General Studies on Hybrid Rice

At China National Hybrid Rice Research and Development Center

Eight Weeks in 100% Humidity

By Wyeth Haglan Lynch

About Me

My name is Wyeth Lynch and I had the honor of being a 2004 Borlaug~Ruan International Intern for the past summer. I live on a small farm northwest of Bevington, Iowa with my family. We raise sheep, beef cattle, and hay. I attend Martensdale – St. Marys public school where I am a senior.

How I became an Intern

Articles in area newspapers first introduced me to the World Food Prize Foundation. After deciding to pursue the possibility of attending the World Food Prize Youth Institute, I asked my science teacher to sponsor me, then wrote and submitted my paper. When I attended the Institute in October 2003, I had not expected to have the honor of listening to some of the world-renowned speakers. It was a privilege to see and hear their views about the world.

As the final day started I made two goals, to get through the presentation of my paper with minimal embarrassment, and to pick up a form for the chance at a summer internship. I applied and sent in my essay, not wanting to miss out on an opportunity to explore a part of the world, and study a field pertaining to world food security. On the drive home after the interview for the internship, my father talked about where he would go if given the opportunity. He said he would like to go to China because of the diversity of the people, geography, food, and culture. I had just told the interview panel that I did not have a particular place in mind to go if was chosen as an intern. However, I told them I was interested in crops and growing methods out of the ordinary compared to alfalfa, corn, and soybeans. Rice seemed to me be one of the farthest removed staple crop from these "typical" Iowa crops.

China and Rice

As the nation of China is associated with rice, so also is Yuan Longping, more specifically with hybrid rice.

Yuan Longping, co-laureate of the 2004 World Food Prize, and founder of the China National Hybrid Rice Research and Development Center, has been named the father of hybrid rice. The first research on hybrid rice in 1964 was done by Mr. Yuan, who at that time was teaching crop genetics and breeding. Professor Yuan Longping has been and still is an intricate part of this ever expanding field.

History of Hybrid Rice and Professor Yuan

In February of 1966 Professor Yuan published the first paper over hybrid rice. During 1967, with the backing of the government, Professor Yuan assembled a research team, to quicken the pace of the development of the badly needed new rice varieties.

In the winter of 1970, a break-through for hybrid rice came on the island of Hainan. There a student under Professor Yuan discovered a wild rice plant that was naturally male sterile, known as a wild abortive (WA). This finding is considered a break-through because much of the Cytoplasmic-genetic Male Sterile (CMS) lines today have some relation to this wild abortive plant.

In 1971, the government (along with Mr. Yuan Longping) setup a provincial research team in the Hunan Academy of Agriculture Sciences. Up to this time the research team that Mr. Yuan belonged to was operating out of Anjiang Agriculture School, known as the birth place of hybrid rice. The next year Professor Yuan again helped the Chinese government in setting up a nation-wide network on rice breeding (the first Chinese extension service). This national network included ten provinces and more than thirty institutes upon its founding in 1972. Through this new system, information could be shared and Professor Yuan was able to pass his new technology around China. Professor Yuan developed the first successful CMS line in the latter part of 1972.

Between 1973 and 1975, Professor Yuan and his team were able to successfully over come the three biggest obstacles in production of good hybrid rice varieties. The complications were to stabilize the maintaining ability of male sterility in maintainer lines, to find and stabilize the restoring ability in the restorer line, and to make the F1 hybrids show strong heterosis.

A fourth obstacle to make the new hybrid successful in the commercial sector was overcome in the latter part of 1975 when 80 Kg/mu (a measure of volume, Kg/~333.33m^2) seed production was reached. The previous amount of seeds able to go into the market was between 20 to 30 Kg per mu in seed production. This small seed production rate made the seeds impractical for farmers to buy and raise.

During this time of vast leaps and bounds in the hybrid rice field Professor Yuan's team of research scientists and laboratory technicians grew and grew. By the early 1980's the research team was too large for the provincial Hunan Academy of Agriculture Science. So in 1984 with the government backing, Professor Yuan Longping founded China National Hybrid Rice Research and Development Center. It is the first such center in the world specifically created for the research and development of hybrid rice.

The China National Hybrid Rice Research and Development Center is located in Changsha in the Furong district. The center and all center related satellite buildings are surrounded by walls and all the professors and their families live in the apartment buildings on the center. The main complex and phytotron (artificial growing environment) are located on a small rise from the valley where the test plots for not, only CHRRDC, but also the local agriculture college are located.

