By all accounts, Norman Borlaug was a hardworking and humble man. When the phone call came to tell him that he had won the 1970 Nobel Peace Prize, he was out working in the wheat fields. His wife, Margaret, had to deliver the news to him. As he received other awards throughout his life, colleagues say he remained focused on the work.

“He had all these awards—the Congressional Gold Medal, the Nobel Peace Prize, the Presidential Medal of Freedom, the National Medal of Science—and yet in all my time visiting with him, he never mentioned one. He kept at it, and even up to his death he was still promoting agricultural science,” says ASA and CSSA Fellow Ronald Phillips, Regents Professor at the University of Minnesota.

Through dedication and lifelong effort, Borlaug was credited with saving a billion lives and earned the nickname “Father of the Green Revolution.” But while his accomplishments are oft-reported, the research that led to them is less well known. So on the occasion of his 100th birthday, we look back on his tireless efforts, the research that led to a revolution, and the circumstances in which he was able to change the course of agriculture.

Early Life and Moving to Mexico

Borlaug was born in 1914 in Saude, near Cresco, IA. He grew up working on the family farm and left Iowa after high school to pursue a degree at the University of Minnesota. To finance his studies, he worked several jobs,
one of which was with the Civilian Conservation Corps starting in 1935. The Corps helped the unemployed, many of whom were starving as they faced harsh living conditions during the Depression. Borlaug’s experience in that job gave him a firsthand glimpse at how access to food could change lives.

Late in his undergraduate studies, Borlaug attended a talk by plant pathologist E.C. Stakman. He was inspired by what he heard and decided to continue his studies with Stakman in both a master’s and a Ph.D. program. When Borlaug completed his degrees in 1942, World War II was under way. He took a job with DuPont where he conducted research for the United States armed forces.

Meanwhile, a new venture had started in Mexico. At the prompting of U.S. Vice President Henry Wallace, the Rockefeller Foundation and the Mexican government teamed up to form the Cooperative Mexican Agricultural Program (OEE), an effort focused on revitalizing agriculture in Mexico. Stakman was involved in the establishment of the OEE, and through his efforts and those of J. George Harrar, the project leader, Borlaug joined the program in 1944 after turning down an offer to stay at DuPont.

When Borlaug began his work in Mexico, there were no Mexican agricultural scientists with an advanced degree in the country. There were also no graduate schools with agricultural programs in Latin America. One mission of the OEE was to train Mexican scientists to address the challenges of food production in Mexico. In the absence of an extension program, the scientists would take the new technologies to farmers so that they could be tested, modified, and distributed.

Stem Rust and Shuttle Breeding

One of the first problems Borlaug addressed in Mexico was that of stem rust. Stem rust is caused by a fungus, *Puccinia graminis*. Spores of the fungus travel through the air and land on wheat plants where they cause brown lesions. Nutrients that the grain would use are instead taken up by the fungus, and the fungus can weaken the plant leading to breakage, desiccation, and shriveling.

Three epidemics of stem rust from 1939-1941 wiped out wheat in the Yaqui valley of Mexico. An experiment station had previously been constructed in the valley, but when Borlaug
arrived in 1945 as part of OEE, it was in shambles. Despite the poor state of the station, he slept and worked there depending on the support of the local farmers who would loan equipment and help as needed.

Breeding rust-resistant varieties of wheat was a slow process taking up to 10 or 12 years. To speed up the process and take advantage of both of Mexico’s growing seasons, Borlaug suggested a new technique called shuttle breeding. He wanted to grow wheat in the cooler central highlands near Mexico City in the summer and then shuttle selected plants to the warmer northwestern Yaqui valley during the winter for a second round of breeding and selection. The different latitudes, elevations, and climates of these two locations allowed Borlaug and his colleagues to breed and select plants twice in one year.

Borlaug faced criticism for his idea of shuttle breeding, even from others at OEE. A widely held belief at the time was that seeds needed to rest after harvesting in order to store energy before being planted again. Also, shuttle breeding would mean double the work each year—and double the costs.

Despite the resistance, Borlaug forged ahead with his breeding plans. Not only did the wheat grow in both locations allowing the breeding to progress more quickly, but there was an unexpected side effect. Wheat that was grown during shorter days in the north was then taken south when the days were longer. Not only were the selected plants adapted to different climates, but they were adapted to a wide range of day lengths. This achievement meant that wheat grown in Mexico would tolerate day lengths at different latitudes and could be cultivated in various regions of the world.

The success of shuttle breeding, a technique still practiced today, allowed Borlaug and his colleagues to make great progress in his first 10 years in Mexico. They made thousands of wheat crosses in that time, and through those efforts, they discovered a gene called Stem Rust 31, or Sr31. The gene provided protection against stem rust when present in wheat, and by another stroke of luck, it also increased yields. Farmers learned of the success of the Sr31 seeds and enthusiastically adopted them, drastically reducing the threat of stem rust.

