To Work for the Resource-Poor Farmer:

A Summer of Research and Exploration at The World Vegetable Center

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by:

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Regarding:
'The World Vegetable Center'
The Asian Vegetable Research and Development Center
Shanhua, Tainan, Taiwan

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Catherine's Grandfather and I at the Flower Market, Taipei

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Acknowledgments

I am forever grateful to countless people whose work, passion and dedication has made the amazing opportunity of my internship at the World Vegetable Center possible. Foremost, I am indebted to the World Food Prize Foundation, Dr. Borlaug, Mr. Ruan and Ambassador Quinn for realizing the dream of giving high school students the chance to experience and research in far off cultures to truly understand the lives of world's impoverished people and those who are trying to help them. The World Food Prize Symposium and the subsequent events have become a defining part of my life over the past year. They would not have occurred if not for the excitement and pioneering of Mrs. Micki Zartman and the guidance of Mrs. Laura Brennan. Lisa Fleming was a wonderful mom-away-from-home, to whom I could describe my travels and experiences to and seek advice. Dr. Lumpkin, Dr. de la Pena, and Ms. Shu-mei Huang gave me countless freedoms and opportunities. They allowed me to learn more in just two months than I ever thought possible. Finally, to my parents and friends for there constant support, even with the 12-hour time difference, and the much appreciated care packages from home.

Scientific Abstract

Three varieties of *Brassica rapa* cvg. *chinensis* (Pak Choi) were evaluated using 76 SSR molecular markers in order to determine the genetic diversity available in the Brassica population held by the AVRDC- World Vegetable Center Genetic Resources and Seed Unit. The data collected on these three varieties were added to data previously collected on 96 other varieties in the Brassica family, including two other closely related species (Choysum and Kailaan). A thorough Genetic Map was constructed to show the evolution of the Brassica varieties and the degrees of relatedness (Nei-Li similarities) between varieties, on the genomic level.

As plants are becoming increasingly hybridized, it is essential to determine the variability in a population in order to understand how quickly diversity is being lost (comparing wild and heirloom varieties to commercial varieties), as well as to gain a more thorough understanding of the varieties at ones' disposal in the seed bank. Due to its very large collection, it can be difficult to assess all the varieties in a meaningful way. This research (the assessment of genetic diversity) is critical to maintaining and creating an efficient plant breeding program. When looking for new ways to hybridize crops for certain traits or resistances to diseases, already having an understanding of how different varieties are related can allow for more efficient and effect breeding programs.

This experiment is designed to extract DNA from the samples; to run Simple Sequence Repeats Polymerase Chain Reaction (SSR PCR) with the samples using primers to isolate and amplify the specified regions; and to run the PCR product through Acrylamide gels, using 54 different primer pairs to evaluate each sample. The bands evident on the gels are then compared to previously run samples and are evaluated at 76 separate molecular markers that exhibit polymorphism among the sample varieties. In the conventional sense, there is not a hypothesis, rather the actual genotypic relatedness of varieties is being compared and assessed to compile a genetic map of Brassica varieties.

The outcome is a more complete genetic map, now comparing the relatedness of Extra Dwarf Milky White, Joi Choi, and Dwarf DR Green to other *Brassica rapa* cvg. *chinensis* varieties, as well as other species in the Brassica family.

Due to this project, there is now a more complete understanding of three new commercially grown Brassica varieties. The protocols were written in a concise and step-by-step

manner that will be used in the lab in the future, which will make it easier to run these assessments more quickly and efficiently.

My Background in the World Food Prize

My sophomore year of high school I was searching for science fairs to enter when I came across a flyer for the World Food Prize. I interpreted the application as actually for the World Food Prize itself, for those who have made a great and far reaching impact on the world in the areas of food security and food research. While my science fair project, which looked at the translocation of mRNA through grafting *Glycine max.*, was pretty good, it hadn't quite saved millions of people yet. But I put the brochure away, to hopefully pull out again in a couple more years when I felt I would be a little more worthy.

