My Time in Taiwan

AVRDC- The World Vegetable Center
Tainan, Taiwan

Juanita Falice
Philadelphia, PA
The World Food Prize
Borlaug Ruan International Internship

Table of Contents

Thank You

I’m not even sure how I got here. There are these vague images in my head of my teachers telling me I should go to the World Food Prize paired with short clips of those same teachers telling me I ought to apply for that internship. My friends, my family, and people from my church all pushed for me to “just go for it” and “give it my all.” I am so glad they did. About a year ago all of this was just a far-fetched idea to me. I couldn't imagine myself actually being accepted into the program. I would love to say that this has simply been like a dream, but it hasn't. Dreams are something you construct and play out subconsciously with some outside influence. I couldn't have possibly done this alone. This was a gift. A gift given to me by a network of people who have faith in my ideologies, abilities, and goals. I knew I had made it when I got the letter on the fancy paper with gold lettering. It made me feel like Charlie Bucket when he found the golden ticket in his candy bar.

First and foremost, I want to thank the World Food Prize for providing me with this amazing experience, especially as a high school student. I always imagined that when I ventured out of the US for the first time I would be in college and it would be a part of a study abroad program. I knew I wouldn't have the financial means before then. It is remarkable in itself that the WFP provides students with the opportunity to work with and learn from world-renowned scientists. It is even more amazing that all of your expenses are paid for. To me this means the WFP values the minds of all youth and sees promise equally, regardless of race, gender, or financial standing, which sadly is not a reality of all youth programs. It is so rare that a prestigious program such as this is accessible to everyone. This whole experience has become such a special part of my life and for that I am forever indebted to everyone at the World Food Prize who made this a reality for me.

I also want to give a special thanks to my agricultural teacher, Mrs. Jessica McAtamney. When I think of perseverance and the value of hard work, she is who comes to mind. I have seen this woman single-handedly put together events and opportunities for students at my school, all because she wants to make sure her students have exposure to as many experiences as possible. She is the only reason I heard of the WFP. Not every student gets blessed with a teacher who truly is invested in where their students end up in life. In fact, I think this is another rarity. She put together a fundraiser for me to get the money I needed to go abroad for this internship. Without her I may have declined the invitation. It is with the utmost gratitude that I thank Mrs. McAtamney for all she has done for me over the years.

I wouldn't have been able to do any of this without the love and support my family gave me and continues to give me each and everyday. It is much easier to pursue your dreams when you have a loving and encouraging support system like I have. My brothers and sisters have all been wonderful examples to me, but I would like to specifically thank my mother and father for always pushing me to do the best that I could. They always did their best to guide me in the right direction and support me in all of my goals. I would also like to thank my church family for supporting me spiritually through prayer. It is a true blessing from above that I was able to go on this internship and gain as much as I have from the experience.

Who I am

They say you don't really know yourself until you hit your forties and I totally agree. Being barely 18, I have no idea who I am yet but I know my passions and I know the things that make my heart beat a little faster. I love the idea of feeding the world. I love the feeling of dirt under my nails and sweat on my brow. I love opportunity, chance, patience, and hard work. Most of all, I love the collision of differentiating perspectives. I find it absolutely world altering to think that there are 7 billion minds on this earth, all a little different. We are all harboring the sustenance needed to fuel a better world, but I think we are just awaiting the correct collision. Truly, I am no more than my thoughts and intentions. I think a global perspective is the mending of differentiating perspectives. It's more than just understanding, sympathy and compassion for the woes of a place other than our own. A true global perspective should beckon at our morality and push us to be the change we want to see. I intend to continue to follow my heart and do my best to gain that true global perspective, but currently my perspective is awaiting the correct impact.

I am from Philadelphia. Below the ever popular New York City and adjacent to the New Jersey coast. If NY tires you out and the shores of NJ sedate you beyond comfort, make your way to Philly. It's a huge city with lots of people who love to eat, but Philadelphia isn't exactly a hot spot for agriculture. We are known for our art, culture, and our cheese steaks. Driving around Philly you could probably count all the farms you pass on one hand. I remember growing up occasionally helping my grandmother tend her small garden in her backyard and never thinking much of it. Somehow I thought of her garden to be a less significant, trivial image of where vegetables actually came from. The tomatoes at the supermarket were much larger, shiny, and neatly packaged in Styrofoam and plastic wrap. Their colors were brilliant: an array of deep reds, bright greens, and my favorite, sunshine orange. Her weather beaten tomato plants never produced anything that beautiful. Nothing but dull greens smeared with milky reddish orange patches and imperfections inflicted by insects. In fact, I found this to be true of many of the small gardens around my neighborhood.

Looking back I realize I was evaluating tomatoes wrong. In fact, I was probably evaluating vegetables wrong entirely. Aesthetics are nice, but they are not what are important when profiling vegetables. We are what we eat. Its much more important that our produce is nutritionally sound, abundant, and readily available to the hungry. I may be a die-hard city kid but agriculture is obviously something very important to our world, but also very personally significant to me. I ended up at the only agricultural high school in my city and I don't think that was an act of chance. I ended up a part of my school's farm club, participating in many urban farming youth programs, and occasionally skipping last period to work at my school's farm. I grew very fond of farming astoundingly quickly and my interests have not strayed too far from it. This January I will be attending Warren Wilson College in Ashville, North Carolina and majoring in Environmental Science and pursuing a degree in sustainable urban agriculture.

In eleventh grade my Ag teacher told me I needed to attend the World Food Prize and she would help me to prepare. Before she even told me what it was I had agreed. Mrs. McAtamney is the teacher who helped me to develop my interest in farming so I see her as someone I'd educationally follow blindly. Initially I was accepted to go in 2012, but due to some legality issues with my school district I was not permitted to attend. This gave me a whole year to think

about what it meant to go. To me, it meant networking with like-minded people and I felt that this was the opportunity of a lifetime. I was delighted when Mrs. McAtamney told me she'd figure out a way to get me there the next year. I don't know how she did it, but she succeeded. In October of 2013, during my senior year, I attended the World Food Prize Global Youth Institute.

Internship Location & Host Background

I spent my internship seven thousand, nine hundred, and sixty miles away from my home where the water tasted a little different and the people were a little shorter. In fact, everything was a little smaller. The super market ceilings were a little lower, the steps a little shorter and the busses much more compact. I spent my internship in Tainan, Taiwan and had an amazing, differently proportioned, experience that I will remember forever. Some of my favorite places I visited were the religious temples that focused on particular gods. Although I visited a few really cool locations outside of Tainan, including Kaohsiung (another city) and Xiao Liuqiu (a nearby island), my host center truly became like another home to me. I lived in a dorm on AVRDC's campus for the duration of my time in Taiwan and now AVRDC is the place I miss most.

"***Prosperity for the poor and health for all"*** **- AVRDC**

AVRDC- The World Vegetable Center, (previously known as The Asian Vegetable Research and Development Center) is an nongovernmental, international, nonprofit organization headquartered in Shanhua, Tainan, Taiwan with locations in Thailand, Tanzania, Mali, Uzbekistan, India, and Korea. Founded by the Asian Development on May 22nd in 1971, The World Vegetable Center envisions a world where today's developing countries have access to fresh and nutritionally sound vegetables are able to successfully produce their own vegetables, and thrive economically. Through increased and improved production and consumption of nutritious vegetables, AVRDC hopes to attain this vision. Primarily, AVRDC uses conventional breeding methods to improve vegetable crop varieties. Some of their methods include tissue culture and molecular marker assisted breeding. When genetic constraints inhibit the use of conventional breeding methods for the betterment of vegetable lines, AVRDC explores the benefits of genetic modification based firstly on their safety and usefulness. Though GMOs are highly controversial, AVRDC believes is it imperative we consider all options as the need for attainable nutritious food. Initially AVRDC only focused on Asia-specific vegetables, but today is known as an international world leader in vegetable research and development.

