The Green Revolution was built on manipulating genes to breed higher-yielding, disease resistant crops. Here’s an ode to one of its pioneers, Sanjaya Rajaram. Few people are aware of the heroes behind the surge in yields of wheat and other crops that began in the 1950s and ’60s, literally rescuing the world from mass starvation. Many of us know the name Norman Borlaug, the American agronomist known of the ‘Father of the Green Revolution, who eventually won a slew of honors including the Nobel Peace Prize. Few are aware of his most influential partners.

The International Maize and Wheat Improvement Center (CIMMYT), where Borlaug began his research in 1942, recently renamed one of its most historic and successful wheat experimental stations to commemorate the legendary wheat breeder and World Food Prize laureate Sanjaya Rajaram, a former director of their Wheat Program. Rajaram passed away in February 2021. He is one of Borlaug’s most impactful collaborators.
Sanjaya Rajaram at the Centro de Investigaciones Agrícolas del Noroeste (CIANO) in Ciudad Obregón, in Mexico’s Sonora state. Credit: Gil Olmos/CIMMYT

Located in El Batán, southern central Mexico, CIMMYT is a storied wheat and maize breeding station operated by CGIAR, the global agricultural development consortium. CIMMYT began in 1943 as the Cooperative Wheat Research Production Program, a joint venture by the Rockefeller Foundation and the Mexican Ministry of Agriculture, a pilot program to ensure food security in Mexico and abroad through selective plant breeding and crop improvement, giving support to Mexican and international breeders. The initial goal was to breed rust-resistant, higher-yielding wheat.

The nascent program was headed by Borlaug, who would go on to innovate not only new and revolutionary varieties of wheat, but revolutionary approaches to plant breeding. The most consequential of those was ‘shuttle breeding,’ which began when he set up another station for cultivation 700 miles away in a part of Mexico that allowed a second planting per year, doubling the rate of iteration. Borlaug led breeding efforts in India as well. His efforts resulted in a dwarf wheat that was rust-resistant and greatly increased yields. He was awarded the Nobel Prize in 1970, known as the father of the Green Revolution,
and credited for saving hundreds of millions from starvation.

**Rajaram’s career**

But Borlaug didn’t work alone. Rajaram was born on a small farm in India in 1943. He studied genetics and plant breeding at the Indian Agricultural Research Institute in New Delhi. After receiving his Ph.D. from the University of Sydney, he joined CIMMYT in 1969. Rajaram quickly distinguished himself and Borlaug appointed him as head of CIMMYT’s wheat breeding program at just 29 years of age in 1972.

According to CIMMYT:

> His leadership and commitment to wheat improvement resulted in the release of more than 480 varieties of bread wheat with increased yield potential and stability, along with wide adaptation and resistance to important diseases and stresses.

> These varieties include the spring and winter wheat cross Veery, which was released in 36 countries; new approaches to disease resistance, for instance ‘slow-rusting’ wheat varieties; and largely reduced foliar blight susceptibility in semi-dwarf wheat. Rajaram’s wheats are grown on some 58 million hectares worldwide and approximately 30 million hectares in South Asia. One of his wheats, PBW 343, is India’s most popular wheat variety. His varieties have increased the yield potential of wheat by 20 to 25 percent.

Among Rajaram’s broader innovation was his work in applying the concept of *durable resistance* to rust in wheat and triticale. Durable resistance was a concept introduced in 1971 by the Australian plant pathologist Dr. Roy Johnson.

From his Johnson’s obituary [PDF]:

> [Johnson] was the one who talked to his friend David Bowyer, a medical pathologist, about the elusive concept of a desirable quality of disease resistance that had been variously characterized as horizontal, multigene, field, partial, adult-plant, and other things that were meant to describe the good quality but did not always add clarity to the concept. The issue was substantially resolved after Roy described the way he saw the quality: the resistance he sought was resistance that was effective for a number of years before it broke down. David innocently suggested that the desirable quality of resistance was that it should endure. Thus in 1971 Roy coined the term ‘durable resistance’ (Johnson & Law, 1973) which was to pass into the vocabulary of plant pathology. After the event it seems too obvious to be important, but like many good ideas it took a keen insight to be the first to perceive the obvious.

**Manipulating genes the old fashioned way**

Rajaram’s work involved systematizing for CIMMYT how they would go about pursuing and achieving durable resistance. They developed processes of mapping available genes for resistance, programs of epidemiology for rust pathogens. This involved identifying the appearance of resistance breakdown and
mapping the spread of rust, varying the genetics of cultivars to introduce gene combinations that conferred resistance to keep ahead of the pathogen, and widening out the genetic base for resistance using European triticales, rye, and wheat.

Durable resistance as a strategy uses multiple ‘minor’ genes with cumulative effects so that resistance doesn’t break down with the loss of one gene when the disease population adapts as a result of selection pressure. CIMMYT coordinated research around the globe, in Mexico, Australia, the Netherlands, the US, Canada, Scotland, and England.

The innovation that won him the World Food Prize in 2014 was the “crossing of winter and spring wheat varieties, which were distinct gene pools that had been isolated from one another for hundreds of years, [which] led to his development of plants that have higher yields and dependability under a wide range of environments around the world.”

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As with Borlaug, Rajaram was also active in wheat breeding in his home country of India (he became a citizen of Mexico). In 2014, he was encouraging new investments in breeding beyond wheat, strong agronomic practices, greater care and precision in the use of fertilizers and pesticides, and encouraging
greater adoption of genetic engineering. In an interview with the Financial Express in India, he had this to say:

Advances in wheat alone will not solve our problem. We need to give more attention to monsoon dependent crops such as millets, sorghums, maize and legumes and oilseeds. Progress in these crops will enhance our capacity to meet food security.

... [Wh]eat and rice have been sustained for 50 years. We have maintained small genetic gains. However, the potential to maximise these gains lies in good agronomic practices, especially timely planting. Chemical fertilisers and water played a great role. The response in increased output wouldn’t have been possible without dwarf varieties. For this, a lot of credit goes to Borlaug and IRRI short rices. We have scope to maximize production by bringing mechanisation, water use efficiency through modern irrigation systems, micronutrients’ application and growth hormones and in certain situations conservation agriculture. We need to give good seeds to all farmers. We need to reach out to the difficult regions with these technologies.

Chemical fertilisers and pesticides were a big part of the Green Revolution but the adverse impact of indiscriminate use is being felt on the soil as well as people’s health. How does India deal with the conflicting needs of feeding a billion-plus population without compromising health of the soil or the people

We cannot apply chemicals indiscriminately. This has polluted our precious water systems and environment. We need precision agriculture to avoid these problems. In certain situations, GM crops in control of insects and diseases will help, as in cotton.

We need the best technology to enhance productivity of our agriculture. It would be shameful if we let GM technology pass. But it must meet the requirement of not damaging environment. We must invest in this technology to remain an independent player. We are today very dependent. Investment in GM crops will help enhance the capacities of crops against drought, heat, flooding and salinity.

CIMMYT is renaming their experimental station in Toluca, State of Mexico, Mexico. Located in a valley 2,630 meters (8,628 feet) above sea level with a cool and humid climate, it is the ideal location for wheat breeding and has been a crucial part of their shuttle breeding system. A virtual event to remember Rajaram and officially dedicate the Toluca station in his honor is tentatively planned for May.

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