The Peruvian Potato Adventure

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The World Food Prize Foundation
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La Molina, Lima, Peru

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I. Acknowledgements

First, I would like to thank **The World Food Prize Foundation** (WFP), **Dr. Norman Borlaug,** Nobel Peace Prize Laureate and visionary leader, **Dr. Kenneth Quinn**, former U.S. Ambassador to Cambodia and the President of the Foundation, and **Mr. John Ruan III**, the current Chairman of the WFP Foundation, for their unending fight for global food security and for the immense generosity that realized the Borlaug-Ruan International Internship for myself and my fellow interns. Their vision has opened my eyes to the pressing but oft-overlooked issues in our society and ignited in me the passion to make a difference among billions of people.

Special thanks to **Lisa A. Fleming,** Director of Global Education Programs of the WFP, who refused to be daunted by her incredibly busy schedule, for her enormous support and care throughout the summer as I acclimated to a new environment. Also, thanks to **Keegan Kautzky,** Director of National Education Programs, for his tireless efforts and everlasting devotion to the program.

I would also like express my deepest gratitude to **Dr. Pamela Anderson**, Director General of the International Potato Center (CIP), for extending this opportunity to work at CIP, which gave me greater insight and a new perspective on food security issues as well as the renewed resolve to spread awareness and combat these issues.

Thank you, **Dr. Min Kwon**, without you I would have been forever lost in Peru. As my mentor and guardian, Dr. Min was a father to me in a foreign land and an inspirational role model. His humility and generosity, as well as his patience and selfless concern and for others influenced my values and challenged me as a human being.

I want to thank **Dr. Jan Kreuze**, Principal Virologist, and **Dr. Jürgen Kroschel,** Head Agroecologist of CIP for taking me under their wings. It was a tremendous honor to work with internationally renowned scientists and contribute to their research. To everyone in the Virology and Agroecology Divisions at CIP, I extend my sincerest thanks for welcoming me with such warmth.

I particularly want to thank my mentors and my friends, **Pablo Carhuapoma, Frank Plasencia, Betty Flores, and Esther Yvonna,** for bearing with my broken Spanish and guiding me in the culture, as well as work at CIP. All of you made my experience in Peru special, and I treasure the memories we shared together.

I want to thank my friends in San Diego for encouraging and supporting me during my internship. Special thanks to **Justin Song** and **Allison Zhao** for encouraging me to apply for GYI and subsequently the BR Internship, and thanks to **Mr. Brinn Belyea** of Torrey Pines HS for being my teacher advisor.

Finally, I would like to thank my parents, **SeonYoung Kim & SuYoung Yu**, for their unconditional love and everlasting support. They have never failed to inspire me and deserve the whole credit for who I am today. Thank you for always encouraging me to do my best and to audaciously pursue my passions across continents and oceans in the truly globalized world of today.

II. Introduction

A Korean proverb tells us that "the start is half the task" referring to how often our resolve to do something is not acted upon and left to waste. In 2011, Justin Song, a previous Borlaug-Ruan Intern to Brazil from my school, introduced me to The World Food Prize and the incredibly youth program it offers, suggesting that I pursue the program and the internship as well. I was inspired, I had the resolve, and most importantly, I acted.

My paper on minimizing environmental degradation and impact of climate change in Bangladesh brought me to the 2012 Global Youth Institute where I first learned about the true extent of the dire need for global food security. While I knew all my life in the back of my head how crucial the fight to feed the world was and still is, only then did I comprehend the full magnitude of the task at hand. I wanted to join the fight, I yearned to make a difference, and I applied to be a Borlaug-Ruan Intern.

One seemingly insignificant decision completely turned my life in a new direction. My time in Peru as a Borlaug-Ruan Intern was entirely a transformative experience that renewed my resolve and solidified my vision for the future.

So Reader, I sincerely hope this paper has an impact on you and guides you to act. To The World Food Prize Foundation and staff & 2014 Intern Evaluators, I want to express my deepest gratitude for providing such a precious opportunity to students and I ask that you commend your efforts and your dedication to fostering a new generation of leaders. Future Borlaug-Ruan Interns and current students, I hope you desperately yearn for and actively seek out your goals and pursuits, undaunted by fear of the unknown, for the most valuable, the most treasured encounter and experiences are those unpremeditated, unforeseen, unexpected.

