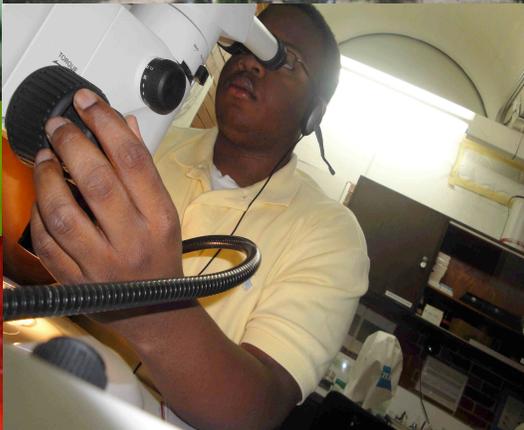
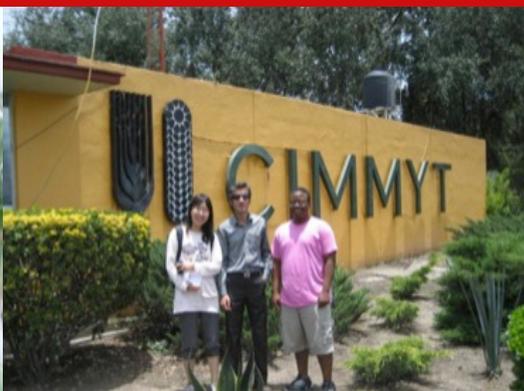


# Sowing the Seeds of Hope: Growing Solutions to Chronic Hunger One Maize Plant At A Time



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2009 Borlaug-Ruan Intern  
International Maize and Wheat Improvement Center  
El Batán, México  
June 9-August 5

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# Acknowledgements

First and foremost, it is absolutely imperative that I express my sincere gratitude to each and every person who made my internship possible. There is no way I could ever sufficiently express my appreciation for this absolute blessing. That being said, I would like to extend a special thanks to Ambassador Kenneth M. Quinn, The Ruan Family, and to the entire World Food Prize Family as a whole for their support and tireless effort to make this dream a tangible reality. I thank Mrs. Lisa Fleming for always being available to me and ensuring that I was well, you are truly the best. Thank you to Dr. Kattoula, my AP/Honors Physics teacher for believing in me and helping me believe in myself. Without your guidance and prodding, I would have never mailed my application. To Dr. Howarth Bouis of Harvest Plus, you deserve all the credit for introducing me to the WFP and making all of this possible for me from day one with your support and financial backing. I want to also thank my family and friends for being extremely supportive in my quest to do things that will make a real and important difference in the lives of people I will never get to meet.

I must especially recognize Dr. Norman Borlaug for the foresight and dedication to the cause of chronic hunger. In light of his passing, I take personal responsibility for preserving the memory of a great humanitarian who had the courage, character, determination, and zeal to take on the great task of feeding more people on this planet than anyone else along with championing the importance of ending persistent hunger in a world full of wealth. It saddens me that we live in a society where professional athletes and stars garner more attention than this man, the very personification of the beautiful good in all of us. Although I regret that I never had the honor of meeting Dr. Borlaug in person, his memory and presence will always stay with me and I think about him everyday. Without his passion and desire to feed the world, countless lives would be lost and I would be unable to benefit from the program. Even though Dr. Borlaug is no longer with us, he left behind a strong legacy that we must fiercely advance and advocate for. We all have a duty to continue our work in the name of mankind and in the name of such an inspirational, special human being. His absence has dealt a mighty blow to not only the agricultural and scientific community, but to the world as a whole. But because we work together and stand on the shoulders of a giant, we are that much closer to realizing our goal.



To my amazing supervisor Vanessa Prigge, Vielen Dank für Ihre Unterstützung während und nach meinem Aufenthalt! From my first day at CIMMYT until the moment I got into the car to head for Benito Juárez, you were of tremendous help. Everyday you made sure everything went well with me. From checking on me when I was sick to monitoring my progress in the greenhouse, I could not have achieved the competency I did in doubled haploid research without you. You tested my comprehension of concepts and helped me to understand anything I needed help on. Without your guidance, I would not have been able to travel all over Mexico for research and visiting. Your warmth and candid German honesty will never be forgotten and I will appreciate you forever. You made me feel at home thousands of miles away from Georgia by opening up your home and sharing a part of your life and work with me. I have no clue how I would have survived without you. To Norma Hernández, your genuine kindness and authentic concern for my happiness my CIMMYT experience significantly more incredible than it would have been without you. From taking care of the logistics of my arrival and departure to and from Mexico to explaining my CIMMYT employment to me, your assistance and caring nature was an essential component of my pleasant stay. Whenever I needed help, had a problem, or just wanted to talk to someone, I could always count on your help along with Dr. Kosina to make things right.



Finally, I want to say thanks to all the CIMMYT scientists, staff, and all of the friends I made in Mexico. George, Ciro, Pablo, Kate, Ricardo, Gustavo, Mary, Allison, Jiro, Dan, Deb, Yuna, Hee-on, Hu, Sangmi, Germán, Bish, Heleen, Eloise, Laura, Valentín, Mike, Mohammad, Liliana, Dr. Tom Payne, Dr. Kevin Pixley, Tania, Aldo, Elvira, and everyone in the ABC Labs, I took away special memories from each of you during my stay. Your hospitality and fun times still resonate with me long after the fact and I am proud to have been able to forge relationships with all of you.

## My Personal Background/Youth Institute

My name is DeAndré Harper. I am currently a freshman at Georgetown University from Atlanta, Georgia studying Modern Languages at the Faculty of Languages and Linguistics and International Politics. As a student from Hillgrove High School in Powder Springs, Georgia, I attended the Youth Institute in October of 2008 after writing a paper on food security and the impact of environmental degradation in Costa Rica. Dr. Howarth Bouis of HarvestPlus brought the World Food Prize to my attention and intrigued my interest in attending the symposium because in Georgia, The World Food Prize was relatively unheard of. Before Dr. Bouis, I had never heard of the foundation. I found myself interested in the internship program after witnessing the immense concern and passion the attendees and special distinguished guests had in regard to solving global chronic hunger. I remember one story in particular at the Hunger Banquet where a woman from Kenya lived in a household where her mother was left to fend for herself by her father with nine children to feed and care for alone while he took another wife. After I heard that story along with many others, I became forever committed to the cause of erasing chronic hunger. When I heard the accounts of the previous interns, I was quite intimidated. I sat in awe and could not fathom that I would be able to do anything remotely like what they had done. After all, I had absolutely no background in agriculture. Now, many months later, I sit here writing my intern report.



**Figure 1** Taking a break from the fields of Agua Fría where temps regularly to 105 °.

## International Maize and Wheat Improvement Center

During the summer of 2009, I spent my internship at El Centro Internacional de Mejoramiento de Maíz y Trigo. The International Maize and Wheat Improvement Center, known by its Spanish acronym, CIMMYT, is an international, not-for-profit research and training organization. With partners in over 100 countries, the center applies science to increase food security, improve the productivity and profitability of maize and wheat farming systems, sustain natural



**Figure 2** The main entrance and gates to CIMMYT Headquarters in El Batán/Texcoco where I worked and lived.

resources in the developing world, and stomp put poverty in the developing world. The center's outputs and services include improved maize and wheat varieties and cropping systems, the conservation of maize and wheat genetic resources, and capacity building.

CIMMYT belongs to and is funded by the Consultative Group on International Agricultural Research (CGIAR) and also receives support from national governments, foundations, development banks, and other public and private agencies. In 1944, Dr. Norman Borlaug was appointed geneticist and plant pathologist assigned to organize and direct the Cooperative Wheat Research and Production Program, a pilot program sponsored by the Government of Mexico and the Rockefeller Foundation. The program was dedicated to conducting research in a multitude of disciplines, including plant breeding, entomology, cereal technology, genetics, agronomy, plant pathology, and soil science so that the wheat shortages present in Mexico could be addressed. At that time, Mexico's farmers raised less than half of the wheat necessary to meet the demands of the population, frequently losing much of the harvest to rust disease. After working for 13 years, Dr. Borlaug and his team managed to develop shorter wheat varieties that were rust-resistant and produced higher yields, while responding better to fertilizer than the older varieties. His work led Mexico to become self-sufficient in wheat production by 1956 – a tremendous feat for the developing nation. Dr. Borlaug's wheat sparked what came to be known as the Green Revolution – suggesting that plant breeding could end world hunger. In the 1960s, other countries adapted the so-called "Mexican innovation model," hoping for the same success. In the late 1960s, the Rockefeller Foundation and the Government of Mexico expanded the Cooperative Wheat Research and Production Program into what is today The International Maize and Wheat Improvement Center.