**Lodging and Semi-Dwarf Wheat Varieties**

In addition to stem rust, Borlaug and his colleagues found themselves facing another problem at the time. During World War II, nitrate was produced in large volumes for use in explosives. With the war over, the factories switched to making nitrogen fertilizer for agricultural use. Increases in fertilizer use led to better crop growth and higher grain yields. But along with increased yields came heavier heads of grain and a problem for wheat—lodging.

Lodging occurs when stalks collapse under the weight of the grain and fall over. This can ruin the crop and lead to large reductions in yield.
To prevent lodging, Borlaug wanted to breed the tall, thin stalks common in Mexico with shorter wheat stalks. In the early 1950s, he received a dwarf variety called Norin 10 from Orville Vogel, a researcher with the USDA-ARS at Washington State University. It was with that genetic material that Borlaug began to produce stronger, higher-yielding Mexican varieties.

The new Mexican semi-dwarf varieties had multiple benefits. The shorter wheat produced stronger stalks and two to three times more grain than standard varieties. Also, Borlaug bred the shorter varieties with the stem rust-resistant wheat he had produced earlier, creating semi-dwarf wheat that was resistant to the disease and could be grown in a range of climates.

These new varieties greatly changed the picture of wheat production in Mexico. By 1963, 95% of the wheat grown in the country came from Borlaug’s breeding programs. Around 75 varieties had been created. The wheat harvest that year was six times larger than the harvest just 19 years earlier when Borlaug had arrived in Mexico.

Also in 1963, CIMMYT (The International Maize and Wheat Improvement Center) was established. CIMMYT remained under the jurisdiction of the Mexican government at that time, but as recognition of the organization grew, it became clear that additional funding and reorganization was necessary. In 1966, CIMMYT became a non-profit institution and was formally launched.

A few years later, the CGIAR Consortium of International Agricultural Research Centers was founded to further support and disseminate agricultural research around the world. CIMMYT was one of the first research centers to be supported through CGIAR and is one of 15 such centers today.

Taking Borlaug’s Work beyond Mexico

As international concerns about food production rose, so did interest in Borlaug’s work and his successes in Mexico. India and Pakistan were facing dire food shortages and hunger in the mid-1960s. Massive imports of grain were required to keep the countries from famine. Facing this, agricultural officials, while initially reluctant, turned to Borlaug and his colleagues for help.

In 1965, seeds of two of the best semi-dwarf wheat varieties were shipped from Mexico to Asia—250 tons to Pakistan and 200 tons to India. The trip was not an easy one. The shipment was held up in Mexican customs and was delayed crossing the Mexico–United States border. Soon after the wheat was loaded onto a freighter and had started its voyage, war broke out between India and Pakistan.

Because of the numerous delays, there was no time to determine the quality of the seeds or the proper seeding levels once the shipments arrived in Asia. Instead, the seeds were immediately planted. It quickly became obvious that the seeds were germinating at only half the rate that...
Borlaug had expected, so he ordered the seeding rates be doubled. Later he discovered that the cause of the poor germination had originated all the way back at the beginning of the journey. The seeds had been damaged in a Mexican warehouse where they had been improperly fumigated.

Despite the obstacles in shipping the seeds and getting them to grow, that effort produced the highest-yielding wheat fields those areas of Asia had ever seen. The next year, the Indian agricultural minister imported 18,000 tons of wheat seed from Mexico. The year after that, the Pakistani agricultural minister asked for 42,000 tons. Between 1965 and 1970, India’s wheat crop went from 12 million to 21 million tons. The Green Revolution had begun.

Many of Borlaug’s ideas and principles spread to other parts of the world as well. His work with wheat laid the foundation for the development of high-yield semi-dwarf rice varieties that brought the Green Revolution to China. In the early 1980s, Borlaug was recruited to help bring his methods to Africa, and the Sasakawa Africa Association (SAA) was founded to run the project. Between 1983 and 1985, the yields of maize and sorghum doubled in developed African countries.

Success and Criticism

The spread of practices and seeds developed by Borlaug was driven by his hard work, but also by his ability to engage and interest all of the stakeholders from farmers and students to policy-makers and administrators.

“He was good at something most scientists aren’t good at—public relations,” explains ASA and SSSA Fellow Ed Runge, professor at Texas A&M University. “We all need to...
make connections, and I think Borlaug was superb at that. He could talk to a farmer. He could talk to Indira Gandhi [the third Prime Minister of India]. He could talk to anybody.”

Education was very important to Borlaug. Both in Mexico and as he traveled on consulting trips, he recognized the shortage of trained people throughout the world as well as the untapped potential of people willing to learn. While scientists were doing good work, they rarely left the laboratories to interact with the farmers or teach others. One way in which Borlaug addressed the need for education was by establishing a training program in Mexico for recently graduated agricultural students.

