Norman E. Borlaug

1914–2009

BIOGRAPHICAL *Memoirs*

A Biographical Memoir by
Ronald L. Phillips

NATIONAL ACADEMY OF SCIENCES

NORMAN ERNEST **BORLAUG**

March 25, 1914–September 12, 2009

Elected to the NAS, 1968

Norman E. Borlaug

By Ronald L. Phillips

> *"He cultivated a dream that could empower farmers;*
> *He planted the seeds of hope;*
> *He watered them with enthusiasm;*
> *He gave them sunshine;*
> *He inspired with his passion;*
> *He harvested confidence in the hearts of African farmers;*
> *He never gave up."*

The above words are those of Yohei Sasakawa, chairman of Japan's Nippon Foundation, written in memory of Norman E. Borlaug. The author is the son of Ryoichi Sasakawa, who created the Sasakawa Africa Association that applied Borlaug's work to Africa—the focus of much of the scientist's efforts in his later years. The passage reflects Borlaug's lifelong philosophy and his tremendous contributions to humanity. His science of wheat breeding, his training of hundreds of developing-country students, and his ability to influence nations to commit to food production are recognized and appreciated around the world.

Borlaug was one of only five people to have received all three of the following awards during their lifetimes: the Nobel Peace Prize (1970); the Presidential Medal of Freedom (1977); and the Congressional Gold Medal (2007), which is the highest award that the U.S. government can bestow on a civilian. (The other four were Mother Teresa, Martin Luther King, Nelson Mandela, and Elie Weisel.) Borlaug was elected to the National Academy of Sciences of the United States in 1968 and in 2002 received its Public Welfare Medal, which recognizes "distinguished contributions in the application of science to the public welfare." At a White House ceremony in 2006, President George W. Bush awarded him the National Medal of Science, the country's highest honor for scientific achievement. Over the years, he was awarded more than 50 honorary doctorates from universities around the world and a seemingly endless number of other prizes and awards.

Borlaug's accomplishments have been reported in numerous publications (Vietmeyer 2008, 2009, 2010, 2011; Hesser 2006; Bickel 1974; and many others). Because his life and accomplishments have been documented so extensively, this memoir reflects some personal observations by one who knew him via the University of Minnesota, mutual research interests, and involvement with the World Food Prize.

Reducing hunger through improved-yielding wheat

Borlaug has commonly been called the father of the "Green Revolution" because of his tireless efforts, beginning in the early 1940s, to make Mexico self-sufficient in wheat production; and his subsequent saving of millions of people in India, Pakistan, and elsewhere from starvation through high-yielding wheat varieties. By 1963, Mexico was an exporter of wheat, and wheat yields in Pakistan and India nearly doubled between 1965 and 1970. Similarly, "miracle rices" developed at the International Rice Research Institute (IRRI) by Hank Beachell and colleagues significantly raised the yields of rice and benefited poor people across Asia.

Norman E. Borlaug holding wheat selections that provided food for starving people.

Thus Borlaug needs no introduction to people in many countries. But in his home country of the United States relatively few members of the public know his name. So even though this is a man who would seem to "need no introduction," he does need one for many of his compatriots. Born March 25, 1914, on a farm near Cresco, Iowa, Borlaug lived a long and active life up until his death at 95 on September 12, 2009. Even in his nineties he was writing op-ed pieces, supporting population control, encouraging agricultural research and food production, and articulating the need for inputs such as fertilizer, water, seed, and capital. He recognized the role of governments in providing these resources as well as in building infrastructure—e.g., roads and bridges—to facilitate markets.