# The Global Maize Program

CIMMYT's Global Maize Program specializes in breeding varieties of maize that are high yielding and adapted to withstand specific environmental constraints. Center scientists use both traditional cross-breeding as well as modern high-technology methods such as molecular markers to develop new varieties. Additional efforts focus on a variety of agricultural aspects such as proper seed storage, natural resource management, value chains, the benefits of using improved seed, and appropriate machine use and access. Maize is the most important cereal crop for food in sub-Saharan Africa and Latin America, and a key feed crop in Asia. Declining soil fertility and environmental stresses like drought, insects, and diseases affect crop production and health in less developed regions. Climate change and degraded soils threaten the food security of millions, especially in sub-Saharan Africa. Lack of access to seed and other inputs, underdeveloped markets, and low investment in research and extension worsen farmers' marginalization in low-income countries. Partners include national agricultural research institutions, non-government and community-based organizations, seed sector organizations, regional research networks, other CGIAR centers, private companies, and advanced research institutions worldwide. Generous support for the Global Maize Program's work comes from national governments, international funding organizations, foundations, and agencies, and private companies. Since many of CIMMYT's resources are directed into this program, I developed a quick interest in the technology integrated with the science after taking over nine honors, advanced and Post-AP science courses in high school.

## Drought Tolerant Maize for Africa Initiative

Drought has an overwhelming importance to Africa, affecting people's livelihoods, food security and economic development. Effective approaches to combat current impacts of drought and the looming threats of climate change are of uttermost importance. The DTMA Initiative joins the efforts of people, organizations and projects supporting the development and dissemination of drought tolerant maize in Sub-Saharan Africa (SSA). The work builds on CIMMYT's recognized efforts to develop and perfect the science of breeding for drought tolerance in maize.

### The Drought Tolerant Maize for Africa (DTMA) Project

The Drought Tolerant Maize for Africa Project is part of the DTMA Initiative and is supported by the B&MGF and Howard G. Buffet Foundation to accelerate drought tolerant maize development and deployment in 13 countries in SSA.

### Rationale

Maize is life to more than 300 million of Africa's most vulnerable. It is Africa's most important cereal food crop. When recurrent droughts in Sub-Saharan Africa ruin harvests, lives and livelihoods are threatened, even destroyed. And unfortunately, the situation may become even worse as climate change progresses. Developing, distributing, and cultivating drought tolerant maize varieties is one highly relevant intervention to reduce vulnerability, food insecurity and the damage to local markets accompanying food aid in Sub-Saharan Africa.

### Drought tolerant maize varieties – a reality?

Maize is by nature a highly diverse crop and its tolerance to drought can be significantly enhanced through appropriate breeding techniques. CIMMYT and IITA have been working for over 10 years with national agricultural research institutes to adapt these breeding techniques to Sub-Saharan Africa. As a result, over 50 new maize hybrids and open-pollinated maize varieties have been developed and provided to seed companies and NGOs for dissemination, and several of them have reached farmers' fields. These drought tolerant maize varieties produce about 20-50% higher yields than other maize varieties under drought. I was assigned to this program and I stuck with it because the work is so important to many rural farmers and remote populations around the globe. Without this work, what would they do?

The Global Maize Program encompasses the following programs/projects:

Insect Resistant Maize for Africa (IRMA)



Drought Tolerant Maize for Africa Initiative (DTMA)

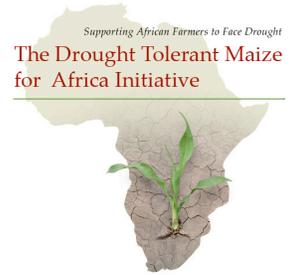


Water-efficient Maize for Africa (WEMA)



Effective Grain Storage Project

Consorcio Sudamericano de Maíz (CONSUMA)



## The Goals and Missions of the Program

The Global Maize Project, through research like or similar to my research, seeks to use maize, one of the three major staple foods in developing countries, to:

- Provide diverse, high-yielding varieties that withstand and thrive in infertile soils, drought, insect pests, and diseases.
- Conduct crop and natural resource management research to help farmers exploit the full potential of improved seed and to preserve and enhance soil and water resources.
- Explore new market opportunities for smallholder farmers.
- Work with a range of partners to generate and share knowledge and techniques, ensuring that research results reach farmers' fields and make a difference.
- Offer a rich assortment of training opportunities in maize breeding and crop management research (in-service courses, visiting scientist appointments, pre- and post-doctoral fellowships, among others).

## Background of People I Worked With

This summer, I worked primarily with **Vanessa Prigge**, a Ph.D. student at Universität Hohenheim in Stuttgart, Germany, **George Mahuku**, a Senior Scientist and Pathologist from Zimbabwe, **Gustavo**, a temporary worker in the bodega who was a great help to me throughout the entire summer, and **Ciro Sánchez**, a CIMMYT Head Technician in charge of physiology and doubled haploid field trials. I also had the great pleasure of working with **Dra. Natalia Palacios** and **Dr. Kevin Pixley** working with maize that is genetically fortified and bred for high vitamin and micro-nutrient content, especially pro-Vitamin A, in both the laboratories and field station trials.

## Background for Experiment

### What were the objectives of my study?

The objectives of my study were to find tropical and subtropical maize germplasm that displays a high spontaneous chromosome doubling rate after in vivo haploid induction and to study male and female fertility in haploid plants of tropical origin.

### Haploid vs Diploid

"Haploid" refers to the number of chromosomes in a reproductive cell, like sperm or ovum. In grasses like maize, the reproductive cells—pollen and ovules—contain half the chromosomes of a full-grown individual. Fertilization

joins the genetic information from the two parents, and offspring carry paired sets of chromosomes, reflecting the diversity of each parent. Haploid maize has 10 chromosomes. Diploid maize has 10 pairs of chromosomes.

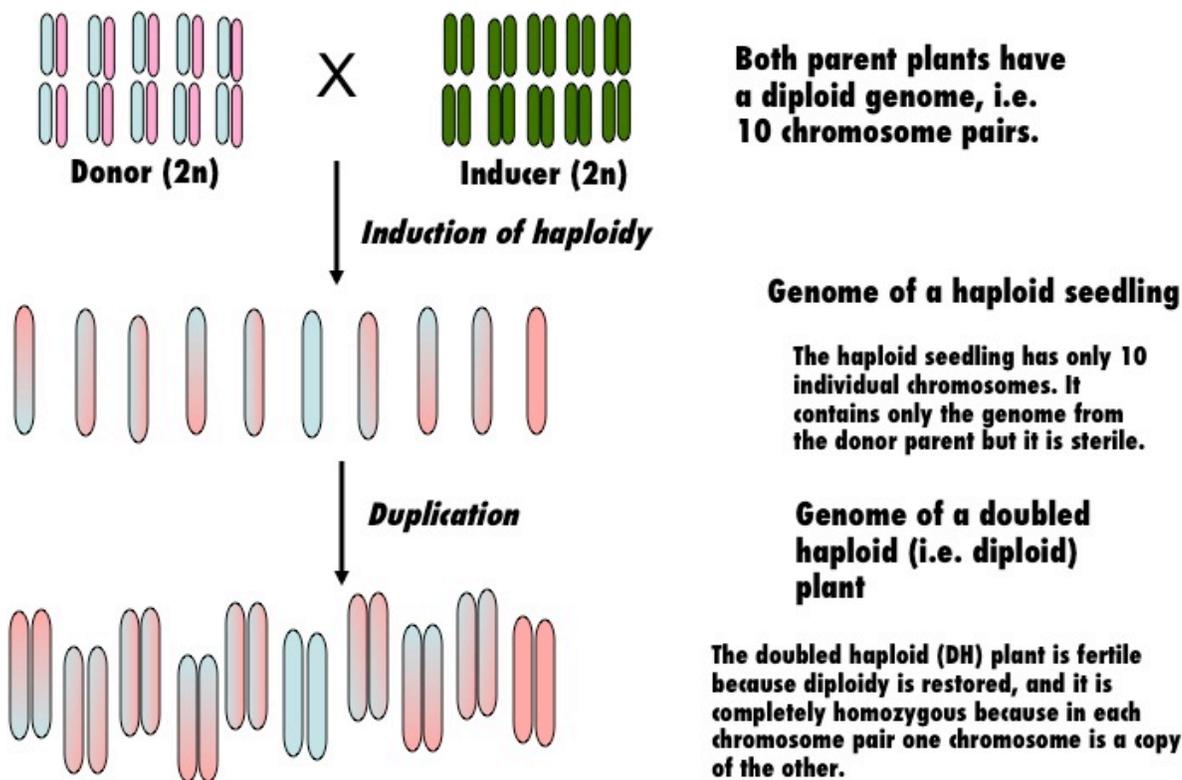
## What does the DH Technique allow us to do in our study?

The DH technique allows breeders to speed up the development of homozygous inbred lines and, therefore, new and improved hybrid or synthetic maize varieties reach farmers' fields earlier. This study seeks to identify germplasm that, when incorporated into current breeding materials, will enable breeders to produce DH lines without the necessity to apply toxic and environmentally hazardous mitotic inhibitors such as colchicine for chromosome doubling of haploid plants. Especially for maize breeding programs in developing countries which may not have access to colchicine or lack facilities and safety measures for its handling, the results expected from this study will greatly facilitate application of DH line development for accelerated release of improved varieties.

