[Dr Mersie] The IPM Innovation Lab Parthenium project objectives are to (i) scale up rearing and release of *Z. bicolorata* and *L. setosipennis* in Ethiopia and Tanzania, (ii) evaluate establishment and impact of released agents, (iii) evaluate new agents, (iv) obtain permits and release agents in Uganda and Tanzania.

In Ethiopia, parthenium biocontrol mass-rearing facilities are sited at Guder Campus of Ambo University near Ambo, Wollenchiti near Adama, and at Haramaya University. Wollenchiti has a plant nursery (5m x 10m) and five large cages (5m x 7m) for biocontrol agent rearing. During May 2016, 16 staff from other rearing sites were trained on mass-rearing techniques. Challenges to implementation activities have included staff turnover, frost (Jan-Feb, all sites including Wollenchiti), pests and predators at rearing facilities, and the production of sufficient suitable stock plants. Various improvements have been undertaken including additional, trained staff, improved plant production, upgrades to facilities and additional breeding cages

at three rearing sites, and predator control. Release sites were fenced to prevent destruction, and releases have been conducted in the west, central, north and east of Ethiopia. A small number of *Z. bicolorata* were released from the Wollenchiti rearing facility during 2014, and about 10 500 during 2016. Following releases at Wollenchiti in September 2016, rapid spread and extensive defoliation were observed. About 15 800 *Z. bicolorata* and 2300 *L. setosipennis* have been released up to June 2017.

[Prof Nigatu] In Ethiopia, parthenium is called "Kinche arem", "Biyabisaa", or "Faramsissa". Dugda Dora, Kobo and Jijiga are severely invaded. Sorghum yield losses between 40% and 90% are reported, with estimates of $ 1-1.6 million lost income at district level in Babile and Hirna. Maize, barley, watermelon, timber (*Eucalyptus*), sorghum, common bean (16-87% yield loss) crops are affected by parthenium. During 2016 and 2017, *Z. bicolorata* and *L. setosipennis* were reared at Haramaya University mass-rearing facility. About 3000 *Z. bicolorata* were released at six sites on Haramaya campus, with some impact observed. About 2500 *Z. bicolorata* are currently in culture.

[Ms Assema] A study on gender factors affecting women's interest and ability to participate in biological control assessed the conditions for adoption of parthenium biocontrol practices. The existence and influence of parthenium on agricultural production was well known to about 130 female farmers interviewed from Hirna (Tullo district), with taints in milk and honey production reported. Some use parthenium for medicinal purposes and as a broom for house-cleaning. Traditional weed control methods are not effective. Survey participants and key informants showed keen interest to cooperate and use biological control; they are responsible for weeding. Hence, women should be utilised in the adoption of biocontrol.

[Dr Azerefegne] Few studies have been conducted on parthenium in southern Ethiopia. Nechisar National Park and several national parks are invaded. Animals feed on stems during the dry season. Spread occurs at new, large, state-owned, irrigated sugarcane farms and following road construction activities. Parthenium is used as bedding for animals during transportation and discarded on arrival, contributing to spread. The use of parthenium as a compost was investigated. The biology and establishment of *Z. bicolorata* in the Rift Valley is to be investigated (MSc study). Released in 2016; some egg predation was observed.

[Dr Zewdie] More than 1.5 million hectares are invaded by parthenium. Parthenium is utilised to cover charcoal sacks, and during animal transportation.

[Mr Amare] *Zygogramma bicolorata* was assessed at three sites (Gorfu, Guder campus, Guder hospital compound). About 80 adults/m^2 were released, and monitored for three months after release. Plant and beetle parameters were assessed (10 plants). About 50 eggs per plant were observed in July, and 32.9 in September. A maximum of 4.9 adults per plant were recorded at Gorfu in September, with a reduction in eggs and larvae with time. Defoliation ranged from 57-92% during July to September, and plant height decreased.

[Mr Zegeyne] About 4000 *Z. bicolorata* (2000 x 2 sites) and 400 *L. setosipennis* were released around Finote Selam (Amhara region) on 20 June 2017. Sites were fenced and surrounded by bamboo mats. Oviposition has been observed.

