THE UNIVERSITY OF UTAH

July 13, 2010

The Cycad Society, Grants Committee

Dear Grants Committee

The cycadales, a fascinating gymnosperm taxon, is unusual in that many members of this taxon are known to be insect pollinated (most gymnosperms are not insect pollinated) and their cones are thermogenic and produce volatiles (not reported in other gymnosperms). My major research focus on cycads has involved investigating the role that these cone traits (volatiles and thermogenesis) play in the pollination process, a process which results in vectoring pollen between pollen cones on one plant to ovulate cones on a separate plant. To accomplish this goal, my colleagues and I have been identifying key traits that likely mediate the pollination process, either through manipulation of a specific pollinator behavior in some species or through facilitating an anemophilous or ambophilous process, i.e., where wind alone or a combination of insect and wind are vectors. In some cycad systems, specialist insects are driven out of there home pollen cones where they breed and feed by cones that become thermogenic and emit repellent levels of volatiles, and later in the day insects return to cones when cone volatile emission levels and cone temperatures subside.

Previous studies have involved a focus on specific taxa in specific geographical areas. We are interested in broadening our view to examine species across a broad geographical expanse. In particular, the genus *Cycas*, with ~ 110 species and very wide geographic range, has had little study in this regard. A study of this genus *in situ* would involve many expensive trips across an area from eastern Africa and Madagascar through southeast Asia to northern Australia, and east into islands of the Pacific. An ideal way to examine species in this genus is to use a living collection as found in only a couple of gardens in the world. Montgomery Botanical Center in Coral Gables is one of these gardens. In addition to having research access to MBC's living collection asset, I have been offered use of a specialized gas chromatograph mass spectral analyzer, a triple quadrupole mass spectrometer, at the University of Utah Department of Chemistry for minimal or no charge for the next year. This state of the art GC- MS is ideal for qualitative and quantitative analysis of floral, fruit and botanical volatile chemistry. Agilent Technologies and the Department of Chemistry are looking for projects to demonstrate the capabilities of this instrument and they have expressed an interest in the cycad project. They, however, will not provide certain chemical standards nor costs of getting the biological samples.

Thus, we propose a collaboration between myself and Montgomery Botanical Center staff members Claudia Calonje and Michael Calonje to obtain the volatile samples from cycad cones. In addition, Jim Muller, who is the chemist in charge of training and upkeep of the GCMS at the University of Utah will help to train individuals to use the GCMS to analyze volatile samples. We will use previously established methods for analyzing cone thermogenesis and volatile collection. Thus, we are requesting funds ($ 2,500) to accomplish the following: *i*) travel from Salt Lake City to the Montgomery Botanical Center during coning events of particular species to provide some training for MBC personnel, *ii)* funds for express mailing perishable samples between Miami and Utah, and iii) funds to purchase chemical supplies and chemical standards for chemical analysis. In the end, we hope to demonstrate the variety of cone chemicals produced and emitted by a diverse set of *Cycas* taxa as well as representatives from other genera as cones are available. The results should lead to making predictions about the pollination process for future testing in the native habitat and to finding common traits among species. The research may lay the ground work for others interested in the pollination of cycads. We are willing to accept funds below the $2500; however, this will limit the extent of the work that we can accomplish.

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Enclosed are the application materials and a brief resume. I have read and understand the conditions and responsibilities that accompany the award of a TCS grant and I agree to abide by these conditions.

Thanks for all of your time and consideration.

Kind regards,

Dr. Irene Terry
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Other collaborators:

Claudia Calonje
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Montgomery Botanical Center

I.Project Description

The diversity of cone volatile chemistry and thermogenic profiles within the genus *Cycas*

Abstract

The genus *Cycas* comprises just over 110 taxa species of the over 330 cycad species world- wide, and the geographic range of the species in this genus far surpasses that of all other cycad genera, with a distribution extending from eastern Africa and Madagascar through southern Asia, Philippines, Indonesia, northern Australia and islands of the western Pacific. Successful ollination is key to the ongoing survival and health of any cycad species. For the genus *Cycas*, relatively little is known about the pollination process in this genus, save for a few key pollination studies and surveys of insects in Asia, Australia, India and Philippines and Guam, and a couple of Pacific Islands. Cone traits clearly are associated with attraction and likely repellency of some insects affecting pollination. We wish to extend our understanding of the cone traits of this genus by using analytical techniques established for other cycad species. This should reveal the diversity of the chemistry and biophysics of the cone traits in *Cycas* and will aid in making predictions about pollination process of many species in the genus *Cycas* and will promote interest in follow up studies of the pollination process. We propose to use the living collection at the Montgomery Botanical Center to study cone traits of a number of *Cycas* species as cones become available during the 2010 -2011 year. This will involve studies of the thermogenic and chemical emission profiles of male and female cones. Chemical analyses will involve the use of some of the latest qualitative and quantitatively advanced gas chromatographic mass spectral instruments available.