## Principles of The DH Technique

**Donor-** gives genes to be expressed

**Inducer-** a molecule that starts gene expression through transcription.



## Through what steps can our work in this process be achieved?

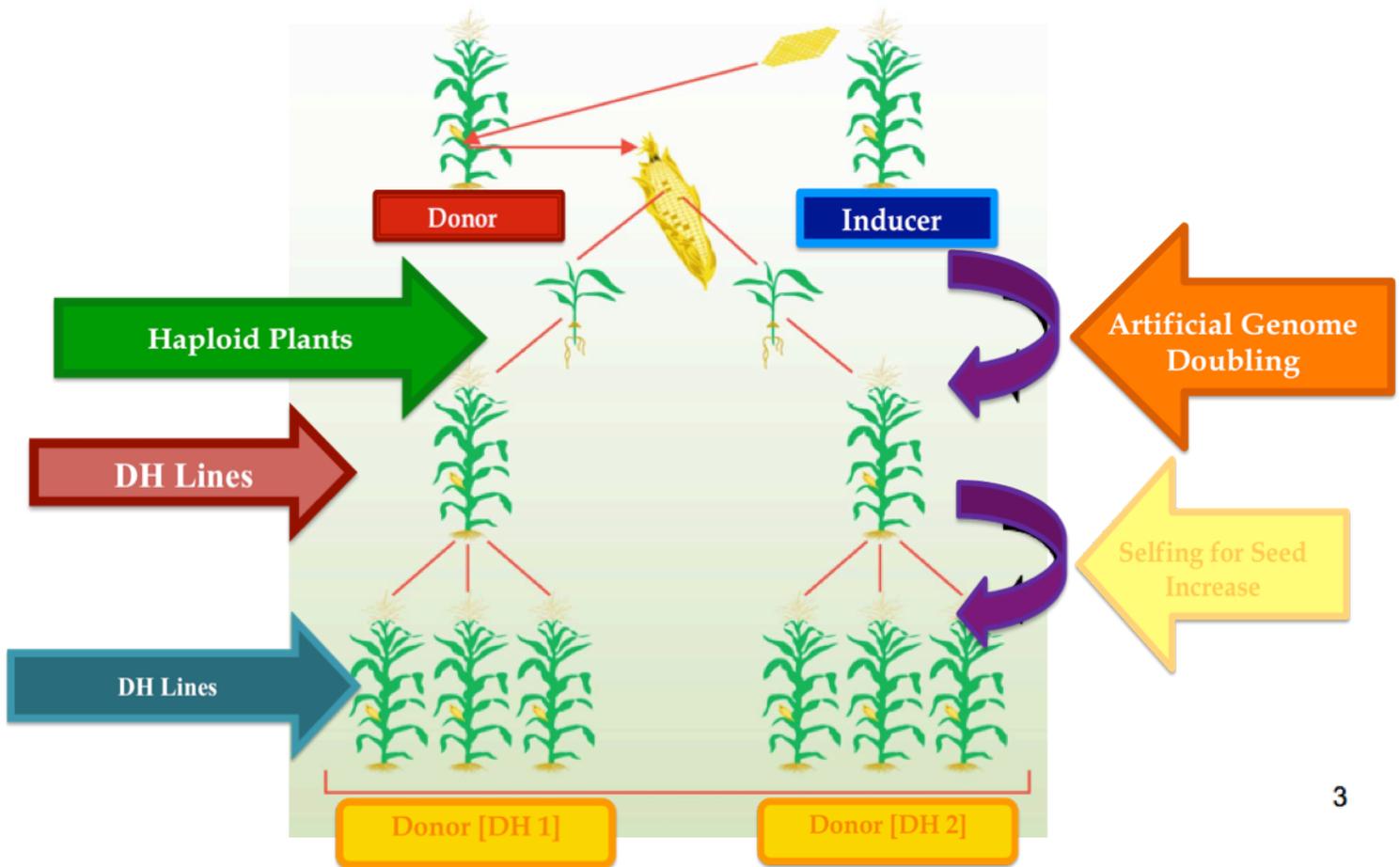
- Induction cross using inducer genotypes
- Identification of kernels with haploid embryo
- Artificial genome duplication→ generation D<sub>0</sub>
- Selfing→ generation D<sub>1</sub>

# The DH Technique/Research

## How do we create doubled haploid lines by in vivo haploid induction?

Traditionally, inbred lines were formed by subsequent selfing for 6-8 generations. Although the breeders evaluated the lines already in early generations, it took at least 6 agronomic cycles until the line was sufficiently homozygous, about 99.2% pure, to expect that it would not change its performance anymore. Using the doubled-haploid (DH) technology, we can generate completely homozygous inbred lines in only two cycles that are genetically 100% pure. Next to this immense saving of time, there are other advantages compared to the traditional method of inbred line development which will be discussed shortly.

The basic principles of the DH technology are completely homozygous (i.e. genetically stable) inbred lines are produced from heterozygous (i.e. segregating) material via a haploid stage. The segregating donor material is pollinated by an inducer genotype which has the ability to induce haploidy. Planting seeds with a haploid embryo results in haploid plants that have only 10 single chromosomes instead of 10 pairs of chromosomes and are not fertile. To restore their fertility and enable us to multiply their seed, haploid seedlings are treated with a chemical that doubles their chromosome set, i.e. makes a copy of every chromosome. This generates diploid plants that have 10 chromosome pairs and are fertile. Since one chromosome of each pair is a copy of the other chromosome of the same pair, the resulting plants are completely homozygous. And it took only two cycles to develop these completely homozygous inbred lines: induction cross in cycle 1, artificial genome duplication in the off-season followed by transplanting to the field, and selfing for seed increase in cycle 2. The next pages will explain the required steps visually in more detail.



**Figure 3** This diagram illustrates the process that starts with the donor and inducer materials and how they advance through the DH process to the desired results of homozygous, stable lines that do not change.

## Step One: The Induction Cross

CIMMYT uses specific maize inducer genotypes that, when used as pollen parent, have the ability to trigger development of haploid embryos in the seeds resulting from this so-called induction cross. For an efficient production of haploids, the rates of induction have to be high. The rate of induction is defined as the number of seeds with haploid embryo divided by all seeds investigated. These rates vary from 2% to 10% depending on the inducer used. An induction rate of 8 to 10% is common among currently employed inducer genotypes at CIMMYT.

The induction rate is the number of haploid kernels divided by the total number of kernels harvested. For example, an induction rate of 10 % means that an ear with 300 kernels bears 30 kernels with haploid embryos. To identify seeds with haploid embryo requires a marker phenotype. For example the lines RWS and UH400, the two inducer lines employed by CIMMYT, pose a red marker in the embryo and the stem. Due to their Central European origin, they are badly adapted to the Mexican tropical environments. Attempts are currently being undertaken at CIMMYT to develop better adapted inducer genotypes that can successfully be used for in vivo haploid induction in tropical environments. Additionally the inducer has to produce enough pollen and has to have acceptable agronomic characteristics to facilitate maintenance. The donor plants, which are crossed with the inducer, have to be a type of heterozygous germplasm.

Characteristics of the inducer:

- High induction rate (8-10%)
- Embryo & endosperm marker (R1-nj)
- Antocyanine stalk color marker
- Good pollen production

Inducer	Induction rate [%]	Reference
Stock6	2.3	Coe 1959
WS14	2.0 – 5.0	Lashermes y Beckert 1988
KEMS	6.3	Shatskaya et al. 1994
RWS	8.12	Röber et al. 2005

Characteristics of the donor:

- Heterozygous
- Non-antocyanine colored (preferably white & yellow germplasm)

RWS has the most favorable induction rate!



**Figure 4** The poorly adapted inducers RWS and UH400 do not fair well in the Mexican climate. However, while these lines are ugly and do not look healthy, the cross produces a beautiful and uniform product that is well-suited for use in the DH technique.

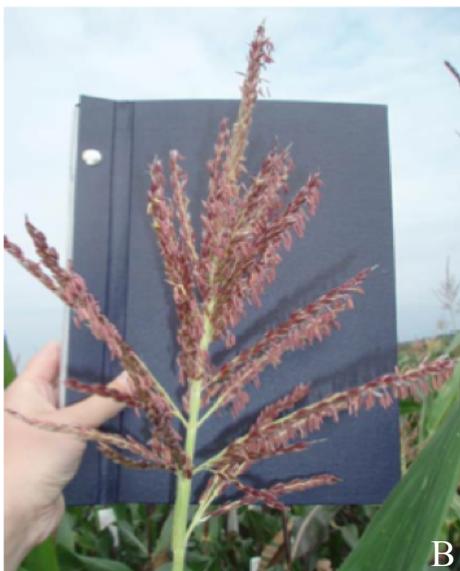


**Figure 5** Protecting and cutting back silks

Shoot bagging is designed to prevent pollen from landing on the emerging silks and occurs daily once the corn has begun tasseling. The young shoots emerge where leaves join the main stalk (a). As soon as the shoot tips are visible, they need to be protected with a shoot bag as the silks will push up the young husk leaves. Shoot bags can be used to gently separate the shoot from the stalk (b-c) before placing the bag over the shoot tips (d). Shoot bags should be tucked securely against the stalk to prevent them from blowing or falling off (e). When the silks are visible through the shoot bag, cut them with a knife to a length of about 1/2 - 1 inch long (f) and replace the shoot bag until pollinated. To pollinate, remove the shoot bag from silks previously cut and pour pollen from tassel bag onto receptive silks. Cover ear with empty tassel bag and secure to main stalk. Harvest ears when mature or dry.