Being an Ohioan, the World Food Prize Youth Institute had previously been unknown to me, but Mrs. Micki Zartman's continuous efforts changed all of that. By a series of coincidences, Mrs. Zartman came in contact with my Science Research Advisor, Mrs. Laura Brennan, who then told me about all the WFP opportunities.

Suddenly Cornell application essays were pushed aside, the Siemens Westinghouse Science Competition application was delayed even longer and all my attention became focused on a little 4,000 word essay; I had two weeks to write it. The end product combined my passions for economics and biotechnology to address international development. The paper, entitled *The Impacts of Economic Policy on the Social Conditions in Tanzania*, allowed me to do in depth research

into a dynamic yet impoverished country and to analyze the impact of polices by the World Bank and IMF.

After discussing my paper at the Ohio State University with a panel of experts, I was selected to attend the World Food Prize Symposium. While the symposium proved to be an incredible experience in itself-to meet and mingle with the leaders in academia, business and the public sector-my focus had always been on the international internship.

The World Vegetable Center

The Asian Vegetable Research and Development Center's (AVRDC) simple and yet so vastly complex mission is to help the resource-poor farmers through improved production and consumption of vegetables in developing countries. AVRDC, more commonly known as the World Vegetable Center, was founded in 1971 and dedicated in 1973 in Shanhua, Tainan, Taiwan, as the headquarters of an international vegetable research program. Taiwan was selected, opposed to sites in countries in Africa and South Asia, because of the diverse climates available throughout Taiwan, the relative political stability and the more developed nature of the country. The Center is a non-profit organization with a US $12-15 million yearly budget and is primarily funded by donor countries (such as Taiwan and Germany) as well as the Asian Development Bank.

Over my two month stay, it gradually became clear to me how the 13+ units within AVRDC collaborat interdisciplinary to work for a common goal. Through visiting, working in, having long discussions with head scientists and touring all the AVRDC units, I was given the

unique experience of actually seeing what all the units were studying and how their projects overlapped. I was continually astounded by the diversity of projects, all linked with the common theme of helping the resource-poor farmer.

Major aspects of the research are focused on breeding for and developing disease resistant plants. After visiting Mycology, Virology, Bacteriology and Entomology I was surprised that farmers can actually get any crops to market considering the oppositions they are facing. There is no longer doubt in my mind as to why certain countries are still developing and why those countries are centered around the tropics- there are just so many forces from heat and humidity with periods of intense rain which are prime conditions for an army of dead adversary. Therefore, developing staple crops that are resistant to as many of these diseases as possible will make a huge impact on the lives of the farmers and their families. The Center also has a 55,000+ accessions Germplasm unit from which breeders find a multitude of potential crosses. Only through collaboration and cooperation within the Center as well as the international community can strides be made to improving the lives of the malnourished and food insecure.

Molecular Markers Lab

I was informed a couple weeks before my internship that I would be working on 'molecular markers in plant breeding.' Neither concept meant much to me at that point, but over the course of my first month in Taiwan I learned just how those valuable and complex concepts are linked, utilized and how we hope to apply them in the future.

At AVRDC I was under the care and instruction of my advisor Dr. Robert de la Pena, head of the Molecular Markers Lab. The vast majority of my first month was spent in the lab working with Ms. Shu-mei Huang, who turned out to be one of the best teachers I have ever had.

I was graciously given exactly the type of project I desired; one that allowed me freedom to explore a new area, work independently, problem solve issues that are sure to arise in any scientific proceeding, and a project that would actually be useful to other researchers in the fight against world hunger. My project was to evaluate three Brassica varieties using SSR molecular markers order to determine the genetic diversity available in the Brassica population held by the AVRDC- World Vegetable Center Genetic Resources and Seed Unit. One way to increase global food security is through plant breeding. My project will aid plant breeders in choosing what varieties to cross. This project was truly a learning experience; it was exceedingly challenging at times with frequent struggles and modifications, but ultimately fully satisfying in knowing that I had independently made a contribution to scientific knowledge that plant breeders could utilize to improve the lives of resource-poor farmers around the world.