Uganda:

[Ms Agoopio] Parthenium was first reported in Uganda in 2009 although earlier introduction *ca.* 2004 is suspected. It was likely introduced via cereal food aid shipment and cross-border movement of trucks. Used for medicinal purposes (deworming), and as an ornamental in nurseries and wedding bouquets (Mbarara district). Lake Mburo National Park, former refugee camps and settlements, crop fields and grazing lands are invaded. The highest infestations are in the northern region (refugee camps), followed by the east, central, and western regions. Dense infestations occur around a refugee camp in Pader district where impact is being evaluated and biocontrol will be introduced. An inter-ministerial unit met in August 2015 and formed a committee. Awareness is being raised, and NARO is working on control methods particularly in two districts. Local government will provide regional support. Stakeholders agreed on biocontrol as a management intervention and an application has been submitted to import *Z. bicolorata* and *L. setosipennis*. Permission from USAID will also be required. Host range testing is to be conducted on selected crops.

South Africa:

[Ms Strathie] Three insect agents and a rust fungus were introduced into South Africa. All agents have established, with variable performance at different sites. Although not a rapid disperser, *Listronotus* has established more readily (up to 50% of sites) than *Zygogramma* which has limited establishment (less than 20% of sites) so far, although extensive defoliation has been observed at some sites. Factors affecting establishment have been investigated. Soil moisture and type is critical. Temperature (upper and lower) is important.

Cultures of agents were supplied to Ethiopia and Tanzania, and training provided.
The numerous factors that may affect agent establishment and performance were discussed.

Israel:

[Prof Rubin and Dr Yacooby] In Israel, proposed parthenium management is a national research initiative, supported by the Chief Scientific Office, Ministry of Agriculture and Rural Development. Parthenium was first documented in Israel in 1982, in the Bet-She'an Valley. In the late 1980's it was present in the Jezreel Valley, and in 1993 in the Jordan Valley (very hot). By 2016, it was recorded in the Hefer Valley, northern Israel, on a large horse farm, and in Hala Valley (about 3km from Lebanon border). Spread occurs via livestock feed suppliers and livestock farms. Studies on seed biology, germination, chemical control (pre- & post-emergence herbicides), biocontrol (*Epiblema* from *Ambrosia* species, with no success so far), and physical control (flaming) have been conducted. Optimal germination occurred at 25°C, with reduced germination if seed was buried. Pre-emergent herbicides that were assessed included atrazine, metribuzin, clomazone and diuron - the latter was most effective. The most effective post-emergence herbicide was Glufosinate ammonium 1000g/ha. Studies on the distribution, biology and seed viability under different conditions, and management have been conducted. An application for the introduction of biocontrol agents has been submitted to authorities.

Ambrosia confertiflora, a perennial weed reaching 2-3 m in height, has allergenic pollen, sexual and vegetative reproduction, difficult to control, and impacts severely on agricultural production. In 1982 it was recorded in Bet-She'an Valley, 200m bsl. It invades intensive agriculture (high pesticide use). Rearing on an artificial diet failed, but an average of 2.8 moths per stem were reared on whole plants. Three generations occurred between March and October, with winter diapause during November to February. Repeated releases of adult moths weekly into field cages inhibited stem growth. Effects of herbicides and pesticides commonly used in agriculture in Israel are being studied.

Planning for financial year 2018:

Near-future plans include the scaling up of *Zygogramma* and *Listronotus* in Ethiopia and Tanzania, and securing a permit for importation of agents into Uganda.
Releases of agents are to be conducted in southern Ethiopia (irrigated sites, some have sandy soils). Tepe area has clay soils, Arbe Minch, Rift Valley has light soils; south west will probably be successful.

Western highlands – *Z. bicolorata* release intended for Medessa and Majalla, *L. setosipennis* suitable for Jijiga (drier, warm). Gojam area has good soils.
ARARI – roadsides towards Gondar are heavily invaded by parthenium. Bahir Dar almost entirely invaded.
Secure sites such as military barracks and university campuses will be utilised for releases.
In Uganda, land has been fenced, agreement of community obtained, import permit should be received within 1-2 weeks, student recruited to study impact on crop production (2 major crops – maize and another). Permit from USAID is required.
Israel – USAID country missions could be approached for funding.
Work plan requires focus on capacity building, gender issues, publications, and indicators to be addressed.