## Visual and Scientific Criteria for Selecting Inducers

To classify how valuable and purposeful inducers are for our use with the Double Haploid technique, the following criteria are equally assessed of each material. The criteria are (A) antocyanine colored stalk with a rich coloration, (B) a big, highly branched tassel with good pollen production, (C) the flowering time is around 70-80 days, coinciding better with tropical material, (D) good plant and ear aspect, (E) antocyanine colored endosperm and embryo, and (F) high in vivo haploid induction rate.



## Step Two: Identification of kernels with haploid embryos

I had to carefully classify all kernels harvested from the induction crosses according to the scheme shown below in order to distinguish between kernels with haploid and diploid embryos. The kernels with white embryo and blue endosperm are the ones of interest for DH line production since their embryo is haploid and contains only donor genome. Only these kernels were subsequently advanced to create DH lines. The kernels with both a blue embryo and endosperm were normal F1 crossing kernels containing in their embryo genetic information from both the donor and the inducer. If the kernel's embryo and endosperm were both white, then it was normally a contamination issue and they were discarded.

### Clasificación de granos:

- Categoría 1: Embrión blanco + Endospermo blanco  
 ⇨Autofecundación, contaminación o inhibición
- Categoría 2: Embrión azul + Endospermo azul ⇨F1 (Diploides)
- Categoría 3: Embrión blanco + Endospermo azul ⇨Haploides



**Figure 6** A visual and text description of how we classify the kernel types and what we use, haploids (Category 3).

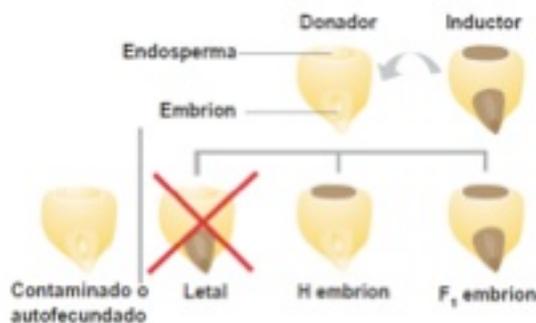
### Selection of the haploid seeds

The key to successful commercial application of the double haploid technique is a system for efficient selection of the haploid seeds. The selection is based on distinguishing between haploid embryos and diploid embryos. Visual markers associated with a color, morphological and biochemical markers can be used for identification.

The marker for identification have to possess the following characteristics:

1. easy, cheap and early detection
2. sure to distinguish
3. independent of the environment and the genetic wealth of the donor
4. dominant expression (e.g. R1-nj (Nanda and Chase 1966, Neuffer et al. 1997).

For example the R1-nj gene belongs to a family of genes that regulate the expression of anthocyanin pigment. The R1-nj allele produces a phenotype with scutelum and purple aleurone grains F1 (Li et al. 2001). These two features can be used as marker in the embryo and the endosperm.



**Figure 7** This diagram shows the different types of kernels, where we desire the H embryo in the middle above. Kernels with no color are contaminated and unable for use, blue embryos and kernels are false plants (diploids), and the white embryo and blue endosperm are what we select out for use.



**Figure 8** Working in the bodega with other workers and scientists sorting and classifying maize kernels.

## Step Three: Artificial Chromosome Doubling

### Germination of Haploid Seeds

The seeds are usually germinated and left over a course of several days covered in a temperature-controlled warehouse room.



### Preparation of seedlings for colchicine treatment

Once the germinated seedlings have a coleoptile length of about 2cm, their tip is cut to allow for easy penetration of the colchicine solution during the treatment.

### Chemical treatment over night

The prepared seedlings are immersed in colchicine solution for 8 hours over night. Only specially trained staff may handle this staff and personal protective equipment including respiratory masks need to be worn at all times.



### Plant into pots

After treatment, the seedlings are potted and recover from the treatment and regain



and left in the greenhouse for a few days to strength.

### Transporting to the field station

The small plantings are prepared and put in crates to be transported to the appropriate field station for trial planting and growth.



## Transport to the Field

Once the plantings arrive, they are simply placed into the ground in their biodegradable containers, irrigated, and the monitoring begins.

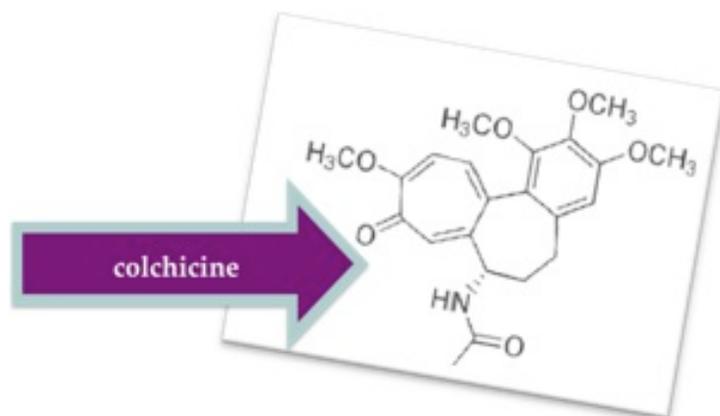


## Colchicine

Colchicine is a plant alkaloid that works as mitotic inhibitor. Mitosis is the process of nucleus division in somatic cells. After DNA replication, the microtubules pull the duplicated chromatids towards the two poles. Following, the cell divides into two daughter cells. Colchicine disrupts mitosis by binding to tubulin. In this way the formation of microtubules and the polar migration of chromosomes is inhibited. The result is a single cell with doubled chromosome number.



**Figure 9** Colchicine inhibits mitosis, which subsequently results in one diploid cell with duplicated chromosomes.



## Step Four: Self Pollination for Seed Increase/False Elimination

I pollinated in order to create more seeds to grow, test, and check material that was viewed as promising for my study. While the plants of my study were growing in the greenhouse, I had the chance to learn from the staff of Agua Fria's experimental station on how to self- and cross-pollinate maize plants. Also, I learned that the female flower ("jilote" in Spanish) needs to be shoot-bagged (or "jiloteado" in Spanish) before its silks emerge so that no unwanted pollen fertilizes it and controlled pollinations can be performed. "Jiloteando" consisted of covering the female flowering of the silk before it began to emerge and could be pollinated outside of our desired and controlled pollinations. Also as an essential component of the fourth step, I had to eliminate false F<sub>1</sub> plants because they rob other plants that are important to our study and trials of nutrients, light, water, space, and large and deep root system span. On top of that, the false plants are already double haploids. They can contaminate other haploid plants when it is time for female silks to emerge, potentially making material that could be useful for our purposes meaningless. Their vigor and size prove that they are already diploid. The goal is to find fertile haploid material in our trials that is promising and that we can advance in the future. In addition, false plants easily till over and can harm or destroy other plant material that can possibly be haploid. We seek haploids, which are absent of stalk color and without the same endosperm and embryo color as double haploids.



**Figure 10** I performed pollinations in the fields of Agua Fria transferring pollen in bags to the silks of desired plants.



**Figure 11** Examples of false plants established in our trials. As you can see, the  $F_1$  diploid plants are very vigorous, have wide and hanging leaves, and purple stalk coloration. They tower over all of the other potentially haploid.

## Materials

For materials, haploid seeds of 90 donors (30 landraces, 30 improved open-pollinated varieties, 30 single crosses) were planted in 5 seed plots in a lattice experimental design with two replications in the greenhouse in El Batán during the 2009B cycle (April-November). These donors were current maize breeding populations and were kindly provided by CIMMYT breeders from Zimbabwe, Colombia and Mexico. They had been crossed with haploid inducer genotypes in 2008A cycle to produce the haploid seeds via the processes described earlier. We recorded several data on agronomic and fertility-related properties on an individual plant basis (See list of recorded traits on next page). Before flowering, we put shoot bags on the female flower to protect the silks from pollen contamination. If pollen was available, we self-pollinated the plants. Two self-pollinations in two consecutive days were performed if anther score was  $>1$ , i.e. no pollen was visible upon touching. We used countless laboratory supplies including Farmer solution, enzyme solution, pipettes, graduated cylinders, mini plastic jars, alcohol, seeds, plants, pollination bags, microscopes, petri dishes, cameras, root tips, glass slides, Kim-wipes, computers, Fieldbook software, journals, pencils, pens, blades, boots, hands, feet, and everything else imaginable in the fields.

## Methods

We used a few methods to ascertain the condition of our maize materials.

- Visual assessment of ploidy level (haploid or diploid) based on plant habitus on every individual plant of the experiment
- Confirmation of ploidy level on one representative plant of each plot by counting chromosomes in root tip squash samples (using chromosome counting to identify the samples I worked with as either haploid or diploid maize, I collected root tips, treated them in a solution to inhibit further division, macerated the root samples, and spread them onto a slide to view and count)

A pollen viability test was initially planned to be performed in the experiment to assess pollen viability of haploid plants. This involved collection of pollen and germination of pollen grains on a specific medium, followed by incubation for 2 hours and, subsequently, counting under a microscope the number of pollen grains that grew a pollen tube. I did some initial practices on this technique but we later on discovered that most haploid plants produce few to no visible pollen and, therefore, decided that we would rather use this pollen for the self-pollination instead of a germination test. And, we originally wanted to use the flow cytometer machine at CIMMYT to assess whether particular plant samples were haploid or diploid, but the CIMMYT machine had not been used in a decade and did not function properly. Thankfully, CIMMYT was able to work out an agreement with a scientist and professor from UNAM (Universidad Nacional Autónoma de México) in Mexico City where we could check a certain number of samples per visit to the university.

