From Southeast Iowa to Southeast Asia:

A summary of Eight Weeks in the Paddy

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"For people in rice cultures, rice means just about everything that is important: birth, death, wealth, power, strength, fertility, virility, vitality . . . Life itself."

Rice is life for over half of the world's population. During my summer as a World Food Prize Borlaug-Ruan International Intern, rice was my life as well. Rice is a major part of life at the International Rice Research Institute (IRRI) in Los Banos, the Philippines - in the lab, in the field, and in the cafeteria. After 168 meals of rice, I have truly acquired a first-hand appreciation of rice and its significance in the Asian diet. As I had the opportunity to experience Filipino culture, I saw variations in the use of rice that I could have never possibly imagined: drying on the shoulder of the road next to stop-and-go traffic, idealized in the rice rituals of the Ifugao natives, and even as *McRice* on the value menu at McDonalds. Yet, more important than the extensive use of rice in daily lives is the crisis of food insecurity for the millions of rice-dependent men, women, and children who must struggle to survive.

Directly correlated to rice production and consumption is the problem of overpopulation I observed in the Philippines- also common to every country in the developing world. When I was born, there were 4,524,808,000 people on the earth. Since then, the population has increased by 32% with 24 people added every ten seconds. The world's population is projected to expand to 8 billion over the next fifty years with much of this increase occurring in Southeast Asia, where half of the population is already poor and malnourished. This was a topic discussed extensively at the *World Food Prize Symposium* and also was the focus of my discussion paper for the *WFP Youth Institute*, but to see it first-hand was a completely different story. At one point I was told that it was the father's job to earn the money and the mother's *job* to be pregnant – to have a baby, then another, and another, etc. In the Philippines, the average family has *six* children. A speaker at the 2001 World Food Prize Symposium said population control is not the answer to eliminating poverty. After a second of shocked silence from the audience, he continued- but it is part of the solution. I strongly agree with the second half of this statement- as population increases in Asia, the demand for rice, land, and water is also elevated. Soon there will simply not be enough resources to go around. Therefore in 1960, the International Rice Research Institute was created in response to the impending situation.

IRRI's motto says it all: Rice Science for a Better World. The institute's objective is *to help poor rice farmers in developing countries grow more rice on less land using less water, less labor, and fewer chemical inputs without harming the environment.* Rice production arguably is the most significant economic activity on the planet, but its consumers are among the poorest in the world. The theme of my internship was the **importance of improving rice yield**: how it is being done, why it should be done, and what the future has in store.

I was assigned to study within the Crop, Soil, and Water Sciences Division switching supervisors every two weeks, which divided my internship into four segments. This enabled me to experience multiple projects combining a range of the diverse aspects of rice research conducted at IRRI. I explored the topics of drought resistance traits, yield barriers, rice physiology, and rice production.

Drought is a serious issue for rice farmers, especially since most ecosystems suitable for rice growing have well defined wet and dry seasons. Water is necessary for the growth of rice and lots of it. In fact, two to three Olympic-sized swimming pools of water are required for one hectare of rice. This matter is becoming more and more of an issue due to foreseeable water shortages in the future caused by overpopulation. Population growth means more people to feed. More people will need more rice. More rice will need more water. More people will need more water.

One solution to the dilemma is mass screening of rice varieties for drought resistance traits. This sounds like a great idea- why go the long route of gene manipulation, if a tolerant species may already exist naturally?   To do this research, one would need a database of rice varieties from around the world.   But, where would you be able to find one of those? Luckily, IRRI has one! As one of IRRI's marquee projects, it has created the world's most comprehensive collection of rice genetic resources. Since 1962, IRRI's Genetic Resources Center has been at the forefront of international efforts to systematically collect, conserve, characterize, and share traditional and wild rice varieties. Today the Gene Bank holds around 100,000 species of rice donated by over 100 countries worldwide.