The Entomology Department

The Entomology Department at AVRDC- The World Vegetable Center is devoted to bettering the understanding and bio control of currently prevalent and potentially prevalent agricultural pest species. Taiwanese farmers experience extensive crop damage by tropical agricultural pests. To avert these pests some farmers over use chemical pesticides due to a lack of education or funds. By developing information easily attainable to farmers about less harmful pest management options, we can decrease the use of harmful chemical pesticides that not only harm the soil, but also a hazardous to farmer and consumer health.

Dr. Srinivasan Ramasamy

Dr. Srini is the Head of the Entomology department at AVRDC. He studied agriculture at Tamil Nadu Agricultural University and obtained his B. Sc. in 1998. He then went on to concentrate on Agricultural Entomology and obtained his Masters in 2000. In 2003 Dr. Srini earned his PhD from TNAU and AVRDC. Although Dr. Srini is a widely trained Entomologist, he focuses much of his research on insects that feed on Legumes, Solanaceous and Brassica vegetable crops. His research is published in 100 publications, 38 of which are peer reviewed. He also published two field guides for safer vegetable production and 1000 copies have been distributed throughout Africa and Asia. As of now, Dr. Srini is responsible for the total portfolio of 4.0 million USD including planning, monitoring, implementation, and management of human resources and budgets for AVRDC.

Dr. Jan Chang

Dr. Chang is a broadly trained Ph.D. with specialties in plant molecular genetics, phylogenetics, systematics, molecular evolution, population genetics, bioinformatics, genetic engineering, and DNA marker development. He is a Postdoctoral Research Fellow in the Department of Entomology. Initially, Dr. Chang believed he wanted to work in computer software technology so he got his B.S. in Mechanical Engineering from Tamkang University (Taipei, Taiwan.) He then went on to receive his M.S. in Computer Science from Boston University. Unsatisfied, Dr. Chang transferred to Tufts University in Medford, MA and obtained his M.E. in Biomedical Engineering. He finally received his Ph. D. in Biomedical Engineering and Biotechnology from Boston University in 2012. Dr. Chang and Dr. Srini have collaborative research papers published by AVRDC, many including extensive molecular investigations of the legume pod borer in order to develop effective control strategies.

Preparations For Pest Populations

Effects of heat-shock on survival and reproduction and quantitative monitoring of PBP gene expression pattern of cabbage head caterpillar and amaranth leaf webber adults

Introduction

As ectothermic poikilotherms, insect's livelihoods directly correlate with the temperature and humidity of their environment. Higher temperatures are known to shorten insect larvae and pupa stages. At either temperature extreme they experience mortality, a decrease in successful reproduction, fluctuations in distribution, and many other effects. In the field, insects naturally experience fluctuations in the parameters of their environment due to solarisation.
Heat stress denatures proteins, causes desiccation, alters membrane and enzyme structures and properties, and entertains the up regulation of heat shock proteins (HPSs). HSPs are one of the most widely studied responses to heat stress with more than 12,000 creditable references to date. Due to the variability of environmental conditions (namely humidity and temperature), insect's survival depends on their ability to transition between these regimens. HPSs allow insects to maintain homeostasis concurrently with the variability of their natural environment by

functioning as molecular chaperones that aid in the appropriate interactions of proteins (Feder, 1999). It is imperative that we continue to further our understanding of how agricultural pests will respond to rising global temperatures because climate change, specifically global warming, will alter the life history of many species of insects, including these agricultural pests.

It is also important that we understand the mating patterns of agricultural pests. Mating is initiated by an interaction between the female moths pheromone biosynthesis activating neuropeptide (PBAN) and the male moth's odorant binding proteins (OBP) (Eureka, 2011; Vogt, 1991). In order for the female's sex pheromones to pass through the male's aqueous antennal sensillum lymph and be received by the highly specific receptor neurons, an OBP must be present (Zhang, 2012). OBPs are specified by three general classes being pheromone binding proteins (PBPs), antennal binding proteins (ABPs), and general odor binding proteins (GOBPs). PBPs carry out pheromone perception while GOBPs carry out general odorant perception in an insect's olfactory system. PBPs are synthesized during antennal development and only bind to the interspecific pheromones released by a corresponding mate.

This study focuses on how *Spoladea recurvalis* (Amaranth Leaf Webber) and *Crocidolomia binotalis* (Cabbage Head Caterpillar), which belong to the Crambidae family and are tropical and subtropical, respectively, respond comparatively to heat stress in terms of survival and reproduction and when *S. recurvalis* is the most reproductively active according to the adult male's PBP expression at different stages of adult life. Reportedly, CHC has a geographical distribution of South and Southeast Asia, Australia, South Africa, Tanzania and the Pacific Islands and is known to feed on cabbage, Chinese cabbage, and cauliflower (Sastrosiswojo, 1992). ALW has a heavy geographical distribution in Africa and the islands between North and South America but can be found all over the world. It is known to infest Amaranthaceae, Chenopodiaceae, and Portu- laceae plants (Shirai, 2006).

Materials and Methods

Insects

Insects for this study were collected from colonies maintained at the insectary of AVRDC- The World Vegetable Center. The *C. binotalis* larvae were reared on 10- 11 week-old potted cabbage plants until pupation. The *S. recurvalis* larvae were reared on amaranth leaves until pupation. Pupa for both species were collected and kept individually in transparent Insects for this study were collected from colonies maintained at the insectary of AVRDC- The World Vegetable Center, Shanhua, Taiwan. The *C. binotalis* larvae were reared on 10- 11 week-old potted cabbage plants until pupation. The *S. recurvalis* larvae were reared on amaranth leaves until pupation. Both species were kept at 27$\pm$ 1° C, and 70$\pm$10% RH, 14:10 h (Light: Dark) until pupation. Pupa for both species were collected and kept individually in transparent 1 ounce cups with lids until eclosion.

Heat Shock

Newly emerged *S. recurvalis* and *C. binotalis* adults were put individually in thin walled test tubes (plugged with cotton and sealed with lids), and immersed in a water bath pre-set to these four high temperatures for these durations:

Temperature (°C)	Duration of Exposure (min)
40.0	0, 120, 180, 240, 360, 540
42.5	0, 30, 60, 90, 120, 150
45	0, 5, 10, 12.5, 15, 17.5
46.5	0, 2.5, 5, 7.5, 10, 12.5

Table 1. Exposure Temperatures and Duration.

C. binotalis specimens were tested under all of the temperatures and corresponding durations while *S. recurvalis* was only tested at 40.0°C and 46.5°C. For each temperature and time combination, three replications were treated; five pairs per replication. A piece of cotton saturated with ten percent sugar solution was placed at the bottom of the tube to prevent insect desiccation.

Surviving adults were placed in pairs in transparent plastic cups with cotton saturated in ten percent sugar solution and covered with nylon nets to be monitored daily for egg laying and longevity. Hatching larvae were monitored daily and hatched larvae were reared on respective host plants until pupation. After adult emergence the sex of the moths was recorded to identify the sex ratio for each replication.

