HAWAII DEPARTMENT OF AGRICULTURE
HONOLULU, HAWAII

May 19, 2006

To: Chairperson, Board of Agriculture
Through: Plant Industry Administrator
Through: Agricultural Pest Control Manager
From: Exploratory Entomologist
Subject: Report on Out-of-State Travel

1: NAME OF PERSON TAKING TRIP, TITLE OF POSITION, AND DATES COVERED

A. Mohsen M. Ramadan, Exploratory Entomologist
B. Date of Departure - December 24, 2005
C. Date of Return - February 24, 2006

2. PURPOSE OF TRIP

Survey the *Erythrina* species in East Africa to identify the Erythrina gall forming wasp, *Quadrastichus erythrinae* Kim, and its natural enemies for possible use in a biocontrol program in Hawaii. Conduct field studies to determine incidences of galling and rates of parasitism in native Erythrina trees of tropical East Africa. Prepare and export samples of infested leaves and associated parasitoids to the Hawaii Department of Agriculture (HDOA) Insect Quarantine Facility for parasitoid emergence, colonization, and host specificity studies.

3. ACTIVITIES AND ACCOMPLISHMENTS

The Erythrina gall wasp (EGW), *Quadrastichus erythrinae* (Hymenoptera: Eulophidae), is a new pest of economic significance to introduced and native Erythrina trees in Hawaii and the western Pacific Region. It was first discovered attacking coral trees in Mauritius and Reunion, and subsequently dispersed across the Indian Ocean to East Asia and western Pacific countries (Singapore, India, Taiwan, China, Japan, Philippines, Thailand, Hawaii, and Guam). It was first detected on the island of Oahu in April 2005, and became wide spread throughout the major Hawaiian Islands in less than a year. The wasp oviposition and larval activities in the plant tissues cause the leaves, stems, and petioles to swell and produce galls that distort the plant. Under high population outbreaks in Taiwan, infested plants usually die and loss of trees can reach 100%. The preferred hosts are members of the genus *Erythrina* in the family Fabaceae, and no other alternative hosts were discovered outside this genus. Eggs, deposited in the young leaves and stems, and larvae, are protected in gall chambers, making control of the pest with conventional insecticides difficult. The potential ecological and social impacts of this pest are

tremendous, given that the coral tree is an important landscape species in the State of Hawaii. The native wiliwili, *Erythrina sandwicensis*, is an important component of the dry forest.

Related *Quadrastichus* species are not considered pests of Erythrina in Africa, and there have been few studies on Erythrina gall formers in this presumed continent of origin. Insects that are unimportant in their native habitat may reach damaging levels if released from the control of their natural enemies through invasion of new geographical areas. This indicates that exploration for EGW in Africa may detect potential natural enemies suitable for use in Hawaii's biocontrol program.

The magnitude of infestation and complexity of the problem in Hawaii suggest that eradication and other control measures, pruning and chemical control, are not feasible and biocontrol is thought to be the only long-term solution.

Q. erythrinae is a newly discovered wasp and its exact origin is unknown. Limited information is available on the distribution and biology of related species in Africa. No previous efforts have been made to study the parasitoids of any Erythrina gall wasps. Similar eulophid gall formers of the genus *Quadrastichus* are recorded from *Erythrina* species in South Africa and no systematic survey of its natural enemies was ever conducted prior to this report. A South African wasp, *Eurytoma* sp. (Hymenoptera: Eurytomidae), was reported to emerge from the galls but it was suspected to be another gall former.

This exploratory trip has been funded by the Agricultural Research Program, Agricultural Development Division, Hawaii Department of Agriculture, to determine the origin of this wasp and to conduct surveys for its associated parasitoids in the native range. Tanzania was selected as the starting point of exploration because of the number of *Erythrina* species recorded to be endemic to this country was more than anywhere else in Africa. The Tanzanian collaborator on the project is Dr. Francis S. Magingo, Head of the Botany Department, College of Agriculture at Dar es Salaam University. He allowed for examination of the department's herbarium records and gave information on possible field assistants in the Forestry Division, Ministry of Natural Resources, and various botanical gardens in Tanzania. The Ministry of Natural Resources at Dar es Salaam issued collection and export permits.