The IRRI Gene Bank operates similar to a real bank; rice samples may be deposited and withdrawn on request. However, it differs in that samples may be withdrawn without a deposit, encouraging the free flow of germplasm on a *global* level. Best of all, the requests are fulfilled free of charge! As more advanced rice cultivars become heavily used, traditional varieties will begin to disappear. The preservation of such varieties is necessary to maintain a diverse genetic pool that can be drawn upon by researchers as insurance for long term biodiversity and sustained food security. As a variety is deposited into the Gene Bank, each of its traits are systematically characterized and cataloged. When a major barrier to rice production presents itself in any region of the world, a researcher need only request varieties with specific characteristics and the area is on their way to reinstated food security. A recent example of how the Gene Back can be used is Cambodia. After war destroyed the rice fields of Cambodia, IRRI germplasm allowed farmers to replant their fields immediately.

This is an especially convenient system for the scientists at IRRI who are literally next door to this amazing resource. Researchers such as Tina Botwright, an Australian post-doc studying at IRRI whose guidance I worked under for the first two weeks, are able to benefit directly from the Gene Bank. During my time with Botwright, I investigated the inner-workings of rice growth physiology- especially the way in which plant height is affected by abscisic acid (ABA) and gibberelic acid (GA) - growth hormones found naturally in rice plants.

My first task was experimental set-up, meaning I was able to jump into the lab and get down to business right away. This involved preparing the nutrient solutions, counting and sterilizing seeds, and finally waiting for the incubator to do its magic. The experience reminded me of chemistry class, except I never had to wait in line to use the scale! It may have been only thirteen varieties, but that still meant quite a bit of seed and a lot of lab work. The arrangement of the seed is rather complicated; it cannot be done logically like a vegetable garden. Instead, no seed of the same variety may border another of its own for fear that a disease will come along and wipe out the whole row, rendering the entire experiment worthless. Once the germinated seed had been arranged in the trays, nature was allowed to take its course within the shelter of an outdoor growth enclosure.

The samples were divided into six trays for six different treatments: two controls, an addition of ABA at time of seeding, two days after, nine days after, and an addition of

GA two days after seeding. Adding the nutrient solutions and hormone solutions was "bucket chemistry," as in we literally mixed it all up in a huge orange bucket with a big stick- similar to a scene from *Harry Potter's* potions class. From then on it was my responsibility to keep the plants healthy and happy by monitoring the pH of the nutrient solutions every morning. Every few days, I would also record the height measurements of each seedling- as in out in the sun on my hands and knees with a ruler! Within days there was already a distinct variance in the growth patterns of the ABA and GA treated trays. The gibberelic acid caused hyper-elongation of the stem and leaves. Meanwhile, the abscisic acid treated trays produced an assortment of results, stunting some varieties and leaving others unaffected.

Two weeks later, it was harvest time. However, I had already moved on to my second assignment by that time. Nevertheless, I was able to discuss the results with Botwright. Using averages as a simplistic approach of assessing the data, we were able to compare the effects of the treatments. On evaluation with the control, the addition of GA at two days into the seeds' growth caused stem elongation in the beginning but did not carry through to the end of the fourteen-day trial. Adding ABA on the second day had a more profound effect of stunted growth in comparison to addition of ABA at nine days which had a lessened stunting effect and addition at the very beginning which had little to no effect. *(Refer to Figure 1)*

The next step is to continue development of the cultivars that displayed particularly outstanding responses to the GA and ABA. This research is significant not only in drought tolerance, but also in improvement of plant vigor- speed in which the plant establishes itself in the soil. In relation to other crops, the vigor of rice is seriously lagging. A more vigorous rice crop would lesson competition from weeds and improve water-use efficiency as more ground would be covered in a shorter amount of time saving the small-scale farmer significant quantities of money and resources. In the long term, these results may eventually be useful in breeding natural ABA for drought resistance and natural GA for increased plant vigor.

The start of the third week with Dr. John Sheehy's group was a brand-new beginning. His group is one of the smallest at IRRI, but also one of the most impressive that I worked with. The respect and sincerity with which they treat each other is entirely inspiring. Dr. Sheehy's support staff is entirely Filipino, providing me with many opportunities to satisfy my burning questions about what I had been seeing and experiencing since I had arrived. I especially appreciated the friendliness and acceptance with which I was welcomed into the group, rendering the experience all the more worthwhile and rewarding. Dr. Sheehy, an international scientist recruited from Great Britain, was very concerned that I get a complete understanding of *all* the projects in his unit.