Background and goals

Cycads are considered the most ancient extant lineage of gymnosperms with fossil evidence appearing at least by the Permian (Norstogn &Nicholls 1997). Within the cycads, the genus *Cycas* is considered the most primitive based on both morphological characters and molecular data (Brenner et al.2003). The genus *Cycas* is the most speciose, with over 100 of the ~330 species of cycad, and it has the widest geographic distribution ranging from eastern Africa to islands of the western Pacific, and south to northern Australia. Despite its placement among cycads, relatively little is known about the reproductive habitats of this genus as related to the pollination process. Cycads are dioecious with insects as pollen vectors, and detailed studies have demonstrated an intimate plant-insect interplay. i.e., between male plants that release pollen and specialist pollen vectors that place pollen at the micropylar tip of the ovule. These ovules are sometimes hidden within a true cone structure, as in members of the Zamiaceae, or hidden among layers of sporophyll tissue, as in the genus *Cycas* of the family Cycadaceae. In either case, the timing and placement of pollen at the tip of the micropyle is critical, and a wind-vectored system may not allow such fine-tuned accuracy. Numerous studies have established that specialist insects, usually beetles (primarily weevils, lizard beetles, or sap beetles), or thrips are highly specialized to carry out this process in cycads (Stevenson et al. 1998). More surprising is the choreography between the plant cone and insect vector in terms of the cone traits that mediate the behavior of specialist insect pollinators (Terry et al. 2007). In the end, to adequately conserve these plants in habitat, the specialist insects that vector pollen must be conserved as well.

Much has been learned about the pollination process of a few cycad species that have been studied by determining cone traits that are responsible for mediating the pollinator behavior. Because very little is known about cone traits within the genus *Cycas*, and because of the number of species in the genus and its basal status among cycads, we believe that the living cycad collection at the Montgomery Botanical Center (MBC) in Coral Gables offers an ideal situation to obtain cone trait information from a large number of *Cycas* species in an efficient and timely manner. To accomplish this in habitat would take a great deal of travel time (likely many years) and money with a high probability of failing to find

coning plants in many instances. We are confident that we can learn much from the living collection of cycads at Montgomery Botanical Center about the cone traits and then make predictions about the pollination process. Our goal in this project is to examine the thermogenic patterns and volatile emissions of cones in as many species of *Cycas* as cones become available at MBC during the year funding period.

Methods

Living collection at Montgomery Botanical Center
We will utilize the living cycad collection maintained at Montgomery Botanical Center. MBC maintains the most extensive research collections of cycads in the western hemisphere. One area of strong representation is the genus *Cycas*. MBC has 72 *Cycas* species, representing around 64% of the taxonomic breadth of the genus. Extensive population depth adds additional value to these collections. The co-location of this taxonomic and population diversity in one place will expedite the basic research into cone thermogenesis and pollination biology of *Cycas*.

Analysis of cone thermogenesis
We will use techniques established by previous studies to examine and describe thermogenesis in a number of cycad species (Terry et al. 2004). We have equipment already available for this part of the project from our earlier work. Cycad cones have a daily thermogenic spike generally known to occur during a metabolic burst that may last from several hours to many hours during the day (Tang, 1987; Terry et al. 2004; Roemer et al. 2005; 2007). A further thermogenic boost is obtained through the alternative oxidase pathway, whereby the metabolic electron transfer process bypasses the production of ATP leading to loss of that energy to heat dissipation. In brief, we will use thermistor and thermocouple data loggers attached to cones in field conditions at MBC to determine the timing and level of thermogenesis in both pollen and ovulate conspecific cones. We will compare these profiles across an array of *Cycas* species.