The search for natural enemies was conducted for eight weeks in Tropical East Africa in the Kwazulu-Natal province of South Africa and nine regions in Tanzania (Arusha, Manyara, Mara, Zanzibar, Da es Salaam, Morogoro, Iringa, Kilimanjaro, and Mwanza). Fifteen districts in these regions, ranging from a low elevation of 25 m (Zanzibar and Dar es Salaam) up to 1578 m elevation (Iringa and Manyara), were visited for observations on Erythrina gall formers and their parasitoid assemblage. Regions and districts selected for the survey were based on knowledge of herbarium records of the Botany Department at Dar es Salaam University, and interview of forestry officers at the Ministry of Natural Resources and botanical gardens. Tanzania and all of East Africa during this trip were suffering from the worst drought to hit the region in more than three decades. Not all

Tanzanian regions were surveyed. However, there was time to inspect sites from a wide range of habitats including natural forests, plantations, botanical gardens, and parks. The collection data sheets have details of each site.

In every district, one-day trips to nearby villages were conducted to inspect Erythrina trees and determine incidences of galling and rates of parasitism. Infested Erythrina parts were examined at the hotel using a dissecting microscope. Leaf and stem samples with evidence of parasitism were prepared for shipment to the HDOA Insect Quarantine Facility in Honolulu.

Unlike South Africa, the Erythrina trees in all districts of Tanzania are not popular trees and are not used for landscaping. On the other hand, the South African coral tree, *Erythrina lysistemon*, is the most common city tree in Kwazulu-Natal province.

Seven shipments were sent from Tanzania and Kwazulu-Natal, one of which was destroyed by USDA-APHIS-PPQ in San Francisco, California. Another shipment was hand carried to Hawaii (Table 1). Shipments comprised of 36 lots of infested leaves and stems collected at different villages from nine *Erythrina* species: *E. latissima*, *E. abyssinica*, *E. sacluxii*, *E. lysistemon*, *E. crista-galli*, *E. caffra*, *Erythrina* sp., *E. variegata*, and *E. variegata* var. *orientalis*. Erythrina trees in Tanzania were not easy to find. Large areas were surveyed just to find a few leaves infested with galls. Most trees were defoliated at this time of the year and some had old leaves still intact. On defoliated *E. abyssinica* trees, the gall formers were reproducing on the seedpods but not on flowers. Gall forming incidences and plant damage were not noticeable in Tanzania. From 5-20 leaves per tree were found to be infested with galls. Shrubs, saplings, and suckers had much more galls than large trees. A dominant parasitoid, *Eurytoma* sp. (Hymenoptera: Eurytomidae), parasitized more than 95 % of the galls. Samples from Kwazulu-Natal showed that parasitism by a different *Eurytoma* species was #10 %.

This survey confirmed the rarity of gall wasp infested leaves of native and introduced *Erythrina* species in Tanzania. That was attributed to the parasitoids' activity. Erythrina samples produced a handful of potential biocontrol agents, three of which are the major biotic mortality factors causing significant reduction in galling incidences of Erythrina trees during this season (Figure 1-9). They are ectoparasitoids (a eurytomid and two eulophids) whose larvae develop within the galls on larvae and pupae of the gall wasp. Results of gall dissections disclosed three additional parasitoids (unidentified species of Eulophidae, Eucoilidae, and Eupelmidae) whose biology remain unknown. Formal identification of the three parasitoids is pending.

The eurytomid wasp (unidentified *Eurytoma* species) deposits eggs in galls containing immature stages from early larval instars to pupae of the gall former (Figures 1-3). In some incidences, the parasitoid larvae were feeding on pharate adults of the gall former (Figure 4). The parasitoid larva can develop on one individual host but in most cases, it will tunnel to adjacent galls destroying up to three individuals of the gall former. Hence, the variable size difference of emerging parasitoids. Perhaps, this predatory feeding

behavior of *Eurytoma* sp. occurs during high infestation levels of the EGW, as seen in Hawaii.