With the threat of global warming and elevated temperatures becoming increasingly relevant, it is especially pertinent to explore the magnitude of influence the phenomenon will have on agriculture and food production. Crops will be forced to adapt to the changing climate or perish. The starting point of my project was Dr. Sheehy's theory of thermal burden as explained in his collaborated article, "Temperature of rice spikelets: thermal damage and the concept of a thermal burden." More often than ever before, plants will be in danger of crossing the threshold temperature for damage. Thermal burden is a term describing the difference between the temperature of a non-transpiring object and the temperature of the air. Plants are able to ease the thermal burden through transpirational cooling. Using this concept and a lot of physics and algebra, Dr. Sheehy devised a series of equations to calculate the stomatal resistance of a rice plant. My project was to test its applicability to actual practice.

My assignment included the setup and use of an instrument called a porometer, which had never before been used at IRRI. A porometer measures the stomatal resistance of the leaves, or how freely water is being released from the plant. Stomata are little openings on leaves that allow the plant to transpire and maintain a reasonable temperature, in short – they are the sweat glands. The stomatal resistance is the measure of how open or closed the stomata are. The lower the resistance, the more open the stomata are and the more water the plants are losing. This form of water loss is important because it is linked to crop yield and photosynthesis.

Three researchers and I spent two long, hot days out in the field taking measurements of potted and field plants with the porometer, infra-red thermometer, dry bulb and wet bulb thermometers, and the sunscan meter. The potted plants allowed us to find the mass of the water loss, because the pot constricted the water supply of the roots.

Therefore the difference between the initial weight and the final weight of the potted plant equals the amount of water the plant lost through its stomata. The equations from the theory also ask for both the temperature of transpiring and non-transpiring plants. To find this we smeared a leaf with Vaseline, which turned it into a dry body because it could no longer transpire and maintain its heat, and then we used the infra-red thermometer to record the temperatures of the Vaseline-covered leaf and a regular leaf. The air temperature was recorded using dry bulb and wet bulb thermometers, while the sunscan probe measured the radiation input from the sun. In order to compare the accuracy of our results, there were six potted plants and six field plants, and we performed five trials over the two days to not only check our accuracy but to also compare readings from different times of day: mid-morning, late-morning, and early afternoon.

The most straightforward computation was the value of the thermal burden (*temperature of non-transpiring leaf minus air temperature*). Next came the "messy" calculations. Using the collected data, we could work from water loss- (*using weights of the potted plants)*- to calculate stomatal resistance and from the stomatal resistance- (*the porometer readings)*- to calculate water loss. However, when it came to computing the final results, we had a few surprises with the final numbers. The magnitude of the calculated values was not reasonable, so we went back and discovered unit label mistakes with our calculations and also minor errors within the original article. But as Dr. Sheehy asserts, "The excitement of science is the unpredictable, the unexpected, the surprises. The most interesting things happen by accident."

Even so, the next step Dr. Sheehy and his researchers will take is to use the porometer as an additional screening method of selected wild rice varieties. Their goal is to change the photosynthesis ability of rice, which has a C3 system, in order to increase the efficiency of its water and nitrogen with a more economical C4 version of photosynthesis as found in maize. Interestingly, rice that has been engineered to express certain C4 genes from maize has shown superior yield and photosynthesis traits due to a change in stomatal conductance. The wild rice varieties, selected from the archives of the IRRI Gene Bank, are the participants of a search for the missing link between the development of the photosynthesis abilities of rice and corn. Dr. Sheehy believes that it is possible for rice to undergo this type of metamorphosis, but such a feat is projected to involve major engineering changes at the cellular level.

Fortunately, mother nature may have already provided a short cut. Despite key differences in cellular structure, all of the genes necessary for a C4 system, and also in some cases active C4 enzymes, have been discovered to already exist in C3 plants. Now the trick to complete understanding of a possible transition lies in the search for a rice species that is somewhere in the middle of the two photosynthesis methods. Success would set off a second green revolution as the rice plant would be able to use half the amount of transpired water and a third less nitrogen and still raise yields to levels impossible to achieve by even the best of today's rice varieties with C3 systems.

