Oregon State University Extension Service
Special Report 1017
June 2000

Warren E. Kronstad Honorary Symposium

February 18, 1999

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A Salute to Dr. Warren Kronstad for Three Decades of Dedicated Effective Service on Scientific and Educational Fronts Toward Improving Food Production and the Well-being of Humankind

Norman Borlaug

It is a great privilege and honor for me to participate in this symposium honoring my close friend Dr. Warren Kronstad–one of the great wheat scientists and most effective teachers of this century. Dr. Kronstad is a man of many talents. Above all, he is a kind, understanding, friendly and good human being. As a teacher/professor, he is peerless, as is manifest by the large number of former students who currently occupy important positions in public sector research and/or educational institutions or in private sector research organizations, not only in the U.S., but around the world. As a research scientist, Warren has superb imagination and vision. Moreover, he is an excellent organizer of research, as is indicated by the genetic diversity and magnitude and efficiency of his breeding program and by the phenomenal commercial success on farmers' fields of the varieties he has produced. Dr. Kronstad is labeled, by most of his scientific colleagues, as a wheat breeder and wheat geneticist who has produced some of the best wheat varieties in the Pacific Northwest; he is much more. He is an all-inclusive agricultural scientist–an integrator across all scientific disciplines that bear on wheat production, e.g., varietal improvement; agronomic practices; disease, insect, and weed control; and grain quality. Because of this breadth of interest and understanding, he has been highly effective in assisting Pacific Northwest farmers' organizations increase wheat yields, production, and family income. These same skills have made him very effective as a consultant in many developing countries, where his counsel has improved the orientation and focus of research programs as well as improved crop management practices on farmers' fields, which in turn has increased wheat yields and production. For example, Dr. Kronstad (and several members of the Oregon Extension staff) played a key role in the successful introduction of the high-yielding semidwarf Mexican spring wheat varieties into Turkey, which dramatically increased wheat production. Without this introduction of improved agronomic and crop management practices, the high-yielding Mexican varieties would have had only minor impact.

Over the past 3 decades, Dr. Kronstad has visited the Mexican Wheat Research Program (CIMMYT/INIFAP) many times. On each occasion, he has stimulated our staff with lively seminars and discussions for which we are grateful. Over the years, his lectures and seminars have made important impacts on hundreds of young wheat scientists from developing nations around the world who have been studying and training at CIMMYT. As a result of this inspiration, many of these young scientists subsequently have studied and received graduate degrees at Oregon State University or at many other Universities.

I am fascinated with the progress now being made by the Cooperative International Winter Wheat Shuttle Breeding Program, being jointly developed by Oregon State University and the International Maize and Wheat Improvement Center (CIMMYT), under the joint leadership of Dr. Warren Kronstad and Dr. Sanjaya Rajaram, Director of the CIMMYT Wheat Program. I predict that this breeding program will have a big impact on wheat production in the winter wheat production of the Middle East, eastern Europe, former Soviet Union countries, and China within the next decade.

Dr. Rajaram, in a few minutes, will report on the progress being made by that important program.

The Early Years of International Agricultural Research Programs to Assist Food-Deficit Developing Nations

I have been requested to give a brief summary of the early years of international agricultural research programs and something about their contributions to increasing world food production.

The first foreign technical assistance program in agriculture, initiated in 1943, was the Cooperative Mexican Government-Rockefeller Foundation Agricultural Program (known as the Office of Special Studies [OEE] of the Secretaria de Agricultura y Ganaderia). It was a pioneering adventure. It preceded by 5 years the establishment of the Marshall Plan, which assisted in the rehabilitation of war-torn Europe, and President Truman's Point 4 Foreign Assistance Program (which later evolved into USAID) by 6 years.

The OEE had four major objectives: 1) to train a corps of young Mexican scientists in all of the scientific disciplines that influence crop production; 2) to conduct the research to produce the varieties and the information needed to increase the production of the three most important food crop-maize, wheat, and beans; 3) to transfer the improved technology to farmers' fields to increase production; and 4) to transfer leadership for continuation of the research program to the new team of Mexican scientists as soon as scientifically feasible. Later, potatoes, vegetables, oilseeds, and forage were added; still later, poultry and animal sciences were added.

I joined the program in 1944 and have been continuously involved in international agricultural research and production programs ever since. In 1945, I assumed the leadership of the wheat research and production program, organized to develop information to support an integrated wheat crop production management system, including: varietal improvement (breeding), restoration and maintenance of soil fertility, improved agronomic practices, plant protection (diseases, insects, and weed control), and economic policy.

