

# Norman Borlaug: The Man I Worked With and Knew

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## Abstract

Much has been written about Norman Borlaug the agricultural scientist and humanitarian whose achievements are recognized with many accolades; to add to those writings is a difficult task. This brief paper is an attempt to provide a personal perspective on Norman Borlaug that can come only from someone who has worked closely with him throughout his professional life. I have endeavored to recollect my early impressions of working with Borlaug as a wheat breeder in Mexico and to highlight his innovative approach to wheat breeding, as well as his views on global population and food security, fertilizers, organic agriculture, biotechnology, and conventional academia. His work ethic was instrumental in his vision for the international agricultural system as an instrument of change in the world. His spirit serves as a reminder to future agricultural scientists that the battle must be vigorously engaged and can be won.

## INTRODUCTION

As we begin the twenty-first century, disquieting concerns about the future of mankind and its ability to sustain itself have been loudly articulated (1). Given projections for world population by mid-century, food, feed fiber, and fuel production have to be doubled on existing farmland. Consequently, the big issues facing agricultural production systems are (a) food security, (b) efficient resource utilization, (c) enhanced soil, water and air quality, biodiversity, and ecosystem health, and (d) economic viability and social responsibility. As the challenges of feeding the world's population have never been greater (2), it is appropriate to critically assess the capacity of world agriculture to respond to these momentous challenges (3). In so doing, we should reflect on a man whose gargantuan achievements in stimulating agriculture output, particularly with cereals, set him apart from all other luminaries of the past century. That man was Norman Borlaug, who was awarded the Nobel Prize for Peace, largely because feeding people and staving off hunger are a prerequisite for sustaining peace. He was often quoted as saying "World peace will not be built on empty stomachs," a statement that was to describe his life-long mission.

Norman Borlaug has been lauded as an outstanding scientist who impacted the lives of many, as well as a visionary, hero, humanitarian, orator, and a great communicator. Volumes have been written about Dr. Borlaug (e.g., 4–7). In a comprehensive overview of Borlaug's life, Leon Hesser (6), an agricultural administrator who worked with Norman in Pakistan in the late 1960s, and later a journalist, described Norman's humble beginnings in Iowa, the course of his academic career at the University of Minnesota, how he came to Mexico with the Rockefeller Foundation, his revolutionary approach to wheat breeding, and his influence in the Indian subcontinent and China as the driving force behind the Green Revolution, and later in Africa, the most intransigent area of the world for agricultural development, and yet the most needy. A recent review by Quinn

(7) provided a concise synthesis of his life, with special emphasis on the legacy of his achievements, his inspiration for future generations of scientists and leaders, and his global recognitions, in addition to his role in establishing the World Food Prize, agriculture's equivalent of the Nobel Prize. Like Borlaug himself, Quinn lamented the declining support for agricultural research and development.

The many articles about the life and work of Dr. Norman Borlaug were mainly penned by journalists and other acquaintances; less has been heard from people who interacted with him at various stages of his long career. Now, just one year after his death, it is difficult to write something about Norman Borlaug that has not been written before. Anyone undertaking that challenging task can only hope to bring an additional prospective on a life so well described. With due humility, I am attempting to do just that.

As a wheat breeder hired by Dr. Borlaug in the late 1960s, I had the privilege of working with the great man himself side-by-side in the experimental fields of El Batán, Toluca, and Ciudad Obregón managed by Centro Internacional de Majoramiento de Maize y Trigo (CIMMYT) for many years. I fondly remember his love of nature; on occasions in the field when he would hear the "chanate" bird sing, Norman used to whistle to imitate the bird. Later as Wheat Program Director, I interacted closely with him as a senior colleague and personal friend while he was at CIMMYT after official retirement. As a mentor and inspirational colleague, I was privileged to gain a unique insight into Norman Borlaug, the scientist and the man. With a sense of awe and honor, I approach the task of formulating my abiding impressions of a man whose presence dominated my life for four decades.

As a background to presenting recollections on Dr. Borlaug, I believe the dedication he made in his personal copy of Hesser's book (6) establishes the privileged professional and personal relationship I had with him. It is a dedication I greatly treasure.