Increasing rice yield is an ongoing process that is necessary to combat hunger caused by rapidly increasing population and the ever-changing conditions and obstacles faced by rice farmers. The goal of the researchers in crop physiology is to compare new varieties with established varieties and assemble an improved picture of how yield can continue to be increased. The main research in this department takes place on a long-term basis, in that they must amass data from at least three to four growing seasons to compile any valid results. The physiology of rice yield takes many forms. During my stay with Dr. Peng, an international scientist recruited from China, and his researchers over week number five and six of my internship, I was able to experience a taste of each. They range from basic assessments of plant height, tiller number, and dry weight to the more complicated methods of analysis including root density, leaf area index, and nitrogen content.

The most straightforward measurements are plant height and tiller number- both are evident upon observation alone. However, determining the number of tillers, which is a shoot including roots, stem, and leaves, took a bit of practice for me. The tricky part is to tell the difference between a newly formed tiller and an outer growth of a more developed tiller. In my opinion, tallying tillers is much harder than the seasoned veterans make it appear- practically an art. I made it into a game; I would count the tillers, and then let an expert *tiller-counter* tell me what number I should have ended with. Dry weight assessment is also quite simple, but it is a process that involves two phases: first the stem, leaf, and root components of the plant must be separated, and then each component must be dried and massed.

The more complicated is the method of analysis, the fancier and more expensive is the machine. The leaf area index can be determined by feeding the leaves onto a transparent conveyer belt traveling over a light source. A camera above the light source captures the shadow; the sum of the areas of all the shadows, as calculated by the machine, is the *leaf area index* of the sample. Root density is measured somewhat similarly, except it requires more patience and precision to ensure that what starts as a tangled mass of roots becomes flat and separated as they are arranged on the circular transparent disk where a single sensor spirals from the outer edge to the center tracking the patterns of light and dark. The result is the *root density*. The most complicated and time-consuming assessment is, by far, analysis of nitrogen content. Normally IRRI researchers send samples to a separate lab for nitrogen analysis, but to save time and money, Dr. Peng's group performs the two-day process themselves. A small, precise amount must be measured out of each sample- that has already been separated, ground, and dried- and then must be returned to the drying oven for the night. The following day is when the majority of the labor takes place: digestion, distillation, and titration of the samples. The last phase is to enter the data into a spreadsheet and calculate the final result, which is the *nitrogen content*.

My final two weeks at IRRI were unique from any of the other rotations. My new supervisor Dr. Bas Bouman, an internationally recruited scientist from the Netherlands, recommended that I take a training program entitled the *Rice Production Course*. It is one of the most popular training courses offered by IRRI and the most basic, but arguably the most valuable.   The Rice Production Course is the oldest class offered by IRRI, yet also the newest, having been updated and revamped after the previous session in January. It began as a semester long course exploring every aspect of rice and its production; it has now evolved into an intensive two-week class covering the production of rice from *A-Z*. Participants traveled from all over Asia- the Philippines, Indonesia, Laos, Malaysia, Nepal, and Bangladesh- as well as from Zimbabwe, the Netherlands, and France to take part. The titles and occupations of the partakers varied as much as their nationalities.

Among my twenty-four classmates were researchers, extension workers, students, businessmen, IRRI employees, and farmers.

The objective of the course is *the distribution of knowledge*. IRRI's research is phenomenal to the enhancement of rice science, but it does no good if the target audience cannot access any of it; actual farmers and rice producers must be taught how to implement the new technology into their fields. This aim is achieved through the exploration of topics such as seed production, land preparation, crop establishment, water-saving techniques, Integrated Pest Management (IPM), and harvest and post harvest management. For those of us who had not experienced as much exposure to rice farming, there were also sessions on rice morphology and species, growth stages, environments, and identification of weeds, diseases, and pests.

The class was much more than a series of lectures; it was an interactive, get your hands dirty, wade in the mud type of experience. Some days we found ourselves knee deep in the paddy transplanting seedlings by hand, and on others, we were seated behind the wheel of a tractor. Ironically, my first time to drive a tractor was on the soccer field outside of the IRRI training building, even so, I was still more experienced than most. The instructor giving the lecture on tractor safety, an Australian named Joe Rickman, asked if anyone in the class had ever driven a tractor. One hand was half-raised. Then he asked everyone who knew how to drive a car to raise their hands. Only five people out of twenty-four raised their hands. To say the least, it was quite an interesting lesson as a half dozen tractors controlled by people who had never taken a driver's education class criss-crossed a single soccer field in crazy, random patterns!