As with all my future experiences at AVRDC, we dove directly into the protocols and Shu-mei explained concepts to me along the way. On my first full day in the lab we prepared my samples for the DNA Extraction. The previous day my samples of Pak Choi (Extra Dwarf Milky White, Joi Choi, and Dwarf DR Green) had been collected in the field off of seedling plants, so the DNA would be more viable for extraction. I first pulverized my freeze-dried samples (freeze-drying is a much better alternative to conventional methods of constantly adding liquid nitrogen

to the sample so that it could be ground using a mortal and pistil) and then quickly ground the leaves to a powder using a Mini Beadbeater.

In the spirit of independence and learning, I opted to do the more complicated DNA extraction technique that did not utilize an expensive kit. Therefore, my second day in the lab, I was handed two similar DNA Extraction protocols and set off to hybridize them into the one I would use. All the trainees at AVRDC were Masters or PhD students or representatives from seed companies; I was the youngest intern they have ever had and the first one for the United States. I tried very hard throughout the internship to maintain the high expectations that were associated with an intern from the World Food Prize. My second lesson for that day was in 'mM.' I had never actually seen that unit before, but not wanting to seem incompetent on only my second day, I used what conversions I could think of to figure out how much of a given chemical I needed based on the volume of the final solution, the molarities of the chemical solution and the number of mMs indicated. I can not describe the relief I felt when I was correct and when I was later told that none of the other trainees could even understand the math when it was explained to them. At the time I thought it was supposed to be basic. I felt that failure was not actually an option and always strove to accomplish everything that was requested of me.

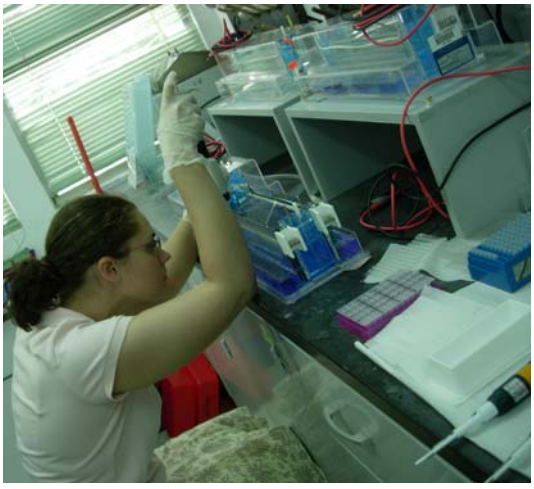
To extract the DNA from my samples (the complete protocol I prepared is in Appendix A in the extended edition of my paper), I first mixed Tris-HCL, EDTA, NaCl and Proteinase K before adding in the Sodium Metabisulfite right before the solution was added to the plant sample tubes. I then thoroughly vortexed the samples and added 20% SDS , again shaking afterwards to incorporate. The samples were incubated at 65˚C for ten minutes, Potassium Acetate was added and the samples were stored on ice before centrifuging down for 20 minutes at

4500 rpm. This step separates the DNA-containing supernatant from the plant residue material. I transferred the supernatant into a new eppendorf tube and added cold isopropanol; the DNA becomes visible at this time as a milky/clear cloud of fibrous strands suspended in the middle of the tube. The samples rested in -20℃ for two hours to allow the DNA to condense further before centrifuging them to force the DNA into pellet form in the bottom of the tube. I removed the supernatant and 'washed' the pellet with 70% ethanol three times, centrifuging and extraction the supernatant each time. The now very pure DNA pellets were dried over the weekend in the hood.