Volatile sampling and chemical analysis
Numerous established techniques have been used to sample and analyze floral and vegetative volatiles. We will use methods established by Terry et al. 2004 that have served to capture the cone volatile emissions for both qualitative and quantitative purposes. In brief, we will use Porapak Q 80-100 mesh, as the chemical adsorbent, packed in Pasteur pipettes. A battery powered pump will withdraw air from a bag-covered cone (food-grade polyethylene bag) through the tube at 100 ml/ min. for a sample period of 60 min. Chemicals captured on Porapak will be eluted with dichloromethane into 0.5ml vials. Samples will have a preliminary gas chromatography- mass spectrum (GC_MS) run to determine how many chemical peaks, and to establish timing of a GC-MS program that best separates chemical peaks. Internal standards will be determined after preliminary runs to find those best suited for comparing with other chemical peaks whose retention times are different from the chemicals in the samples. Based on preliminary analyses as to chemical identifications, we will purchase chemical standards to compare with GCMS results of the identity. Both quantitative and qualitative results will be tabulated. Sexes within each species (where both sexes are available) will be compared and species within particular *Cycas* subgenera and species complexes can be compared, as they become available. In addition, we may be able to examine some species in more depth, including time of day association of volatile emissions with thermogenic peak and cone stage effects. This should allow us to make predictions about potential pollinator time of day activity and potential pollinator groups that fly or move between cones at particular times of day. In addition, we can compare the diversity of the chemical and thermogenic profiles across related *Cycas* groups and how well these traits map onto available phylogenies. We will use Agilent Triple quadrupole GC-MS for chemical identification and quantification.

Triple quadrupole- GCMS A typical gas chromatograph mass spectral analyzer has one quadrupole mass analyzer for filtering ions of certain mass to charge ratio *(m/z)* for a given voltage that is used in chemical

identification. Increased accuracy of chemical identification is achieved by using a linear series of three quadrupoles, referred to as a triple quadrupole, whereby more filtering can take place after the initial mass filtering from first quadrupole separates out ions. The second quadrupole acts as a collision cell to further dissociate the parent ion into fragments which are then further mass filtered in the 3rd quadrupole. This process aids in the elucidation of chemical structures. The University of Utah has a new model of the Agilent 7000A Triple quadrupole GC/MS and this will be used for analyzing the chemical samples, in addition to single quadrupole GC-MS that is also available.

References

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Roemer R, Terry I, Chockley C, Jacobsen J. 2005. Experimental evaluation and thermo-physical analysis of thermogenesis in male and female cycad cones. *Oecologia,* 144: 88-97.

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Tang, W. 1987a. Heat production in cycad cones. *Botanical Gazette* 148: 165-174.

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Terry,I., G. H. Walter, C. Moore, R. Roemer & C. Hull. 2007. Odor-mediated push-pull pollination in cycads. *Science* 318: 70.

II. How the project fits the goals of the TCS We believe that this collaborative project highlights several TCS goals:

1. To conserve and promote the conservation of existing populations of cycads;

Without knowing the pollinator and the pollination process, little can be done to conserve the plant in its entirety in habitat. A start in understanding this process is to determine how the cone traits affect pollinators of a cycad. This may lead to protection of pollinator species if the plant species is considered endangered.

2. To educate its members and the public as to the conservation challenges, scarcity, and possibility of extinction of this group of ancient plants;

Public presentations have been and will be used to promote interest in cycads, including the fascinating life history of these plants. We believe that this will, in turn, help promote interest in conservation of these plants. There has been considerable interest by both scientists and lay workers in the natural history of cycads.

3. To promote research, field trips, botanical exploration, and horticultural interest in cycads;

Our goal is to promote more research, both in situ as well in the living collections of cycads in a "common garden" setting. We believe that this research will build a foundation upon which researchers in different geographic areas can add by studying cycads in native habitats.

4. To coordinate and cooperate with other local, regional, national, and/or international organizations for the benefit of cycads;
This collaboration will involve two US national non-profit entities, the University of Utah and the Montgomery Botanical Center. The focus at MBC is the at the heart of cycad conservation efforts. In addition, current research in my laboratory focuses not only on basic research on pollination but also how we can identify conservation priorities related to the pollination process. To conserve plants with specialist insect pollinators, the pollinators must also be conserved. The study proposed herein will build on this foundation by adding to our knowledge of the diversity of cone traits involved in the pollination process.