Pheromone Binding Proteins

Head tissue samples were collected from *S. recurvalis* male moths at day two through six in their adult life span. For this experiment we dissected 5 moths for each day, totaling twenty-five moths. These head tissue samples were first stored in RNAlater and we extracted the total RNA of each sample using the Geneaid Total RNA mini kit. We then reversed transcribed the total RNA samples using SuperSAMscript reverse transcriptase to synthesize the first strand cDNA. The cDNA samples then underwent PCR at these settings:

	1 (Initial Denaturation)	2 (Denaturation)	3 (Annealing)	4 (Extension)	5 (Final Extension)
PBP	94°C-5 min	94°C-30 sec	65°-30 sec	72°C-1 min	72°C-7 min
β- actin	94°C-5 min	94°C-30 sec	60°C-30 sec	72°C-1 min	72°C-7 min

Table 2. PCR Program

PBP and β-actin were amplified using gene-specific primers designed from *Spoladea* transcriptome data. β-actin was used as an internal control for this experiment. This program was repeated for forty cycles. The amplified PBP and β- actin then underwent electrophoresis for results.

Results: Heat Shock

Adult immediate survival to heat shock temperatures

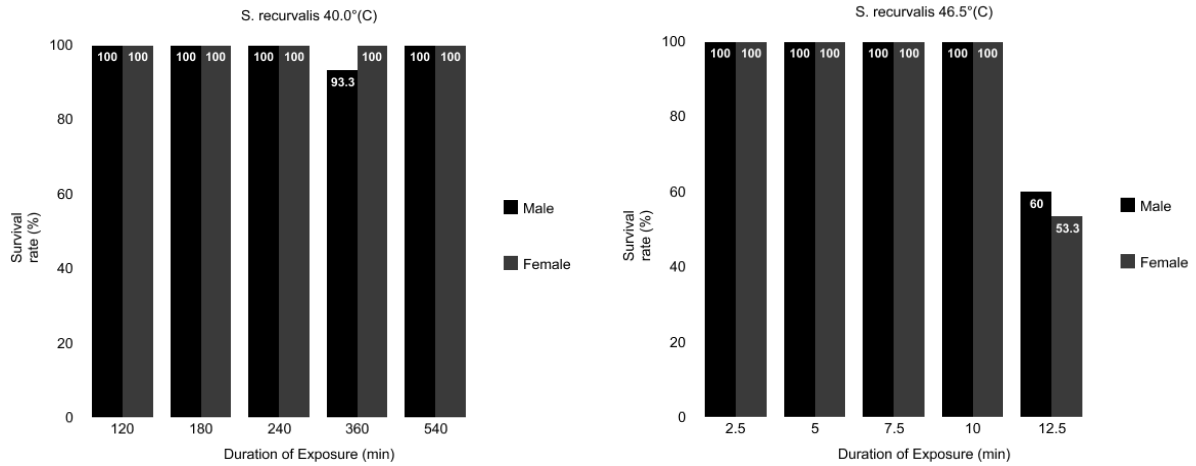
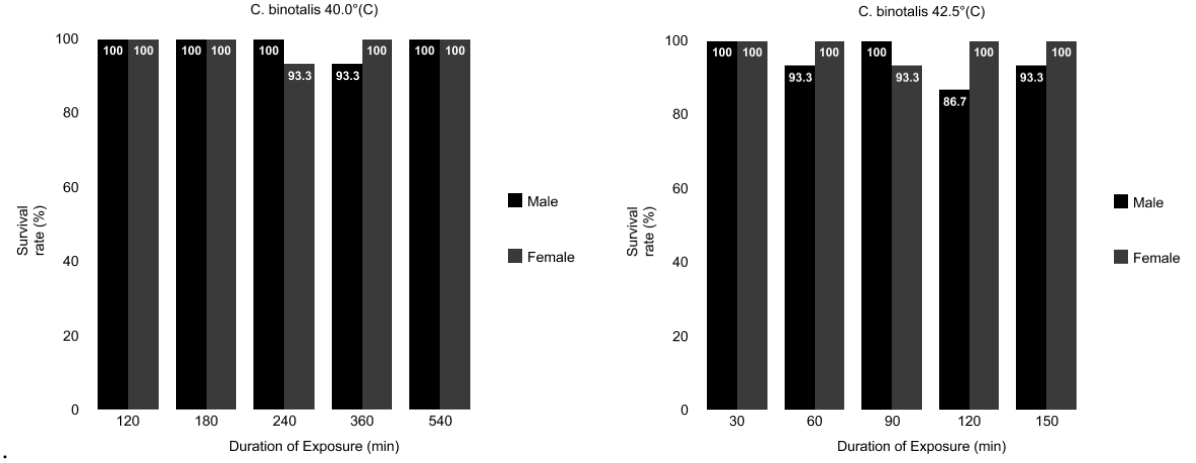


Figure 1. Shows the immediate survival rates of *S. recurvalis* 2 hours after exposure to high temperature treatments. S. recurvalis was not treated at 42.5° or 45.0°. There is a 100% survival rate for controls (27± 1° C, and 70±10% RH, 14:10 h (Light: Dark)) at both temperatures. The numbers at the top of the bars indicate the survival percentages and the species' gender specific data is positioned adjacently to one another.



.

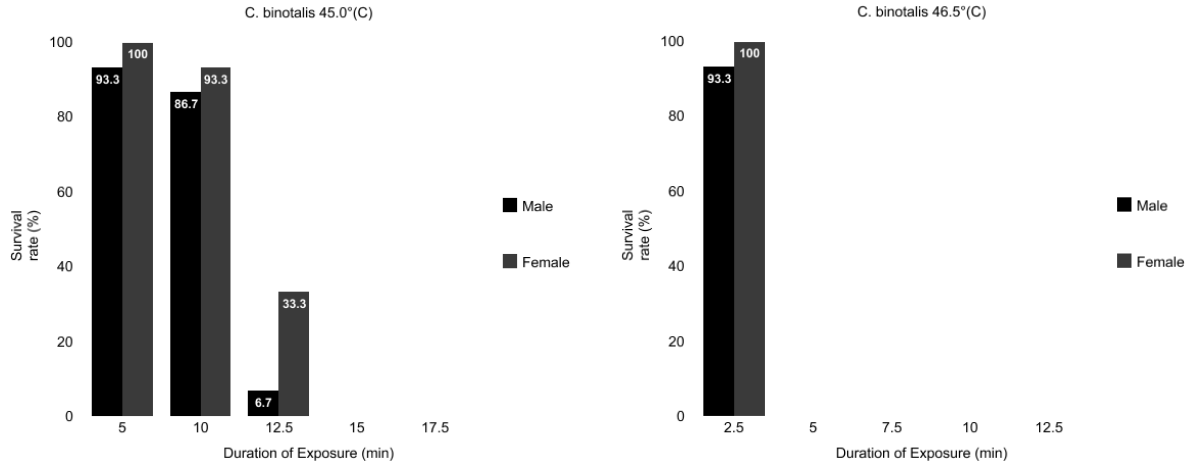


Fig. 2 Shows the immediate survival rates of C. binotalis at the four high temperatures after a 2-hour resting period. There was a 100% survival rate for all controls (27± 1° C, and 70±10% RH, 14:10 h (Light: Dark)) at all temperatures. The numbers at the top of the bars indicate the survival percentages and the species' gender specific data is positioned adjacently to one another.