CNHRRDC Projects and General Goal

The China National Hybrid Rice Research and Development Center is intertwined with the government on many levels, from provincial to national, because much of the center's work is government backed. All of the Centers core projects are, at least partially funded by the People's Republic of China.

The goals of the programs at CNHRRDC are all to improve the quantity, quality, durability, affordability, and accessibility of hybrid rice.

There are three programs that the center is now putting much of its time and effort behind. They are: The Super Hybrid Rice Breeding program, Studies on Basics of Molecular Marker Aided Breeding for Yield Enhancing Genes from Wild Rice, and gene introduction from distant relations. The Super Hybrid Rice Breeding program consists of two sub-programs; CMS line breeding and Two-line system breeding. The studies on the program "Basics of Molecular Marker Aided Breeding for Yield Enhancing Genes from Wild Rice" are a continuation of the collaborative work done between CNHRRDC and Cornell University in 1995. The National Hi-Tech Research and Development program or 863 program promotes Photo- and/or Thermo-sensitive Genetic Male Sterile (P(T)GMS) Breeding of hybrid rice, and partially funds most CNHRRDC projects.

My Work

The work I was involved in flowed through many of the main projects that CNHRRDC is undertaking. This work was basic lab work that Ph.D. candidates and lab technicians do. However, I was allowed to assist professors and their students in these tasks both in the laboratory and in field assignments. This type of base laboratory work was a great opportunity to see how a functioning agriculture research lab operates. My schedule changed weekly exposing me to a broad array of research techniques.

The first week I arrived I was shown the different test plots and the locations of the phytotron. Dr. Q. Y. Deng introduced me to the sowing and transplanting of rice in small plots for seed production of hybrids and cold water treatment of elite Thermal Genetic Male Sterile (TGMS) lines for multiplication.

My supervisor, Dr. Deng, is a research professor in the Molecular breeding field at CNHRRDC. He obtained his PhD. in Agronomy from Hunan Agriculture University under the supervision of Professor Yuan Longping. As are many of the professors at CNHRRDC, Dr. Deng has more than one job. He is now a part-time professor at Center South University and a mentor to PhD. candidates.

Because of the type of work Dr. Deng does in the molecular breeding department, the main body of work comes during the vegetative stages of growth. Early- and middle- summer until first crop harvest and then late summer and fall till late crop harvest are usually his seasons of greatest workload of field and lab work.

The second week was the first full week of work , filled with laboratory assignments and collecting field sample. I worked with Ms. Duan Meijuan, a research scientist at the center, and her assistants. We performed screening, transforming, and transferring of transgenic plants for C4 genes indoors and outdoors.

These processes are just a few steps on the tedious road of regeneration for plants who have been genetically transformed or altered in the lab. As the new growth grows the dish must be changed and new chemicals and mediums must be used. I was involved in a step that kills the bacteria that helped the rice to regenerate. The bacteria must be neutralized so the plant can continue onto a full plant again.

The third week I worked with Dr. M. L. Cao and his students doing transformation of anti-senescence genes through a number of approaches. The transformation of anti-senescence genes is needed to slow the process of aging in a plant. The slower the aging the greater the number and fuller the rice heads can become, thus increasing the yield.

The fourth week was my first basic lesson in the two different hybrid rice techniques, Three line and Two line. Dr. Deng and I, along with some of his students, selected and moved plants from the field to the phytotron at the right stage of panicle development so to change the plant to fertile.

I was involved in the observation and recording of data in the field, treatment of plants in the phytotron, and seed production experiments. I performed these experiments with Professor C. S. Zhou and Dr. Q. Y. Deng.

Two-Line and Three-Line Explanation

As for now there are only two ways to successfully produce hybrid rice. These two are Three-Line and Two-Line hybridization. Other methods such as a genetic switch method are still in the research and development phase.

Three-Line

The first and oldest of the two methods of producing F1 hybrid rice is the CMS method. CMS stands for cytoplasmic-genetic male sterility. This genetic code is used to produce a special sterile line of rice, referred to as CMS line or A line. The A line is male sterile chiefly because many of the CMS lines have abnormal flowering developments such as irregular anther or pollen formation. Genetically, the interaction between the cytoplasm, which is sterile, and the nucleus, which contains male sterile genes, cause the sterility. A line is the first of three lines of rice in the CMS method or three-line method.