About Me

I am a senior at Torrey Pines High School in San Diego, California. Born in South Korea, I am able to speak fluently Korean, English, and now due to my cultural immersion in Peru, Spanish. Languages were the bridges that opened new opportunities for me throughout my life, connecting nations and people together into an accessible community, which influenced me to take up learning Mandarin Chinese as well. Though we know not where the paths of life will take us in the future, I plan to study International Relations and Environmental Science in college. I aspire to work as a United States Diplomat or Ambassador to the United Nations, in the hopes that I can help connect the nations and cultures together in the global community. I am

enthusiastically involved in science and math olympiads as well as Quiz Bowl, an academic competition. In my free time, I enjoy reading, listening to music, and playing sports, especially tennis, badminton, and table tennis.

My Home and My Family

What is home but a place where you are welcomed, where you are loved, and sincerely cared for? Peru, in the two months of my stay, truly felt like another home, thousands of miles and a continent away from my San Diego haven, one that I would not hesitate to return to.

The Park Family graciously welcomed me into their home. By mere coincidence, I was able to stay with a Korean family, which had its own benefits and drawbacks. Mr. Jae Min Park made sure that I would adjust easily to a new culture, and Mrs. Hee Sook Kim, his wife, genuinely cared for my well-being.

Above all, the single most influential individual during my stay in Peru was **Dr. Min Kwon**, a graduate of Seoul National University and a researcher at Highland Agriculture Research Center in South Korea. He worked at CIP and stayed at the same homestay with me, and thus, he was essentially my guardian and my father in Peru. He taught me directly and indirectly from his actions how to be a scientist, but more importantly, how to be a citizen of the global world we live in today. I was astounded by his infinite wisdom and magnanimous heart, always willing to serve, to go out of his way to help those less fortunate. And I was even more amazed at how much love and respect he received from the people at the International Potato Center and the community in Lima, despite his relatively short stay of 2 years. I have no doubt that he is truly someone that South Korea and the world needs in this time and age.

III. Centro Internacional de Papas (CIP)

The International Potato Center (CIP) is located in La Molina, a relatively wealthy quarter of Lima. It was founded in 1971 as a research and development institution to address global food security and sustainability through various Andean tubers, mainly *papas* and *camotes*, potatoes and sweet potatoes. CIP is a member of the Consultative Group on International Agricultural Research (CGIAR) Consortium, a global partnership of organizations united in the fight for a food secure future through its emphasis on improving rural poverty, nutrition, and management of natural resources. CIP also has numerous offices in over 30 nations

throughout the world, which increases CIP's breadth of resources and capacity to strengthen root and tuber science and technology in a diverse array of settings.

Mentors

Dr. Jürgen Kroschel is the Head Agroecologist of CIP and graciously took me under his wing to guide me on my project. I shared an office with and mainly worked with **Pablo Carhuapoma**, my best friend during my stay. We were the only two people who had a mathematical background and essentially, all of the research divisions of CIP relied on us for help and advice with their projects. Although almost everyone left work at 4:30 PM promptly, Pablo and I often stayed until late hours working together and played table tennis between work to blow off steam.

Dr. Jan Kreuze is the Principal Virologist at CIP and my assigned advisor. Unfortunately I could not work with him too much due to his schedule and his travels. But I was able to work indirectly with him through **Betty Flores**, who was an amazing friend and mentor. She encouraged me to be confident with the Spanish language and made sure I experienced the Virology lab and the Peruvian culture to the fullest.

IV. Research

In this paper, I will explore the effect of climate change on parasitoids of the Potato Tuber Moth (PTM) and their use as effective biological controls. As global temperature increases, PTM will be able to proliferate into previously colder areas before global warming. I will address the potato production of South Korea specifically in that context. Lastly, I will discuss food security in South Korea, and how it can be a step to promote food security in other parts of the world.