The reoccurring theme over the two weeks was a push for the farmers to act as researchers within their own fields. Farmers who are able to diagnose problems and counteract with an appropriate solution will be able to increase yields much more effectively than by relying on a limited amount of experts. Experts, such as researchers at IRRI, give recommendations, but these are suggestions based on generalizations. Farmers who are able to assess what is best for their field will be able to use their money and resources to their full potential. Techniques using significantly less equipment and resources were explained in great detail, such as setting aside small plots of land for experimentation with nutrient combinations and pest prevention.

An important lesson of the course was that it does not take a huge breakthrough to create a significant impact on yield. A majority of the time, the simpler things are what make all the difference- for example, using weed-free seeds, proper cleaning, improved milling procedures, and correct storage. Nevertheless, rice farming is hard work! After the two-week course, only ten percent of the class wanted to go into it (this includes a few participants who already were rice farmers), but for millions there is no alternative. To help them earn five dollars, two dollars, or even one dollar more has a tremendous consequence within these peoples' lives. The two keys to provide hope for these millions are increasing profits and decreasing the drudgery.

In my spare time, I conducted a mini-survey by email to satisfy my own curiosity. I asked fifteen IRRI employees to state their opinions on *the food security situation in the Philippines, the most significant issue facing today's farmer in developing countries, the impact created by IRRI, and the likelihood of the world being fed in the 21st century*. I received nine replies. It was interesting to note that answers did not seem to be influenced by nationality, whether recruited nationally or internationally.

All felt that the food security situation in the Philippines was unstable- due to factors such as uneven distribution, severe weather, land degradation, and overpopulation. The most significant issues facing today's farmers in developing countries included water scarcity, land degradation, the pressure to produce higher yields with less inputs, lack of youth interested in becoming the next generation of farmers, land loss due to population and industry, and relatively high production costs to produce high yielding, high input technology. When asked if the efforts of IRRI were making a difference, the responses were exceedingly positive! For support, respondents cited the Green Revolution of the 1970's, the release of new IRRI rice varieties, its training programs, and all the small breakthroughs that make a big impact in the lives of ordinary farmers. I also asked the same question that was asked of all the student participants of the 2001 WFP Youth Institute: *Can the world be fed in the 21st century?* I received mixed answers on this one- two thirds were optimistic, while one third replied with no. Even the ones who said yes admitted that in order to do so great changes needed to be made in distribution, access, land use, population control, and international policy.

I had thought that living in the Philippines for eight weeks would give me no choice but to immerse myself in the Filipino culture. On the contrary, IRRI is such a multi-cultural community, with staff including recruits representing six continents, that I learned as much about countries that I have never seen as the one in which I was physically located. I was exposed to people from Indonesia, China, Portugal, India, Nepal, Scotland, Australia, and Burma- to name a few.   This diversity gave me the chance to explore interesting discussion topics such as Portuguese nightlife, the British school system, and Filipino traffic patterns, while trying to grasp Australian humor, Nepalese poker strategies, and the Asian love for videoke.

However, I was not ignorant of my host country. I was struck most by the friendliness of the people. One cannot walk down a street without being compelled to answer a "hello" or a "good afternoon" thrown out by a traveling stranger, quite a change from the "mind your own business" attitude that seems to prevail back home. Everyone loved to chat; the locals' favorite questions were "What is your name?" "How old are you?" and "Are you married?" It is not uncommon for one to meet a stranger in a park and after a short conversation, receive an invite to join the family barbeque. Or, stroll along the beach and end up taking part in a sing-along with a group of locals while sitting in the sand watching the sun go down over the ocean.

One afternoon during one of my first weeks, Dr. Sheehy arranged a driver and a guide to take me to Jubileeville located shortly outside the IRRI gates. Jubileeville is a shocking example of the purpose for IRRI's existence. It exemplifies the poverty that IRRI is fighting to eliminate. Shacks are patched together with tin and cardboard; fences are made of old tires and scraps. My guide told me these workers earn only about 100-200 pesos for a day's work, which translates to 2-4 dollars on which a family typically the size of six must survive. The work that they do is not easy, long hours of backbreaking work in the heat- but there is only work during the planting and harvesting seasons. Other times of the year, the workers must scrape together an income from whatever work they can find. It was meant as an eye-opener, and it certainly was! The experience showed me why the work at IRRI has the potential to make such a tremendous impact on people not only in the Philippines, but also in all rice growing third world countries.