To My Grand “Amigo” and Scientific Colleague-Sanjaya Rajaram. It has been for me a great privilege and satisfaction to see you develop into the greatest present-day wheat scientist in the world. You have made and continue to make many important contributions to further improving world wheat production but also to other cereal crops. You have trained hundreds of wheat scientists from countries around the world. Moreover, you have learned to work effectively in many different countries with political leaders of different ideologies. And finally you are a scientist of great vision. You are not afraid of change. You are determined to use new technology, e.g., transgenic GMO to further agricultural production. Located as you are at present, in ICARDA, you are in part of the world (West Asia and North Africa-WANA) which will require great further increase in food production in the next three decades. I am confident that with your leadership this goal can be met. Best Wishes and Keep Fighting, Yours Sincerely, Norm Borlaug. 13/4/07

## HOW I KNEW NORMAN BORLAUG

In a long professional life that was dominated by my association with Norman Borlaug, my early experiences were punctuated by sporadic references to Dr. Borlaug that later evolved to an acquaintance and finally a life-long scientific association and friendship. My first recollection of the name of Dr. Borlaug stems from when I was a graduate student at the Indian Agricultural Research Institute (IARI) New Delhi and Dr. Borlaug was invited by the Government of India and the Rockefeller Foundation; he was hosted by the Head of the Division of Genetics, Dr. M.S. Swaminathan, who himself was later to achieve worldwide celebrity status as an agriculture scientist.

Subsequently, as a PhD student at the Agricultural Faculty of the University of Sydney, the name of Dr. Borlaug assumed a more tangible focus in my life as my mentor at that time was Professor I.A. Watson who,

coincidentally, was a fellow student with Borlaug under the celebrated Professor E.C. Stakeman at the University of Minnesota. The name of Borlaug was inseparably linked to the concept of rust resistance of short-strawed semi-dwarf wheat, the subject of my doctoral dissertation in 1968. At an International Wheat Genetics Symposium in that same year in Adelaide, Borlaug stressed the need for young scientists to tackle the emerging issue of rust in wheat; Watson strongly recommended me to Borlaug, a suggestion that was ultimately to dictate the course of my life as a wheat breeder, and I entered the orbit of Norman Borlaug and the realm of the CIMMYT in Mexico. But it was sometime before this transition would occur.

Returning to India from Australia, I journeyed from Varanasi to New Delhi, where I met Dr. Swaminathan, director of IARI. A professional position with IARI was in the offing, but it was delayed by bureaucratic red tape. At that time, the notion of the Green Revolution was taking hold in the Indian subcontinent (8). Dr. Robert Glenn Anderson, a wheat breeder from Canada, headed the Rockefeller Wheat Program in New Delhi and was the driving force behind the promotion of the short-strawed, “miracle” wheat varieties that originated from Dr. Borlaug in Mexico. Borlaug wanted me to join his program as postdoc in Mexico, and accordingly I accepted the offer to work with Glenn Anderson and the Rockefeller Foundation in India for a period of six months. This life-changing decision came at a time of momentous change in the world, when questioning and protests were the order of the day, and after three months, the postdoc offer in Mexico matured. At the same time, a temporary offer from IARI was made, with a view to permanency. Swayed by Glenn Anderson and lured by the challenges offered by Borlaug and CIMMYT, I reluctantly declined the offer from IARI and set my sights on Mexico in May 1969.

The Mexico that I first saw was an impoverished state with a poor rural population and a floundering agriculture. Through the zealous efforts of Borlaug and his colleagues, that sorry situation was to be drastically

transformed within a relatively short few years. The Center in Mexico had been operated by the Rockefeller Foundation since 1945 and became CIMMYT in 1966; it joined the Consultative Group on International Agricultural Research (CGIAR) in 1971. As a raw 27-year-old from India, I vividly recall my first real meeting with Norman Borlaug at the Center's office at Londres 40 in Mexico City. At that time, Borlaug, now in his 50s, was a larger-than-life figure in the Rockefeller Foundation's Wheat Program. Although CIMMYT was led by Edwin J. Wellhausen, as Director General, and Robert D. Osler as his deputy, Norman Borlaug was the dominant force in the Center. His presence was all encompassing.

In the CIMMYT of those years, Borlaug was clearly an authoritative figure who had an extraordinary belief in what he was doing; he possessed an iron will and energy to implement it. Such an approach served him, and indeed CIMMYT, well in those days when the wheat breeding program was being established. Consensus of colleagues had little part in the

professional ethos that permeated CIMMYT at the time. Facing the challenges that he did in Mexico, and being cut off from the mainstream academic and research institutions in the United States, Borlaug could ill afford the luxury of conflicting opinions, especially from neophytes, that could have thwarted his unshakeable goal of making a difference in Mexico and throughout the food-starved world through stimulating wheat output. Notwithstanding Borlaug's dominating image, I was not overawed, but felt a considerable empathy with him given our common poor, small-farming backgrounds.

Following a two-year postdoctoral period (1969–71), I became wheat breeder/rust pathologist/geneticist under Dr. Borlaug (**Figure 1**) and our professional and personal relationship intensified despite the fact that he was now achieving increased international fame for his work in Mexico and especially in India and Pakistan. Borlaug reached the pinnacle of his career with the Nobel Prize for Peace in 1970, recognizing his contribution to world



**Figure 1**

Dr Norman Borlaug (*right*) with Dr Sanjaya Rajaram in Mexico.

peace through enhancing world food production. “Peace does not come from empty bellies” was the famous phrase attributed to him so often. The iconic story of his wife, Margaret, driving to the field at the Toluca station to inform him that he had been selected to receive the coveted prize has been told many times. I was one of those present to witness this low-key but momentous communication, and the manner in which Norman almost incredulously reacted to the news and then nonchalantly proceeded to get on with the business at hand—making selections in the field with international students and staff.