He also continually pushed for better support for farmers, both through government funding and training. Later in his life when he was involved with SAA, he worked to bring simple technologies that many take for granted, such as irrigation and fertilizers, to poorer farmers in Africa.

“Dr. Borlaug was very practical. He understood what small-holder farmers needed and fought for them to be provided every tool available,” says Robert Fraley, Executive Vice President and Chief Technology Officer at Monsanto. “He believed in training the next generation and engaging young people.”

In the midst of great success, the Green Revolution also had its critics. By using more fertilizers and water and cultivating a single crop, some believed that Borlaug’s techniques were damaging the environment, depleting water and soil resources, and hindering biodiversity.

While he acknowledged the critiques, Borlaug maintained that they were smaller concerns than the starvation and political unrest facing many hungry nations. He would also note that thousands of acres of land had been saved from agricultural development through the increased yields of the new varieties. He continually pushed for improved practices that would maximize water use and conserve soil while maintaining the high yields necessary to feed the population.

Challenges Remain

Borlaug worked and consulted up until his death. Late in life he helped address the newly emerged stem rust that was plaguing parts of Africa. While stem rust had been largely absent from the world’s fields since Borlaug had introduced the stem-rust resistant varieties decades before, a new strain—called Ug99—appeared in the late 1990s. A super-strain that can escape the defenses of 90% of the wheat varieties grown throughout the world, Ug99 spread from Uganda, to Kenya, Ethiopia, Yemen, and Iran.

In 2005, Borlaug saw first-hand the devastation that Ug99 was causing in Kenya. Upon returning to his office at CIMMYT, he wrote to the director

In the late 1990s, a new strain of stem rust—Ug99—appeared. Borlaug saw it as the most serious threat to wheat and barley in 50 years and called for increased funding to fight the new strain. He is shown here consulting with Kenyan and CIMMYT leaders near wheat plots in Kenya. Photo by Kay Simmons (USDA-ARS).
March Borlaug Celebrations

ASA, CSSA, and SSSA

To celebrate both National Ag Day and the anniversary of Norman Borlaug’s birthday (both are 25 March), the Societies have planned several activities:

• Agronomy t-shirt sales to members to be worn during National Ag Day (see opposite page)
• Congressional Visits Day (CVD)
• News release about Norman Borlaug’s contributions to agronomy
• Coordinated social media campaigns with CGIAR and The Borlaug Institute
• Distributed Coolbean the Soybean children’s book to Wisconsin fourth-grade classrooms in celebration of National Ag Literacy Week, on behalf of the Wisconsin Soybean Board, which generously supported the publication of the book (available at www.societystore.org)

Borlaug Summit on Wheat for Food Security

To celebrate the life and legacy of tireless hunger fighter Norman E. Borlaug and inspire a new generation to carry on his work, the Borlaug Summit on Wheat for Food Security will bring together thought leaders, policymakers, and representatives of leading agricultural research-for-development organizations, both public and private. The Summit will be held 25–28 Mar. 2014 in Ciudad Obregón, Mexico and is being organized by CIMMYT, PIAES, and the Borlaug Global Rust Initiative. See http://borlaug100.org/.
calling for more funding to fight the new strain of fungus. The Global Rust Initiative was established to coordinate breeding and testing activities around the world. By 2009, the year Borlaug passed away, CIMMYT had created 15 varieties of high-yielding wheat resistant to Ug99.

Beyond stem rust, agricultural researchers still face many issues today. They strive to find ways to feed the world while protecting the earth and its resources. For many in the field, Borlaug’s work and words were a challenge to continue the fight against hunger and to do so in a way that would incorporate and address as many aspects of food production as possible.

“The greatest thing he did for the field of agronomy was to begin to show people that they had to think about multiple parts of the system,” says ASA, CSSA, and SSSA Fellow Jerry Hatfield, lab director at the USDA-ARS. “If you think about what he did in the Green Revolution, it wasn’t about genetics, and it wasn’t about fertility, and it wasn’t about water. It was about all of those different things together.”

So 100 years after he was born, and with the world population continuing to grow, Borlaug’s legacy still resonates. He continues to call us all to action with words he spoke in 1970 at his Nobel Lecture: “I cannot emphasize too strongly the fact that further progress depends on intelligent, integrated, and persistent effort by government leaders, statesmen, tradesmen, scientists, educators, and communication agencies…we can and must make continuous progress.”

C. Schneider, Science Communications Coordinator for ASA, CSSA, and SSSA

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**New! Agronomy T-shirt**

To celebrate the anniversary of Norman Borlaug’s 100th birthday and National Ag Day, ASA developed an Agronomy t-shirt.

The t-shirts are designed to help “break the ice” with people in explaining the science of Agronomy.

T-shirts are priced at $25, $27 for 2X and up. For more information, and to order, visit [agronomy.org/about-agronomy/tshirts](http://agronomy.org/about-agronomy/tshirts)