Borlaug received all three of his academic degrees from the University of Minnesota—a B.S. in forestry (1937), and an M.S. (1940) and Ph.D. (1942) from the Department of Plant Pathology with a minor in plant genetics. He was greatly influenced during

his graduate work by the famous professor of plant pathology E. C. Stakman and also by H. K. Hayes, a renowned plant breeder and textbook author in the Department of Agronomy and Plant Genetics. Borlaug worked at DuPont in Wilmington, Delaware, from 1942 to 1944. He was hired to be a microbiologist studying bactericides and fungicides. But the bombing of Pearl Harbor led to a change in research goals—to develop an adhesive that could be used in sealing containers of food and other goods dropped in the water near shorelines.

Borlaug's wheat research started in 1944 with a Rockefeller Foundation-sponsored program in Mexico. That program was transferred to the newly formed CIMMYT (the Spanish acronym for the International Center for Maize and Wheat Improvement), which was focused on increasing food production through the breeding of wheat. In his work at CIMMYT as a plant pathologist and breeder, Borlaug developed wheat varieties that were resistant to "stem rust"—a severe fungal disease—and tolerant of many other important biotic and abiotic stresses. He also developed unique wheat varieties that could respond to improved management methods and to a wide variety of environments. In 1948, Borlaug released four dramatically improved varieties—Kentana 48, Yaqui 48, Nazas 48, and Chapingo 48—which were earlier in maturity by about two weeks, resistant to stem rust, and high-yielding. All in all he produced at least 40 important wheat varieties (see Table 1).

Borlaug recognized the potential value of shorter ("semi-dwarf ") wheats possessing stronger stems, which could respond to increased water and fertilizer treatments by producing more grain but would not fall over (called lodging) with a heavy head of grain. He obtained the source of the semi-dwarf genes of Rht1 and Rht2 from Orville Vogel at Washington State University, who had acquired a variety called Norin 10 from Cecil Salmon, an expert on wheat serving with General Douglas MacArthur in Japan. The initial crosses with these genes had considerable sterility, but Borlaug and his team of "hunger fighters"—as he called his disciples—kept selecting for fertility until he obtained lines with good yields.

Another major innovation of Borlaug's wheatbreeding program in Mexico became known as "shuttle breeding." In this approach, one generation was grown at CIMMYT in or near Toluca, Mexico, at an elevation of 2,090 meters, and the next generation in Ciudad Obregon, Mexico, at 38 meters' elevation. This idea was opposed by many because they thought that breeding only in high-yielding environments such as Ciudad Obregon would result in the selection of high-yielding varieties and that good varieties

could not be obtained by breeding in low-yielding environments such as Toluca. Borlaug persisted, however, because shuttle breeding allowed him to grow two generations per year and thereby at least double the progress in a given period of time.

Borlaug worked in the field from early morning (daylight or before) until late evening (dusk or later), breeding thousands of lines of wheat. Anything that would speed up his goal of reducing hunger through improved-yielding wheat was of interest to him. Neither he, nor anyone else, initially appreciated that the shuttle breeding approach would result in wheat lines that were much less dependent on the length of the day. Such "daylength insensitivity" allowed the Borlaug wheats to be grown widely across the world, including India and Pakistan, where millions of people had been starving because of food shortages.

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Technology, training, and political will

Dr. Borlaug's breeding methodologies had several important features. He had the opportunity at CIMMYT to have many additional hands to help make a large number of crosses during each season. He knew that crosses which would yield superior varieties were rare and required thousands of crosses. Carrying out his program in two locations in Mexico became known as "shuttle breeding". The locations were quite different in terms of altitude and many thought the locations were not appropriate for accomplishing his mission. Such shuttle breeding led to the selection of wheat lines that were not very sensitive to differences in the length of the day, known as "photoperiod insensitivity" and allowed his wheats to be grown in India, Pakistan, and elsewhere. He obtained seed that possessed the "semi-dwarf " trait that produced plants that could still stand-upright even with a heavy load of grain in the heads of the wheat. This trait fostered the use of more fertilizer and irrigation, significantly increasing yields. Borlaug was educated as a plant pathologist, so he also concentrated on disease resistant plants, especially resistance to the deadly stem rust strains. In addition to these effective methodologies, he believed in the training of students from around the world, who he called "hunger fighters." He also understood that political leadership from target countries was essential in making a significant impact on food availability. He did not hesitate to promote the growing of his new wheat varieties in countries facing vast starvation. No other scientist had the vision and tenacity to bring all of these features together to fight world hunger.