The second parasitoid is a eulophid wasp, probably *Aprostocetus* sp. (Hymenoptera: Eulophidae), which has a slightly pointed abdomen (Figure 5). It is an ectoparasitoid with a stalked egg that is usually deposited on the paralyzed gall former larva or pupa (Figure 6). This parasitoid develops to maturity on a single mature larva or pupa of the gall former. It also acts as a facultative hyper-parasitoid at the expense of the eurytomid larva. It was the dominant parasitoid in several sites in Tanzania (see collection data). More than one *Aprostocetus* species with tapered abdomens are found in different localities.

A third parasitoid (Eulophidae: Tetrastichinae) is a different *Aprostocetus* species with an ovipositor sheath longer than the body length of the female (Figure 7, 8). It is an ectoparasitoid and can be effective in parasitizing immature stages of the gall formers residing deep inside the stems that cannot be reached by parasitoids with shorter ovipositors (Figure 9).
The three parasitoids from Tanzania and a *Eurytoma* species from Kwazulu-Natal, South Africa were amenable for insectary rearing on EGW in Hawaii. HDOA insectary entomologists are moving ahead in host specificity testing.

4. BENEFIT TO PERSON, DEPARTMENT, DIVISION

This trip gave me an opportunity to work at different institutions and meet new colleagues and collaborators in Tanzania (Dar es Salaam University and Ministry of Natural Resources). Surveys and discussions with botanists in Tanzania revealed that Erythrina trees are not landscape trees but are found mainly in grasslands, open woodlands, and forest clearings. *Erythrina abyssinica* and *E. latissima,* in particular, are highly valued as folk medicine trees, and are left standing in agriculture fields and as ornamental trees around houses. Because of their value as medicinal plants (leaves, bark, and roots), it is speculated that transferring infested plant parts of these trees could be the possible origin of infestations in Reunion and Mauritius. Future explorations will be carried out during different seasons in regions where *Quadrastichus* species that are closest in appearance to the gall wasps in Hawaii are found. The Erythrina gall wasp from Chalinze (Morogoro District) and Masai Camp Village (Arusha District) were the closest to the EGW in Hawaii. Female gall formers varied only in the coloration of coxae and genae (Figure 10 and11). Other features of both sexes fit the descriptions of *Quadrastichus erythrinae* Kim. This suggests that Tanzania is a part of the range of origin, and it is important to examine Erythrina trees from these sites during different times of the year. The Kwazulu-Natal (South Africa) collection produced at least three different parastoids, which emerged from different eulophid gall wasps that are different from the EGW in Hawaii. The parasitoids of the gall wasps collected in Tanzania at Arusha and Chalinze appear to be very promising biocontrol candidates of the EGW in Hawaii.

Table 1: shipments of *Erythrina* gall wasps and parasitoids from Tanzania and Kwazulu-Natal, South Africa.