The post-Nobel euphoria coincided with the founding of the CGIAR in 1971 and a subsequent expansion of CIMMYT’s work in the Indian subcontinent. In that year, Borlaug appointed Glenn Anderson as his deputy in the Wheat Program. Anderson was subsequently to replace Borlaug when Norman reached the mandatory retirement age of 65 in 1977. During the early 1970s, I had the opportunity of working closely with both Borlaug and Anderson; both were active in variety selection at Ciudad Obregón and Toluca. This period allowed me to appreciate firsthand the intellectual depth and breadth and physical energy of these two extraordinary and mission-oriented men, both united in the common goal of increasing world wheat production to help save humanity.

Following his retirement, Borlaug remained active on the global scene, although still with a home base in the CIMMYT campus. While one would have thought that directors of any institution would have thought it a badge of honor to have such a celebrity in their midst, his presence at CIMMYT was not always greeted with undiluted enthusiasm. However, he was a welcome guest in the halls and palaces of potentates and, more importantly, in the hearts and minds of the world’s poor whom he helped. As senior scientist at CIMMYT, my relationship with Borlaug, if anything, deepened; the close professional and personal relationship we enjoyed did not diminish even when he moved to Dallas as Distinguished Professor at Texas

A&M in 1996 and I assumed leadership of the Wheat Program in the same year. Indeed when I moved to the International Center for Agricultural Research in the Dry Areas (ICARDA), another major CGIAR center that collaborated with CIMMYT on wheat with a joint program in the WANA region, we continued to meet either in Texas (when I last visited him in 2008) or when Norman visited ICARDA in 2006. Until his death, he continued to regard me as “my grand amigo and scientific colleague.” I treasure these words from a humble man who did so much for so many.

### **BORLAUG’S STRATEGY AND APPROACH TO WHEAT BREEDING**

Borlaug’s field work involved crosses at Ciudad Obregón and Toluca and shuttle breeding between these locations. The extent of his field efforts can be fully realized by the 100,000 or so crosses he made between 1945 and 1972. Very large numbers of these crosses were rust-resistant, and he grew large  $F_2$  populations (2,000 plants per cross). His shuttle breeding, an entirely new concept, involved segregating populations in two distinct environments, i.e., Ciudad Obregón (Sonora) at 27°N and Toluca at 18°N. The Obregón location is irrigated similar to the Nile Delta in Egypt and the Punjab in India, whereas Toluca is a high rainfall location (1,000 mm during the wheat growing season) situated at 2,600 meters above sea level. Planting in Obregón occurs in November, and the maturation of plants coincides with increasing high temperatures in April and May. The entire harvested materials, after selection, are then transferred to Toluca where planting is done in May and June and harvesting is completed in October and November, when temperatures are declining.

This shuttle methodology allowed Norman Borlaug to harvest two generations of segregating populations per year and cut the length of the normal breeding cycle in half. The procedure inherently allowed only photoperiod insensitive plants to flower at both locations and

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#### **ICARDA:**

International Center  
for Agricultural  
Research in the Dry  
Areas

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complete the maturity period within this very tight time limit. The segregants that behaved outside of this maturity period were discarded. The concept of photoperiod insensitivity was not known to science at this period. It only became apparent when Dr. Borlaug began sending his material to the Indian subcontinent and the Middle East in the early 1960s. I was honored to be part of this pioneering venture under the tutelage of a great wheat breeder.

## **NORMAN'S WORK ETHIC**

With the passing of Dr. Borlaug on September 12, 2009, it was inevitable that he would be eulogized from many quarters for the great scientist and humanitarian he was. Dr. Thomas Lumpkin (9), Director General of CIMMYT, referred to Norman's many personal characteristics "not a team player, but rather the team leader," "curious throughout his life," "informed," "persistent," "determined," and "driven." Lumpkin also described him as a man with tremendous common sense who could be charming, caring, warm, and engaging. In a celebration of Borlaug's life, long-time CIMMYT breeder Art Klatt (10) noted that Borlaug "was the hardest working person I have ever met," "constantly encouraged others to better themselves," "was a leader who led by example, and tirelessly," was "a man of strong ideals," and "was honest and expected total honesty from others." Being close to him for so long, I too can affirm all of these qualities, and many more.