"Neither intimidating nor intimidated"

At mid-twentieth century the world had almost given up on meeting the food challenges of population growth. In a popular 1968 book called *The Population Bomb*, author Paul R. Ehrlich (a professor of biology at Stanford University) argued that population growth would outstrip food production and that it would inevitably lead to widespread starvation. Ehrlich thus echoed the theories of English scholar Thomas R. Malthus a century and a half earlier. The opening of *The Population Bomb* stated: "The battle to feed all of humanity is over. In the 1970s hundreds of millions of people will starve to death in spite of any crash programs embarked upon now. At this late date nothing can prevent a substantial increase in the world death rate."

Without the Green Revolution, such dire predictions might well have come true. But fortunately for the world, Borlaug and his colleagues could usher in an era of significantly increased food production, especially in developing countries. Borlaug nevertheless acknowledged the need for balance between food production and population growth—as stated, for example, in his Nobel acceptance speech: "There can be no permanent progress in the battle against hunger until the agencies that fight for increased food production and those that fight for population control unite in a common effort. Fighting alone, they may win temporary skirmishes, but united they can win a decisive and lasting victory to provide food and other amenities of a progressive civilization for the benefit of all mankind." This call for such unity of effort remains to be realized.

In any case, the Green Revolution has been a tremendous contribution to humanity, driven in part by the determination and work ethic that Borlaug acquired in large part on the Iowa farm of his youth. Of course, Borlaug did not achieve his epic accomplishments alone. He had colleagues such as E. C. Stakman (his former university advisor) and George Harrar (first director of CIMMYT); and he had the faith and support of the Rockefeller Foundation, as described by Vietmeyer (2011). In addition, Borlaug strongly believed in training large numbers of young people (hunger fighters) who could follow in his footsteps by making thousands upon thousands of crosses of wheat varieties and by selecting the best lines year after year.

Borlaug learned that the fruits of research advances could be blocked and not reach the intended people if their governments were not helpful. Not to be easily defeated, he personally would talk to leaders around the world to promote the potential of the Green Revolution and, later, of agricultural production in general. Even his early shipment of several tons of wheat to Pakistan almost never happened. Trucks moving the crop from

Mexico to the port of Los Angeles arrived at the height of the riots in Watts and required several imaginative steps to finally get the wheat onto ships headed for Pakistan. Borlaug was indeed an unusual agricultural scientist in that he believed in a formula that involved research, training and education, and policy. It has been said that "Norman Borlaug was neither intimidating nor intimidated" (Swoboda 2011).

Widely accomplished but also humble

Borlaug was extremely generous with his time after retiring from CIMMYT and accepting a position as Distinguished Professor of International Agriculture at Texas A&M University. For example, whenever his alma mater—the University of Minnesota—invited him back for an event, he would honor the request if at all possible. He loved to visit with students, whatever their school, and tell them to reach for the stars. Even if they did not reach "the stars" (i.e., their lofty goals), he said, they could get close enough to have stardust on their sleeves and achieve more than they ever thought possible. In this way and in numerous others, he was an inspiration to the young (and also to the not-so-young) people he met.

Norman Borlaug examining a greenhouse wheat plant while proudly wearing a University of Minnesota jacket.

Despite his accomplishments that helped to blunt Ehrlich's dire predictions, Borlaug encouraged everyone to keep trying to fight the "population monster." Even in a short speech at his 95th birthday party in Dallas, Texas, he ended by clenching his fists, raising his arms, and saying "we must fight, fight, fight!" He was well aware that a huge challenge still existed, as the world's population would move from today's 7 billion to 9 billion people by the year 2050. Out of the 7 billion people currently on Earth, 1 billion suffer from hunger, and a serious question now and for the future is whether agriculture can meet global demand. Borlaug knew that although the rate of increase in food production had thus far met many of our food needs, the continued and sustained efforts of the world's agricultural enterprise—in the broadest sense—would be needed.