Survival rates at the shortest durations of each temperature (120 min, 30 min, 5 min, 2,5 min, at 40.0°, 42.5°, 45.0°, 46.5° respectively) were consistently upwards of 90% for both species. *C. binotalis* continued its upwards of 90% survival rate trend until 120 min at 42.5° where it dropped to 86.7% immediate survival rate for males and 100% for females (Fig. 2). At 15 and 17.5 min for 45.0° there was a 0% immediate survival rate for *C. binotalis. S. recurvalis* maintained an upwards of 90% survival rate at 46.5° until 12.5 minutes where the survival rate dropped down to a 60% for males and 53.3% for females. Either sex of *Crocidolomia binotalis* could not withstand 46.5° post 2.5 minutes.

Surviving Adult Longevity

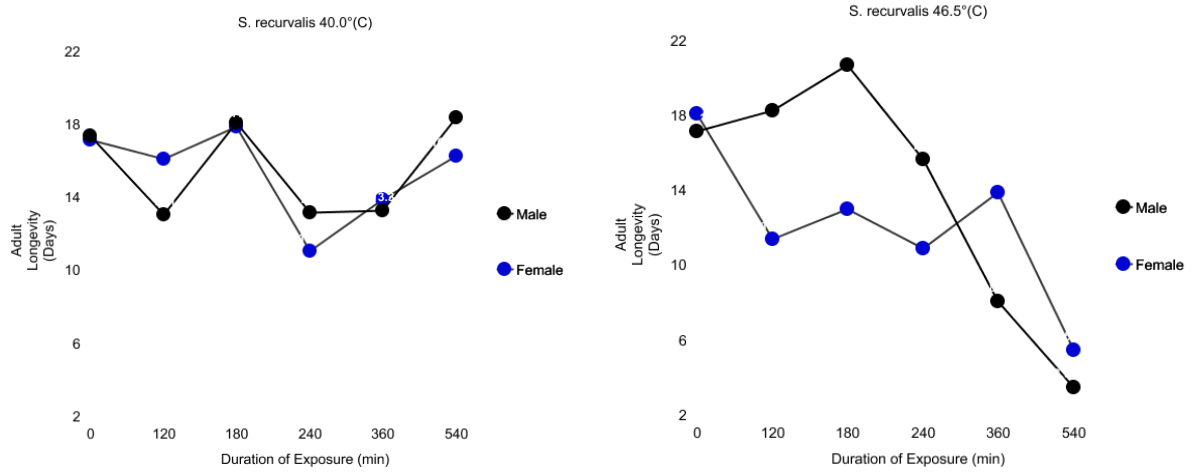


Fig. 3 determines the adult longevity for the *S. recurvalis* specimens heat shocked at 40.0° and 46.5°. The linear relationship between duration of exposure and days lived are depicted in this graph. Male and female longevity is depicted in order to convey longevity variance between the sexes.

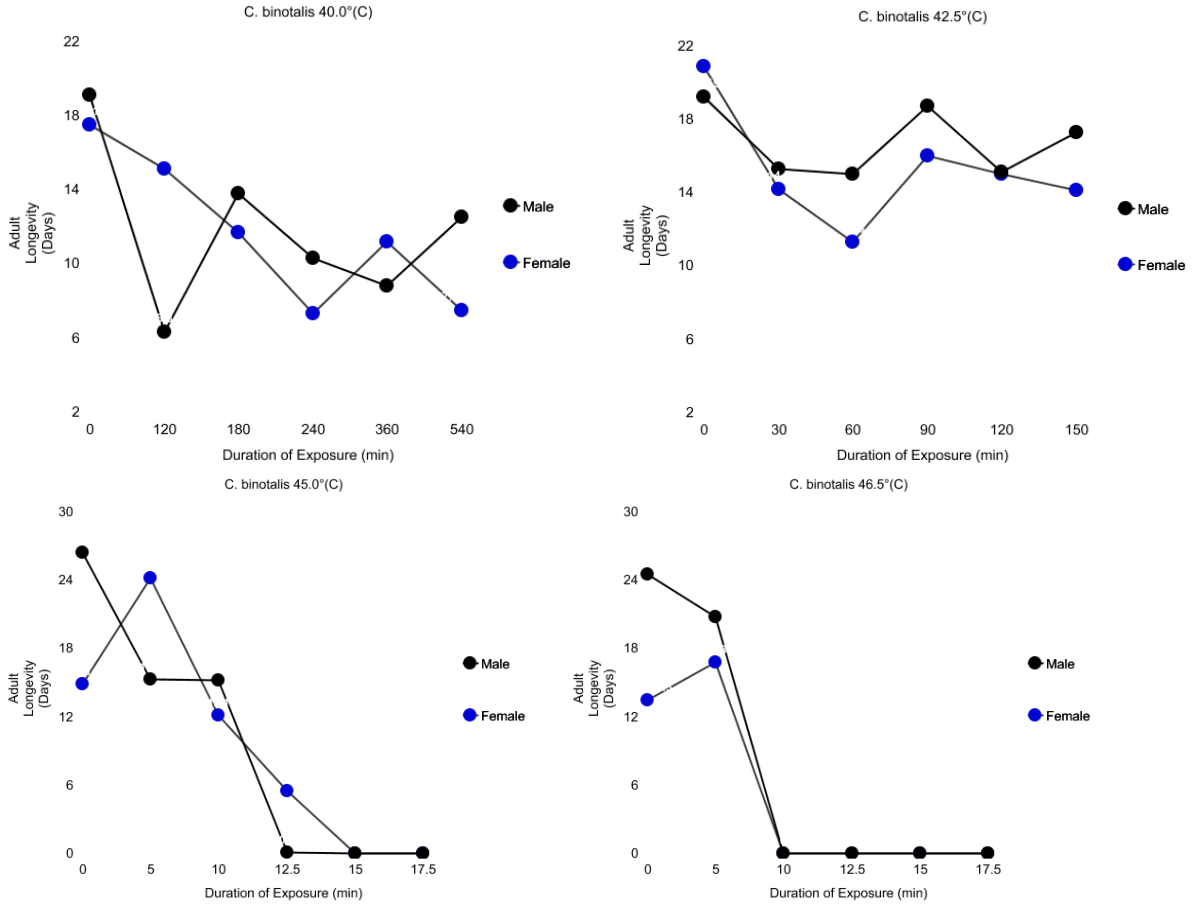


Fig. 4 Surviving adult longevity of *C. binotalis* at all four high temperatures. The graphs depict the linear relationship between exposure duration and days lived out by the surviving adult moths comparatively between the males and females. Points at 0 on the x-axis did not live past the treatment but were kept in the graph for consistency of data.

Surviving *S. recurvalis* and *C. binotalis* adults lived between 1 to 30 days post heat stress. For both species an increase in duration resulted in shorter life spans for both males and females. At 40.0°C both male and female *S. recurvalis* adults produced similar sporadic data points. The graph depicts a crest, a trough, a crest, a trough, and a final crest higher than the first at 40°C 0, 120, 180, 240, 360, and 540 minutes respectively. At. 46.5° *S. recurvalis* produced an overall substantial decline in longevity from 0 minutes to 12.5 where the longevity steadily decreased from 17.2 and 18.1 to 3.5 and 5.5 days (male and female respectively.) At each temperature, *C. binotalis* maintained a decline in adult longevity as the duration increased. There is no significant difference between male and female data.