B line or the maintainer line is the second of the three lines. The only duty the maintainer line has is to multiply the A line. To do this and have offspring and still be genetically male sterile, the B and A line must be almost identical. The main difference between CMS line and B line deals with flowering. Flowering time should be the same but the maintainer line should have male fertile pollen and the abnormalities associated with the A line in the flowering process and development should be reversed.

The third line is called the restorer line (R line). The purpose for the restorer line is as "… a pollinator variety for pollinating the CMS line to produce F1 hybrids that become normal in fertility and thus can produce seeds by selfing" (Yuan et. al., 2003, pg. 11).

The R line has some desirable characteristics that the breeder wishes to have in her or his hybrid population. It is essential for the restorer line to have strong restoring ability ("i.e., the seed set of its F1 hybrids should be equivalent to that of a normal variety." from the book Hybrid Rice Technology [Yuan et. al., 2003, pg. 11]). The restorer line should also have venerable combining ability and agronomic characteristics, along with a well developed flowering system to ensure successful transfer of pollen from R line to A line.

One of the downfalls of CMS line hybrids is the amount of time and effort it takes to make a successful hybrid rice variety this way. Much of this time goes into the breeding of the hybrid seeds.

Steps Involved in Three-line Breeding

In the Source Nursery, each line is grown isolated from each other and any other outside plants as to avoid accidental cross pollination until the right time. The restorer and maintainer lines are selfed here along with CMS line maintaining.

After the correct number of A line and R line seeds are made, the test-cross and re-test cross phases are next. The testcross nursery is used to test the fertility of F1 hybrids along with screening the R and B lines. Since it is simply a test, just twenty plants are needed from each line (on average) for the testcross nursery.

The book Hybrid Rice Technology best identifies the main reason for the re-test crossing phase, it states: "To identify the restoring ability of the male parent again, in the re-test cross nursery about 100 plants are grown for each combination . . . " (Yuan et. al., 2003, pg. 23). The re-test nursery is also used to show that F1 hybrids have normal seed set. The varieties must show normal seed setting rate so the combinations can pass on to the next stage. In addition this is the first stage where F1 heterosis can be seen and recorded.

The fourth stage, called the backcross nursery, lasts an average four to six rice generations. The reason for such a long time is to make the CMS lines and maintainer lines more similar and, also to fortify the male sterility in the CMS line.

The next stage is where the evaluation of heterosis starts. The Nursery for Evaluating Combining ability is used to test and select the best CMS and R line combination. The sixth and seventh stages differ only in size.

The Replicated Yield Trial uses the promising selections from the Nursery for Evaluating Combining Ability to see how each combination does when put up against one another. The plot size is normally larger then 20 mu. The Trial is held over a one- to two- year period, and performance is based on agronomic characteristics, visual observations, and other qualities deemed necessary for combinations to be passed on to the Regional Trial (next stage).