Borlaug's receipt of the Nobel Peace Prize highlighted the necessity of having enough to eat in order to have peace. Borlaug said: "Never think for a minute that we are going to build permanent peace in this world on empty stomachs and human misery. It won't happen, and the sooner our leaders at all levels of society reflect on that, the better."

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Although the Nobel Peace Prize was appropriate to Borlaug's own efforts, he believed there should be a Nobel Prize in agriculture, and he made several trips to Oslo to encourage the Nobel Foundation toward that end. The governing committee concluded, however, that the will of Alfred Nobel, which authorized the various awards, would not allow for a prize in agriculture. Undeterred, Borlaug created his own prize in agriculture—the World Food Prize (WFP)—that he hoped would come to be known as the equivalent of a Nobel Prize. The WFP was first funded by Kraft Foods but later sustainably supported by an endowment from John Ruan, an entrepreneur from Des Moines, Iowa, who made his fortune in the trucking and hospitality businesses. Ruan has since passed away, but his family continues to be highly engaged in the WFP, which in 2012 celebrated its 25th year. The prize of $250,000 has now been awarded to many outstanding agriculturalists; Borlaug chaired the selection committee until his death.

After the WFP was well established, Borlaug also helped to develop (in 1994) an associated Global Youth Institute; each year over 100 high-school youth and their teachers are selected to attend the WFP ceremony and receive training at the Institute. These students are then eligible to apply for an internship at an International Agricultural Research Institute somewhere in the world.

Although Borlaug loved to talk about his research and relate the many and sundry associated stories, he was a humble person. At least with this author, he never talked about any of his awards and related recognitions.

He preferred to discuss science and, in my case, biotechnology. He initially did not support biotechnology, but it didn't take long for him to thoroughly embrace it once he saw its potential applications (Chris Doswell, personal communication). His belief was that all appropriate technologies would need to be applied to gain food security in the future.

Stem rust of wheat.

As far back as 1973 (only three years after Borlaug received the Nobel Peace Prize), this author first heard criticism of the Green Revolution. Critics maintained that the greater use of inorganic fertilizer required by the Green Revolution varieties would lead to pollution of waterways. They also believed that the increased consumption of water was not sustainable, and that the use of varieties so widely grown (monocultures) contribute to the loss of diversity across the agricultural landscape and thus to enhanced vulnerability. The general response by Green Revolution supporters was that impacts on the environment needed to be balanced by the staving off of starvation and deaths of millions of people. But Borlaug, who favored the development of high-yielding varieties throughout his life, also was concerned about the environment. He often discussed how much land did not have to come into agricultural production as the result of increasing yields of crop varieties. He would note that the land not brought into crop production was therefore available for natural habitats.

Long after his official retirement, Borlaug was reinspired to act by another environmental problem—stem rust, a parasitic fungus that feeds on wheat, oat, and barley crops. Problems with this disease had been present for millennia, though generally kept in check—in part by Borlaug's own efforts earlier in his career. However, in 1999, a new form of this disease, first identified in Uganda, was found to be virulent on 80 to 90 percent of the world's wheat varieties. Borlaug recognized the potentially devastating impact of this new strain, called Ug99, and he alerted policymakers in 2004, when he was 90 years old, in a report titled "Sounding the alarm on global stem rust." In response to Borlaug's and others' suggestions, the Bill and Melinda Gates Foundation funded a major effort to combat the disease; now called the Borlaug Global Rust Initiative, this program involves scientists from around the world, and they have made substantial progress in finding resistance. If this program results in preparedness in terms of the availability of locally adapted resistant varieties, Borlaug's initiative may once again lead to wheat varieties that solve important food problems and keep many populations of the world from widespread starvation. Some 15 varieties resistant to the Ug99 family of stem rust have been released in several countries, as reported at the Borlaug Global Rust Initiative conference in September, 2012, in China.