III. Proposed timetable for entire project from start date to completion date

Start date August 2010
-August 2010- Some sample collecting has already begun during the late spring of 2010 from other funds, and these samples are available for chemical analysis. This has given us a head start on use of any TCS funding. We need to purchase chemical standards to begin the analysis.
-Purchase supplies for chemical analysis: vials, chemical solvents, and internal standards, and several independent standards for comparison
-One visit to Montgomery Botanical Center later in the year as specific key species become available. Work with and further train MBC personnel in collecting samples.
-Sample many *Cycas* species during the next year through early to mid-summer 2011, finish extractions, and complete final analyses by August 2011.

IV. Detailed budget including other outside sources, support already received, amount received.

Other sources of funding - The equipment that will be used has been provided through other previous grants from NSF, USDA and National Geographic Society
Travel to from Salt Lake City to MBC in May 2010- 750$, including flight to work with MBC personnel to set up preliminary study.
Basic chemical supplies- $ 250
Data loggers for temperature studies and field pumps for volatile samples- ~ $4,500
Other laboratory equipment for processing and maintaining samples, gases, etc. - $1500
Operational costs for GC- MS-- ~ 15- 20$ per sample-

Funds requested from TCS
Travel-
$750 for travel from Salt Lake City to MBC to set up data gathering and further training

Postage/mailings/express mailing
$200 for express mailing samples from MBC to the University of Utah

Supplies
$1550 for basic supplies for thermogenic measures, and sample standards for chemical analysis

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RESEARCH INTERESTS: Behavioral ecology of insects and insect-plant interactions; chemistry and morphology of host traits that mediate insect behavior; pollination biology of cycads; plant thermogenesis;

EDUCATION

8/79 - 8/83	North Carolina State University, Raleigh, NC Degree: Ph.D. Major: Entomology, Minor: Ecology; Statistics
6/74 - 6/76	University of Florida, Gainesville, FL Degree: M.S. Major: Entomology, Minor: Plant Pathology
8/68 - 5/72	Florida Southern College, Lakeland, FL Degree: B.S. Major: Biology, Minor: Chemistry; French

EMPLOYMENT

2005- present	Associate Research Professor, University of Utah, Department of Biology
1993- 2005	Assistant. Research Professor, University of Utah, Department of Biology Teaching: General biology (1994- 1996); Molecular Evolution Laboratory (1993-1995); Plants and Society (2002-2005); World of Insects (2005)
1984 -1991	Asst. Professor, University of Arizona, Entomology Dept. **Research (70%):** research on population dynamics and management of apple and cotton insect pests; thrips behavior; apple pollination and thrips management system **Teaching (20%)** Courses: Host Plant Resistance, Sampling Insect Populations, Population dynamics, Insect Biometerology, Field Crops Management; Agricultural Entomology; General Entomology; avg. evaluation scores: 3.3/4.00 **Extension (10%)** Deciduous Fruit and Nut Crops in Arizona;
1979 - 1983	Research Asst., Entomology Dept., North Carolina State Univ. - Raleigh, NC: Major advisors: J. R. Bradley, Jr, John Van Duyn, Fred Gould: Investigated and modeling factors (cultivars, planting dates, weather) affecting corn earworm, *Heliothis zea*, populations in soybeans
1976 - 1979	Entomologist; CIBA-GEIGY Corporation - Teaching-Indian River Comm College
May 1977,78,79	Florida Southern College Mini-semester - Dept. of Biology Assistant in teaching riparian ecology, with Museum of Northern Arizona

FUNDED GRANTS AND CONTRACTS:

"Early season insect control", to: Cotton Research and Protection Council, 1986-1987, $17,073
"Compatibility between Western Flower Thrips control and pollination practices in apple orchards", to: USDA, CSRS competitive grants program, Western Region IPM, $24,250 1987
"Combining Western Flower Thrips apple management with REDAPOL fruit set predictions to create a decision support system", to: USDA, Western Regional IPM, $20,000, 1988
"Validation of a bloom period decision support system for apple crop management", to: USDA, Western Region IPM, $20,000, 1989 (50% responsibility with USDA Carl Hayden Bee Res. Lab)

"Development of IPM options for Western Flower Thrips (Frankliniella occidentalis Pergande) that are compatible with apple pollination", October 1, 1987 to: Arizona Commission of Agriculture and Horticulture, $36,000 for 2 years

"Short season production of long and short staple cotton: impact on insect management, yield, and lint quality" 1987-1989 to: AZ Com. of Ag. and Hort.; $57,204 (50% with Jeff Silvertooth, Plant Sciences Department)

"Olfactory cues that attract swarming *Frankliniella occidentalis* males and females" University of Arizona, small grants program; $4808 for 1991-1992

"Insect plant interactions in genetically characterized soybeans: a model system" USDA NRI competitive grants, $110,000 for 1993-1996

"Insect plant interactions in genetically characterized soybeans" USDA NRI competitive grants, $100,000 for 1997-1999.