Reproduction: Oviposition & Eggs

Treatment		**Preoviposition period (day)**	**Oviposition period (day)**	**Total no. Of eggs**	**Total no. Of larvae**	**Egg hatch (%)**
Temp. (℃)	**Time (min)**					
40	**0**	**4.5±0.3**	**7.9±2.8**	**564±240**	**181±158**	**26.4±23.0**

	120	**3.1±0.6**	**5.7±2.7**	**975±510**	**496±590**	**39.9±31.7**
	180	**5.2±1.1**	**8.7±0.4**	**639±406**	**244±422**	**22.3±38.4**
	240	**4.4±0.9**	**7.0±1.6**	**1707±529**	**1051±365**	**61.3±5.6**
	360	**4.5±0.6**	**8.2±1.4**	**1569±158**	**721±226**	**47.0±18.9**
	540	**4.5±1.1**	**10.6±1.3**	**2043±214**	**1169±187**	**57.5±10.1**
46.5	**0**	**4.9±0.2**	**4.7±1.2**	**282±171**	**54±94**	**12.3±21.4**
	2.5	**3.4±0.3**	**7.9±2.9**	**1446±599**	**803±901**	**54.2±7.5**
	5	**4.2±1.0**	**8.1±4.1**	**1807±807**	**945±607**	**49.7±11.5**
	7.5	**3.6±0.8**	**5.9±2.1**	**846±80**	**418±147**	**49.2±14.8**
	10	**9.3±3.4**	**4.8±3.5**	**424±387**	**148±256**	**18.5±32**
	12.5	**8.5±0.7**	**1.2±1.1**	**200±220**	**51±89**	**17.7±25.0**

Table 3 Total *Spoladea recurvalis* preoviposition period, oviposition period, egg count, larvae, and egg percentage data for 40°C and 46.5°C.

At 40°C, *S. recurvalis* had a steady preoviposition period with minimal fluctuations throughout the six durations. At 46.5°C however, preoviposition increased dramatically post 10 minutes. At 0 minutes the preoviposition period was 4.9 days and generally stayed in this range prior to the 10 minute heat treatment, At 10 minutes the preoviposition period increased to 9.8 minutes and continued this trend to 12.5 minutes where a 8.5 day preoviposition period occurred. At 40°C the oviposition period increased a grossing 2.7 days in between 0 minutes and 540 minutes. Contradictorily, at 46.5°C the grossing oviposition period decreased by 3.5 days (4.7 days at 0 minutes and 1.2 days at 12.5 minutes). The oviposition period peaked at 5 minutes with an 8.1-day period. Total number of eggs followed suit to the oviposition data increasing almost fourfold in eggs laid when comparing the untreated adults offspring at 0 minutes and the treated adults offspring at 540 minutes at 40°C. At 46.5°C the amount of eggs laid peaked at 1146 and 1807 for 2.5 and 5 minutes, respectively. Post 5 minutes, the egg count began to decline to 824, then 424, and finally 200 for 7.5, 10, and 12.5 respectively. Hatching percentage data and egg hatch percentage increased correspondingly. Percentages range from 12% (46.5°C control) to 61% (40°C for 240 minutes.)

Treatment		**Preoviposition period (day)**	**Oviposition period (day)**	**Total no. Of eggs**	**Total no. Of larvae**	**Egg hatch (%)**
Temp. (℃)	**Time (min)**					
40	0	**6.6±2.5**	**5.1±2.9**	**581±288**	**443±227**	**76±3.6**
	120	**7.9±1.9**	**4.5±3.9**	**432±382**	**225±228**	**34±30.6**
	180	**6.0±1.8**	**4.0±1.0**	**724±176**	**511±211**	**68.3±16.4**
	240	**6.6±3.4**	**2.7±0.9**	**319±208**	**255±172**	**77.2±13.9**
	360	**9.9±7.3**	**1.7±2.2**	**134±78**	**14±24**	**18.7±32.3**
	540	**7.0±1.0**	**2.4±1.2**	**438±192**	**251±131**	**55.6±15.9**
42.5	0	**8.5±3.4**	**2.9±1.4**	**398±140**	**351±125**	**88±0.6**
	30	**7.7±4.5**	**2.1±0.5**	**394±106**	**322±102**	**82±10.9**
	60	**6.2±1.4**	**5.5±3.0**	**870±625**	**640±434**	**77±14.9**
	90	**5.8±1.3**	**4.5±2.0**	**711±517**	**397±415**	**44±38.2**
	120	**9.2±3.3**	**1.4±0.4**	**338±255**	**277±256**	**58±50.3**
	150	**11.3±1.1**	**0.7±0.6**	**45±39**	**0±0**	**0±0**

45	0	**4.3±0.4**	**5.2±1.1**	**741±291**	**645±285**	**86±3.9**
	5	**7.3±1.3**	**0.7±0.6**	**230±196**	**176±122**	**85±15.4**
	10	**9.3±2.9**	**3.1±3.1**	**278±247**	**108±111**	**37±36.6**
	12.5	**-**	**0±0**	**0±0**	**0±0**	**0±0**
	15	**-**	**0±0**	**0±0**	**0±0**	**0±0**
	17.5	**-**	**0±0**	**0±0**	**0±0**	**0±0**
46.5	0	**7.6±2.8**	**2.0±1.9**	**276±165**	**210±181**	**68±21.0**
	2.5	**9.2±1.0**	**4.3±0.5**	**401±321**	**279±296**	**52±35.8**
	5	**-**	**0±0**	**0±0**	**0±0**	**0±0**
	7.5	**-**	**0±0**	**0±0**	**0±0**	**0±0**
	10	**-**	**0±0**	**0±0**	**0±0**	**0±0**
	12.5	**-**	**0±0**	**0±0**	**0±0**	**0±0**

Table 4 Total *Crocidolomia binotalis* preoviposition period, oviposition period, egg count, larvae, and egg percentage data for 40°C, 42.5°C, 45°C, and 46.5°C.

C. binotalis had fluctuations at 40°C with a preoviposition period generally around 7 days, with one peak at 9.9 days when treated for 360 minutes. At each temperature and shortest duration (40°C; 120 minutes, 42.5°C; 30 minutes, 45°C; 5 minutes, and 46.5°C; 2.5 minutes) the preoviposition was close to 7.5 days. At 42.5°C *C. binotalis* specimens followed a decline in the preoviposition period until 120 minutes where the period spiked from 5.8 (90 minutes) to 9.2 days at 120 minutes and 11.3 at 150 minutes. At 45°C, the preoviposition period increased from 7.3 (5 minutes) to 9.3 days (10 minutes.) All other durations (12.5, 15, and 17.5 minutes) for 45°C experienced a 100% mortality rate at time of heat stress, indicating a heat stress threshold between 10 and 12.5 minutes at 45°C. At 46.5°C, *C. binotalis* could only withstand 2.5 minutes. At this temperature and duration, the preoviposition period was 9.2 days. As the temperatures increased *C. binotalis* preoviposition period lengthened. At 40°C, the oviposition period followed a steady decline from 4.5 days (120 minutes) to 2.4 days (540 minutes) showing a accumulative period reduction of 2.1 days. At 42.5°C, *C. binotalis* oviposition period peaked at 5.5 and 4.5 days at 60 and 90 minutes respectively. At 120 and 150 minutes the period dropped to 1.4 and 0.7, respectively. At 45°C, the oviposition period increased by two days from 5 minutes (7.3 days) to 10 minutes (9.3 days.) At 46.5°C *C. binotalis* adults responded much like their 45°C 10 minutes counterparts giving a 9.2 day oviposition period. At 40°C the number of eggs laid fluctuated between 134 at 360 minutes and 724 at 180 minutes. At 42.5°C eggs laid data fluctuated quite dramatically ranging between 45 (150 minutes) and 870 eggs (60 minutes.) The *C. binotalis* adults treated at 42.5°C for 150 minutes produced 45 egg with a 0% hatching rate. At 45°C, eggs laid stayed under 300, but at 5 minutes the egg hatching percent jumped to 85%, while at 10 minutes the rate dropped to 37%. At 46.5 °C, adults treated for 2.5 minutes produced 279 eggs with a 52% hatching rate. Eggs hatched percentages increased as number of eggs increased for all temperatures.