I asked Jill Cairns, a graduate student from Scotland completing research for her thesis, why she is drawn to agriculture in developing countries. She replied that she is drawn to the field because it is work that significantly impacts people's lives. She especially loves working abroad and seeing the people who really are in need of the help- the people who benefit directly from her research. Dr. Barney Canton, an internationally recruited weed scientist, proposed this question and corresponding answer while presenting a seminar: *Why do we do this research anyway? So these people will not have to work such long hours; so these people will not suffer.* Dr. Bas Bouman, an internationally recruited scientist conducting water management research at IRRI, said that coming to the Philippines has given him new direction. He felt bored in the Netherlands, that his research was insignificant and unneeded; now, he sees that his work has immediate and life-changing effects on the farmers he interacts with. I asked him if he considered himself idealistic. He answered that he is not *idealistic*- but realistic, and such is the attitude that IRRI impresses on the visitor.

> *"For those of us on the food production front, let us all remember that world peace will not be built on empty stomachs and human misery. Deny the small-scale farmers of the world access to modern factors of production and human-kind will be doomed, not for poisoning and environmental meltdown, as some say, but from starvation and social and political chaos."*
>
> *Dr. Norman Borlaug*
> *1970 Nobel Peace Prize Laureate*
> *Founder of the World Food Prize*

My eight weeks have been a feast for the senses: my stomach has survived everything- no matter how strange- that I have exposed it to, my feet have danced the Tinikling- a native Filipino dance, my hands have harvested rice in the terraces of Banaue, my ears have heard the diverse languages resounding within the international community that is IRRI, my eyes have seen the unbelievable poverty within a developing country, and my mind has contemplated how fortunate I am to have been granted this occasion to participate in such an incredible experience. It has been my privilege to spend an entire summer interacting with people who dedicate themselves to alleviating poverty and fighting hunger. I am thankful to the World Food Prize Foundation and the

International Rice Research Institute for offering me this opportunity. Scientists at IRRI deal with more than science; they deal with reality- the real issues of malnutrition and poverty. These are the people that are changing the world. As I have seen and heard many times in IRRI and World Food Prize propaganda: *"A poor man in Asia may live without many things, but he cannot live without rice."*

Rice is life.

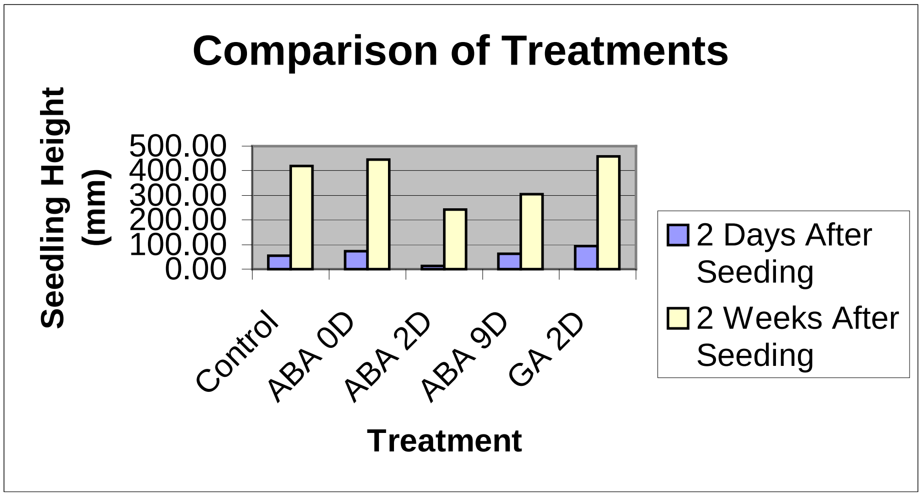

Figure 1

My home for the summer

The IRRI Gene Bank

"Bucket Science"

The six treatments in the outdoor gr

A Long, Hot Day in the Field

The Porometer

Massing samples for Nitrogen Analysis

Finding Root Density

Learning how to drive tractors on the soccer field

Hand transplanting rice in the paddy equals hands-on learning