Monday morning brought the resuspension of the DNA in RNAse and 1x TE buffer. At this point I needed to quantify the concentration of DNA in my samples, using λ DNA. Because all the plant samples were different, varied amounts of DNA were extracted; therefore accurate quantification was critical to have successful PCR amplification and uniform band intensity. I made dilutions of the λ DNA from a 100 ng/μL stock solution so that the total sample of 4μL I would be loading into the gel would contain 200, 100, 50 and 25 ng of λ DNA. I also made two dilutions of my extracted DNA, a high (1/20) and a low (1/30), but had to remember to take into consideration the addition of the 6X loading dye (purpose is the increase the molecular weight of the sample so that it will sink to the bottom of the gel well and not dissolve into the TE Buffer) when figuring the actual dilution. I loaded two replications of my DNA (10μL per well) and the λ DNA into the 1.2% Agarose Gel I had prepared earlier. I ran the gel for 60 minutes at 50V and then took it with Shu-mei to the Bacteriology Lab where we kept the photo equipment. We stained the gel with Ethinium bromide- a very toxic substance that Shu-mei had me research so that I understood the health risks. The EtBr attaches itself onto the DNA molecules in 8-

nucleotide pair segments and can then be visible under the UV light. Shu-mei showed me how to focus and take the picture the first time, and we were able to use the intensities of the λ DNA to make a linear relationship then compare the intensities of my samples to determine their concentrations. Since it was the first time I had loaded a gel, my technique left quite a bit to be desired and I ended up running the quantification again (with 1.8% Agarose gel) using different dilutions since the PCR showed very uneven amplification the first time- implying my concentrations were incorrect.

To learn the PCR procedure, I first ran them on Agarose gels to check amplification, concentration and the viability of the primers. After about a week of making and running gels, checking concentrations, and running PCRs to check the primers I had prepared, Shu-mei taught me how to make and load the 6% Acrylamide Gel- everything before this had just been prep work. The gel consisted of Solution 1 (DDI H_2O, 5X TBE Buffer, Acrylamide) which was prepared in advance, and TEMED and APS (ammonium persulfate that acts as a catalyst to solidify the gel). The gel was formed between two glass plates, which I carefully washed and dried to ensure there were no particles that would disrupt the gel. I quickly poured 50 ml of the gel solution in the 3 mm gap between the plates and inserted a 96 well comb. The first gel I made myself turned out quite well, but subsequent ones showed short well walls; I increased the APS concentration but decided that the age of Solution 1 was the important factor. This

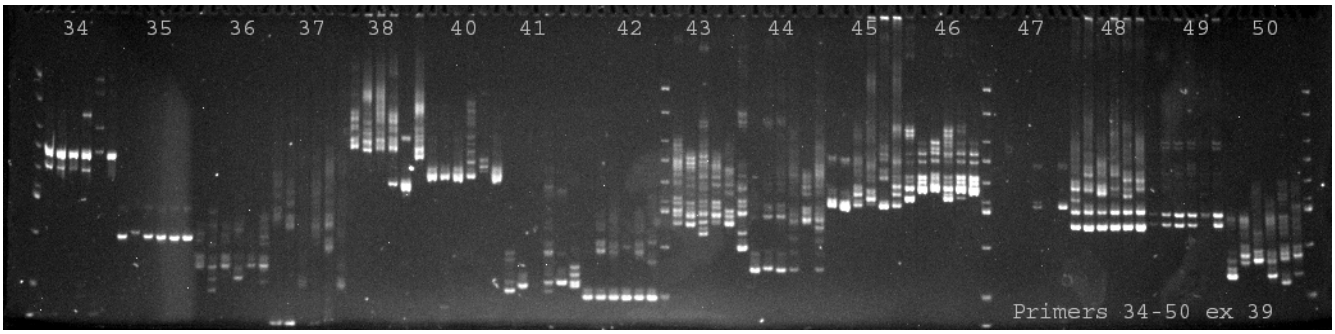


demonstrated how critically important solution age, even a day or two old, is to the success of an experiment.