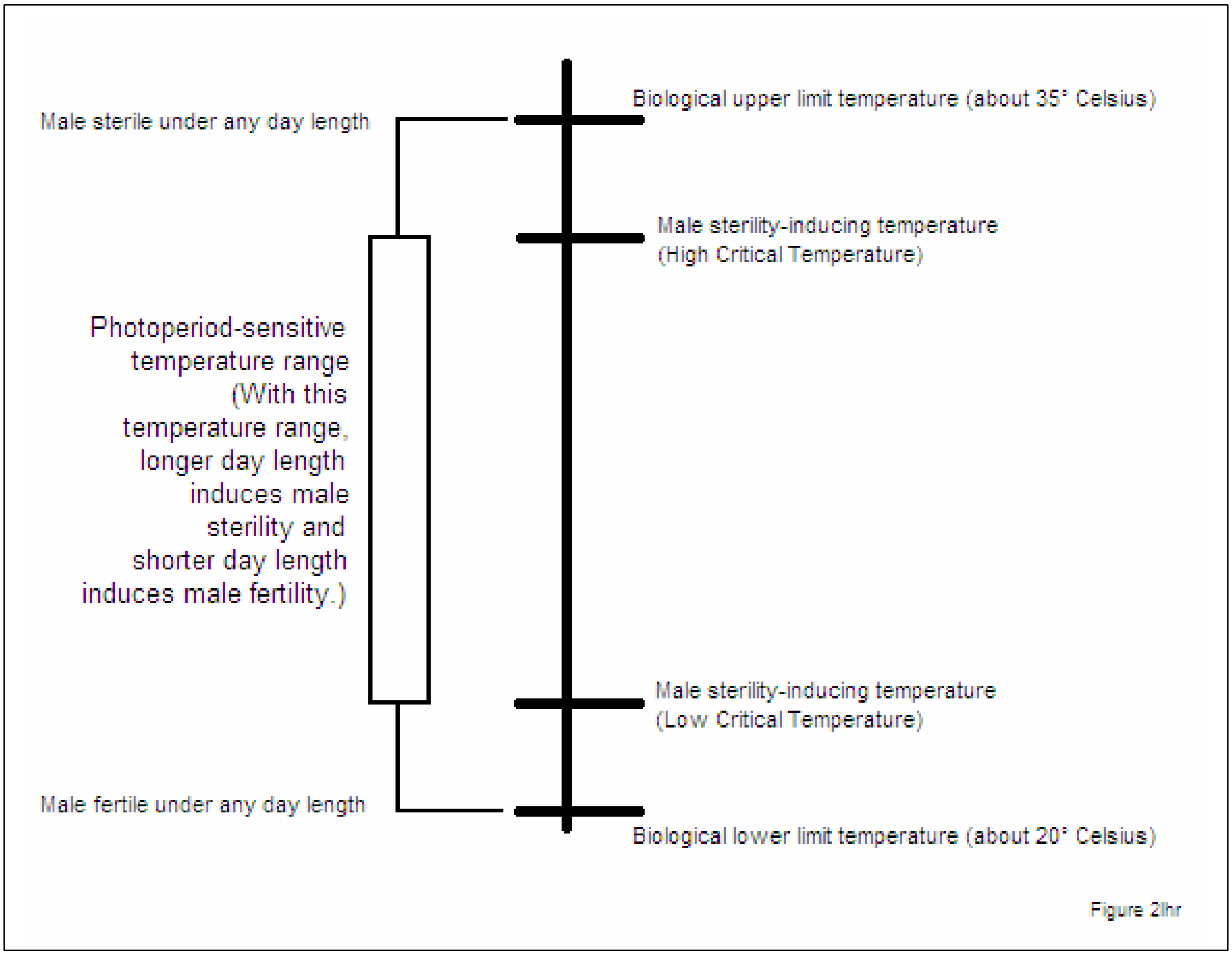
The Regional Trial determines how the new varieties will perform in different environments. The Regional Trial is held in farmers' fields from specific ecological and geographical locations. The trial along with the locations should be carried out according to the standard regulations of the area and commercial industry. After the Regional Trial, those combinations deemed worthy are officially named, marked, and put into production according to amount of interest in each combination. Also any of the steps can be by passed if an outstanding combination is found.

Two line Hybrid Rice

The second method for producing hybrid rice uses a plant type that has an abnormality in the section of gene that dictates whether the plant is male fertile or sterile depending on day- and/or temperature-length. This type of plant is known as Photo or Thermal-sensitive Genetic Male Sterile variety (P[T]GMS). Because the plant's male sterility can easily be controlled with variations in natural conditions a restorer line is no longer needed. This fact significantly cuts down the time it takes to produce new hybrid varieties because breeders no longer have to make restorer lines and check them every generation for the restoring ability.

Although it is easier to control male sterility both temperature and day-length must be factored in for P(T)GMS line breeding. As figure 2lhr, on the next page, shows there are limits on how low and high temperature can be before the amount of light no longer plays a role in inducing either male sterility or fertility

(The figure is a reproduction from the book Hybrid Rice Technology). Those temperatures that drastically affect the plant's sterility, so much that day-length has little effect on sterility are normally hard to achieve. Because of the degree of difficulty most breeders must factor in length of daylight at the plots they use.



(Yuan et. al., 2003, pg. 19)

Although pure PGMS lines have not yet been found, mostly TGMS lines have been bred. The key point for practical usable P(T)GMS lines is for the sterile parent to have very low critical male sterility-inducing temperatures. These lines thus are more useful in place of high temperature, such as tropical and subtropical climates around the equator.

As the alternative name for P(T)GMS method subjects there are only two lines in P(T)GMS type breeding. One is the P(T)GMS variety, which is switched to sterility before flowering. The second is the pollen parent or male parent. This parent is compatible with the particular P(T)GMS variety chosen and it contains feature and/or heterosis that the breeders wish to add.