Owing much to the U of M

Norman Borlaug met his wife, Margaret, at the University of Minnesota, and according to all accounts she was a wonderful wife and mother. Margaret supported Norman's passion for helping to solve the world's food problems, and she carried on much of the necessary activities of raising a healthy family. Their children indicate that the family was strong and that they appreciated their parents.

This author was occasionally asked to write award reference letters about Norman Borlaug, including for the National Academy of Sciences Public Welfare Medal. At the presentation in Washington, D. C., in 2002, I noticed Margaret and, because I had never met her, I introduced myself. In the course of our conversation, she related that they had been married 60 years. For some reason, I responded with the comment, "That's a long time to be married to that guy!" Margaret looked at me and said, "Well, he has been home for only four." This apparently was a fairly accurate estimate of the time Borlaug had spent at home. He worked about half the year breeding wheat at his Ciudad Obregon experiment station and the other half near Mexico City.

This author has visited Borlaug's homestead near Cresco, Iowa, and toured the house where he grew up as well as the one-room schoolhouse he attended for the first through the eighth grades. In visiting these sites—for example, in seeing his boyhood bedroom, which appears very small even with only a twin bed—one wonders how such a modest beginning could lead to the development of a person who would change the direction of the world. A letter in the University of Minnesota Archives perhaps provides some insights. The letter, dated December 5, 1970, was written by Borlaug before he left for Oslo to receive the Nobel Peace Prize. And in his usual humble manner, he thanked Professor Stakman for so positively influencing his life; in fact, Borlaug suggested that Stakman should have received the Nobel Prize instead of him.

To wit:

> *I will never forget the fascinating, stimulating days, months, and years of study in the Tottering Tower. I remember in particular the seminars—both the formal Tuesday afternoon seminars and the informal Thursday night seminars—led by this same professor [Stakman]. Both were an education in themselves, for all subjects were discussed, from philosophy and history to agriculture....The information gleaned in these seminars transcended the fields of plant pathology and covered all aspects of science and indeed life itself."*

Stak, the role you have played in the development of scientific agriculture and agricultural education for the improvement of the lot of mankind in all different aspects is enormous. Indeed there would in all probability have been no Rockefeller Foundation programs in international agriculture had it not been for you. Then, neither would there have been today any International Agricultural Research Institutes such as CIMMYT and IRRI. Had there not been a CIMMYT today there in all probability would not have been a Nobel Peace Prize awarded to agriculture in 1970. Stak, I really believe the Nobel Committee of 1970 selected the wrong man. It should have been Professor E. C. Stakman.

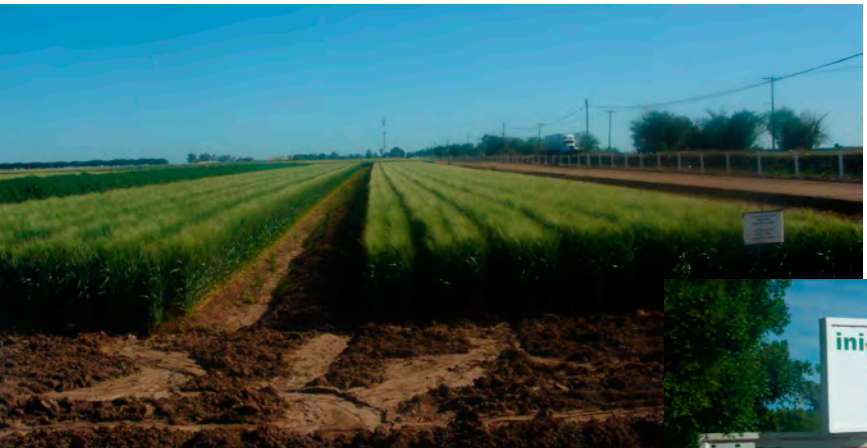
Stak,...the world owes you a great deal. And I personally owe you an enormous debt that I will never be able to repay. Whatever I am as a scientist—recognizing my very great limitations—in large part I owe to you.