Pests and Parasites

The Potato Tuber Moth (PTM, *Phthorimaea operculella*) plagues potato farmers worldwide, in every continent. It damages the potato at 3 different stages: seed potato infestation, leaf infestation, and tuber infestation. The yield for potatoes infected by PTM decreases by 16 tons on average, and many potatoes harvested from infected plants cannot be used or sold due to visible damage (Kroschel). Currently, the main method of controlling PTM is via insectides. Several complications arise by relying solely on insectides. It is estimated that around $704

million a year is spent on insectides across the world, which means some poor rural farmers cannot afford use them and on the other hand, that it contributes to the production cost of the potato, reducing net profit. Also, the insectides are extremely toxic. PTM has developed resistance to strong insectides such as DDT, Endrin, DDD, and Dieldrin, and as a result, the dosage and intensity have increased, now presenting health risks to farmers, their families, and consumers of the treated potatoes (Kroschel).

Therefore, the proposed method of controlling PTM is called "Integrated Pest Management" or IPM, where natural enemies or parasites of PTM are used and proliferated to control the pest itself. PTM fortunately has numerous natural enemies, one of which is *Orgilus lepidus.* But none of the natural enemies can withstand a diverse array of conditions like PTM. Therefore, each of them has to be tailored to a particular area to be effective control and at the same time, not damage the environment or cause an imbalance in the ecosystem.

Modeling the Activity and Establishment of PTM and Specific Parasitoids of PTM

i. Background

The Potato Tuber Moth has proven its ability to survive in a wide variety of conditions. One environment that PTM and most insects shy away from is the cold. However, with global warming, when temperatures increase worldwide, PTM will be able to proliferate even more. The specific parasitoid I investigated was *Orgilus lepidus* (Hymenoptera, Braconidae), which lays eggs inside PTM larva. The eggs hatch and develop inside the PTM larva over a 21 day period ("Orgilus"), and whether the *Orgilus* larva or PTM larva develops into an adult can be differentiated at the adult stage.

Figure 1: Left - PTM, Right - Orgilus

ii. *Methodology*

I was given previously collected "life-table" data of *Orgilus* and PTM larva at different humidity and temperature levels to simulate conditions in different parts of the world. A life-table consisted of an excel sheet with each column being one insect specimen and each row one day. Every day, whoever was collecting the data verified whether the larva is dead or alive and consisted of an excel sheet with each column being one insect specimen and each row one day. Every day, whoever was collecting the data verified whether the larva is dead or alive and records what stage of life (egg,