My most abiding memory of him was his unusual capacity to grasp the core of any issue and to synthesize the most complex situation, as well as his enormous physical stamina and his exceptional work ethic. He had the capacity to work from dawn to dusk without any slackening of pace; for him the field was where the real action occurred and he was at home there. Unlike most other mortals, whether at El Batán, Toluca, or Obregón, the notion of "weekend" was an alien concept to him. He had a visceral intolerance for sloth or lack of zeal of any description and set a hard pace for those who worked alongside him. His philosophy to work was "do as I do,

not only what I say." He was a hard taskmaster for international trainees and was quick to weed out those who could not "stay the course" or "toe the line." During his years in the field as a hands-on wheat breeder, he often had occasions to be explosive, a trait that diminished as he mellowed with age and devoted more time to management and global travel.

After retiring as director of the Wheat Program at CIMMYT, the physical dynamism that characterized Norman in his youth and mature years allowed him to embrace teaching at Texas A&M and serve at the international level with the Sasakawa Foundation, as well as travel the world railing against poverty and serving as agriculture's global ambassador. For him, the failure of the Green Revolution to impact Africa was something he found difficult and his energies were consumed in doing something about it (11, 12).

That indefatigable energy was to remain with him to the end. Despite illness, he was able, at the age of 92, to present a lecture at ICARDA, and answer questions and remain at the podium for more than an hour. He left me, and many others who witnessed it, in awe. Similarly, although increasingly more frail, he was able to give a plenary address to the American Society of Agronomy at the Annual Meetings in New Orleans in 2007. That lecture was an iconic event in the history of the Society.

Although Borlaug was a leader, who commanded loyalty, he did not particularly foster leadership. Each style has its time and place. Inevitably, as a man of such strong convictions, combined with extraordinary achievements, he was to attract a loyal following and a band of fierce critics, many of whom attacked him for his defense of DDT and other pesticides (13) and his open espousal of biotechnology (14). He gave scant concessions to either group.

## **FERTILIZER AND CROP PRODUCTION**

Despite being a geneticist and plant scientist, Norman Borlaug recognized that regardless of the genetic potential of a crop, no yield

increases could be achieved unless the other factors of crop production (water, nutrients) were adequately supplied. He recognized that the main driver of the phenomenal output that occurred during the Green Revolution was largely due to nitrogen (N) fertilizers and to a lesser extent, phosphorus. Indeed, since the initiation of chemical fertilization, particularly since post-World War 2, fertilizer use paralleled crop production. Recent estimates suggest that fertilizer use contributes to at least 50% of global agricultural output (15). The percentage contribution to future crop yields will be much greater.

In his Hignett Memorial lecture at the International Fertilizer Development Center (16), Borlaug presented data that suggested that 40% of the world's 6+ billion people are alive today because of the Haber-Bosch process that underlies the production of 80 million tons of N each year. The increasing use of N in powering crop yields in India, Pakistan, and China was only possible when combined with Borlaug's short-straw wheat varieties that resisted lodging. Between 1970 and 2000, wheat and rice yields more than doubled, and fertilizer nutrient input increased sevenfold.

Although the overuse of fertilizers stemming from the Green Revolution has attracted considerable criticism, with renewed emphasis—and exaggerated claims—of organic manures to supply the crops' needs, the evidence shows that only a fraction of the world's population could be supported by organic fertilization alone. Borlaug often stated that were chemical fertilizers not used, world food output would rapidly plummet, bringing a drastic increase in food prices and widespread famine. In his role in the Sasakawa-Global 2000, Borlaug paid special attention to the issue of nutrient mining in Africa and restoring soil fertility. In his view, eliminating the bottleneck of limited nutrients was the key to raising the continent's people out of poverty. This major leap forward not only required information on fertilizer use but also government policies that promoted the use of fertilizers at prices affordable for African farmers, as well favorable product prices to justify such fertilizer use. Improved infrastructure

was seen as a key issue in achieving the goal of increased fertilizer use in Africa. Borlaug's espousal of the indispensability of fertilizers in feeding the world was reflected in his efforts as a board member of the International Fertilizer Development Center. He believed that government intervention was needed to address Africa's fragmented and dysfunctional fertilizer supply system. His career was peppered with public recognitions, but one which will endure, and one which he would have greatly valued, was the renaming of the International Crop Nutrition Award from the International Fertilizer Industry Association (IFA) as the IFA Norman Borlaug Award in recognition of fertilizers in increasing world food production.