Guder (Ambo) rearing facility and field sites

Currently rearing *Z. bicolorata* (2000 adults in culture) and *L. setosipennis* (700 adults plus supplementary 500 adults from South Africa on 4 July 2017). Three basic structures (wooden frame with thrips gauze netting) for nursery, and rearing of *Z bicolorata* and *L. setosipennis* have been erected for mass-rearing and despite the low technology, they are effective. Raised seed beds are used for seedling production. Mature seedlings are transplanted and held in shade for couple of days before transferred to nursery. Excellent quality stock plants (in terms of vegetative growth) were observed in the nursery and rearing facility. Plants are fertilised daily. Cages containing 100 *Z. bicolorata* or 50 *L. setosipennis* adults are held for oviposition for seven days before plants are renewed. *Zygogramma* larvae are held on plants in open on tables and transferred to new plants as needed. Pots with pupating larvae and eclosing adults are held on shelves in the open in the rearing cage. Releases are conducted several times per month during wet season. Releases were made at Guder and Finote Selam during 2017.

Guder Hospital release site:
About 2000 *Z. bicolorata* adults were released about two weeks prior to visit. Considerable numbers of adults, eggs and young larvae on apical buds were observed in field. *Listronotus* had been released nearby although no oviposition was observed during the site visit on 4 July 2017.

The group met briefly with Dr Tadessa Kenea, the President of Ambo University, Guder campus. He is very supportive of the parthenium biological control project; mass-rearing and student projects are being undertaken at/from Guder campus.

Wollenchiti rearing facility and field site at Koka

Wollenchiti was the pilot rearing facility established in 2013 (reconstructed after floods damaged it during 2013). There are 6 large walk-in-cages, metal framed and covered by thrips screening gauze. Two are used for *L. setosipennis*, three for *Z bicolorata* and the other as a plant nursery. Since a previous visit in December 2015, a room constructed from corrugated sheet metal has been erected to provide storage space, a work area and shelving to hold *L. setosipennis* pupation containers with developing adults. Temperatures reached close to 0 °C on occasion in February. Current min/max temperatures were about 15 °C - 30 °C. Soil in the area was waterlogged after rainfall. Very dry conditions persist from November to March. Rainfall occurs in May, stops in June, rains from July to September.

Rearing of *L. setosipennis* is progressing well at Wollenchiti. There were 21 breeding cages for *L. setosipennis* (2037 adults) and another 400 adults had been released that week. Plants are exposed for seven days for oviposition before replacement, then held in a separate walk-in-cage on tables during larval development, and dissected four weeks after first oviposition date. Pupation containers are housed within the more recently constructed room. Temperatures range from about 1.5 °C to 33 °C. Survival was not affected by the cold temperatures and frost from Jan to March, but development duration increased. The area experiences warmer ambient temperatures at a lower altitude (about 1400 masl) than Addis Ababa.

For *Z. bicolorata*, 20 breeding cages of 200 adults each were housed in a walk-in-cage. Adults are exposed to plants for 2-3 days for oviposition (cf. 7 days at Guder), which results in excellent oviposition and prevents complete defoliation of plants by adult feeding. Plants with developing larvae are held in a separate walk-in-cage. Larvae are transferred to fresh plants about twice during development. Mature larvae and pupae are collected from soil and transferred in higher numbers to pots with soil, to reduce space requirements. Pupation pots are held on wooden shelves in the same walk-in-cage with breeding cages. Newly eclosed adults freely emerge and are collected three times daily.

Field-collected plants are used. Plants were thin-stemmed, weaker than those produced at Guder. Seeds are sown in seedling trays every 10 days. Seeds are soaked in water prior to planting and buried for better germination success. Potted plants on tables are a more successful technique than planting plants into ground as this technique facilitates replacement of fresh plants and ant control.

Useful features of mass-rearing facility include a water tank, potted plants, benches for plants, and shelving for pupation containers.

About 2300 *L. setosipennis* were released from Wollenchiti during March to July 2017. Adults were released at Wollenchiti (300 + 200), Koka (1000 in May 2017), Hirna (400), and Haramaya University (400). At Hirna, about 3000 *Z. bicolorata* were released. Releases from Guder were made at Finote Selam in June 2017 – 400 *L. setosipennis* and 5000 *Z. bicolorata*.