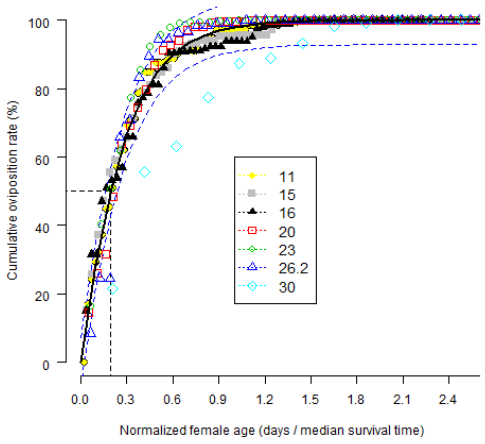


Figure 2: Oviposition Rate

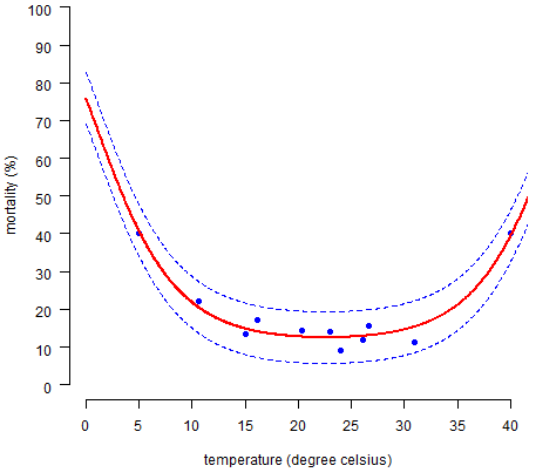


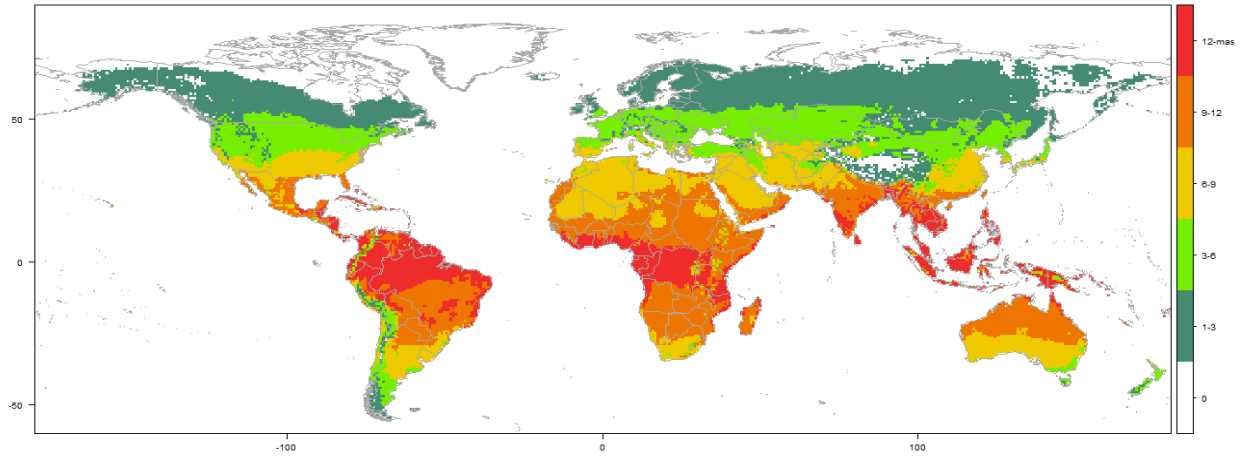
Figure 3: Mortality Rate

larva, pupae, male adult, female adult, or dead). This data was then analyzed through software called ILCYM (Insect Life-Cycle Modeling Software) to conduct statistical regressions and generate phenologies or life-cycle data: oviposition, senescence, development time, and development rate, the necessary components in order to generate three indices: Activity Index (AI), Generation Index (GI), and Establishment Risk Index (ERI). AI is a relative measure of how much a species can spread in a given area; GI is a numerical value of the average number of generations a species can survive in a given area; and ERI is a straightforward survivability rate until adulthood of a species, calculated through 1–(EggMortality)(LarvaMortality)(PupaeMortality).

Once the initial phenologies of *Orgilus* and PTM were done, simulations and validations were conducted. Simulations essentially create hypothetical life-tables based on the rates and probabilities calculated in each phenology. And those simulated life tables are compared to real data of the organisms under fluctuating temperature in the validation step to verify the phenology. Each time there were discrepancies, the phenologies had to be revised with different regression models and evaluated until there were no statistically significant discrepancies.

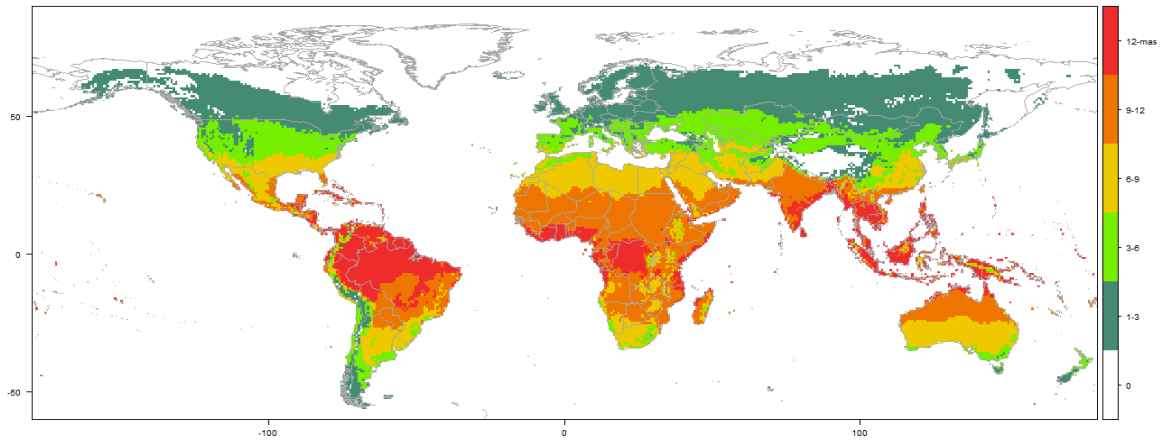
Finally, using the verified data and climate data of year 2000 and 2050 from the WorldClim Database, maps were generated to visually represent the temperature-dependent life-cycle models.