The next step was to evaluate each DNA sample (my three new ones and 3 previously evaluated ones) using 54 different primers; this proved a very lengthy and focus-intensive task. I prepared enough cocktail solution (all of theses steps were done on ice to slow the degradation of the compounds and samples) containing MQ H_2O (double distilled and filtered), 10X Buffer, dNTP, and Taq for 100 samples. I divided the 96 well plate into 16 6-well rectangles (the top left well is well one); each rectangle being for a separate primer. After pipetting 73.5 μL of cocktail into well one of each set of three, I added each primer to the appropriate well one. I then transferred 12.7 μL of solution from well one to the rest of the wells in the set of six. The final step was to add the DNA to each well; I pipetted 2.3μL of DNA to each well; well one corresponded to sample 101, well two to 102, etc). It was only after the first plate that I realized I could use an auto-pipette and could centrifuge down samples between additions. Therefore, my first plate took over 2.5 hours to load and over 150 pipette tips. I also turned out to be missing DNA in three wells- as the loading dye indicated. After thinking for hours on how I could make the process more efficient, I realized the value of auto-pipette, centrifuging and mass cocktail solutions-a classic learn by doing situation.

The first three gels I ran were simply not good, they only had bands in the second wells corresponding to well two of each primer. I knew that the PCR was working correctly, but could no deduce why the other samples were not showing bands. After three days of testing every input to no avail (though it was later found that the Taq I had used for these gels was contaminated), I realized that the primers had a higher molecular weight than the rest of the cocktail, and they

would therefore sink to the bottom of the well, when I pipetted cocktail+primer from well one to the other wells, I pipetted from the bottom each time, so all the primer went into well two. Shu-mei could easily tell that I thought I had made a stupid mistake because I kept signing and glaring at my samples for the rest of the day. The next 9 plates went well and I got the loading time down to 45 minutes per plate.



The first time I saw the 8-tip pipette for loading the gels I was intimidated; the prospect of holding your hand steady, as you evenly insert the 8 tips into a 3 mm wide opening, orienting them into ever third well, and holding the tips steady at the bottom of the well and slowing releasing the samples into the gel made me long for the single pipette days. Needless to say, the first couple gels would not have come out even if there had actually been primer in each well. After running the gels for 45 minutes at 180V and watching the band of blue dye slowing move down the gel and finally out the bottom, I was ready to stain them. Since we had just gotten a new imaging system installed in our lab, I did not need to go to the Bacteriology Lab; I could stay in the lab and use SYBR Save which was also non-toxic. My gels did not show good contrast, the background was gray instead of the desirable black (it took hours of fiddling with PhotoShop to achieve good contrast), which made it more difficult to make out the faint bands. I tried to increase the amount of SYBR Save in the staining solution, but that was only of minimal help.

After I left, it was determined that the imaging system was not operating correctly, so that was why I had poor contrast on my gel photographs.

Having learned from all the obstacles that I had encountered, I was now ready to begin scoring the samples analyzed with the 54 primers. Previous PhD students had evaluated 96 accessions for their theses, and chosen random SSR (Simple Sequence Repeats) markers for 10 of the primers. There were a total of 76 markers to which I would compare my data. To score the gels, using a 1 for the presence of a band and a 0 for the absence, I compared my printouts against the printouts that indicated where the marker bands were. To make the enlarged printouts I had to manipulate my photos of the gels using Adobe Photoshop- the Chinese version

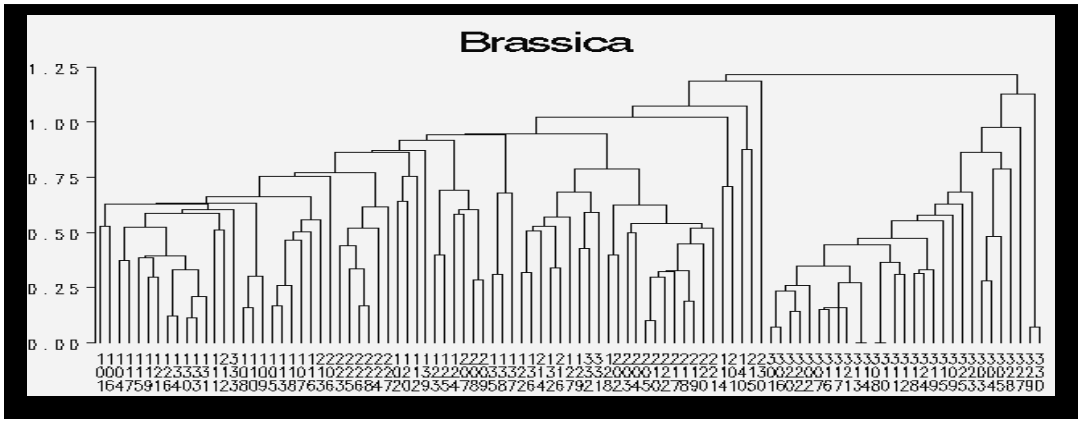
of Adobe Photoshop. Shu-mei showed me how to do about 10 steps to make the images very large, high resolution and easier to read; however when it was my turn, all the options looked rather foreign to me. I was able to find a history of what Shu-mei did, so I matched the symbols on that list to the symbols on all the pull down tabs. I became so accustomed to the Chinese symbols, it took me a long time to figure out the English version when another intern needed help with it.