No and shipping date	Transport and shipper	Shipping points	Days to HDAQF	Cost ($)	Organisms introduced	Notes
MR-06-01 Jan 11, 06	Rohlig Grindrod Airfreight (PTY) LTD, South African Airway, and Quantas	Durban-Johanesburg-NewZealand-Sydney-Honolulu	Jan 12, 2006	292.1 (box: 35X26X37)	*Erythrina* leaves infested with galls. Eulophid gall formers and parasitoids.	Box arrived in excellent condition, held in Sydney released after a call. Examined by: Walter Nagamine
MR-06-02 Jan 16, 06	Rohlig Grindrod Airfreight (PTY) LTD, South African Airway, and Quantas	Durban-Johanesburg-Sydney-Honolulu	Jan 22, 2006	283.1 (box: 40X30X20)	Erythrina leaves infested with galls. Eulophid gall formers and parasitoids.	Examined by: Walter Nagamine
MR-06-03 Jan 28, 06	Air Cargo DHL:	Arusha-Dar esSalaaam-Nairobi-London-Heathrow-SanFrancisco-Honolulu	Feb. 2, 2006	191.7 (box: 3 kg)	*Erythrina* leaves infested with galls. Eulophid gall formers and parasitoids.	Examined by: W. Nagamine, J. Yalemar, R. Bautusta, and D. Cho.
MR–06-04 Feb. 1, 06	Air Cargo DHL	Dar esSalaam-Nairobi-London-Heathrow-San Francisco Gateway CA.	Shipment was destroyed in San Francisco	159.9 (Box: 6kg)	*Erythrina* leaves and pods infested with galls. Eulophid gall formers and parasitoids.	USDA-APHIS-PPQ at San Francisco opened the box and found Erythriina seedpods with lepidopteran larvae contaminants. Officer in charge indicates that seedpods are not listed on the permit and for future shipments; it should read Erythrina plant parts.
MR-06-05 Feb. 7, 06	Air Cargo DHL	Mwanza-Dar es Salaam-Nairobi-London Heathrow-San Francisco-Honolulu	Feb. 14, 2006	90.5 (box: 2kg)	*Erythrina* leaves and stems with galls. Eulophid gall formers and parasitoids.	Examined by: Walter Nagamine and J. Yalemar
MR-06-06 Feb.13, 06	Air Cargo DHL	Mwanza-Dar es Salaam-Nairobi-London Heathrow-New York - Wilmington Clinton Field, Ohio-Honolulu	Feb. 16, 2006	142.6 (box: 5.0 Kg)	Erythrina leaves and stems with galls. Eulophid gall formers and parasitoids.	Examined by: W. Nagamine, R. Bautista, J. Yalemar, and D. Cho
MR-06-07 Feb.22,06	Hand-carried by M. Ramadan	Dar es Salaam-Nairobi-Bangkok-Narita-Honolulu	Feb. 24, 2006	hand carried (box: 5.0 kg)	*Erythrina* leaves and stems with galls. Eulophid gall formers and parasitoids.	Examined by: W. Nagamine, and J. Yalemar

Figure 1: Female *Eurytoma* sp. (ex. Tanzania, MR-06-03, T2-C) searching Erythrina gall for oviposition.

Figure 2: Egg of *Eurytoma* sp. (< 1 d-old) deposited in a gall infested with Erythrina gall wasp.

Figure 3: First instar *Eurytoma* sp., feeding externally on pupa of the Erythrina gall wasp.

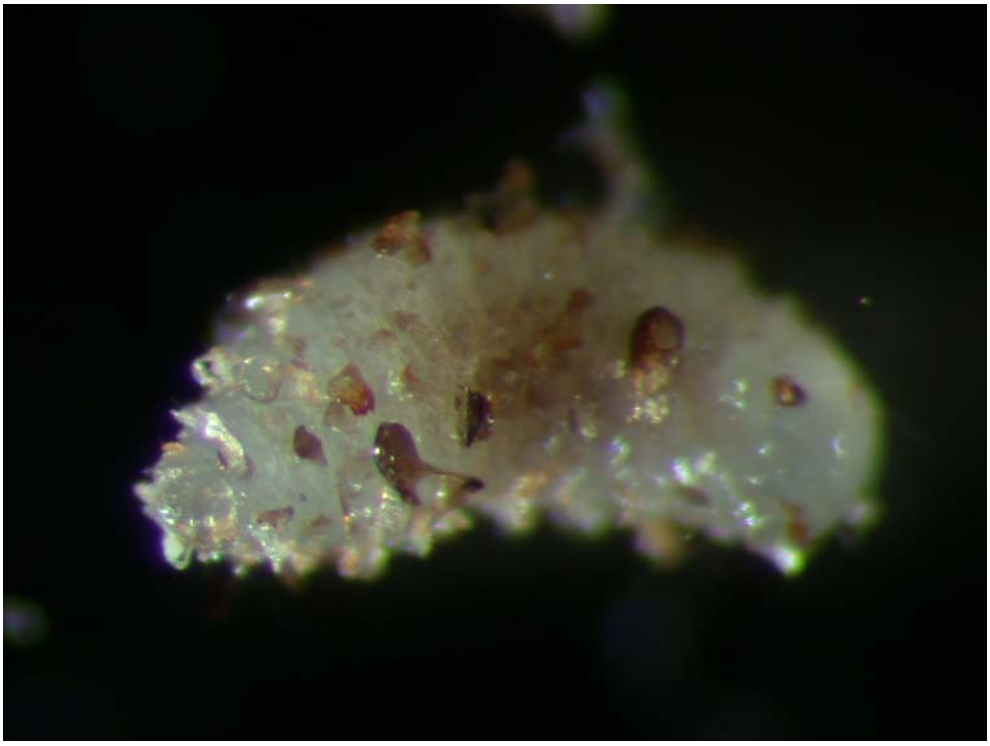

Figure 4: Mature larva of *Eurytoma* sp. covered by remnants of a pharate adult Erythrina gall wasp (a mandible and other host parts shown on larval body).