Figure 4: Orgilus Generation Index 2000



The above and below maps can be used to compare areas where *Orgilus* will be effective in 2000 compared to 2050. With further analysis into more specific quadrangles on the globe, this model will be tremendously useful for large and small-scale farmers to determine what pest control measures will be effective. For instance, in 2050, *Orgilus* will be likely to have fewer generations in southern Africa, and on the contrary, in 2050, *Orgilus* will be more effective in South America.

Figure 5: Orgilus Generation Index 2050



South Korea

Today, South Korea is known for its developed industry; brand names like LG, Samsung, and Hyundai have been commonplace jargon in the world. In 1963, before the economic boom, most people were farmers. By 2000, less than 20% are farmers and half the arable land is gone.

South Korea's main crops are rice and barley. In past years, South Korea only imported wheat from other nations and were mostly self-sufficient without hunger. Although in the past decades, South Korea resisted opening up its market to foreign producers of rice and barley, declaring the need to protect its farmers ("Agriculture"). South Korea is in a volatile situation: the agriculture is dwindling, foreign competitors have access and economic liberty through ASEAN and FTA, and all topped off with climate change undeniably changing the atmosphere and the global temperature.

These maps below were generated using the same principles as noted in the previous section. However, they take into consideration the altitude of a particular area as well. As depicted in the below, PTM models indicate the as climate change progresses, PTM will encroach deeper into the Korean peninsula.