## Data Collected

With each plot sample, we collected the number of plants that germinated out of five seeds, the rate of germination of the seeds, the number of false plants in each plot of a particular maize plant, the rate of misclassification of the plants, visual ploidy (based on our hypotheses), ploidy analysis over two samplings, the date of male flowering, the date of female flowering, the color of the plant's stalk, the plant height, the ear height, the number of seeds per ear, the anther scoring, the number of tassel branches, and the viability of the pollen in a series of fieldbooks created in Microsoft Excel and with other software.



**Figure 12** The photos to the left illustrate the different anther scores from left to right. Score 1: Many anthers have emerged on main and side branches; pollen is released upon touching anthers  
Score 2: Many anthers have emerged on main and side branches; no pollen is released upon touching anthers  
Score 3: Several anthers have emerged on main branch; no pollen is released upon touching anthers  
Score 4: One or few anthers have emerged on main branch; no pollen is released upon touching anthers  
Score 5: No anthers have emerged

## Chromosome Counting

### Lots of Data to Analyze

We spent weeks analyzing hundreds of white root tips after treatment under the microscope visually counting the chromosomes we saw each time which takes a great deal of trial and error. Pablo, sitting to the left, had a great deal of expertise in this area and graciously took time out from his own work to help us. After watching Pablo a few times and understanding his technique, I was able to continue the work on my own along with my supervisor and go through hundreds upon hundreds of sampled and treated newly-grown root tips from the maize plants in our trials.



### Collecting Samples

It took careful digging and several times to collect decent root tips for analysis. Sometimes if the maize plants were dry for an extended period of time, it was very difficult to find new, white growth. We had to clean out dirt, discard bad samples, guard against leaving the samples in the warm bath too long, and letting the samples dry out.



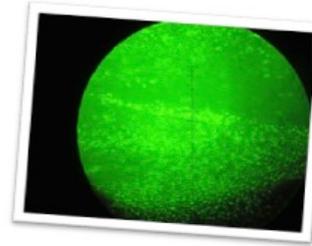
## Cutting Root Tips

After cutting the root tips from the very bottom of the maize plants, we had to VERY carefully cut roots in just the right spots to be able to see chromosomes on the slide under the microscope after we gently chopped up the samples of white root tips.



## Under the Microscope

Once we had the slides under the microscope for viewing after a great deal of preparation and days of work, we had to carefully view microscope imaging and distinguish between debris, undivided clusters, and hidden chromosomes within clusters on the maize root tip slides.



## Chromosome Counting Procedure

1. Dig up around maize plant and take 1cm of a new white tipped root, paying attention as to not damage other roots.
2. Label tube with Plot #, Plant #, and number of roots sampled before putting roots in hydroxquinoline.
3. Wash root samples with distilled H<sub>2</sub>O, wash with cold (14°C) 0.01 citrate buffer solution for 20 mins, then incubate root tips back in their cases.
4. Use the pipette to add distilled H<sub>2</sub>O on the slide to prevent tips from drying out. Take up root tips with a Pasteur pipette w/wide opening and transfer tips to a small glass filled with distilled H<sub>2</sub>O and leave for 10-20 mins before slides are made.
5. Transfer roots to a glass slide and cut the meristematic portion, the part most important for our analysis.
6. Using the Pasteur pipette, transfer individual root tips to onto an ethanol washed glass slide. Then, chop up the root and spread it rapidly on the slide.
7. Put one drop of acetic carmine (dye) onto slide and cover it with cover slip and put prepared slide under microscope using a 20x objective and grey filter.



## Results and discussion (for data analysis study 3, GH trial)

### Evaluation of agronomic and fertility traits

- Of the 900 seeds initially planted in the experiment, 517 were used for data collection.

For discussion:

The remaining 373 plants did not germinate, died during the course of the experiment, or were eliminated actively. Active elimination occurred because they were considered “false” crossing plants. Since identification of seeds with haploid embryo is based on a phenotypic marker being scored by humans, misidentification occurs at varying rates depending on the donor genotype (i.e. the intensity of marker expression) and possibly also the person performing the seed classification. Hence, it happened that diploid F1 crossing kernels were planted in the experiment which had to be eliminated to reduce pollen contamination. F1 plants are easily identifiable by their high vigour, wide and hanging leaves, and purple stalk coloration. We eliminated a total of 171 plants. Poor germination may have been caused by recessive alleles negatively affecting processes associated with germination. Since there is no compensation for negative deleterious alleles in the haploid stage (i.e. no positive allele from the other chromosome can counterbalance the negative effect as is the case in diploid plants that possess pairs of chromosomes).

- Average germination rate was more than 80% (Table 1).
- Assessed across the whole data set, anthesis occurred slightly later than silking

For discussion:

This is unusual. Normally male flowering occurs first and silking can be especially delayed under stress conditions. For example, under drought stress the anthesis-silking interval (ASI) is a measure for stress adaptation: the smaller the interval the better the plant tolerates the stress.

From the literature it is known that in haploid plants male fertility constitutes a bigger problem than female fertility (Chalyk 1994, Geiger et al. 2006). Difficult detection of the generally only few emerged anthers may thus have played a role in belatedly determining male flowering time.

Table 1: Mean, minimum, and maximum values of 13 agronomic and fertility-related traits recorded on individual plants calculated across the whole experiment.

<b>Agronomic traits</b>	<b>Germination Rate [%]</b>	<b>Days to Anthesis</b>	<b>Days to Silking</b>	<b>Stalk Color</b>	<b>Plant Height [cm]</b>	<b>Ear Height [cm]</b>		
Mean	81.40	90.87	88.18	4.19	106.91	58.83		
Min	20.00	69.00	69.00	1.00	30.00	5.00		
Max	100.00	114.00	112.00	5.00	335.00	190.00		

<b>Fertility traits</b>	<b>No. of Tassel Branches</b>	<b>Anther Score</b>	<b>No. of Seeds per Ear</b>	<b>Ear Aspect</b>	<b>Grain Texture</b>	<b>Grain Color</b>	<b>100-Kernel Weight [g]</b>
Mean	10.61	3.48	42.11	4.99	1.06	1.88	17.60
Min	1.00	1.00	1.00	1.00	1.00	1.00	5.00
Max	33.00	5.00	364.00	5.00	5.00	2.00	40.74

- The majority of the plants had green stalk coloration (score 5) with at most some purplish coloration on the bottom of the stalk (score 4) as often occurs in young plants or under semi-optimal nutrient supply. This was expected since all putative F1 plants had been eliminated before. Nonetheless, seven plants with haploid plant habitus showed a purple stalk coloration (score 1). Four of these had been derived from landraces (from Chad, Tanzania, Mexico, and USA), one had been derived from a Zimbabwean OPV, and two from single crosses from Mexico and Zimbabwe. Only one plant (derived from the Tanzanian landraces) yielded 5 kernels, for the remaining anther score was 5 indicating that no anthers had emerged and, consequently, no pollination could be performed.
- Plant height ranged from 30cm to more than 3m while ear height ranged from 5cm to almost 1,5m (Figure 1).

- The number of tassel branches per plant ranged from 1 to 33.
- Average anther score was 3.5 but all types of tassels from fully set with anthers and producing lots of pollen to no anther emergence at all had occurred on individual plants.
- The average number of seeds harvested per ear was 42.11 (range 1-364) and the average 100-kernel weight was 17.6 (5.0-40.7).

For discussion: These numbers are misleading because many of the fully set ears (i.e. kernel numbers > 250 and high 100-kernel weight) may not have actually resulted from haploid or spontaneously doubled haploid plants but from Cat1 seeds (i.e. seeds with non-colored endosperm and non-colored embryo that may have resulted from outcrossing with a non-colored genotype in the initial haploid induction cross). After planting all harvested ears in the field in Agua Fria in 2010A (and perhaps confirming homozygosity status with molecular markers), we should be able to detect heterogeneity in these cases and exclude them from the analysis which may reduce the average value of seeds harvested per ear and the average 100-kernel weight.