Reproduction: Larvae, Pupa and Adult

Treatment		Larval stage (days)	Larval mortality (%)	Pupil wt./ea. (g)	Pupal stage (days)	Pupal mortality (%)	Sex ratio (♂/♀)
Temp. (℃)	Time (min)						
40	**0**	**10.4±0.5**	**53.3±14.6**	**0.0266±0.0008**	**9.2±0.3**	**71.0±6.9**	**0.64±0.3**
	120	**10.1±1.2**	**76.7±19.6**	**0.0266±0.0003**	**8.1±1.0**	**75.2±2.5**	**0.23±0.3**
	180	**11.2±0.3**	**35.0±35.4**	**0.0260±0.0025**	**8.3±0.5**	**69.4±27.5**	**0.25±0.4**
	240	**13.1±0.6**	**57.5±5.7**	**0.0263±0.0052**	**8.9±0.8**	**78.0±12.6**	**0.64±0.4**
	360	**13.1±0.7**	**72.9±6.7**	**0.0258±0.0038**	**9.0±0.9**	**79.6±10.1**	**1.17±1.2**
	540	**12.0±0.2**	**54.3±6.8**	**0.0266±0.0035**	**9.8±0.7**	**86.0±5.1**	**1.42±1.0**
46.5	**0**	**10.4±0.5**	**53.3±14.6**	**0.0266±0.0008**	**9.2±0.3**	**71.0±6.9**	**0.64±0.3**
	2.5	**13.5±1.9**	**81.0±16.0**	**0.0242±0.0025**	**9.7±0.3**	**66.1±16.7**	**0.38±0.5**
	5	**12.8±1.1**	**74.2±3.4**	**0.0251±0.0028**	**7.7±0.6**	**55.4±16.8**	**0.24±0.2**
	7.5	**15.7±1.9**	**88.1±7.6**	**0.0244±0.0070**	**6.8±0.4**	**73.3±9.4**	**0.50±0.71**
	10	**14.6±0.8**	**78.3±16.5**	**0.0172±0.0006**	**10.0**	**70.0**	**0.5**
	12.5	**-**	**-**	**-**	**-**	**-**	**-**

Table 5 First generation post heat stress *Spoladea recurvalis* larval stage, larval mortality, Pupal stage, Pupal mortality, and sex ratio for 40°C and 46.5°C.

First generation post heat stress *S. recurvalis* larvae showed larval stages fluctuating between 10 and thirteen days, while the controls who were left at 27± 1° C, and 70±10% RH, 14:10 h (Light: Dark) had larval stages of about 10 days. At 240 minutes and 360 minutes the larval stage peaked to 13.1 days. All durations had higher mortality rates than the controls, with exception of 180 minutes where the stage was 11.2 days. At 46.5°C larval stages extended past the controls and ranged between 12.8 at 5 minutes to 15.7 (peak) at 7.5 minutes in no progressive or regressive order. At 40°C Pupal weight stayed generally consistent across all durations. Pupal stage followed suit producing data that only frayed from the control by about one day maximum. The control pupa had a Pupal stage of 9.2 days. Pupal mortality almost exclusively increased as the durations became long, with the exception of one slight regression where mortality dropped from 75.2% at 120 to 69.4% at 180 minutes. At 46.5°C Pupal weight varied slightly until 10 minutes where it dropped from 2.44×10^{-2} grams to 1.72×10^{-2} grams. Pupal stage generally digressed as the durations progressed with the exception of 10 minutes where is spiked to 10 days, an overall high for that temperature. Pupal mortality peaked at 7.5 minutes with 73%.

Treatment		Larval stage (days)	Larval mortality (%)	Pupal wt./ea. (g)	Pupal stage (days)	Pupal mortality (%)	Sex ratio (♂/♀)
Temp. (℃)	Time (min)						
40	0	**9.6±0.3**	**24.7±8.0**	**0.03373±0.0028**	**10.3±0.5**	**17.3±18.6**	**1.2±0.5**
	120	**10.6±0.3**	**44.4±19.5**	**0.0387±0.0014**	**10.5±0.5**	**21.1±10.5**	**1.5±1.0**
	180	**10.2±0.1**	**16.5±14.5**	**0.0334±0.0023**	**9.6±0.2**	**23.3±0.7**	**1.3±0.2**

	240	**10.2±0.7**	**30.0±12.0**	**0.0371±0.0020**	**10.6±0.9**	**41.6±33.4**	**1.2±0.3**
	360	**7.6**	**6.7**	**0.0440**	**2.0**	**7.1**	**1.6**
	540	**10.0±0.6**	**26.7±6.7**	**0.0378±0.0031**	**9.9±0.4**	**8.8±10.5**	**0.8±0.1**
42.5	0	**9.2±0.1**	**15.7±14.0**	**0.0350±0.0038**	**9.5±0.0**	**8.0±5.9**	**0.69±0.1**
	30	**9.8±1.3**	**24.4±10.2**	**0.0328±0.0055**	**10.1±0.4**	**15.2±14.7**	**0.83±0.7**
	60	**10.8±0.6**	**24.9±2.2**	**0.0335±0.0006**	**9.8±0.1**	**16.0±12.7**	**0.9±0.1**
	90	**10.5±0.7**	**38.9±14.2**	**0.0367±0.0015**	**9.9±0.5**	**14.7±9.5**	**0.83±0.2**
	120	**9.4±0.5**	**11.7±7.1**	**0.0338±0.0029**	**9.8±0.1**	**9.8±8.8**	**1.28±0.3**
	150	-	-	-	-	-	-
45	0	**8.7±0.2**	**16.9±3.9**	**0.0324±0.0026**	**9.7±0.2**	**11.0±2.6**	**1.0±0.2**
	5	**9.2±0.6**	**10.6±7.5**	**0.0349±0.0031**	**10.0±0.3**	**16.8±10.7**	**0.6±0.1**
	10	**9.1±0.4**	**36.7±32.8**	**0.0334±0.0039**	**9.6±0.9**	**9.7±2.6**	**0.7±0.1**
	12.5	-	-	-	-	-	-
	15	-	-	-	-	-	-
	17.5	-	-	-	-	-	-
46.5	0	**8.2±1.0**	**17.5±2.9**	**0.0334±0.0054**	**9.7±0.2**	**16.6±8.4**	**0.9±0.2**
	5	**9.0±1.0**	**5.6±6.9**	**0.0328±0.0081**	**10.0±0.3**	**18.9±5.4**	**0.8±0.2**
	10	-	-	-	-	-	-
	12.5	-	-	-	-	-	-
	15	-	-	-	-	-	-
	17.5	-	-	-	-	-	-

Table 6 First generation *Crocidolomia binotalis* post heat stress larval stage, larval mortality, Pupal stage, Pupal mortality, and adult sex ratio for 40°, 42.5°, 45°, and 46.5°. Dashes indicate moth desiccation at time of heat stress and are included for consistency of data.