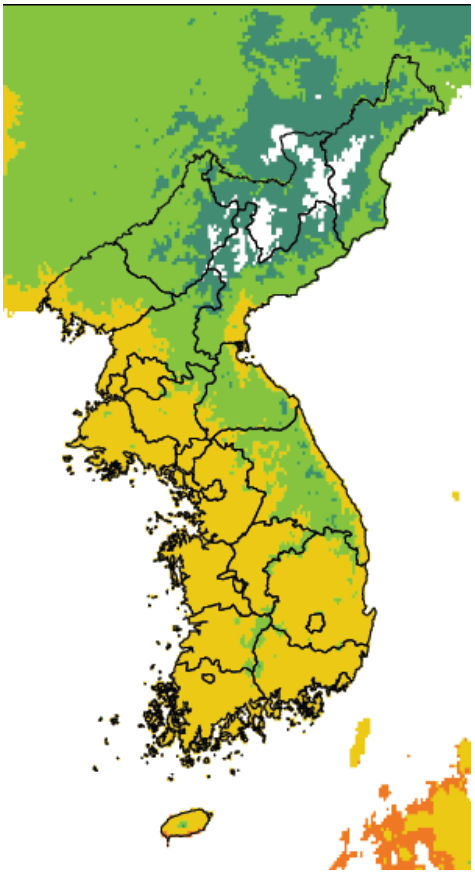


Figure 6: Korea 2000 PTM

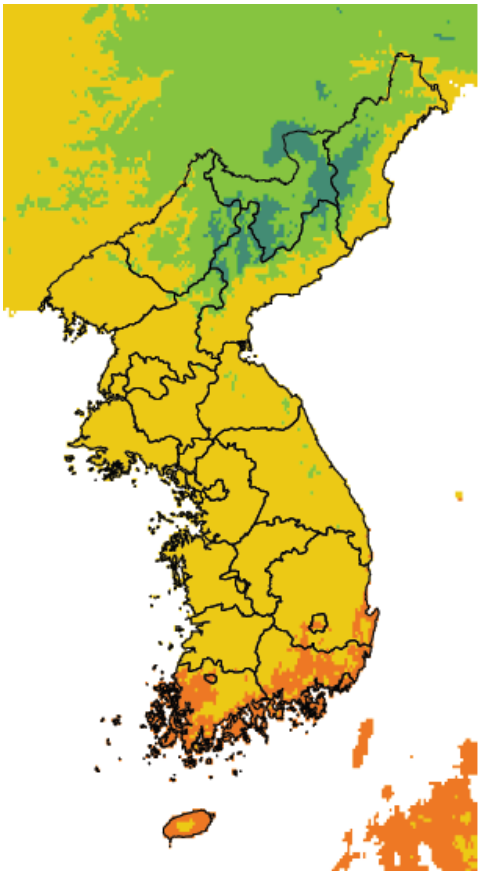


Figure 7: Korea 2050 PTM

Food Security in Korea

As the world grows more cognizant of the hunger crisis it faces, more and more nations are turning to the potato. From China, a country that has long produced 95% of its citizen's grain, to Zimbabwe, a nation trying to avoid complete dependence on South African crops, now foresee potato as the crop that will provide the ever-growing population (CIP). And Korea must take this initiative as well. As the third-most consumed crop in the world, the spud has numerous benefits to be crowned the crop to save the world from hunger. The potato is drought-resistant, naturally containing over 2000 genes that provide defense against desiccation by such means as reinforcing cuticles or increasing solute concentrations to lower osmotic potential (Schlafleitner). Drought lowers yield in most plants as the guard cells on the leaves close the stomata to prevent water loss, which prevents CO_2 uptake, a necessary component for plant growth. For the potato, due to its ability to conserve and retain water, its uptake of CO_2 is less affected. In addition, potatoes have a short growing season, less than 3 months, allowing in many parts of the world to have multiple harvests within a year. And perhaps, most prominently, the potato yields approximately 40 tons per hectare, a disparately high amount compared to other staple crops (FAOSTAT). In 2012, United States produced 41.8 tons per hectare of potatoes compared to 3.11 tons per hectare of wheat and 7.74 tons per hectare of corn (FAOSTAT). As the chief goal is to feed the world supply more food, a dependence on potatoes as a staple crop will dramatically increase total production of crops. Furthermore, potatoes are suitable to be a staple crop due to their high nutrition. They are a source of low-fat carbohydrate, containing more protein and twice as much Calcium than corn ("Nutrition"). Potatoes also contain a high level of carotenoids or anthocyanins, depending on the color of their flesh, both antioxidants believed to prevent cancer ("Nutrition"). Hence, the potato would be an excellent crop for the world to depend on.

However, the potato yield in Korea is only about 23 tons per hectare, a little more than half of the yield in the United States. By working to improve this yield, farmers in Korea can generate more profit and with a solid agricultural foundation, the nation can thrive in other areas. No one factor decides the yield of a particular region. The factors involved could be environmental, ranging from soil chemistry, atmosphere, or even pest damage. Or the effect could be social, a matter of government aid. One potential solution for Korea's farmers could be urbanization by linking their production directly with companies, for it could guarantee a

position in the market. Also, as demonstrated in the maps above, Korea will be more heavily affected by PTM. And whether or not, they choose to use *Orgilus lepidus* as a biological control, Korea will have to be prepared. With careful consideration and understanding of factors influencing potato yield, Korea will be able to not only increase production but develop a lasting potato system.

V. Further Work at CIP

Other Projects

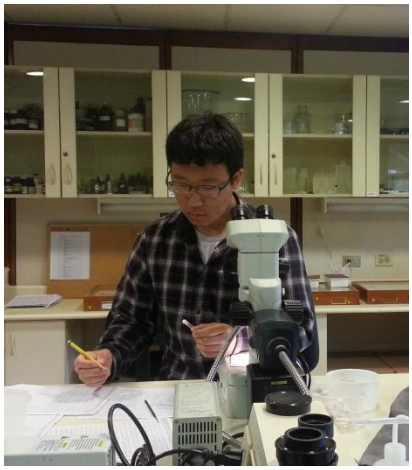
In addition to my main research project on the impact of climate change, I also had the opportunity of exploring different areas of CIP, learning about their work, and helping them with their projects. One of the projects was a side-project from working alongside Pablo. ILCYM, the software we used to model insect life-cycles and predictions, was still in its nascent stage. Pablo taught me to be proficient with R, a coding language, and I was able to help him develop ILCYM into better software. This experience was particularly meaningful, because before coming to CIP, I had absolutely no knowledge computer programming. But after days and nights of struggling through a jungle of code and manuals, I was able to optimize regressions, raster conversions, and maps on the program.