The scoring took more than two days; the bands were of different intensities, some of them were very difficult to see. I would look from the enlarged printout to their master print out, to the photo I had printed out, to the same photo that I had on my computer, to the master photo image. To check my results, I could compare the markers for the three samples I ran that had also been preciously run; I was very relieved to see consistent results. The actual results, the

composite into the Genetic Map with the other Brassica accessions, were calculated in the statistics unit two weeks later.

Statistics

For the conclusion of my molecular markers projects I spent the afternoon with Dolores Ledesma (Didit), the statistician. The data I had collected consisted of 76 markers, the presence of a band denoted with a 1 and the absence denoted with a 0. Thus, my month of work had amounted to 231 1s and 0s. Because of the nature of the data, we had an SAS (Statistical Analysis System), using the Jaccard metric. First, Euclidian Distances (average normal distances) were computed between each of the entries- between my three new entries and the existing 96 entries- and the values were squared. From these values, Average Linkage Cluster analysis was run; cluster analysis is the process of clustering data into groups while not having previous knowledge of the data structure. Based on the distances, the SAS started forming clusters (indicated by the accessions connecting together). Since the SAS software is so cost inhibitive, we sent the data to IRRI, The International Rice Research Institute for analysis. This is just another example of collaboration in the global scientific research community.



This data was translated into the genetic map, showing the level at which the individual accessions become the same. The Y-axis of the map is the Euclidian distance, which indicates how related the accessions are, the smaller the number, the more related the accessions are. My data (accessions 331, 332, and 333) show that 332 is most closely related to 129, and related to 331 at a distance of 0.5905. However, 333 is not clustered with 331 and 332 until a distance of 0.9465, significantly less related.

The data does follow what was expected; the Pak Choi accessions are numbered 101-140, the Choysum are 201-230 and the Kailaan are 301-330. Since my accessions were Pak Choi, it makes sense that they would be more closely related to other Pak Choi accession rather than the Kailaan accessions. This can now be used by plant breeders for their selections of accessions based on genetic diversity and genotypic relatedness.

The Other Units

Dr. de la Pena gave me the amazing opportunity of not only conducting independent lab work in his lab, but to then visit the other 12 units over the second month of my internship. I was absolutely amazed just how much I could learn, observe and do over that next month. The first two weeks were spent in the Nutrition lab working with Koskei, a Kenyan masters student, on the effects of preparation methods on the bioavailability of iron and levels of flavonoids in *Solanum scabrum* (Nightshade). The next two and a half weeks were a whirlwind of 11 units, culminating with a seminar I gave about the World Food Prize and my internship experiences.