At 40°C, first generation post heat stress *C. binotalis* larvae showed an increase in larval stage as the durations increased. Compared to the control, the larval staged increased by 1 day, with the exception of 360 minutes where the stage decreased to 7.6 days. When comparing all of the times and temperatures, there is a gradual decrease in larval stage by 1.5 days. Larval mortality data is sporadic and did not produce any definitive trends. At 40°C, *C. binotalis* pupa were generally heavier than their control counterparts by about 4.5×10^{-3} grams. At 42.5°C, pupa weight was less by about 2.0×10^{-3} grams with the exception of an increase at 90 minutes. At 45°C Pupal weight stayed generally close to the control (3.2×10^{-3} grams.) All adults heat shocked post 10 minutes did not survive the heat stress. At 46.5°C for 5 minutes, the Pupal weight was the same as it had been at 45°C 5 minutes. These were the shortest durations for their respective temperatures. Pupal stage generally did not stray far from the control. The control produced Pupal stage data of about 9-10 days and this trend almost exclusively continued. Pupal mortality data portrayed a 15-20% Pupal mortality at the lowest duration at each temperature, but by the longest surviving duration this number decreased to about 9-10%

Pheromone Binding Protein

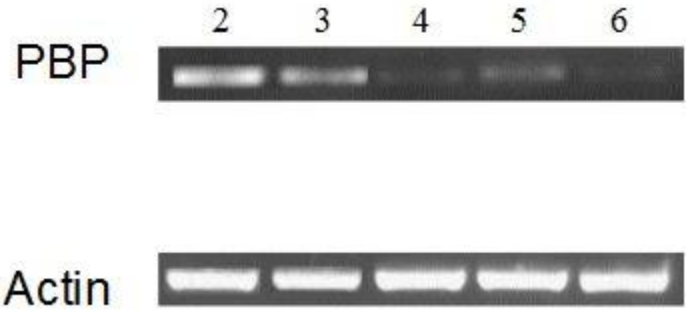


Image 1 PCR results for pheromone binding protein (PBP) prevalence in head tissue of adult male moth at days 2 through 6 of the adult male moth's life cycle. Actin is used as the control.

The PCR results indicate the majority of PBP is produced on days 2 and 3 of the male *S. recurvalis* moth's adult life cycle. Days 4 and 6 show the least while day 5 shows a small bump in PBP production.

Discussion

The survival and reproductive performance of ectothermic organisms is vitally dependent on temperature. Typically, *Spoladea recurvalis* is a tropical species with a widespread temperature tolerance and it is able to survive, develop and reproduce quite efficiently. This species is found all over Africa, Asia, Australia, the UK, much of the Southern US, down through Central America and throughout South America. *Crocidolomia binotalis* is subtropical species with a much more specialized temperature tolerance. It is found in Australia, Indonesia, Taiwan, Thailand, South Africa, Malagasy Republic, Mauritius, and the Philippines. We hypothesized S. recurvalis would respond to heat stress more positively than *C. binotalis*. Our results showed that both species completed the heat stress experiments with different levels of success as the temperatures and times varied, but C. *binotalis* the subtropical species, was able to adapt to rising temperatures better than *S. recurvalis*, the tropical species.

Insects are known to live in a wide range of thermal climates, but there is very little variability in the maximum temperature (40–50°C), which they can survive (Neven, L. 2000.) When temperatures exceed an insect's optimum temperature range, there are two mutually exclusive results: survival or death (Denlinger and Yocum 1998) In a previous article (Mironidis, G., & Savopoulou-Soultani, M. 2010), *Helicoverpa armigera*, another moth species, was subjected to the same heat stress temperatures and durations as our study. Their results showed a significant decrease in survival and reproductive capability in *H. armigera* male and females as the temperatures rose and the durations increased. This species could not withstand 40, 42.5, 45, or 46.5 at 540, 150, 17.5, or 12.5 minutes, respectively. *S. recurvalis* was able to survive all

temperatures and times while *C. binotalis* could not survive 45 past 12.5 minutes or at 46.5 past 2.5 minutes. This shows the distinct variation in these two species ability to survive at rising temperatures.

Post heat shock S. *recurvalis* and *C. binotalis* also showed distinct differences in fecundity as a result of the heat stress. Heat shocked *S. recurvalis* adults at 40°C laid roughly twice as many eggs at this temperature as *C. binotalis* which egg count remained similar to its respective control and while both species controls were similar in untreated control egg count. *C. binotalis* egg hatch percentage generally maintained an upwards of 50% minimum with many durations reaching 60% or more, while S. recurvalis struggled to reach 50% at the midpoint of durations at each temperature. As the temperatures increased S. recurvalis oviposition increased more dramatically than *C. binotalis*, but *C. binotalis* has significantly higher egg hatch percentages. As the experimental durations and temperatures increased, F1 generation *S. recurvalis* egg and larval stages increased in length, while *C. binotalis* stage lengths stayed close to the untreated control. In another study two whitefly species, *Trialeurodes vaporariorum* (Westwood) and *Bemisia tabaci* (Gennadius); post heat stress reproductive successes were compared. The Whiteflies were exposed to 37, 39, 41, 43 and 45°C for 1 hour and the results were recorded. It was found that *B. tabaci, (*the tropical species) was able to tolerate higher temperatures than *T. vaporariorum (*the temperate species) in relation to fecundity. Sex ratio data did not show a definitive sloping trend but peaked for *S. recurvalis* at 40° 360 and 540 minutes and at 46.5°C at 7.5 minutes favoring males. *C. binotalis* sex ratio generally stayed close to untreated control rates.

Due to the variability of environmental conditions (namely humidity and temperature), insect's survival depends on their ability to transition between these regimens. Both of these species re found in Taiwan where the temperatures fluctuate during spring and winter. It is unclear when *S. recurvalis* populations' peak, but *C. binotalis* populations peak in the winter. This may be why *C. binotalis* was better able to adapt to rising temperatures in this study. While S. recurvalis was able to produce more eggs, more *C. binotalis* eggs made it to adult life with success. Climate change is becoming a growing factor for insect population density and location. In response to varying natural temperatures insects must build tolerance, relocate, or cease to exist. By understanding how different species will respond to higher temperatures we can predict population bursts and locations in order to effectively control agricultural pest populations.

Mating is initiated by an interaction between the female moths pheromone biosynthesis activating neuropeptide (PBAN) and the male moth's odorant binding proteins (OBP) (Jurenka, 2011; Vogt, 1991.) Pheromone Binding Proteins belong to the OBP family and allow the male moth to recognize and sexually respond to the species-specific female moth's pheromones, initiating mating. We found that the male *S. recurvalis* moth expresses the most PBP on days two and three of his adult life span. On day four there was a dramatic decrease in PBP production followed by a slight increase at day five and a final regression at day six. We can conclude that the male moth is most reproductively active on days two and three post eclosion, and given the average preoviposition and oviposition period of the female moth, we can obtain a general idea of when to implement IPM strategies in accordance to their life cycle stage to combat these agricultural pests.

Impact on Food Security

One of the largest issues in agriculture is pest control. This issue is not only controversial; it is growing. The diversity of crop pests continues to grow and new strains are being discovered. Left uncontrolled, these pests could swiftly destroy entire fields stifling farmer economic success and causing food shortage. Our world is also experiencing climate change which alters the populations of these insect pests, in some cases making them even more prevalent. A slight rise in temperature could provide optimal conditions for a currently secondary pest. By understanding how these insect pests will respond to climate change we can be more prepared for what may be to come. Increasing our understanding opens doors to new pest management strategies, including strategies that favor the environment. When we take care of our land we take care of our food as well.