If CIP was a body, then I can confidently say that the small office shared by Pablo and me was the heart. Researchers from other divisions like Entomology, Virology, and Integrated Crop Management (ICM) flocked to our office for help and advice. More often than not, Pablo and I were juggling 4-5 different projects at once and frequently worked overtime. But through such an experience, I was able to meet numerous people from different research divisions of CIP and assist them with their projects.

Another valuable experience was working with the virology department, where they were looking for viruses within infected

specimens and sequencing them with a novel technique called “deep sequencing.” I learned that with the full genome, they could develop siRNA (small-interference RNA) to inhibit viral replication and effectively ‘kill’ the virus within infected plants. I was glad I had experience in my UCSD biochemistry internship in the past, as I was already familiar with the lab protocols such as DNA and RNA extraction and Polymerase Chain Reaction. Nonetheless, it amazed me how painstakingly and meticulously each specimen among thousands is probed and tested.

Finally, although I worked mostly with previously collected data from insect life-tables, Veronica from the entomology department gave me a chance to collect life-table data myself, with *Orgilus lepidus* larvae, keeping a record of their development on a daily basis. I had around 150 cassettes with a piece of potato and a larva in each to check each day. It was a long and arduous process, digging through the potato under a microscope without injuring the larva, and not the most agreeable due to my aversion towards insects. But just as I began to love the foreign world of Peru more and more, I soon grew to enjoy the process, marveling at the subtle wonders in the lives of insects. Through these experiences, I overcame my fear of insects, began to embrace the unknown, and grew more Peruvian day by day.



My Travels

Peru is divided into 3 main geographical regions: *la costa* (coast), *las montañas* (mountains), and *la selva* (jungle), with its distinct food and culture, and I got a taste of each one during my stay. I lived and spent most of my time in Lima, which is on the coast. But interspersed between my work at CIP, I was able to travel to various locales in Peru. My first destination was a small, costal town called Cañete, with Octavio Zegarra in order to collect infected leaf samples from sweet potato and potato plants alike. It was my first time out of Lima the city and I saw firsthand the radical socioeconomic disparity in Peru. It was also my first time trying ceviche, a raw seafood dish garnished with lemon juice and spices.

My 2nd longest trip was a week-long trip to Huancayo, a city in the heights of the Andes at over 4000 meters. I traveled with Frank Plasencia to install meteorological instruments at

various points in the mountains. One particularly memorable incident, we were driving on the side of a mountain when we saw the about 100 feet of the path was completely frozen. In order to make way, we got out of the car and broke the ice with shovels and stones for a couple hours. While extremely dangerous, the ambience was indescribably beautiful and serene – a short distance away, I could see snow covered mountains and spotless fields stretched out in front of me. Overall, this trip was the most strenuous experience I had during my stay in Peru – at 4000 meters, the air is very thin and the lack of oxygen makes the body sluggish and heavy. However, even in the isolated mountain peaks of the Andes, there were small communities of people, and I was inspired by the resiliency in their lives, steadfastly working their fields day by day.

The final trip I took in Peru was not a part of work but for pleasure. I traveled with Dr. Min Kwon to the ruins of Caral. As he would soon return to Korea and I back to the United States, we wanted to share a memorable day together. The Caral Civilization predates the better known Incan Civilization by more than three thousand years, as the earliest known people of Latin America, and the city of Caral houses a collection of pyramids in the desert.

VI. My Journey

Culture and Lifestyle

Before I came to Peru, I was told countless cautionary warnings for my safety. I was told to be careful of people – an extension of the old 'stranger danger' in a foreign land, I presume – to be weary of what I ate and drank, and to comport myself in a wise, appropriate manner so as to avoid trouble, among others. Even the man I sat next to on the arriving flight told me to be weary of pickpockets and street violence. The initial impression of Peru from internet searches and hearsay opinions initially made me apprehensive and gave a much skewed perspective of the actual life in Peru.