## **BIOTECHNOLOGY: BANE OR BLESSING**

Borlaug viewed science dispassionately as a means to an end. Although few developments in recent decades have been as emotive or controversial as biotechnology, Borlaug adhered to the more rational, saner view. To him, this new approach (17) based on recombinant DNA produced invaluable new scientific methodologies and products in food and agriculture. In his view, scientific probing of the genome at the molecular level is part of a continuum of our progressive unraveling of the workings of nature. Many of his views on biotechnology were clearly expressed in the Hignett Memorial lecture (16). Biotechnology enabled breeders to select and transfer single genes, thus accelerating the process of conventional breeding and allowing access to useful genes from distant taxonomic groups; such gene alterations have yielded producer-oriented benefits such as resistance to pests, diseases, and herbicides. In his view, biotechnology could lower production costs by reducing the use of crop protection chemicals, thus making production more environmentally friendly. Other potential benefits include tolerance to drought, water logging, heat, and cold. Similarly, he felt that pesticides such as DDT had more benefits to mankind than drawbacks.

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**IFA:** International Fertilizer Industry Association

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Borlaug hoped that one day the genes for rust immunity in rice could be transferred into wheat, barley, oats, maize, millet, and sorghum, thus freeing agriculture of the scourge of rusts that had led to much famine in the world. Another of his dreams was that the genes responsible for the proteins gliadin and glutenin in wheat could be transferred to the rice and maize. In reflecting on the potential benefits, Borlaug recognized the unprecedented adoption of genetically modified (GM) crops in the United States, Canada, and Brazil as well as the resolute opposition in Europe and in most developing countries, a debate that centered around safety concerns and issues of access and ownership (18). Although recognizing that some sectors of society resist change and romanticize the past, Borlaug felt that such opposition to GM crops was irrational and counterproductive.

In his sobering view, the food we eat today and the crops we grow are the outcome of natural mutation and genetic recombination that have occurred over the millions of years of biological evolution. Without discounting possible harmful effects of GM crops in the food chain, Borlaug noted that there is no scientific evidence to substantiate that GM foods are inherently dangerous, pointing out that recombinant DNA has been used in pharmaceuticals for years. This issue is one of misguided public perception. He contended that rigorous procedures are in place to allay any societal concerns about GM crops.

Consistent with his mission to help the poor in developing countries, Borlaug saw the potential benefits for Third World farmers using GM crops, but recognized their dilemma in gaining access to biotechnology, which is mainly funded by private companies such as Monsanto and Syngenta that have to provide an economic return to their investors. He recognized that the high cost of biotechnology research had led to consolidation of ownership by agricultural life science companies, i.e., “genetic imperialism.” He wondered for how long and under what conditions should patents be issued for bioengineered products and urged that such matters

be given the highest consideration at all levels. He was a strong believer in public funding for biotechnology research as a complement to the private sector. Such public research would ensure access for farmers in developing countries and guarantee a continued cadre of scientists required to push back the frontiers of biology to the betterment of mankind. However, he was criticized initially for his close relationship with the large biotechnology companies.

## ACADEMIA AND PUBLICATIONS

Dr. Borlaug’s opinions of the rigorous emphasis on refereed publications in academic institutions, the so-called “publish or perish” view, were shaped by his field experiences in Mexico and in part by his distance from mainstream universities and research centers in the United States. Nevertheless, while maintaining a healthy skepticism for the notion of publishing for publication’s sake, he did report his work in some refereed journals, but more commonly in book chapters and in popular nonrefereed outlets.

Following the publication of his PhD thesis work on *Fusarium* (19), his early work in Mexico focused on rusts in wheat (20). Increasingly, his work with wheat expanded to consider the human dimension (21), with specific concerns expressed in popular media about the future of society (22), the Green Revolution (16, 23–25), and the potential of conventional plant breeding and agricultural research (26) to contribute to world food production. Gradually, his writings contained dominant themes of alleviating hunger (8) and meeting the challenge of feeding the world’s projected population (16, 27). The list of Borlaug’s publications revealed a conviction that a balance was needed between basic, applied, and popular publications.

From his perspective in the experimental fields in Mexico, many refereed publications that emanate from academia had little or no impact and did nothing to address the immediate problems of hunger and poverty that afflicted much of mankind. Although he was not opposed to the principle of academic



publication, he stressed the importance of impact, and that good science was a necessary condition for impact. To him, one good paper far outweighed publications that were part of the “numbers game.” I vividly recall him stating on one occasion that many publications “should be ground up and fed to cows.” Coming from a man who had fed people with his improved wheat varieties, that comment was understandable. Nevertheless, it is a sobering reminder for many who see publication only as an avenue for professional advancement. Regrettably, the number of people who have been fed or taken out of poverty as a result of one’s research efforts never features in the tenure-promotion package. In short, Borlaug was not an advocate of the ivory tower approach.

## CGIAR

With the incorporation of CIMMYT and the International Rice Research Institute (IRRI) into the newly founded CGIAR in 1971, Dr. Borlaug saw the new alliance of existing and future centers as a vital means of transferring agricultural technology, mainly generated in the West, to solve the pressing problems of food production in the least developed areas of the world, particularly India, China, the Middle East, Latin America, and Africa. During some decades of expansion, spawned by a favorable donor environment, the CGIAR was a major player in global agricultural development.