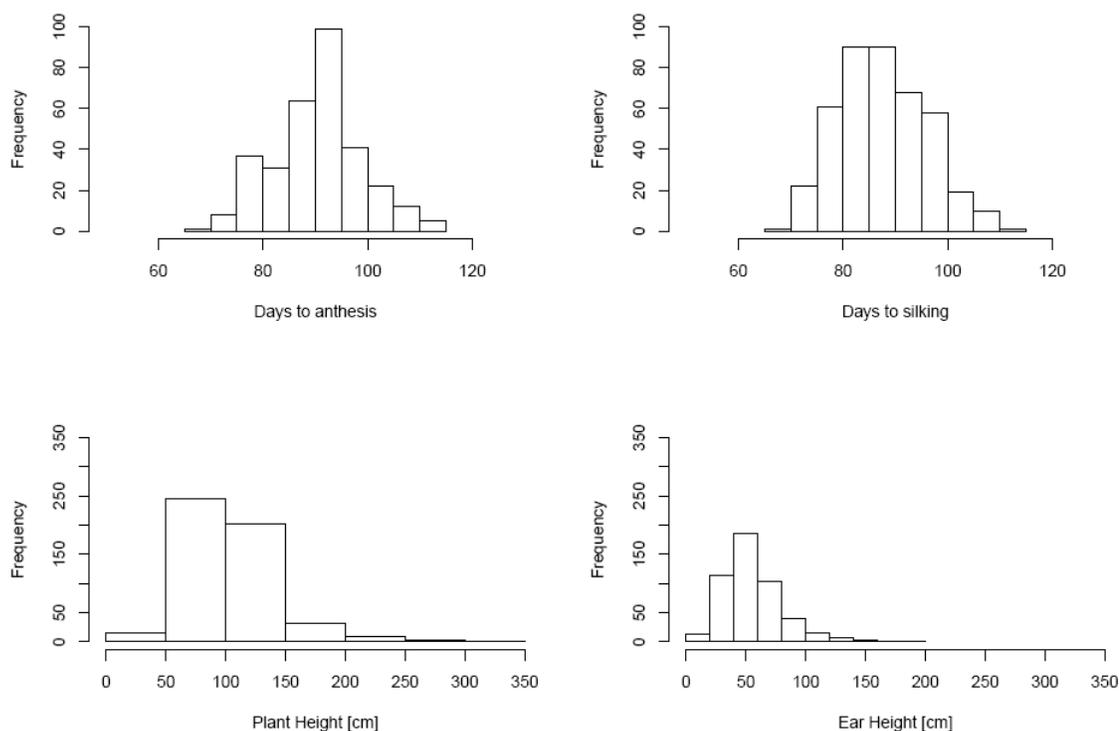


Figure 1: Frequency distribution for the traits days to anthesis, days to silking, plant height, and ear height assessed across the whole experiment.

- The majority of the harvested ears had a very poor aspect indicating that few seeds were produced, that seeds were damaged, or that ears showed ear rot symptoms.

For discussion: this was expected because generally haploid plants have fertility problems and with the little pollen produced only few egg cell can be fertilized so that only few seeds are produced. Also, ears of weak haploid plants might be more susceptible to ear rots than are ears of hybrids.

- The majority of ears bore white seeds of flint type (grain color = 2; grain type = 1).

Correlations between traits came out as expected (Table 2). Strong positive correlations existed between male and female flowering, plant height and ear height, as well as ploidy level and number of seeds harvested per ear. Positive correlation means that if the value of one parameter increases, the value of the other parameter also increases. The higher the coefficient of correlation, the stronger this relationship. It is obvious that taller plants will also have their ear positioned higher. Diploid plants produced more seeds on their ears than did haploids. This also corresponds to our expectations since haploid maize plants are reported to have fertility problems.

Ear aspect was strongly negatively correlated with the number of seeds harvested. This follows our expectations since the score of ear aspect includes the number of seeds present on that ear next to health and general appearance of the ear. Moderate negative correlations existed between ploidy level and anther score, which indicated that diploid plants had a better anther score (1 was the best, 5 the worst) than haploid plants, which corresponds with our expectations. Moderate negative correlations also existed between anther score and number of tassel branches as well as between anther score and the number of ears harvested. This suggests that plants with many tassel branches often had received good anther scores (i.e. scores 1 or 2), and possibly this fertility of the male flowering organ also resulted in the production of more seeds per ear.

Table 2: Coefficients of correlation of selected pairs of traits calculated across the whole experiment.

<b>Trait pairs</b>	<b>Coefficient of correlation</b>
Ploidy level, Anther score	-0.30 *
Ploidy level, No. of seeds harvested per ear	0.71 *
Male flowering, Female flowering	0.74 *
Anther score, No. of tassel branches	-0.26 *
Anther score, No. of harvested seeds per ear	-0.35 *
Plant height, Ear height	0.89 *
Plant height, No. of tassel branches	0.39 *
Ear aspect, No. of seeds harvested per ear	-0.96 *

## **Identification of germplasm with high spontaneous chromosome doubling rate and/or fertility of haploid plants**

Twenty-four haploid plants from four landraces, six OPVs, and seven single crosses had anthers with visible pollen production (anther score 1). Haploidy of these plants was confirmed during flowering via flow cytometric analyses on leaf tissue of the flag leaf. From 15 of these 24 plants, ears with viable seeds were harvested. Average number of harvested seeds per ear was 17.6 (min. 1 to max. 70) for these 15 plants.

A total of 69 ears were harvested from the experiment. From 16 donors we were able to harvest seed from more than one plant (Table 2). These donors constitute interesting candidates for finding high spontaneous chromosome doubling rates. The group includes single crosses and OPVs from Mexico, Colombia, and Zimbabwe, as well as one single cross from Nigeria and one landrace from Thailand. The most interesting candidate is DH08A-151, a single cross from CIMMYT's breeding program in Zimbabwe. Out of the 10 seeds planted this entry produced seeds on seven ears which translated into a success rate of 70%. All of these plants showed haploid plant status, which in two representative plants was confirmed by flow cytometric analyses, and had anther scores of 1-3. Average number of seeds harvested was 34.1 (min.6 max. 70).

Table 3: Population type, origin, and number of ears harvested from entries of which more than one ear was harvested after self-pollination.

<b>Germplasm ID</b>	<b>Type</b>	<b>Program</b>	<b>No of ears harvested</b>
1 DH08A- 151	single cross	Zimbabwe	7
2 DH08A- 152	single cross	Zimbabwe	4
3 DH08A- 76	OPV	Zimbabwe	3
4 DH08A- 147	single cross	Zimbabwe	3
5 DH08A- 134	single cross	Mexico	3
6 DH08A- 68	landrace	Thailand	2
7 DH08A- 77	OPV	Zimbabwe	2
8 DH08A- 97	OPV	Zimbabwe	2
9 DH08A- 112	OPV	Mexico	2
10 DH08A- 71	OPV	Colombia	2
11 DH08A- 106	OPV	Zimbabwe	2
12 DH08A- 89	OPV	Zimbabwe	2
13 DH08A- 166	single cross	Zimbabwe	2
14 DH08A- 137	single cross	Nigeria	2
15 DH08A- 126	single cross	Colombia	2
16 DH08A- 160	single cross	Zimbabwe	2

## What needs to be done to confirm and use these results?

All harvested ears are putative doubled haploid lines that were produced without the use of toxic and costly chemicals for artificial chromosome doubling. The ears will be planted in the coming season in one-row plots in the field in order to confirm their line status, i.e. uniformity within the row regarding plant height, ear height, flowering and ear aspect. If uniformity is confirmed, the DH lines will be returned to the breeding programs from which the donors originated and the respective breeders will evaluate the DH lines in further field trials.

Donors with a high rate of confirmed DH lines should be further investigated for their ability of DH line generation without the employment of artificial chromosome doubling agents. Also, field tests should be conducted to investigate the influence of field conditions on their chromosome doubling ability. Since our experiment was conducted in the greenhouse, nothing is known so far about the effect of stresses such as disease pressure or limited water availability, which occur in field situations. Once donors such as DH08A-151 have reliably produced DH lines without prior artificial chromosome doubling, the genetic architecture of this ability should be studied, and eventually we should be able to introduce this ability into other adapted materials. In the long run, the availability of germplasm with high spontaneous chromosome doubling rates will render the application of toxic chemicals for artificial doubling unnecessary. Especially for small-scale maize breeding programs in developing countries, this will open up the opportunity to rapidly develop new inbred lines using the DH technique and, consequently, improved varieties will reach farmers' field much earlier.

## My Responsibilities and Contributions

I had many responsibilities during my internship at CIMMYT. I started each day by arriving to the office ready to work by 8AM or by 4-5AM if we were leaving for a field station. On most days, I left the office between 5-6PM. However on many occasions, I worked into the night. I was responsible for monitoring the greenhouse maize samples every day, looking to eliminate false double haploid plants, record plant death, special mutations in a given plot of 5 plants, record if seeds failed to germinate, take down female flowering, take down male flowering, note any characteristics that were shared or unique to a plot of maize, and to collect information in all of its forms about my trial mostly everyday in the morning and afternoon time. When we took root samples, I had to create a tag and label for each plant we took root samples from each time we dug for roots. Those labels included the plot number, the number of roots taken, and the source of the roots. At the field stations, Tlaltizapán, Toluca, and Agua Fría, I helped to plant my trials on my first day in Mexico in Tlalti. After they began to grow, I helped to score tassel quality, stalk color, uniformity, vigor, disease resistance, and tilling. We recorded the data in our field books.

In the lab, I was responsible for completing and working on tasks given to me once we arrived. Early on, I frequently had help. But, on many occasions, I was given an assignment that I had to complete on my own after being shown how to do it. These tasks encompassed taking samples of maize plants and preparing them for view on the slides on the microscope, looking at diseases, mutated plants, and other necessary work. I traveled often to Tlaltizapán, Agua Fría, and less often Toluca and helped plant new kernels for trials in the fields along with meeting everyone at the location.

In my office, I frequently kept up with and recorded data from our research in the labs, fields, greenhouses, and in the bodega, where the kernels were sorted. The data recording was very extensive. Finally, since we realized we would not have a functioning flow cytometer at CIMMYT, I helped collect pollen samples for pollen grain tests, collect roots for chromosome counting, I pollinated testcrosses in the fields of Agua Fría and Tlaltizapán, and I covered female silks to prevent contamination in our samples. Although this is by no means everything I did, this provides a rough overview of my work at CIMMYT. Anything that



**Figure 13** I worked with Gustavo preparing the greenhouse soil for new plantings, digging trenches for irrigation to travel, and smoothing out uneven areas.

needed to be done, regardless the task, I was there doing it. From irrigating maize to plowing and digging to assisting other scientists on different projects and departments, I felt accomplished in the fact that I got to experience everything and frequently worked with the temporary workers who spoke no English, strengthening my Spanish and throwing in some English lessons where I could while enjoying their company.