"The evolution of male fighting, anatomical armamentarium and sociality in thrips", submitted to University of Utah, University Research Committee, 5600 to study cycad thrips in Australia and manzanita thrips in western US – 1999-2000

"Impact for conservation of an Australian cycad: A Tale of Two Pollinators" National Geographic Society for 17,100 for 2002-2003 ; a study of the pollination system and conservation of the Australian cycad genus *Macrozamia*.

"SGER: The role of insects in the pollination of the endangered *Cycas micronesica* of Guam " NSF – SGER LTER, CoPI with T. Marler,University of Guam October 2006- March 2008; 33K

"SGER: Using Arrhenius equation models for estimating thermogenic metabolism in cycads" - NSF SGER, Eng. CoPI with R. Roemer, Mechanical Eng. , October 2008- March 2010, 50K

"Pollination of Guam's critically endangered *Cycas micronesica*: a key to horticultural conservation management" PIs I. Terry and T. Marler, University of Guam, to USDA-TSTAR 120,318 for two years, Oct 2009-Nov 2011

"Understanding responses of tightly coupled ecological interactions of biota vulnerable to climate change: endangered Australian cycads and their pollinators," PIs G. H. Walter, D. Booth, I. Terry, R. Roemer to Australian Research Council, 150$ (US$) Start date Jan 2010-December 2012

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2. Bradley, J. R., G. A. Herzog, S. H. Roach, R. E. Stinner, & L. I. Terry. 1986. Cultural Control of *Heliothis* species in southeastern United States cropping systems. In: Theory and tactics of *Heliothis* population management: I. Cultural and biological control. Southern Coop. Ser. Bull. No. 316. pp. 22-28.
3. Terry, L. I., J. R. Bradley, Jr. & J. W. Van Duyn. 1987. Survival and development of *Heliothis zea* (Boddie) (Lepidoptera: Noctuidae) larvae on selected soybean growth stages. Environ. Entomol. 16: 441-445.
4. Terry, L. I., J. R. Bradley, Jr. & J. W. Van Duyn. 1987. Population dynamics of *Heliothis zea* (Lepidoptera: Noctuidae) as influenced by selected soybean cultural practices. Environ. Entomol. 16: 237-245.
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12. Terry, L. Irene and Doug Gardner. 1990. Male mating swarms in *Frankliniella occidentalis*, a Terebrantian Thrips. Journal of Insect Behavior 3(1): 133-141.

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14. DeGrandi-Hoffman, G., I. Terry, Carol Wienhold, and Felipe Morales. 1990. Apple fruit set potentials as flower quality changes during bloom. Southwest. Entomol. 15: 281-289.
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Roemer, R., I. Terry, T. Marler. Comparison of experimental measurements and predictions from biophysical models of thermogenic events in cones of *Macrozamia lucida, M. macleayi and Cycas micronesica*. Memoirs NY Bot Gard. Accepted

Terry, I., W. Tang, and T. Marler. Pollination systems of island cycads: predictions based on island biogeography. Memoirs NY Bot. Gard. (peer reviewed proceedings paper from Int. Cycad Conf. Panama, 2008)Accepted

Terry, I. W. Tang, A. Taylor, R. Singh, J. Donaldson, A. Vovides, A. Cibrián-Jaramillo. Cycad pollination research: past, present and future. For Memoirs NY Bot. Gard. (peer reviewed proceedings of paper from Int. Cyc. Conf, Panama 2008.) Accepted

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In prep.