The whole letter can be accessed via http://purl.umn.edu/105826.

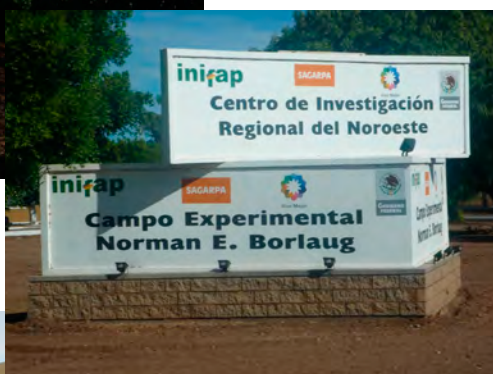
Patron saint of hunger fighters

On March 25, 2012, what would have been his 98th birthday, a bronze larger-than-life statue of Borlaug was unveiled at his beloved experiment station near Ciudad Obregon. Surrounding the statue are the flags of 24 nations that benefited greatly from the Borlaug varieties (Table 1), and he is depicted, appropriately, as being in the field taking notes. This spot is the final resting place for a portion of Borlaug's ashes. A subtle touch is the presence of a class-type ring on one of the statue's fingers. The artist, Alysia McDermott, explained that this was a University of Minnesota ring, symbolizing Borlaug's lifelong appreciation of that highly formative institution.

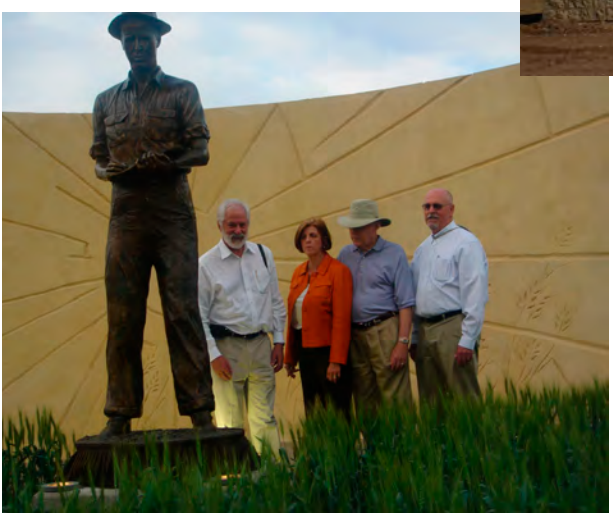
Recently, the experiment station was renamed Campo Experimentale Norman E. Borlaug (CENEB). A mural on one of the buildings displays the statement, "I cannot live comfortably in the midst of abject hunger and poverty and human misery," both in English and Spanish, which sums up Borlaug's philosophy on the importance of food. The experiment station, comprised of 120 hectares, is on land owned by a local farmers' organization, which provided a 30-year lease nearly for free. This advantageous arrangement reflects local farmers' appreciation both for Borlaug's work and the station's ongoing program. Another indication of the local community's respect for him is that the



Impressive wheat grown at the Obregon experiment station.



Norman E. Borlaug's beloved experiment station, renamed in his memory.