When producing hybrids with the two-line method there are only two primary steps; step one is the growing of plants in the source nursery. This, like that of the CMS line breeding, is used to produce seeds for the next step. Both P(T)GMS plants and male parents are produced.

The second step is the test cross-nursery, where the two types of plants are crossed. From this nursery, pollen parents who's F1 hybrids show strong heterosis or desirable traits and high seed setting rate are chosen for further evaluation before becoming a registered restorer line for that particular P(T)GMS line.

Problems for CMS and P(T)GMS Line Breeding of Hybrid Rice

As I have already discussed the process behind each system for producing hybrid rice, it might be evident that P(T)GMS line breeding has a rather large advantage over CMS line.

The amount of time it takes to make a P(T)GMS hybrid from start to finish, on the average, is shorter than that of CMS line breeding. However, CMS line breeding has its strengths. The main benefit that breeders and producers have when they use CMS line for hybrids is the fact that three line system sterility is usually very stable. Only very extreme stresses can force a change to fertility, and usually these stresses kill or greatly harm the plant. However, the restorer gene is a very specific and strong gene and because of this only five percent of the germplasms (source varieties) can naturally restore the fertility. This restorer gene is also hard to maintain because of it specificity. So to make sure each generation of restorer line has the restorer gene, a test-cross has to be performed on each generation after multiplication.

P(T)GMS is opposite of three line in pros and cons. The largest obstacle when producing a successful hybrid line through this method is the fact that P(T)GMS genes are greatly affected by temperature fluctuations.

One way scientists think they can solve this problem is by making or finding a complete Photo Genetic Male Sterile (PGMS) plant variety. If varieties were only PGMS then only light control would be used. This premise can not be put into use until a pure PGMS line is found. Until then scientists must make a region specific hybrid, because temperature flux from lab to field conditions is a major problem.

This problem of how P(T)GMS gains and loses it fertility is also the main positive point for two line system. Because of how two line sterility works within the cell, more then 95% of germplasm (source verities) can be used to restore the sterility of P(T)GMS. This allows a much larger gene pool to be tapped into, thus increasing the genetic variation within hybrid rice.

Hybrid Seed Production and testing Areas

Professor Zhou showed me how and why certain locations were chosen for large-scale test plots and seed production. Locations must be isolated both by the amount of space between other fields (so the wrong pollen does not pollinate by accident) and the time. The time of the rice flowering around the area must be such that crossing does not occur.

New test plots being planted for The China National Hybrid Rice Research and Development Center (in front of a provincial university building).

The Agronomy of Hybrid Rice

The fifth week was spent with Dr. G. H. Ma, an agronomist at the center. We discussed various techniques to get the most out of a plot of land and a bottle of pesticide. But the main focus was on the physical characteristics of Professor Yuan's new plant type.

The crucial point of this plant type is low center of gravity for the biomass. Most traditional plants' biomass is obtained in the stocks and extra leaves of the plant. This extra height created by the stems lifts the center of gravity and raises the chances of lodging (risk of a plant falling over due to wind and/or heavy rain). To achieve a lower center of gravity, the extra leaves and stem height must be reduced, making the ideal height a semi-dwarf. The amount of leaves and lengths of stems are reduced so to increase the biomass the length, thickness, and structure of the leaf must be stronger, longer, and thicker to achieve a higher biomass.

The biomass of leaves is measured in a Leaf Area Index (LAI). To achieve this index the length of all leaves from a select number of rice plants must be measured recorded and averaged. This process of LAI is the main project I assisted Dr. Ma's students with that week.

Dr. Ma and I also discussed other key issues facing farmers that are not related to genetics. The ways the seedlings are raised, fertilizer management, plant physical structure, resistance to disease and many more factors must be added to the equation. Much of this work is carefully looked at by agronomists. The new methods need to be affordable and easy to implement

Sheath Blight, a fungus, is one of the many problems that farmers face every year.

We discussed how developing new hybrid varieties that have high yields alone does not mean that world hunger will be lessened. If these new varieties are susceptible to drought, flood, heat, insects or any number of natural conditions, then they will fail in times of need in the third world countries. Not only do breeders need to research how to build genetic resistance, but so do agronomists, agriculture engineers, and others in the affected fields of study.

Such things as identifying and improving specific transplant procedures and type can significantly raise the number of plants a farmer can obtain from one bag of grain. Such problems are not new to agronomy but only new to the hybrid rice field, a relatively recent field.