Figure 5: Female *Aprostocetus* sp. with pointed abdomen (ex. Tanzania, MR-06-03, T2-C) searching Erythrina gall for oviposition.

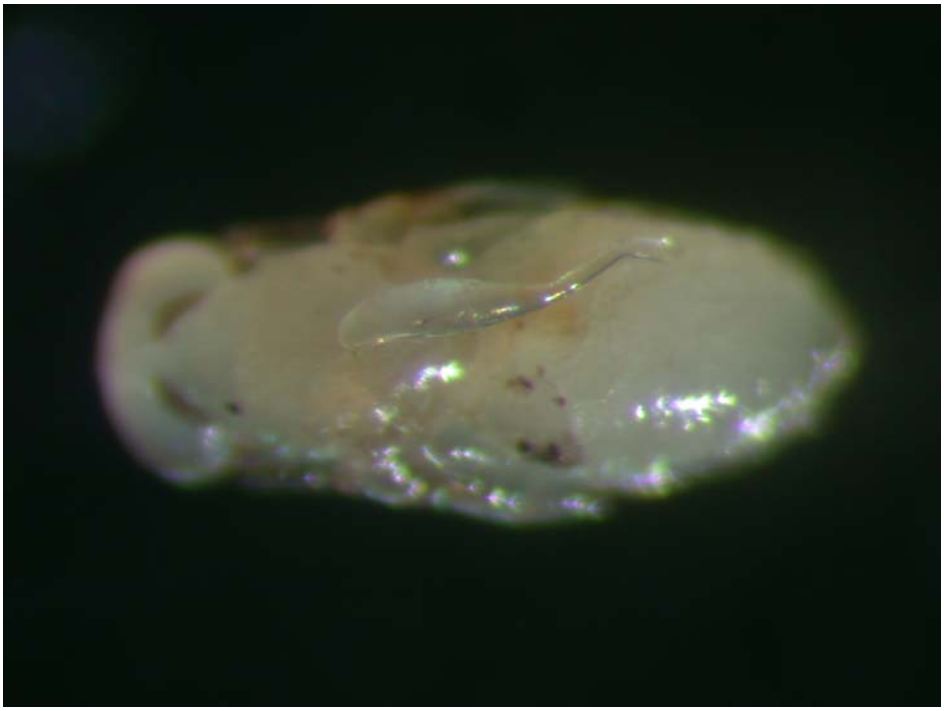

Figure 6: Stalked egg of *Aprostocetus* sp. on a paralyzed pupa of the Erythrina gall wasp (black marks on EGW are the oviposition scars).

Figure 7: Female *Aprostocetus* sp. with long ovipositor (ex. Tanzania, MR-06-03, T2-C) searching Erythrina gall for oviposition.