Germplasm Research and Seed Unit: I went out to the egg plant field and collected leaf and fruit specimens off the parent and hybrid plants to determine if hybridization had actually occurred or if the mother had just self pollinated. Biotechnology: I observed tissue culturing techniques then stomped tomatoes to remove their seeds. Pepper Breeding: I collected flowers off of pepper plants then stained and counted the number of dead/living pollen grains under a microscope. Bacteriology: I mixed 8 liters of 528 culture medium solution, poured 200 culture plates and also streaked plates with bacteria and made an inoculant for pepper plants the following day. Virology: I squished diseased leaf samples onto nylon paper to run DNA hybridization procedures. Organic Program: I visited the organic v.s. conventional fertilizer cabbage test plots. Mycology: I helped inoculate tomato seedlings with Fusarium Wilt and to replant them. Communication: I worked on designing a new website for The Global Horticulture Initiative. Socieo-Economics: I discussed the indigenous vegetable program in South Asia. Crop Management: I compared herbaceous plant grafting techniques with a scientist who had been working on grafting a tomato scion on an egg plant rootstock for the past 20 years. This was of particular interest to me since I had worked on soybean plant grafting for several years back at The Ohio State University. Entomology: I transfer cabbage leaf caterpillars to a new cabbage leaf for future studies on pest resistance. These short summaries merely tell what I did, but in each unit I spent sometimes hours talking to the head scientist about current projects, future goals, collaborations, frustrations and his or her views on global food security. It was in these meetings that I took pages and pages of notes and learned more than I could possible imagine of real world, pertinent information.

Travel and Culture

While my weekdays were spent working in labs, my weekend adventures allowed me to both explore the beautiful country of Taiwan and learn about my fellow interns. I was fortunate enough to travel just about every weekend I was in Taiwan. Given the small size of the country I was able to get a fairly comprehensive view of Taiwan with its mountains, beautiful sandy beaches, flat land agriculture, terraced rice farming, rocky beaches in the south, shrimp farming along the west coast, aboriginal caves on the east coast, the tallest building in the world in the north, and of course, my small town of Shanhua.

If you are a tourist or agricultural researcher, summer is not the ideal time to visit Taiwan. The growing seasons occur in the spring and the fall; the typhoons, rainy season, blistering heat and humidity come in June and July. But I did not let 110̊F and 90% humidity stop me from exploring the country.

Traveling around with my advisor, who had been in Taiwan since January and spoke and read no Chinese, and his family or with a van full of foreign interns lead to many memorable adventures. While navigating one Sunday around Kaohsiung, the second largest city in Taiwan, I came to the realization that the street names where spelled out phonetically in English on the road signs and maps. However, it seems that many people would phonetically translate the same word many different ways- the five maps I had spread across my lap all had different spelling for most of the street names and the name on the sign was usually different from all the maps. So when ever I saw a street sign, I would pronounce the word-no one spoke much Chinese in the

van so my guess was as good as theirs-and look at the spelling on the maps and pronounced ones that looked similar. By the end of the day I had gotten pretty good at identifying frequently occurring sounds, though I would be laughed at if I tried to pronounce those sounds at the center-I'm told I speak Chinese like a robot.

One of the greatest parts of the internship was spending time with young scientists from so many different countries and backgrounds. The third weekend I was at The World Vegetable Center, several of the trainees who had been there for over a year were going to be leaving AVRDC to return home to Cambodia and the Philippines. For their farewell party, all the interns decided to throw an international dinner. On that Saturday morning, seven of the interns and I bicycled to the morning market in Shanhua to buy ingredients for all the international dishes we would be preparing that afternoon. The open air market held all the fresh (still flipping) shrimp, fish balls, squid and a vast array of fruits, vegetables and herbs, several of which were quite foreign to me.

In the afternoon all 11 of us went to work in the Center's large kitchen. I was amazing to see people from so many different cultures, backgrounds and countries all coming together to cook, laugh and sneak quick tastes of the still cooking dishes. Koskei, the Kenyan intern, made a native chicken and vegetable dish; Shari, the Indian intern, made a curry rice and beef platter with a very spicy soup of broth; the Thais created a huge seafood salad; Hai, the Vietnamese intern, mix up the spring roll ingredients and Victor, the Filipino intern, and another Vietnamese assembled the rolls; I, the lone American was in charge of cutting up the fruit and frying the 80-plus spring rolls. The Center's chef was working over the flaming wok, creating a delicious beef dish.