Bronze statue of Norman E. Borlaug, Ciudad Obregon, Mexico, along with Tom Lumpkin (Director General of CIMMYT), daughter Jeanie Borlaug Laube, her husband Rex Laube, and Ronnie Coffman (Borlaug's graduate student).

thoroughfare in Ciudad Obregon leading to the research station was renamed Dr. Norman E. Borlaug Street.[1]

Borlaug took copious field notes and recorded many aspects of his travels; his notebooks are available in the archives of the University of Minnesota and Texas A&M. By contrast, he despised spending time writing reports and often responded negatively to administrative directives. On at least one occasion, he supposedly said, "Do you want paper, or wheat?" Borlaug was a determined no-nonsense individual who favored actions and results over words. Even at 91 years of age, after reviewing the rust-infected wheats in Kenya he wrote a note to the director general of CIMMYT upon returning to Mexico "calling for more funding and threatening to sever his ties with the institution if it didn't happen immediately" (Stokstad 2009). CIMMYT and others responded by creating, with Kenya in mind, several high-yielding disease-resistant wheats.

Still, Borlaug published numerous scientific articles. A sample of these papers, some of which were cited upon his nomination to the U.S. National Academy of Sciences, is listed in the Selected Bibliography below. But the CIMMYT library maintains a list of Borlaug's publications, issued between 1941 and 2007, which total approximately 500 peer-reviewed articles, reports, and commentaries. The book *Norman Borlaug on World Hunger (*Dil 1997) provides reprints of 32 selected speeches and writings.

Many of those privileged to have known Borlaug consider him one of the greatest humanitarians who ever lived (Phillips 2010). We at the National Academy of Sciences are particularly proud to have had him among us. The work of feeding the world will probably never cease, especially if we keep adding a billion people to the planet every 14 years. But it is encouraging that Borlaug's work will be carried on into the future by new generations of hunger fighters.

1 Wheat is grown on the experiment station in a ridgetilling fashion, producing idyllic rows of a beautiful crop. Most of it is durum wheat (for pasta flour), which outyields bread wheat in this locale, the Yaqui Valley of Sonora. About 75 percent of Mexico's production of durum wheat is exported today. Meanwhile, new technologies are being employed; genome sequencing is planned on about 150,000 strains (Ravi Singh, personal communication). Wheat lines are being developed with increased levels of iron and zinc—two micronutrients essential for human growth but generally limited in wheat—and selecting for yield and rust resistances remains as an important activity. So-called "synthetic wheats" are also being developed by CIMMYT scientists in order to produce wheats resistant to spot blotch, Fusarium head blight, and other diseases. Synthetic wheats are derived by crossing durum wheat with a relative, such as *Aegilops tauschii* or *Triticum dicoccum*. Many of the wheat lines currently being developed at the station are semi-dwarf, but taller than the original semi-dwarf types. Among other advantages, these new varieties allow farmers not only to financially benefit from the grain but also to profit from sale of the straw. This adds value to the crop and increases farm income, factors that were important to Borlaug.

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Table 1. Wheat varieties released from Borlaug's wheat-breeding program, sponsored by the Rockefeller Foundation and CIMMYT (Compiled with the help of Sanjay Rajaram, Borlaug's successor as director of that program at CIMMYT).

Name	*Date Released*
Chapingo 48	1948
Kentana 48	1948
Mayo 48	1948
Nazas 48	1948
Yaqui 48	1948
Lerma 50	1950
Yaqui 50	1950
Chapingo 53	1953
Toluca 53	1953
Yaqui 53	1953
Gabo 54	1954
Mayo 54	1954
Sinaloa 54	1954
Yaqui 54	1954
Yaktana 54A	1954
Gabo 55	1955
Gabo 56	1956
Tehuacan 60	1960
Pitic 62	1962
Penjamo 62	1962
Nadadores M 63	1963
Lerma Rojo 64A	1964
Mayo 64 – semi-dwarf	1964
Sonora 64	1964
Inia 66	1966
Tobari 66	1966
Siete Cerros 66	1966
Huamantla Rojo	1967
Noroeste 67	1967
Norteno 67	1967
Nuri 70	1970
Yecora 70	1970
Cajeme 71	1971
Tanori 71	1971
Anza	1973
Yecora Rojo	1973
Portola	1973
Jupateco 73	1973
Torim 73	1973

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