Field visit to Koka release sites:
At Koka, about 25km from Wollenchiti, 1000 *L. setosipennis* and 4000 *Z. bicolorata* were released in May 2017, between river and crop fields. Eggs, larvae and a mature adult *L. setosipennis* were found within stems. Very high numbers of *Z. bicolorata* adults (~250 within 10 mins), eggs, larvae (early and late instar), and some defoliated plants were observed.

Other:
Neochetina weevils on water hyacinth (from Ethiopian Sugar Corporate, Wonji) are being reared at a Fruit Research Training Centre near Lake Tana, for release on Lake Tana and Renaissance Dam near Gombela. Major weeds in western Amhara region area include *Orobanche carinata* on legumes e.g. faba bean, lentil, chickpea; *Argemone mexicana*; parthenium in sorghum; *Eichornia crassipes*; *Opuntia stricta*; *Orobanche minor* in tomato, potato, pepper crops.

Training Activities Conducted:

Program type (workshop, seminar, field day, short course, etc.)	**Date**	**Audience**	**Number of Participants**		**Training Provider (US university, host country institution, etc.)**	**Training Objective**
			Men	**Women**		
Field day	4/7/2017	Parthenium implementation staff at Ambo University Guder Campus	2	3	Virginia State University and ARC-PPRI	View Parthenium biocontrol mass-rearing facilities, field release sites, and provide technical recommendations

Workshop	5/7/2017	Researchers	12	4	Workshop participants from USA, Ethiopia, Uganda, Israel and South Africa	Parthenium biocontrol
Field day	6/7/2017	Workshop participants	10	5	Ambo University Guder campus staff	View mass-rearing facilities and field release site
Field day	7/7/2017	Workshop participants	10	5	Wollenchiti rearing facility staff	View mass-rearing facilities and field release site, provide technical recommendations

Suggestions, Recommendations, and/or Follow-up Items:

- In general, good progress has been made in Ethiopia in terms of: expansion to three mass-rearing facilities situated in different parts of the country, higher levels of technical expertise are apparent in several project participants, and generally an improved understanding of Parthenium biocontrol techniques, attributes and constraints exists. Efforts to retain key, experienced and productive personnel have facilitated progress. Technical problems impacting on plant and insect production have been addressed. Some field research on biocontrol agents has begun.
- Concerted efforts are now required to mass-rear and release biocontrol agents as widely as possible in Ethiopia, at as many suitable sites as possible. Release sites should be carefully selected in terms of site characteristics, level of disturbance, and location. Release strategies (number of individuals to be released and number of releases per site) for regions and the country should be planned.
- The low technology mass-rearing facilities are functional and productive. They are effective during the wet season although challenges occur during the dry season in terms of production of suitable plants, maintenance of plant and insect cultures without temperature control, exposure to extreme temperatures, delayed development of insect agents. These aspects impact on production outputs. Any attempts to reduce temperatures falling below about 20 °C would extend plant and insect production beyond the current limits and improve outputs.
- A suite of natural enemies will be required for the biological control of Parthenium so future consideration of additional agents is important, as *L. setosipennis* and *Z. bicolorata* will not perform equally at all sites and

seasons, or be suitable for all of the habitats and conditions in which Parthenium invades.