The biggest dilemma facing a field is weeds. Rice losses because of weeds in Asia have been averaged around 20% according to riceweb.org. One major factor contributing to that fact is that weeding must been done by hand, and the times when weeding would do the most good labor is often not available. For some rice farmers in Asia weeding is the activity that requires the biggest labor input. Sometimes, in upland rice fields, the field becomes so weedy that the farmer abandons the field. This shows the severity of the weed problem for part of the rice farm population. Although herbicide use is on the rise so too are herbicide resistant weeds. The herbicides also help kill the "good" bugs that reside in the field, the predatory insects who prey on those insects who harm the rice.

Insects harm a much smaller percentage of rice than the weed population. Only when opportunities arise for infestations do we see mass amount of rice destroyed because of pests like insects. Man's efforts to control pests have been partially successful, but in cases where over application and wrong usage occurs so do infestations.

The book Hybrid Rice Technology suggests a strategy called IPM for dealing with pests, disease, water management, and many more areas that rice farming needs to improve on. This strategy is a package of many suggested features such as using natural enemies of pests. "The key techniques of IPM are as follows:

- Evaluation and utilization of multi-resistant hybrids.
- Control by cultural management.
  - To disinfect the seeds with chemicals
  - To seed sparsely and raise vigorous seedlings
  - To establish suitable plant population
  - To apply organic manure and lessen nitrogen fertilizers
  - To irrigate intermittently during the whole growth stage
- Strictly control diseases in hybrid seed production plots
- Use and protect natural enemies. For example, there are 380 species of 74 families in Hunan, China, among which there are 29 dominant natural enemies such as spider and ladybug to rice insect pests.

Rationally use chemicals if needed. Chemical used should coincide with the forecast of rice disease and insect, the growth stage of rice and control threshold." (Yuan et. al., 2003, pg. 119)

I spent the sixth week with Dr. X. Q. Li. During my time with Dr. Li, I tested pollen fertility through a number of methods and also performed crosses in the test field. The sterilization of a plant variety must be known before a cross is done so it can be assumed that no outside pollen had disrupted the crossing.

The work I dealt with on my sixth week of the internship crossed over into almost all areas of study at CNHRRDC. Checking and rechecking the fertility of plants must be done at almost every step in both Two Line and Three Line hybrids.

DNA Transformation

I worked with Dr. B. R. Zhao my last official week of laboratory work. Dr. Zhao researches total DNA extraction and injection of distant relations of rice. The goal is to broaden rice genetic diversity. Genetic Engineering and DNA transformation are two methods of introduction of new DNA.

The best known and most widely practiced of the two methods is Genetic Engineering. This method is very specific, taking only the DNA the scientist wishes and putting that into the plant. However, the specificity of this process takes a very long time compared to DNA transformation. Also, only a small percentage of possible helpful DNA can be located and implemented.

DNA transformation, most specifically Genomic DNA Transformation, is much simpler and takes less time than Genetic Engineering. The biggest draw back to DNA transformation is the ratio of variant to non-variant plants. Variant plants show a trait that is different from the check (recipient plant which did not receive any new DNA). Low ratios along with the fact that the variant plants must be refined and purified are the two main detractors of this method for transferring DNA of distant relations. The simplicity of only having to extract the genomic DNA from the donor and put it into the recipient plant (without actually placing the genes in the recipient's DNA structure) so the recipient rice "decides" which DNA to include means that much more crosses can be done in a shorter amount of time than DNA Engineering..