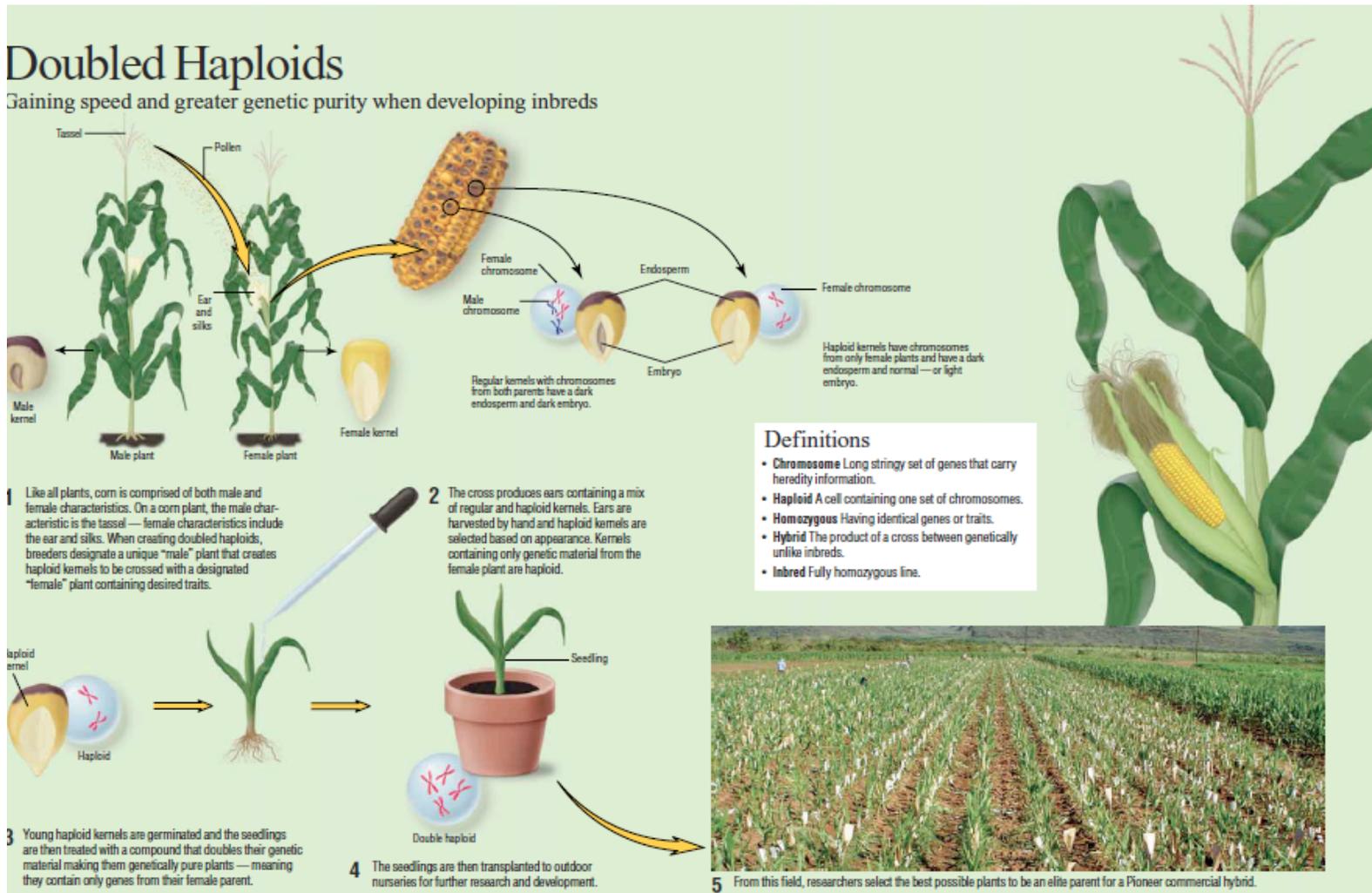
**Figure 14** On this day, I planted seeds with **Ciro, Head Lab Technician** and **Helmut** during his visit from Germany at the beginning of our trial in Tlaltzapán on my first full day.



**Figure 15** Here, I am labeling **DH trial maize** and covering silks of plants in the tropical **Agua Fría** station.



**Figure 16** In the greenhouse I am observing and checking on maize trial plants and recording findings after irrigation in **El Batán**.



**Figure 17** Shown above is a full diagram of the double haploid trial process from the parents to the fields for trial experiments in search of the most superior material available to advance (Courtesy of Pioneer Hi-Bred).

## How Does This Affect Food Security?

The whole point here really is that the DH technique makes inbred line development double as fast as the traditional method for line development (which is continuous selfing for 6-8 generations). That means breeders have genetically stable parents available much earlier and thus can create and evaluate new hybrid and open-pollinated varieties earlier, so improved new varieties reach farmers' fields earlier. The doubled-haploid system trims off several time-intensive generations and dramatically speeds inbred development. And, farmers need new varieties to be prepared for the many challenges they face, such as biotic stresses (diseases, insect pests, parasitic weeds) that persist in their growing environments and abiotic stresses (such as drought, heat, flooding) which may even be aggravated by the effects of climatic change. And if my research project is successful, it will open the door for many small-scale maize breeding programs in the developing world to use the DH technique for their inbred line development, following the important mantra of this year's Borlaug Dialogue, "Taking it to the Farmer", where the real difference will be made at the level of smallholder access. This way, not only does CIMMYT get its new varieties to the farmers faster, but all maize breeding programs around the world will be able to do so.

In the long run, we can expect the rate of spontaneous doubling or fertility of haploid plants to occur in higher rates in every subsequent new cycle of DH line development. Why is that? Because intense selection occurs during the haploid phase. Only those haploid plants and seeds that are selfed and made into DH lines are receptive towards being doubled or allow doubling to occur. Then, if we combined these DH lines to new crosses or mixtures and induce them to make new pure lines from them, then usually a higher percentage of haploid plants survive the treatment and become new lines. This is because step by step, lethal recessive alleles, which are usually masked by dominant non-lethal ones, are eliminated because during the haploid phase there is no compensation, usually provided by the dominant allele, for their negative effect. This negative effect could affect germination or female flower fertility or pollen production. So, in 20 years, we may not even need to look for alternatives for colchicine treatment because the populations, the mixtures of genotypes, which we use to extract inbred lines from, will be improved regarding the suitability for DH lines production.

## Reflections

I find the fact that I came to Mexico with little knowledge of agronomy nothing short of amazing. I initially was intimidated since other interns who lived in the Midwest already had extensive experience in agronomy. And, I had never lived by myself for eight weeks in a foreign country. I had the benefit of AP Chemistry, AP Biology, Post-AP Advanced Genetics/DNA Research, AP Spanish VI and Forensics during my last semester of high school prior to my trip to Mexico City, but I had never been introduced to plant science in depth. I walked away with a vast and substantial knowledge of maize and technology in agriculture as well as growing methods after reading many journals in Mexico and through actual experience. Now, as a international affairs and politics major, I have a deeper understanding of what the consequences and implications of failed and poorly implemented policy are from a perspective of the voices working on the frontlines. Sometimes people on the ground are ignored in favor of politics or outdated thought processes and this simply cannot continue to happen. Hunger is a silent killer we have the capacity and resources to end NOW.

I have fallen so in love with plant science that now, I have started a garden in my backyard where I grow different types of lettuce, red and yellow tomatoes, melons, peppers, cucumber, and other fruits and vegetables used extensively in my household without chemical fertilizers. I missed the hands on agricultural work so much after my departure that since I have returned home, my previous brown thumb has turned a solid green. I have redone my entire yard turning beds that once only had mulch and pine straw into lush areas with flowering and shade trees, groundcovers, shrubs, assorted perennials, and more recently annual plants that I grow from seed after the last frost. I am amazed that something I disliked so much before has transformed into a hobby I use to relax.

Living in Mexico during the summer, I realized that there are so many incorrect preconceived notions perpetuated by the media about a wonderful and beautiful country that are completely untrue. Being a native of the South, I can say that the warmth and welcoming nature of the Mexican people surpasses our hospitality! People opened their hearts, homes, and resources to me and I have never enjoyed a place away from home so much. Lastly, after two months in Mexico, my Spanish improved significantly. Despite being the President of the Spanish Honor

Society at my school, I learned that even five years of Spanish after skipping Spanish V and going straight into AP VI, no classroom can replicate the learning experiences of actually using a language constantly with live, native speakers. Upon my arrival to CIMMYT, there were many people who assumed I had no knowledge of Spanish, and the things people will say when they do not believe you understand is quite interesting— it created lots of laughs for me and others when I unexpectedly jumped into the conversation and commented in Spanish.