The PBP project allows us to pinpoint on which day(s) of the male S. recurvalis moth's adult life cycle he is the most receptive to the female's pheromones. On these days the moths are the most reproductively active and with this information agriculturalists can implement an IPM strategy at vital moments in order to effectively reduce their population growth. Some of these vital moments may include the preoviposition period of the female moth. BY knowing this we could prepare the crops with an insecticide that kills eggs. Knowing when the Pupal stage is going to be we could release the agricultural pest's corresponding parasitoid. This information allows us to create a plan of attack that most effectively controls a specific agricultural pest in a timely fashion thus securing a more successful, abundant crop.

Personal Growth

"It is always the simple things that change our lives. And these things never happen when you are looking for them to happen. Life will reveal answers at the pace life wishes to do so. You feel like running, but life is on a stroll. This is how God does things."

-Donald Miller

A Better Perspective

I was initially very skeptical of Ambassador Quinn's belief that we would all come back a different person. I didn't think two months could be enough time to truly change. It was two months of late nights, weird food, new people, and a new kind of freedom I was not accustomed to. Although those things may have been brand new to me, they are not what changed who I am. What changed me was seeing that the sky is the same as it was back home. All over the world we all wake up to the same burning sun and we all say goodnight to the same glowing moon. For me, sitting at home watching the news was almost like peering into a different world. The problems, the advances, the wars, the heart wrenching stories from places I had never been seemed to be so unearthly. From a universal standpoint, these places are right in my backyard. Going to Taiwan helped me to see that we all live on the same planet. That may sound silly but what I mean is we aren't as far off from each other as it seems.

AVRDC, the center at which I spent the duration of my internship, is in Tainan on the southwestern coast of Taiwan. On July 23, 2014 a plane crashed in Taipei killing 48 people and injuring 10. Although Taipei is 109 miles away from Tainan, my family still called me frantically to see if I was okay. This made me wonder if the world seems smaller in the face of danger. This is also true with the outbreak of Ebola in Africa. I know many people who are under the impression that essentially everyone on that entire continent has Ebola. A good friend of mine recently re routed her flight itinerary because one of her lay overs was in Houston, where a single case of Ebola was discovered. If tragedy truly does make the world seem less wide, how is it that we merrily go on everyday while thousands starve and succumb to curable diseases? It is the perception of uninhibited disaster. You can't predict a plane crash and currently Ebola has no cure. This makes these things more fear evoking and also makes them seem closer. What if we could see hunger this way?

I know famine and malnutrition aren't uncontrollable epidemics, but they are uncontrolled. Shouldn't that be enough to set off global alarms? Just because they aren't impending dooms for everyone doesn't mean we should just hear about them and move on. Honestly, I haven't changed my lifestyle a bit. I still do the same things and live the same way. What has changed is what I want. Now I want to stop seeing the world as one-dimensional. This isn't because I visited a place and looked into the eyes of a small child plagued by hunger and disease. Taiwan is very much like home. Its full of convenient stores, a bustling inner city, a luminous night life, art, big buildings, business and everything most developed countries have. It wasn't where I was that made me feel a change; it was being 8,000 miles away from home that changed me. I didn't think being that far away from familiarity would be so familiar. I know back home we live day to day unmoved by what goes on around us globally. I'm sure the urbanites of Taiwan live the same way. If at the other end of the world people are living pretty much the same as I am, well then who's going to make the difference?

I used to feel like the world would just work itself out. Like the people who are already working to make a change would eventually prevail, just like how technology is continuously advancing. Being that the advancement of technology is a much more lucrative business and therefore more popular, I realized if anything pertaining to the advancement of a developing nation were to occur, it needs to happen because of a selfless effort. Taiwan has undoubtedly aided in the growth of my global perspective and I am very grateful. I now see that the world truly needs more people who are just truly interested in the betterment of others. I am an individual of the next generation of world leaders. My generation needs to make the change. I don't want to sit in wait for a better day anymore.

References

Chapman, R. F., and Stephen J. Simpson. *The Insects: Structure and Function*. Fifth ed. US: Cambridge UP, 2013. Print.

Feder, Martin E., and Gretchen E. Hofmann. "HEAT-SHOCK PROTEINS, MOLECULAR CHAPERONES, AND THE STRESS RESPONSE: Evolutionary And Ecological Physiology." *Annual Review Of Physiology* 61.1 (1999): 243-82. Print.

Hughes, Lesley. "Biological Consequences of Global Warming: Is the Signal Already Apparent?" *Trends in Ecology & Evolution* 15.2 (2000): 56-61. *Trends in Ecology & Evolution*. 2000. Web. 3 Nov. 2013. <http://dx.doi.org/10.1016/S0169-5347(99)01764-4>.

Jurenka, Russell, and Ada Rafaeli. "Regulatory Role of PBAN in Sex Pheromone Biosynthesis of Heliothine Moths." *Frontiers in Endocrinology* 2 (2011): 1-8. Print.

Mironidis, George K., and Matilda Savopoulou-Soultani. "Effects of Heat Shock on Survival and Reproduction of Helicoverpa Armigera (Lepidoptera: Noctuidae) Adults." *Journal of Thermal Biology* 35.2 (2010): 59-69. Print.

Neven, Lisa G. "Physiological Responses of Insects to Heat." *Postharvest Biology and Technology* (2000): 103-11. Print.

Sastrosiswojo, Sudarwohadi, and Wiwin Setiawati. "Biology and Control of Crocidolomia Binotalis in Indonesia." *The Sixth International Workshop on Management of the Diamondback Moth and Other Crucifer Insect Pests*. Tainan, Taiwan: AVRDC World Vegetable Center, 2011. 81-87. Print.

Shirai, Yoichi. "Flight Activity, Reproduction, and Adult Nutrition of the Beet Webworm, Spoladea Recurvalis (Lepidoptera: Pyralidae)." *Applied Entomology and Zoology* 41.3 (2006): 405-14. Print.

Sorensen, Jesper Givskov, Torsten Nygaard Kristensen, and Volker Loeschcke. "The Evolutionary And Ecological Role Of Heat Shock Proteins." *Ecology Letters* 6.11 (2003): 1025-037. Print.

"Spoladea Recurvalis." *Spoladea Recurvalis*. Web. 16 Sept. 2014. <http://www.cabi.org/isc/datasheet/28245>.

Vogt, Richard G., Robert Rybczynski, and Michael R. Lerner. "Molecular Cloning and Sequencing of General Odorant-binding Proteins GOBPI and GOBP2 from the Tobacco Hawk Moth Manduca Sexta: Comparisons with Other Insect OBPs and Their Signal Peptides." *The Journal of Neuroscience* 11.10 (1991): 2972-984. *The Journal Og Neuroscience*. 1991. Web. 12 Sept. 2014. <http://www.jneurosci.org/content/11/10/2972.full.pdf>.

Vogt, Richard G. "Molecular Basis of Pheromone Detection in Insects." *In Comprehensive*

Insect Physiology, Biochemistry, Pharmacology and Molecular Biology 3 (2005): 753-804. Print.

Zhang, Tian-Tao, Xiang-Dong Mei, Ji-Nian Feng, Bente G. Berg, Yong-Jun Zhang, and

Yu-Yuan Guo. "Characterization of Three Pheromone-binding Proteins (PBPs) of Helicoverpa Armigera (Hübner) and Their Binding Properties." *Journal of Insect Physiology* 58.7 (2012): 941-48. Print.

MLA formatting by BibMe.org.

Pictures