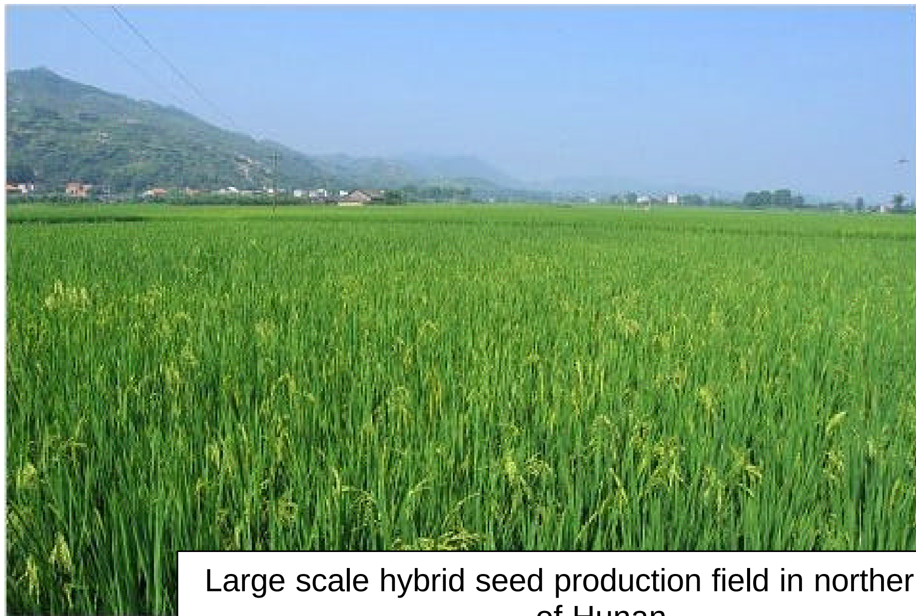
Genomic DNA transformation is chiefly practiced in China and I was involved with the DNA transformation of Barnyard Grass (Echinochloa) into rice. The extraction of DNA from the Donor (Barnyard grass) takes around two days and the introduction of that DNA depends on which method the scientist or breeder is using.

The first and easiest method of introduction is Spike Stock method. This method uses a small hypodermic needle to inject the DNA solution into the stock. The injection is done right below the panicle in the upper most internode, after the plant has undergone meisosis. From there the DNA solution is absorbed and used in producing the new seeds. This method is easiest because: each injection transfers DNA of the Donor to the whole panicle and this method does not disturb the flower or its growth process.

The Pollen Tube Pathway method is the second method for DNA Transformation. This method must be done 1- 3 hours after flowering. The rice flower is cut so the pistils (male part of the flower) are thrown out but the rest of the flower remains intact. After the pistils are removed the DNA solution is injected into the flower. The solution follows the pollen tube pathways to the naked end of the egg.

This procedure needs be done to each non-pollinated flower on a plant because each flower only has one egg, unlike other crops like cotton. After the transformed seeds are harvested the process of refining and crossing begins.

The last full week I spent traveling to a company's seed production site (picture below) and I was given a tour of a large scale hybrid seed production area. I accompanied Dr. Zhou on this trip.



Large scale hybrid seed production field in northern part of Hunan

Results

Because my schedule changed between professors I was not able to see the end product of any one of the projects in which I participated. However, I can postulate the probable outcome to some of the projects.

The DNA extraction I helped Dr. Deng's students with is part of the process of refinement and testing of new rice hybrids. Most of the plants will need to go through another backcross to refine the genes and then be put into a large-scale test plots.

Other projects that I was more directly involved with such as Leaf Area Index count with Dr. Ma are also part of a process. This specific project is one of the key factors in determining a good hybrid variety. All work done at CNHRRDC is work done toward the center's general goal of better hybrid rice varieties for the future.

Impressions

My first impression of China was a country of grandeur and beauty from the orchids in the Hong Kong terminal to the hills, fields, and water surrounding the airport. The climate is hot, similar to an Iowa August day except the humidity never dissipates and the temperature drops only a few degrees at night. I was able to measure the ambient humidity each day by the amount of time it took me to sweat through my shirt.

The people of China I met were some of the kindest people. Professor Yuan welcomed me to the center and to lunch with his family for the Dragon Festival Reunion. I experienced a large traditional meal of chicken's foot, boiled goose egg, pig's ear, strange fruits and many other items I had never eaten before much less heard of.

Dr. Deng and his daughter were most welcoming and helpful. They took time out on their weekends to take me sightseeing in Changsha and surrounding areas. They, along with Dr. Liao and Mr. Zhou, helped me celebrate my 17^{th} birthday with a cake and fireworks.

The wonderful tradition in the hotter climates in China of an afternoon break from 12 to 3 o'clock was one of my favorite parts about the Chinese way of life. This break is one thing I wish America would have as a tradition.

In July I was able to attend a Symposium at China Academy of Agriculture Sciences in Beijing. It was an opportunity to meet the other WFP interns in China and listen to world renowned speakers. I also visited the Forbidden City and Summer Palace in Beijing. I learned to always be prepared for rain or be willing to be totally soaked. The next day was also wet but Divindy, my guide, and I went to the Great Wall anyway. It is a magnificent structure.