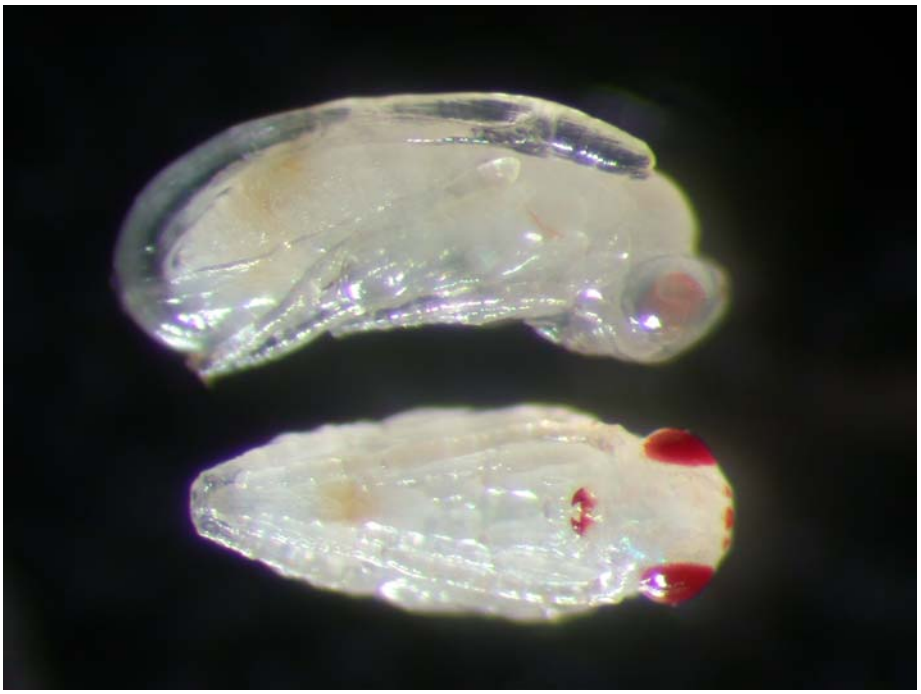

Figure 8: Pupal stage of *Aprostocetus* sp. 2) dissected from Erythrina gall. Male (bottom) and female (top) with long ovipositor curved over abdomen.

Figure 9: First instar ectoparasitoid *Aprostocetus* (typical of sp.1 and sp.2) feeding on a paralyzed larva of the Erythrina gall wasp (black mark on host is an oviposition or feeding scar).

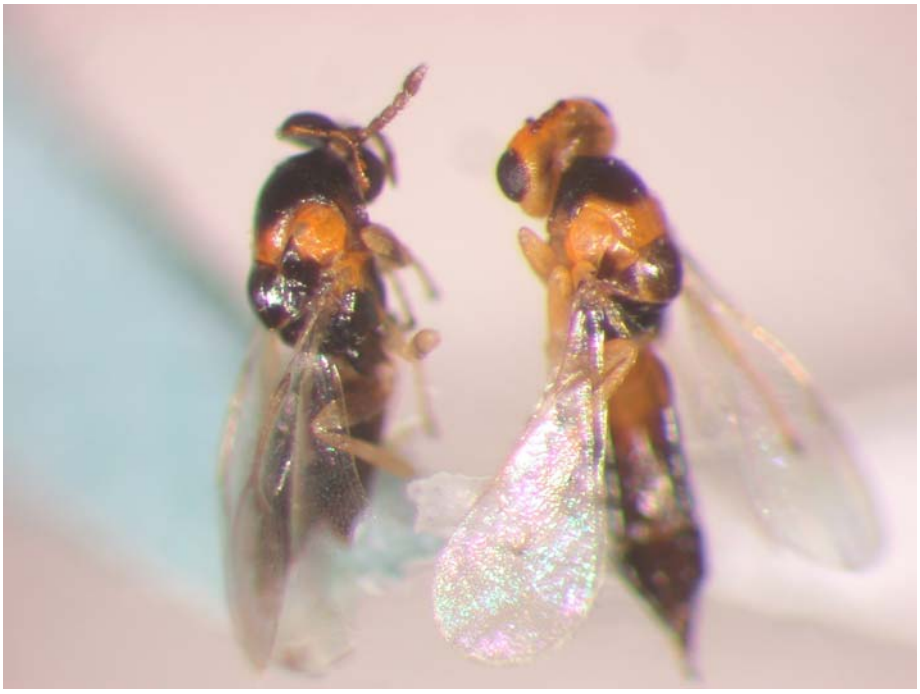

Figure 10: Female EGW from Hawaii (left, with dark hind coxae and genae) and Tanzania (ex. Chalinze and Arusha, with pale legs and genae). Photo credit: Walter Nagamine, HDOA.

Figure 11: Male EGW from Tanzania (Arusha and Chalinze), typical of *Quadrastichus erythrinae* in Hawaii. Photo credit: Walter Nagamine, HDOA.