However, Borlaug expressed concerns about the increasing bureaucracy in the system, the multiplicities of donors with different political agendas, and a shift from core funding to project-driven funding; in his mind, this was a crime. In his view, short-term, donor-driven projects were anathema to the longer-term goals of the international centers. With the inevitable restructuring of the CGIAR (28), in the views of many, this will only increase bureaucracy by adding another layer of management oversight. Given his stated views that the CGIAR was deviating from its mission to help farmers, Borlaug would probably not have grounds for optimism.

Dr. Borlaug was a firm believer in the value of agricultural research (11, 18, 26, 29, 30). Perception of current developments in the area of international agricultural research are concisely encapsulated in his personal reflections (18) just two years before his death.

Unfortunately, agricultural science—like many other areas of human endeavor—is subject to changing fashions and fads, generated from both within the scientific community and imposed on it from external forces. Increasingly, I fear, too much of international and national research budgets are being directed towards “development bandwagons” and increasing bureaucratic red tape that will not solve Third World food production problems, and for which scientists are ill-equipped to deal with.

Today’s leaders of international agriculture would do well to ponder those prescient words.

Notwithstanding his misgivings about the direction of the CGIAR, his role in the establishment of ICARDA in 1977 is fondly remembered (31). His initial introduction to the region in 1960 was part of a three-man mission from FAO (Food and Agriculture Organization) to establish a project within the region that embraced the testing of short-straw, high-yield Mexican wheat varieties for adaptability and to set up a training program in wheat improvement and production for young scientists from the WANA region. Such proposals served as a catalyst for the eventual establishment of ICARDA, with its headquarters at Tel Hadya, subsuming the existing Arid Lands Agricultural Development (ALAD) Program (1968–1977). The image of Dr. Borlaug standing on top of the hill at Tel Hadya in 1977 (**Figure 2**), overlooking the Center’s newly established experimental fields, is symbolic of his influence on the evolution of the Center. His visit in 2006 was a homecoming in many ways. Despite the global celebrity that he had become, he never lost the common touch for farmers (**Figure 3**), and farmers everywhere treated him as their friend.



**Figure 2**

Dr. Borlaug (*left*) at Tel Hadya in 1977 when ICARDA was founded.

## APPROACH TO TRAINING

As a quintessential hands-on field scientist, Dr. Borlaug was a believer in applied research and the practical approach to achieving results. For him, theory lectures without work in the field were meaningless. As a breeder, the crosses and selections must be done on site, and one should observe the unique characteristics of each variety throughout its growth cycle. With this philosophy, Borlaug initiated the first International Wheat Training Program in Mexico in 1958. When the CGIAR was founded in 1971, the CIMMYT training program was a prototype for other centers to follow.

The early years of the training program in Mexico were supported by funding from FAO and involved many young scientists from the Middle East, a region of the world where wheat output needed to be greatly increased to feed the region's expanding population: Although the Middle East is the center-of-origin for wheat (32), the entire region was food deficit with hardly any country being sufficient in wheat. That early connection through training was the beginning of a relationship between Dr. Borlaug and this historic part of the world. Through his years at CIMMYT, the hands-on approach to training remained and was still the most significant among CGIAR centers not

only for wheat (33–35) but also for maize (*Zea mays*) (36). Borlaug was uncompromising in his insistence of practical training, something that required some international trainees to overcome ingrained cultural impediments to physical work. In his view, academic training should be left to universities. In his later years teaching at Texas A&M, he attempted to inculcate the applied and theoretical approaches to agricultural research among his students.

## THE NOBEL PRIZE AND OTHER ACCOLADES

The awarding of the Nobel Prize for Peace for his groundbreaking work on wheat improvement and its implications for the developing world in particular was the high point of Dr. Borlaug's career. While graciously accepting the award, in his mind he did it on behalf of others who also had major roles in agricultural research and development. Borlaug graciously acknowledged those on whose behalf he accepted the Prize. The historic announcement and the euphoria of the Prize in Oslo were things we who worked with him shared. We too were honored by the Prize, as we had been part of the team of such a luminary. Although he found no great satisfaction in his new celebrity status, Norman used the publicity surrounding the Prize and the other recognitions that subsequently came his way (Presidential Medal, Congressional Medal, and many more) to gain political support in helping with international agricultural research and development.