The trip back to Changsha from Beijing was by train. It is by far the best way to travel. The scenes along the rail lines gave me a sense of another side of life; trash collectors, slums that line the tracks in Beijing, and the farmers who herd their livestock dangerously close to the fast moving cars.

YaLi Li, the son of Dr. X. Q. Li was my interpreter, guide and companion and I am grateful to him for that. He helped setup the opportunity to talk with students studying English on several occasions in their schools. These experiences gave me a chance to not only help others learn English but also learn more about Chinese ways.

During these occasions and others like them, I found that in diversity is humor. My tall height and large feet were a source of amusement and conversation.

The CNHRRDC conducts research which attracts peoples from around the world to learn about hybrid rice. During my stay at the center I met students and researchers from many rice producing countries.

China and Future Food Growth

In China, future growth in food production will come primarily from raising land productivity as the amount of new land cultivated will not increase. Grain crops such as rice and wheat are the staples for which productivity must increase to feed the population.

China's rice yields per hectare have continued to rise since 1960 due to a number of factors: increased spread of irrigation, increased use of fertilizer and improved seed stock. The use of Biotechnology has helped to develop more pest, drought, and lodging resistance rice varieties. The new varieties and techniques hopefully will be able to keep up with the increasing population of the world and the every growing amount of crop land lost to urban sprawl.

On my trips into the country I could tell that the technology both non-agricultural and agricultural was not divided equally. When the test plots that were rented by the center were being harvested there was a small combine to harvest. Smaller areas would be started by hand using electric threshers. When the ground needed to be tilled, machines with gas powered engines were used unless the field did not permit them from being used (odd shaped or new field). Water buffalo were used in these fields.

In the more rural country, water buffalo were predominant over the "mudding" machines. However, the use of machine threshers and large compactly one-man sprayers does show that the technology is moving into Chinese farming practices through China's extension service.

The Experience

An experience such as this one is both an honor and mind-opening. To go to a foreign country, learn about their culture, food, and way of life requires a person with an open mind. However, no matter how open one feels they can always be surprised by what they do and don't do when a situation arises.

This experience has shown me that in the face of a foreign language and general cultural differences you can over come and adjust. I now know how basic parts of cultures are shared throughout the world and throughout time. The farmers in China help each other out during the harvest times. In fields you can see dozens of men and women bending over, cutting, drying, threshing, and stacking rice. This is reminiscent of the era when farm families in America's heartland would gather together to put up hay or harvest the crops.

Aided with this assured knowledge that everyone is fundamentally the same, it became easier to understand how and why people from another culture lived like they do, not only in China, but all around the world.

World Food Security

My views on world food security were lightened in tone after my trip. When writing my Youth Institute essay on the silent food crisis in Haiti, I felt Haiti's food situation had little hope of getting better anytime in the near future. However, upon seeing so many dedicated scientists working to improve not only quantity but also quality, my feeling towards world food security became more optimistic.

Knowing that not only China, but also IRRI, and other food organizations and institutes were taking an offensive role against the food crisis really helped me see that everyone, no matter what their occupation can help people. I hope when I graduate from college that my road of life leads me back to Asia to help raise awareness and funds to combat food insecurity.

Acknowledgements

I give thanks to all the individuals at the World Food Prize Foundation for their work on and dedication to the Borlaug~Ruan Summer Internship program. The support of Lisa Fleming, Ambassador Quinn, Norman Borlaug, and the Ruan Family is invaluable. This opportunity is a treasure offered to students. An equal amount of gratitude goes to the staff, cooks, coordinators, secretaries, interpreters, and everyone at CNHRRDC for putting up with a rather large Iowa kid with big feet. A great deal of thanks goes to Dr. Deng, Dr. Zhou, Professor Yuan, and Yali Li. Dr. Deng was my supervisor, coordinator, and friend during my stay. Dr. Zhou is the person most responsible for allowing me to see commercial hybrid rice production and visit China's largest national park. Professor Yuan invited me to CNHRRDC and into his family gathering. Yali Li is one of my dearest friends and translator for the majority of my stay.

Many more deserve thanks, such as the students at CNHRRDC both international and domestic for making my stay educational and more enjoyable during the work week.

Conclusion

In conclusion, this experience is one that none so far can measure up to. Being allowed work along side men and women changing the world for the better by increasing food, is one I will never forget. I do regret however that I was not able to see most of the projects final form, a majority will not be finished for several years, and most are always on going.

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