- Plant quality at the Guder facility appeared better than at Wolenchiti at the time of the visit; techniques at each facility should be compared. A large culture of *L. setosipennis* was being reared at Wollenchiti; techniques should be compared to improve the *L. setosipennis* culture at the Guder facility.
- At Guder rearing facility: Pots with pupating *Z. bicolorata* should be enclosed within a separate large cage for ease of collection of newly eclosed adults and to prevent escape. Bud removal on plants for *L. setosipennis* should be halted at an earlier stage than currently occurs as current methods provide insufficient flowers for oviposition in breeding cages.
- At Wollenchiti rearing facility: Plant quality was not ideal for *L. setosipennis* at the time of visit (thin stems, shortage of flowers, 2-5 eggs per flower observed resulting in overcrowding which leads to reduced adult progeny) so exposure time for oviposition should be reduced or the number of breeding cages should be increased, to maximise outputs from oviposition into adult progeny. Use only dilute bleach (not water) for moistening of soil. Place *Z. bicolorata* pupation pots into cage/more confined environment to more easily collect newly eclosed adults. Place thermometers in shade. Place sticky ant bar around table legs to prevent ants in pots. Fertilise plants daily. Nip buds weekly on plants for *Z. bicolorata*. Transplant field-collected plants at younger stage (more foliage, flowers and thicker stems are required).
- Based on experiences in Australia and South Africa, *Z. bicolorata* is more challenging to establish than *L. setosipennis*, particularly in areas with hot, dry conditions and erratic rainfall. Selection of release sites should take cognisance of the attributes of each agent. Clay soils or those that retain soil moisture should be selected for releases, particularly for *Z. bicolorata*. Waterlogged soils or sites with very sandy soils should be avoided. Larger numbers of *Z. bicolorata* will be required at sites without high rainfall, but with good soils and moderate temperatures, than at higher rainfall sites with good soils.
- If persistence of an agent is observed at a site within a few months of release, it would be more productive to continue releases at other sites rather than inundatively release beetles at only a few sites. This is particularly relevant for *L. setosipennis* which does not disperse rapidly, but also true for *Z. bicolorata*. It also spreads the risks associated with site destruction. Release strategies should be planned.

- Studies on field populations of biocontrol agents should be undertaken for longer than three months (ideally throughout the wet season and beyond, with repeat assessments during the following wet season).
- Control sites for field population studies should be sited in close proximity to experimental sites to minimize site and microclimate variability.
- A standardised monitoring sheet should be developed and used to record agent establishment, with parameters monitored periodically (at least once or more per year). National and regional performance of agents should be assessed.
- If field sites are in danger of being destroyed, or once agents are well established and spreading (establishment is confirmed at least one year after release), *Z. bicolorata* adults can be collected (if numbers are high) and redistributed to new sites.
- It is encouraging that Parthenium biocontrol activities have begun in Tanzania with a successful start to mass-rearing of *Z. bicolorata* following importation in March 2017; these activities should be further supported. Uganda too will soon import Parthenium biocontrol agents for assessment. Technical expertise and practical training can be obtained from facilities in Ethiopia, with support from South Africa. Israel too have initiated procedures towards the introduction of biological control.
- The IPM Innovation Lab project has certainly facilitated the initiation and expansion of biological control of *Parthenium hysterophorus* in East Africa and beyond, and efforts should continue. Biological control remains the most cost-effective, long-term, sustainable solution for the management of Parthenium, and is critical for integrated management of the weed, particularly in resource-poor countries.

List of Contacts Made:

Name	**Title/Organization**	**Contact Info (address, phone, email)**
Wondi Mersie	PI for Parthenium Project, Virginia State University- USA	804-524-5651, wmersie@vsu.edu
Amer Fayad	Assoc. Director, IPM-IL, Africa Coordinator, Virginia Tech- USA	540-231-9668, afayad@vt.edu
Lisanework Nigatu	Assoc. Professor, Haramaya University- Ethiopia	910105100, lisanework@yahoo.com
Balaynesh Assema	MSc student, Haramaya University- Ethiopia	918800678, belassema@gmail.com
Ferdu Azerefegne	Researcher, Hawassa University- Ethiopia	911876563, azeref@gmail.com
Kassahun Zewdie	Researcher, EIAR- Ethiopia	911186481, kassahunzewdie@yahoo.com

Samuel Assefa	Researcher, GIZ ET- Ethiopia	911471534, samuel.assefa@giz.de
Lidya Alemayehu	Researcher, VSU-Parthenium Project- Ethiopia	0913246933, sintualemayhu@gmail.com
Tesfay Amare	Instructor, Ambo University-Ethiopia	0963307801, tesfayshire@gmail.com
Wallelign Zegeye	Researcher, ARARI- Ethiopia	251-0818742095, wallelign@yahoo.com
Melkamu Birhanie	Researcher, ARARI- Ethiopia	251-0963801558, birhaniemelkamu@gmail.com
Winnifred Agoopio	Entomologist, NARO- Uganda	256-777-780872, agwinnie@gmail.com
Tuvia Yaacoby	Researcher, NES-TOV LID- Israel	972-506241705, tuvia.yaacoby@mail.huji.ac.il
Baruch Rubin	Professor, The Hebrew University of Jerusalem- Israel	972-54-8820054, rubin@mail.huji.ac.il