I. Terry, R. Roemer, G. Walter. Temperature and volatiles of cycads mediate pollinator thrips behavior. For Functional Ecology Data analysis stage

Terry, I., R. Raguso, C. Moore, and T. Marler. *Cycas micronesica* cone volatile production and insect attraction. For *J. Chemical Ecology* data being analyzed

Terry, I. and T. Marler. *Cycas micronesica* pollination: the role of wind, nitidulid beetles and the microlepidopteran, *Anatrachyntis* sp. For Biotropica. Final data collection- September 2010

Conference Proceedings, Newsletters and Reports; (non-refereed)

1. Terry, Irene. 1985. Control of early season cotton insects. Cotton: A College of Agriculture Report, Series P-36: 179-185.
2. Terry, Irene, Ben B. Barstow and Leon Moore. 1986. Early season insect control for Arizona: effect on cotton yield. Univ. Az. Coop. Ext. Serv. Bull. 8648. 6 pp.
3. Terry, Irene. 1986. Comparison of three and four bract squares on several selected Deltapine cultivars. Cotton: A College of Agriculture Report, p-36: 197-199.
4. Terry, Irene, Ben B. Barstow. 1986. Early season insect control: effect on cotton yield and fruiting. Proc. Beltwide Cotton Prod. Conf, Las Vegas, pp. 181-183.
5. Silvertooth, J. and I. Terry. 1989. Short season cotton production in Arizona: effects on yield and insect management. Cotton: A College of Agric. Report, P39: 180-184
6. Mosupi, P., I. Terry, T. F. Watson. 1990. Synergism of permethrin by formamidine in resistant and susceptible strains of Heliothis virescens. Proc. Beltwide Cotton Prod. Conf. 231-235.
7. Silvertooth, J., T. F. Watson, I. Terry, and J. Malcuit. 1990. Evaluation of date of planting and irrigation termination on the yield of Upland and Pima cotton. Cotton: A College of Agric. Rep., 40: 6-15. 10 pp.
8. Terry, I., and J. Silvertooth, and C. Summers. 1990. Planting date and irrigation termination date effects on pink bollworm in Upland and Pima cotton. Cotton: A College of Agric. Rep., 40, 4 pp.
9. Terry, I. 1990. Bionomics of Frankliniella occidentalis in apple orchards of the southwestern USA. Proceedings of the Third International Symposium on Thysanoptera. 3: 91-95.
10. Terry, I., and J. Silvertooth, and C. Summers. 1991. Pima and Deltapine 90 grown for short season: effects of planting date and termination on pink bollworm management. Proc. Beltwide Cotton Prod. and Res. Conf. 705-707.
11. Silvertooth, J., T. F. Watson, I. Terry, and J. Malcuit. 1991. Evaluation of date of planting and irrigation termination on the yield of Upland and Pima cotton. Cotton: A College of Agriculture Report. 87:1-14.
12. Terry, I. and G. DeGrandi-Hoffman. 1991. A decision support system for *Frankliniella occidentalis* in apples. Conference on Thysanoptera 2pp. (abstract)
13. Terry, I. 1991. Swarming behavior in *Frankliniella occidentalis*. Conference on Thysanoptera, 2pp. (abstract)
14. Terry, I., and J. Silvertooth, and C. Summers. 1991. Pink bollworm management in Pima and Upland cottons: planting date and termination date effects. Cotton: A College of Agriculture Report. 87:136-145.
15. Terry, I. The Pecan Aphid Complex in Arizona. 1991. Proc. 2nd Ann. AZ Pecan Growers Assoc. Conf. 2: 3pp.

16. Terry, I. Copulatory behavior of the western flower thrips, *Frankliniella occidentalis*. Fourth International Symposium on Thysanoptera. 8pp.
17. Terry , I. , G. Lark, et al. 1994. Molecular phylogeny as a tool for soybean breeding III. Soybean Genetics Newsletter. 21: 245-256.
18. Terry, I., L. Woolstenhulme et al. 1995 Molecular phylogeny as a tool for soybean breeding IV. Soybean Genetics Newsletter. 22:251-259.
19. Terry, I. 2000. Western flower thrips. SOMS Handbook of Integrated Pest Management . 6 pp
20. Terry, I. , K. Chase, J. and G. Lark. Using recombinant inbred lines to identify Quantitative Trait Loci for insect resistance in soybeans. International Conference on Host Plant Resistance 8 pp.
21. Terry, I. 2002. Thrips- the primeval pollinators? Seventh International conference on Thrips biology. Pp.157-162. In Mound, L and R. Marullo (eds). Proceedings of Thrips, Plants, Tospoviruses: The Millenial Review. Reggio de Calabria.
22. Terry, I., G. Walter, C. Moore, P. Forster, P. Machin and J. Donaldson. 2004. Cone volatiles of selected *Macrozamia* species and their possible role in pollinator specificity and species isolation.pp 155-169 In Ed. A. Lindstrom (ed.). Proceedings from the 6TH International Cycad Conference on Cycad Biology, Nong Nooch Tropical Botanical Garden, Thailand. 155-169.
23. Chemnick, J., R. Oberprieler, J. Donaldson, I. Terry, R. Osborne, W. Tang, and P. Forster. 2004. Insect pollinators of cycads: protocol for collecting and studying cycad pollinators. The Cycad Newsletter 27 (5): 3-7.
24. Terry, I. and T. Marler. 2005. Paradise Lost? Tipping the scales against Guam's *Cycas micronesica*. The Cycad Newsletter. 28 (3-4): 21-23.