What I would soon discover were the kindest, warmest, most welcoming people I have ever encountered in my life. When I first arrived at the International Potato Center, Mercedes Suito – affectionately called 'Meche' – gave me a thorough welcome, introducing me to all of the departments at CIP declaring, *Te presentó Daniel Kim.* Although I studied Spanish for 4 years at school in San Diego, I suddenly realized how little I actually knew. I was able to understand most of the conversation, but to converse with others was a daunting task. Initially I was self-conscious and got by with small murmurs and nods, with an occasional *sí* or *gracias* when appropriate. But I gradually gathered up more courage as the people were extremely encouraging. My virology mentor and friend, Betty Flores, would practice her English with me and encourage me to do the same in Spanish. To my surprise, in the short two months of the internship, my Spanish improved more than it ever had in 4 years. Determined to make the most out of this opportunity, I would study new phrases and words at night to practice the subsequent day. Towards the end of my internship, my grasp on English was becoming tenuous. I was completely immersed, and I loved it.

One notable distinction I found during my stay is that, Peruvians are extremely open and hospitable. They do not keep 'polite' distances in their relationships as typically done in the United States, which is evinced by their means of greeting with a kiss and a hug between friends. Also, growing up in a Korean culture, the use of honorifics was heavily stressed in my upbringing and I understood the formal 3rd person in Spanish to be of similar nature. But Peruvians rarely used the formal 3rd person tense, only for people held in high regard or respect and not immediately present in the conversation. After meeting once or twice, everyone is considered a friend.

Reflections

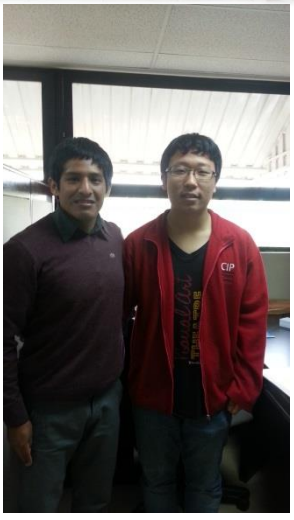
8 x 2.5 = 20. 15 ÷ 2.5 = 6. I grew accustomed to multiplying or dividing any number by 2.5, the exchange rate between U.S. dollar and Peruvian soles. At first it was for convenience – I did not know exactly what 15 soles meant or if I am paying a reasonable amount when a taxi driver asks for 70 soles. Yesterday, I converted my 5 dollar Subway into soles, wondering how much my Peruvian friends might have paid, or if they could have paid. But 2.5 became more than a monetary conversion factor. It was a lens through which I saw two worlds.

In Lima, there's San Isidro, Miraflores, Larco Mar, Jockey Plaza – the districts for the rich elite. And immediately adjacent there's La Victoria, Jesus Maria, Surco – ramshackle neighborhoods reserved for the poor and naturally dangerous. The two coexist as if blind to the obvious disparity, the rich perhaps out of myopic contentment and the poor out of resignation. But this is reality: even within Lima, there is hunger, there is poverty, and there is lack.

My summer at CIP gave me tremendous experience and knowledge of the work that is being done to combat global hunger and poverty. I learned the impact of climate change on crops worldwide, novel technique to cure viral infections in plants, and even how to differentiate a Potato tuber moth (*Phthorimaea operculella*) cocoon from those of its parasites *Orgilus* or *Liriomyza*. I realized that fighting for global food security is a complex and interdisciplinary issue that will require the best of us in the near future. Scientific research and innovations in the field of agronomy are important, in fact, absolutely crucial if we want to feed the world. However, there remain questions of extensive policy, of egalitarian outreach, and of equitable welfare. One group of people cannot do it. It will take the cooperative effort and selflessness of the global community. We can light the fire, but the fire needs to spread.

Moreover, I learned about independence, about maturity, about myself. I realized that it is the initial uncertainty that makes what becomes certain infinitely more beautiful and valuable. A little more than a year ago, I made a choice, a decision with consequences unforeseen. It led me here today, there and back from the International Potato Center, Lima, Peru. I can say with absolute certainty, that I have been forever transformed through the Borlaug-Ruan International Internship. The pertinent issues of world hunger that I ignorantly relegated to a corner of my mind are now a personal struggle. But I am optimistic. I see a future blossoming with a new generation of leaders, of possibilities, of opportunities, and the realization of global food security.

VII. Photos



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