As there is no separate Nobel Prize for agriculture, Borlaug set a process in motion that led to the creation of the World Food Prize (6). This Prize was designed to honor "exceptional and unique achievements in improving the quantity, quality, and the availability of the world's food as well as the access of human beings to it." Many luminaries in the varied fields of agricultural science (from equally varied backgrounds and nationalities) were subsequently to receive the Prize, with the first in 1987 being given to Dr. M.S. Swaminathan, who played a role in my early professional life

in India. Were it not for a twist of fate, spiced with bureaucracy, I may have remained in India with Dr. Swaminathan rather than with Dr. Borlaug in Mexico. It was source of immense satisfaction to Dr. Borlaug that two CIMMYT fellow scientists, Dr. Evangelina Villegas, a cereal chemist from Mexico, and Dr. S.K. Vasal, a geneticist from India, shared the 2000 Millenium Prize for creating high protein maize. Throughout his career in Mexico, Evangelina was almost inseparable from Borlaug and was a great source of support for him as a loyal colleague and friend.

### POPULATION, FOOD SECURITY, UG 99, AND CLIMATE CHANGE

From his early years, Dr. Borlaug expressed his concerns about global population and food supply. In his view, political leaders, including the Pope, did little to stem the “population monster.” He constantly advocated family planning. Not to detract from the Green Revolution, he felt that it only gave the world a breathing space of 30 years. Initially, he assumed that producing “mountains of grain” was the solution to world hunger. Later, he realized that food security could only be achieved by giving developing countries the technical means to economically produce their own food; enabling government policies were essential to achieve this goal. I was part of a much-heated discussion in Eva Villega’s house with Borlaug on UG 99, a virulent strain of stem rust of wheat. Although the virulent strain of rust UG 99 is endemic to East Africa and now seems to be confined to that region, it was my contention that while the initiative would revitalize CIMMYT, the focus should be on food security and the menace of yellow rust rather than this strain of stem rust. Although much is



**Figure 3**

Dr. Borlaug with grateful farmer from Syria.

currently made of biofortification in ensuring improved nutrition, Borlaug was not a proponent of this approach. Climate change has been a dominant scientific and media concern in the past decade, but Borlaug seemed to have mixed feelings about it. I do not recall him expressing any forceful views on climate change, as he was accustomed to do with respect to other subjects.

### SUMMARY POINTS

Few brief summaries can do justice to someone of the stature of Norman Borlaug.

1. Coming from humble beginnings, he was embued with extraordinary zeal to help poor farmers and the rural poor through his efforts as a plant breeder.

2. He achieved exceptional success in improving wheat output, first in Mexico and later in India, China, and Pakistan.
3. With his emphasis on improved wheat and rice varieties together with chemical fertilizers and irrigation, he was justifiably called the father of the Green Revolution.
4. Although the varieties he produced have now been supplanted by newer ones, his approach endures.
5. He was one of the most acclaimed public figures in the past century and influenced more people than anyone else in terms of improving nutrition and livelihoods.
6. Norman Borlaug made great personal sacrifices in his career as scientist and media star, a path that took him away from his wife and children often and for great periods of time. Family life was subservient to his career-driven life.
7. Although criticized by environmentalists, Borlaug had a love of nature and believed that fertilizers were more beneficial for the environment by reducing pressure on marginal land and nature reserves; similarly, he saw biotechnology as being environmentally friendly by reducing pesticide use.
8. His scientific achievements and his dedication to helping his fellow humans will inspire future generations of agricultural scientists.
9. I know of no scientist in specialized disciplines such as genetics who had such an encyclopedic view of global issues.
10. Although Dr. Borlaug was almost superhuman in his achievements, he was still a human being, possessing the same frail human traits as we all do.

### FUTURE ISSUES

Dr. Borlaug would have wanted to see:

1. An increased awareness of food production in an overcrowded, mostly urbanized world population.
2. A reprioritizing of international funding from the developed world for agricultural research and development in lesser-developed countries where food crises are most likely.
3. Greatly expanded support for CGIAR centers.
4. Greater focus by international research centers on the problems of the rural poor.
5. An enhanced recognition that the earth has limits to support mankind. The “population monster” that he spoke of must be held at bay.

### DISCLOSURE STATEMENT

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### LITERATURE CITED

1. Cribb J. 2010. *The Coming Famine: The Global Food Crisis and What We Can Do to Avoid It*. Collingwood, Austral.: CSIRO

2. Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, et al. 2010. Food security: the challenge of feeding 9 billion people. *Science* 327(5967):812–18
3. Federoff NV, Battisti DS, Beachy RN, Cooper PJM, Fischhoff DA, et al. 2010. Radically rethinking agriculture for the 21st century. *Science* 327(5967):833–34
4. Bickel L. 1974. *Facing Starvation: Norman Borlaug and the Fight Against Hunger*. New York: Reader's Digest Press
5. Dil A, ed. 1997. *Norman Borlaug on World Hunger*. San Diego, CA: Bookservice Int.
6. Hesser L. 2006. *The Man Who Fed the World*. Dallas, TX: Durban House
7. Quinn KM. 2008. Dr. Norman Borlaug: twentieth-century lessons for the twenty-first century world. *Adv. Agronomy* 100:1–13
8. Borlaug NE. 1983. Contributions of conventional plant breeding to food production. *Science* 219:689–93
9. Lumpkin T. 2010. Norman Borlaug: Hunger Fighter, Hero, Humanitarian, and the Heart of CIMMYT. Speech delivered March 25, Ciudad Obregón, Mex.
10. Klatt A. 2010. *A Personal Recollection*. Texcoco, Mexico: CIMMYT
11. Borlaug NE, Dowswell CR. 1995. Mobilising science and technology to get agriculture moving in Africa. *Dev. Policy Rev.* 13(2):115–29
12. Quiñones MA, Borlaug NE, Dowswell CR. 1997. A fertilizer-based green revolution for Africa. In *Replenishing Soil Fertility in Africa*, ed. RJ Buresh, PA Sanchez, F Calhoun, pp. 81–95. *Soil Sci. Soc. Am. Spec. Publ.* 51, Madison, WI: SSSA
13. Borlaug NE. 1974. In defence of DDT and other pesticides. *Pesticides (Bombay)* 8(5):14–19
14. Borlaug NE. 2000. Ending world hunger: the promise of biotechnology and the threat of anti-science zealotry. *Plant Physiol.* 124:487–90
15. Stewart WM, Dibb DW, Johnston AE, Smyth TJ. 2005. The contribution of commercial fertilizer nutrients to food production. *Agronomy J.* 97:1–6
16. Borlaug NE. 2003. Feeding a world of 10 billion people. The TVA/IFDC legacy. *Travis P. Hignett Meml. Lect.*, March 14. Muscle Shoals, AL: Int. Fertil. Dev. Cent.
17. Borlaug NE. 2004. Foreword. In *The Frankenfood Myth: How Protest and Politics Threaten the Biotech Revolution*, ed. H Miller, G Conko. Westport, CT: Praeger
18. Borlaug NE. 2007. Sixty years of fighting hunger: personal reflections. *Euphytica* 157:287–97
19. Borlaug NE. 1945. *Variation and variability of Fusarium lini*. Univ. Minn. Agric. Exp. Stn. Tech. Bull. 168:1–40
20. Borlaug NE. 1954. Mexican wheat production and its role in the epidemiology of stem rust in North America. *Phytopathology* 44:398–404
21. Borlaug NE. 1965. Wheat, rust and people. *Phytopathology* 55:1088–98
22. Borlaug NE. 1973. Civilization's future: a call for international granaries. *Bull. Atomic Sci.* 29(8):7–15
23. Borlaug NE, Narvaez I, Aresvik O, Anderson RD. 1969. A green revolution yields a golden harvest. *Columbia J. World Bus.* 4:9–19
24. Borlaug NE. 1976. The green revolution: Can we make it meet expectations? *Proc. Am. Phytopathol. Soc.* 3:6–21
25. Borlaug NE. 2003. The green revolution: its origins and contributions to world agriculture. *J. Bioresour. Sci.* 4:11–22
26. Borlaug NE. 1986. Accelerating agricultural research and production in the third world: a scientist's viewpoint. *Agric. Hum. Values* 3:5–14
27. Borlaug NE. 1992. World food security and the legacy of Canadian wheat scientist R. Glenn Anderson. *Can. J. Plant Pathol.* 14:253–323
28. Borlaug NE. 1997. Feeding a world of 10 billion people: the miracle ahead. *Plant Tissue Cult. Biotechnol.* 3:119–27
29. Deane C, Ejeta G, Rabbinge R, Sayer J. 2010. Science for development: mobilizing for global partnership. *Science* 5(1):1–7
30. Borlaug NE. 2004. International agricultural research. *Science* 3003:1137–38
31. Nour MA. 2002. *ICARDA 25: A Promise of Hope*. Tel Hadya, Aleppo, Syria: ICARDA.
32. Harlan J. 1992. *Crops and man*. Madison, WI: Am. Soc. Agron. 2nd ed.



33. Swanson BE. 1975. Evaluation of the CIMMYT wheat training program. *J. Agronomic Educ.* 4:85–89
34. Villareal RL, de Toro E. 1993. An assessment of a wheat improvement research training course for developing countries. *J. Natl. Resour. Life Sci. Educ.* 22(1):38–43
35. Villareal RL, de Toro E. 1993. Competency evaluation of participants in a wheat improvement research training course. *J. Natl. Resour. Life Sci. Educ.* 22(1):44–48
36. Bell MA, Lafitte HR, Violic AD, Palmer AFE. 1993. Practical wheat and maize crop management research courses for developing countries. *J. Nat. Resour. Life Sci. Educ.* 22(1):27–30