By the time dinner came around, together we had created 15 dishes from America, Kenya, Philippines, Vietnamese, Taiwan, Cambodia, Korea, China, Thailand and India When the other guests from the Center arrived, the number of dishes exceeded 20 and now also include Indonesia, British and Chinese. Considering even the dishes that the South Asians considered very mild were spicy hot to me, I kept my distance from the dishes from Korea whose smell even made my eyes water. It was such a special and memorable experience to just hang out and have a party with people who I would miss so dearly after I left. Food is a great venue through which to explore and initiate cultural understanding, it sparks conversations, family stories and endering photos. One favorite is of couple Thais taking a break from their chopping to pose with peace signs while Koskei took their picture.

These short accounts of a couple events do not do justice to the numerous and vastly diverse set of experiences I had traveling through Taiwan. The food: served family style in a small restaurant with the cooker out on the front sidewalk after a long day of adventuring through Taitung; the new foods, and American favorites, that would be brought to me almost daily by researchers in the labs; the night, afternoon and morning markets with cunning bartering of pointing at the fruit I wanted and handing the seller money then waiting for my change; or my favorite cafeteria dish of white rice, steamed pak choi, and beef with snow peas. The loanrd bicycle: three holes in the basket, cracked tires, countless laps around the Center each evening or

trips into town with cars and scooters whizzing by as you pedaled in the dark on the edges of a busy road. The karaoke: a South Asian obsession, singing at 9am on the bus across the mountains to the aboriginal caves, at the karaoke club on Saturday night, at the international dinner and at a bridal shower. The Filipinos: two guys in their late twenties, trips to the pool hall, drizzling days at the spa with drives through the country, movies in Tainan and cooking calamari freshly brought from the afternoon market. All are people and events I will never forget.

Final Thoughts

I left AVRDC with a much clearer, realistic perception of what is actually happening to fight world hunger, the vast complexity of the issue, and my own ideas and thoughts on the best global course of action. There is simply no silver bullet, no panacea-as William Easterly would say-to the problem of world food security and international development. The battle will be long, hard, seemingly impossible at times, but regardless, there is no goal more noble or necessary.

While there, the dinner table discussion I learned to avoid was regarding why the U.S. government was not financially supporting AVRDC. One reason may be providing that support to Taiwan could complicate relations with China and that the U.S. chooses to support development otherwise. But from what I've seen, top down approaches to development have a history of failing publicly and miserably. I am by no means arguing that international bodies have been utterly unsuccessful in actually aid people at the very bottom of the economic ladder, convincing real life results would refute those claims. However, I've merely noticed that much foreign aid never seems reach those for whom it is actually intended. Countless scandals have arisen in the past decades, too many that the scandals do not garner the shock value that they ought to, in which government officials have simply pocketed foreign loans, leaving their countries not only still impoverished, but now in a vicious cycle of debt, debt relief, more embezzlement, and yet again more debt. Why not circumvent part of the system and invest part of

that money in institutions that have a proven track record, transparent operations, and whose results are directly felt by those forever condemned to be ignored by the current more conventional programs?

Centers like AVRDC are not giving charity to resource-poor farmers. Charity can be used up in a week and it leaves them in the same predicament as they were before. AVRDC is genuinely improving the livelihood of these people and their families by developing for them and showing them new techniques and varieties that will make them more food secure. These centers are also producing public property, everything they develop or innovate becomes the property of every person all over the world. There are no copyrights, no reliance on seed and fertilizers that must be bought from the developed world every year at drastically fluctuating prices; only a commitment to giving the deserving farmers the ability to make a better livelihood. This is the grassroots development that focuses on the people that would be left behind by many top-down approaches to development.

I am a scientist first. I find hours spent in greenhouses conducting experiments and probing the yet uncharted depths of science to be my passion. Yet, after this summer I've gotten a glimpse of what the actual problem of food security really looks like. Even if earth shattering innovations are made in the lab, if there is not a stable political and economic climate in countries, the gains will be fleeting and vastly below their potential. My other passion is economics. My dream is to work with governments and international bodies to create viable developments plans that are not overly dependant on foreign aid and that identify that the incentives must be correctly identified and in place for the plans to be successful. This summer was an experience that allowed me to be immersed in a new culture, new research opportunities, but most importantly the most pressing problems facing mankind and their potential solutions.