What I did not expect was the personal relationships that would develop over the course of my stay. I lived next door to Mohammed, a guy in his mid-twenties, from Iran. We both had prematurely moved to false assumptions and preconceived notions about each other and our countries before we really got to know one another. We had moments of misunderstandings and disagreements, but we were able to learn more from one another than Persian and English. We learned a global literacy and forged an understanding that even though we were different, our fates, dreams, and hopes for our lives and ourselves were indelibly tied together. My reality shaped his reality and vice versa. At that moment, it clicked. As a generation and society, we have a blank canvas where we can paint strong bonds in the form of strong relations and compassion. Had I been asked before this trip, I would have never thought that I would be in the kitchen at 2AM talking with him about global politics and the contested election between Mahmoud Ahmadinejad and Mir-Hossein Mousavi. I could not even predict that I would ever be in discussions about virtually every continent and country on the planet with its citizens. And, we were all there tied by the desire to come together for a common cause of good, hunger and food. To quote Dr. Borlaug, “Food is the moral right of all” and it is my moral responsibility to do all I can and bring awareness. I learned that medicine in a hospital or a private practice is not in the cards for me anymore like I always thought it would be. I want to dedicate my life to providing the medicine of caring and the healing that comes from dedicating your life to uplifting others, wherever they may be in the world. I cannot suppress the interest that this unique internship has sparked in me in agriculture and international development. The WFP truly succeeded in their mission of inspiring youth because I had not previously thought of the area. I now have an insatiable hunger that is in my gut, but not from famine. And, the only way that I feel my soul will be fed is to travel far and wide to advance my excitement of the world and fix the causes of poverty, equality and human rights.

Because I am a bit of a nerd and got exposure to language at an early age, I have learned many languages and continue to learn multiple new languages in college now. I have enough knowledge to at least communicate well in seven languages. But by the time I am finished, I want to be fluent or greatly proficient in fifteen. The way I learn, languages are easy for me to pick up based on the way my brain works. From my experience, people greatly appreciate the effort taken to respect and acknowledge their culture, learn their language, and are genuinely kinder because of it. I see it as an opportunity to use a gift and a talent that I can pair with diligence to equal unlimited possibilities in this world. While I eventually want to be the US Secretary of State, this special program taught me that the destination is of little importance; it is the journey you take to get there that will fulfil your life’s purpose.

## Cultural Experiences

During my stay in Mexico, I adapted very well to the cultural differences after initial difficulty, the varying customs, the language, dialect, and navigating Mexico City on my own. Mexico is becoming more and more like the United States in many ways. Part of me will always have a special place in my heart and I learned so much about Mexico and its diverse landscape in only two months that I consider myself a true citizen at heart. Even though I had to learn the dialect differences from Spanish from Spain and South America, I felt comfortable enough to translate for visitors to the center on excursions outside of CIMMYT that spoke no Spanish. Some things I had to adjust to were paying to use the restroom in some places, using buses, the Metro, and taxis as primary transportation all the time, and navigating such an enormous city. The Mexican cuisine was much better than anything in the United States that is deemed authentic, and I was also able to enjoy many different foods from all over the world in D.F. While in Mexico, I fought several stomach viruses, amoebas, and illnesses when ordinarily at home I get sick 1-2 times a year. Many times being ill took a lot out of me, but I only missed my work for a day or two because of illness. Sometimes, I just chose to work through it. Also, the beautiful architecture and amazing museums were a highlight along with many historical



**Figure 18** Taking a photo on the lower levels of the Pyramid of the Sun in Teotihuacán during a visit.

landmarks and places for sightseeing ancient ruins. Many cities have beautiful colonial and Spanish architecture along with colorful streets. At the same time, I appreciated the times I was able to see poverty as I was able to experience empathy for the people. There is no excuse for allowing fellow humans to live in substandard conditions. I witnessed a community of homes built out of cardboard and trash along with people who lived out of street stands at night after the occupant during the day closed.

At CIMMYT and in Mexico, I learned a great deal about fútbol (soccer). Before, I had only watched it occasionally in the U.S. and in Querétaro, I went to my first fútbol game. I developed an affinity for Mexican music and Latin dance during my stay from constant exposure and previous knowledge. I appreciate the people on the hall of my dorm for tolerating my constant singing and music in Spanish. Now I think it had such an influence on me that my Mexican/Latin music collection on my iPod rivals my English collection. Lastly, I adapted well to the food and traveling all around the country. I was able to spend time in México D.F (the capital city), Veracruz, Oaxaca, Texcoco, Teotihuacan, Guanajuato, Guadalajara, and other cities and states in Mexico.

## How The Experience Changes Me

Wow. I absolutely have to start off my description of my experiences in Mexico with just that one word. This summer was nothing I expected and everything I was not prepared for. I remember on the day I left, my parents said to me “We’re happy that we have been able to give you all you need to get you to this point in your life. But, we now have to ask something more of you. If you do nothing else in life, just take what we have given you and turn it into something much bigger than yourself or any of us.” I think after this experience, I am well on my way to fulfilling that wish. It was amazing, challenging, difficult, draining, frightening, fun, exciting, exhilarating—every adjective you could conceivably think of. Everyday I think back fondly in some way about an experience I had in Mexico, good or bad. I simply just see things out of a different lens now and had the time of my life. What I saw in Mexico drastically opened my eyes to the issue of food security and the DIRE importance of the issue. I was face-to-face with what I recognized before but never truly experienced before in my life in Mexico City. My perspective on the world is not the narrow, acute scope of the stereotypical average teenager. It is a global perspective that leaves no one out. On the way back home on the plane, I looked at the back label on my can of orange juice and caught myself thinking in a way I had never quite done so in the past. I scanned over the gray letters...Product of oranges from Mexico, Brazil, Argentina, Costa Rica, and/or the USA. Normally, I would have just read that and moved on. **But this time was truly different.** A simple line of text on the back of the orange juice had much larger implications than it ever did before. It made me think long and hard about what my role in changing the world is. More than any other time in history, our planet is a dense web, bonding and tying us all together. Our collective fates rest in our understanding, concern, and willingness to uplift one another into a world of equality and opportunity for all. I was fortunate enough in Mexico to make friends from every corner of the world, and I know how important the bonds we forge between our seemingly distant but ever so close friends are. As our world becomes a smaller and smaller place, the fortitude and moral character we show in grabbing ownership of the fate of our world and making the effort to extend the hand of friendship and common humanity will define our generation. I finally grasped that no matter the language you speak, the human soul only has one language— *caring enough to make a difference*. **Our collective sum is greater than our separate parts.** Before, I felt ashamed and responsible for living a comfortable life when so many are suffering needlessly. But I learned in Mexico that feeling culpable for a problem much older than you wastes a golden opportunity to do something about it when I can begin removing poverty from relevance myself. In the words of Nobel Prize winner Albert Camus, “Your successes and happiness are forgiven only if you generously consent to share them”.

A woman begging in the streets of Coyoacán came to mind with a baby in her arms and two youngsters beside her—as she begged and pleaded from a man who was clearly wealthy for money for food in rapid Spanish, he shouted and pulled away. After her repeated attempts to get his attention, he turned around and spat on her. I thought...**she only wanted to feed her children.** What kind of world do we live in where that would ever be okay? I broke away from the group I was with I remembered the voice of Brazilian President Luiz Inácio Lula da Silva and thought about his assault on poverty in his country, reducing the rate of poverty in Brazil by more than 30% since he took office. «Números da economia pouco significariam se não traduzissem sensível melhora na qualidade de vida da população brasileira, comida é uma necessidade». “Economic numbers mean nothing if we can’t translate them into a sensible improvement in the quality of life of the Brazilian people, food is a necessity.” I remembered the paper I

wrote in 2008 for the symposium about Costa Rica and the people. Industrialization was taking away land for food growth with the Intel processor plant. With all of the income Intel generates its products manufacturing in Latin America, why couldn't they do more? Then it hit me, you cannot rely on anyone else to be the change you seek.

I knew that I grew during my trip because my prevailing thoughts had proven to me that I felt the pain, emotion, and stories of people in despair who were suffering but did not give up. I felt like I had really for the first time authentically been able to put myself in the shoes of the people I met and saw in the streets, hungry and in poverty. Some days I would go without eating just thinking about what I saw. But instead of forgetting about it once I became reacclimated to American society, I took another route. I am obviously no politician, but I have developed a list of signature and important issues that I believe will dominate and define our generation. Over the next eight years, I have committed my time to exploring and aiding the issues of poverty, education, hunger, and malnutrition from my own neighborhood where I have already started these efforts, to nearly every part of the globe.

What I will remember most about this internship is not every detail on the double haploid kernels and the exact specifics of the chromosome counting protocol, but what a profound effect the people I met along the way had on me. The people you encounter and the stories I have lived, heard, witnessed, and saw first-hand have left a stamp on me like a fingerprint—one that will follow me wherever I go until I take my last breath on Earth. The overall experience changed who I was because it tore away all preconceived notions from my mind and I walked off the plane in Atlanta a totally new and rejuvenated person who knew he had a new job to do from that day forward. In conclusion, I would like to end my report with a quote from Mother Teresa. "Being unwanted, unloved, uncared for, forgotten by everybody, I think that is a much greater hunger, a much greater poverty than the person who has nothing to eat...We must find each other." I believe strongly in ending the problem of chronic hunger but I also believe that if we love, embrace, and empathize with one another instead of choosing indifference or hate, our other issues will more readily take care of themselves.

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