Teaching at University of Utah

General Biology (1994, 1996; 1998)

Molecular Evolution Laboratory (1993; 1994)

Biol 1330 Plants and Society (since Spring 2002 to current), re-evaluated & approved for General Education Science Foundation credit, 2003, evaluated 2008 and approved.

Biol 1310 World of Insects (Spring 2005 -2008) re-evaluation & approved for Gen. Education Science Foundation credit- 2005; reviewed & approved for General Education Science Foundation, 2009

Seminars presented since 2008

Speaker for two talks at 8th Int. Conf. on Cycad Biology and Conservation- Jan 11-18th, 2008, Panama City, Panama; Plenary session, " Island biogeography and insect pollinators of cycads" (Terry &Tang); "Modeling cycad cone thermogenesis" Terry, Roemer and Marler

Organized insect research workshop for 8th Int. Congress on Cycad Biology, Panama City, Panama, Jan11-18th, 2008

Invited speaker at symposium, **Terry, I.** G. Walter, R. Roemer, and C. Moore. 2008. Heat and odour of *Macrozamia* cycad cones offer mixed cues to their host specific thrips pollinators. Invited participant, Symposium 17.02, "Floral rewards and advertising". (Organizers, S. Johnson, R. Raguso, S. Nicholson). 2008 International Congress of Entomology, Durban South Africa, July 8, 2008.

Presenter at Systematics of Thysanoptera workshop, University of California- Riverside, with organizers Laurence Mound (CSIRO, Australian National Insect Collection) and Mark Hoddle (UCR)- 3 presentations: thrips as pollinators, thrips behavioral studies, thrips flight mechanics

October 14, 2008. Pollination of cycads- University of Utah Museum of Natural History, to docents and volunteers

Invited participant and speaker at Gordon Research Conference, "Floral and Vegetative Volatiles", August 9th-14th, 2009, Magdallen College, Oxford England, "Temperature and volatile oscillations in Macrozamia cycad cones" **Terry, I.,** G. Walter, R. Roemer, C. Moore, D. Booth

Participant and speaker at 9th International Symposium on Thysanoptera and Tospoviruses, August 31-Sept 4th, 2009. 2 presentations. 1) "Too cold to smell? Temperature-dependent responses by *Cycadothrips* to cycad cone host cues." **Terry, I.,** G. Walter, R. Roemer, C. Moore, D. Booth. 2) " Made for one another: *Cycadothrips,* pollen and Australian *Macrozamia* cycads" **Terry, I.,** G. Walter, R. Roemer

October 2 and 3, 2009- University of California, Berkeley. Two talks: cycad pollination biology and cone thermogenesis;

UNITED STATES DEPARTMENT OF AGRICULTURE
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Subject: Letter of Recommendation for Dr. Irene Terry

Date: July 14, 2010

To: The Cycad Society Board of Directors

Dr. Irene Taylor is currently conducting research on the pollination biology of cycads. She came into this field as an entomologist with extensive experience in observing and manipulating insects. By applying these special skills to experimental studies of *Macrozamia* she has revealed how thrips pollinate this genus and how they respond to the chemicals emitted by the cones. Cone chemicals sometimes attract and sometimes repel pollinators in her theory of "Push-Pull" pollination. These groundbreaking discoveries are new, not only for cycads, but in entire field of pollination biology. Her work is cutting edge and is crucial not only in understanding how cycads reproduce, but also in how to effectively conserve wild cycad populations. Her work on the chemicals in *Cycas* cones and their relationship to insects found in this genus promises new and exciting discoveries. I believe no one currently in the field of cycad biology is doing research more important than Dr. Terry.

Sincerely,

William Tang
Entomologist
USDA APHIS PPQ