When the wheat research program was initiated, 55 percent of total national wheat consumption was imported. Although most of the wheat was grown under irrigation, yields were low and stagnant, the national average being 750 kg/ha (11 bushels per acre)–with yields as low as 500 kg/ha (7.5 bushels per acre) in the "worn-out" soils of central Mexico. There had been three devastating stem rust epidemics in the State of Sonora (the best wheat production area in the country) in 1939, 1940, and 1941. This indicated breeding high-yielding varieties with resistance to this pathogen had to be given top priority, especially if the use of fertilizer was to be introduced to increase yield on "worn-out" soils.

Let me describe several key factors that strongly impacted wheat production in Mexico during the Quiet Wheat Revolution of the 1950s, when Mexico became self-sufficient and in the 1960s, which gave rise to the so-called Green Revolution (wheat) in Pakistan, India, China, Turkey, Chile, Argentina, Portugal, Spain, Australia, Brazil, and in the spring wheat regions of U.S. in the late 1960s and early 1970s.

Training of Mexican Agricultural Scientists

The great shortage of agricultural scientists qualified for conducting agricultural research in the country indicated that training of a new generation of scientists had to be given high priority. Filling the short-term need was the establishment of a "hands-on internship" type training of recent agricultural graduates, so they could effectively assist in developing the research programs. Then, the brightest and well-motivated young scientists were sent abroad for graduate training. It took 16 years before sufficient staff had been trained to the master and doctorate levels to meet the needs of the ongoing research program and, in addition, provide staff for the Graduate College in Agricultural Sciences in Chapingo–the first in Mexico, and the second in Latin America.

Shuttle Breeding Method of Varietal Development

The *shuttle breeding* was a method based on necessity to save time in the development of stem-rust-resistant varieties; later it was also shown to have other valuable benefits. With the breeding methods then in use in the world, only one segregating generation (of breeding materials) was grown each year. The breeding dogma of the era dictated that this was necessary to assure good adaptation and success of a new variety–a good fit between genotype and the environment. The dogma implied that the segregating populations had to be grown and the individual plants in segregating generations selected in the area and during the crop cycle where the new variety was to be grown commercially. Therefore, it took 10 to 11 years to cross; select; and evaluate for yield, yield, disease-resistance, and milling and baking quality, before beginning to multiply seed of a new variety for release to farmers. At that time, little was known about the importance of photoperiodism in the adaptation of wheat and other cereal crop varieties.

Recognizing the frequency and destructiveness of recent stem rust epidemics, it was absolutely essential to cut in half the time required to breed a new improved variety. This theoretically was possible by locating two contrasting environments favorable for the development of the wheat plants in two different seasons of the year. This was achieved by planting on the Coastal Plain of Sonora at an elevation of 39 meters and 29°N latitude, in early November, when the days were growing shorter. Artificial epidemics of stem and leaf rust were generated, and plants with the best agronomic type combined with adequate rust-resistance were selected in April; those with good plump seed were shuttled to Toluca Valley, about 700 miles to the south at 19°N latitude and at an elevation of 2640 m, where they were planted in early May when day length was increasing. At this elevation, temperature~ are ideal for the development of the wheat plant during the summer season; moreover, fr .ent rains foster the development of heavy epidemics of stripe, leaf, and stem rusts and Septoria leaf blight. In October, the best disease-resistant plants were selected, and seed of those with good plump grain were shuttled back to Sonora for planting in November. Through the shuttle breeding method for handling segregating populations, the first stem-rust-resistant varieties were produced in 4 years and grown in farmers' fields in the fifth year, half the time normally required with the orthodox methods of the era. These varieties also proved to be well adapted and high yielding throughout all wheat-growing areas of Mexico. Mexico became self-sufficient in wheat production in 1956.

Breadth of Scope of Genetic Diversity in the Mexican Wheat Breeding Program

From the beginning–and continuing to the present in the CIMMYT program–large numbers of crosses are made each year, involving genetically diverse parents. Strong vigorous selection pressures are exerted for agronomic type and disease resistance in all segregating generations. Early-generation, multilocation yield testing is employed to identify outstanding lines, while all others are eliminated.

Expansion of the Rockefeller Foundation Mexican Experience to Other Countries

The original purpose of the Cooperative Agricultural Program was to see what could be accomplished to improve the agriculture *in one country*–Mexico. When the positive results of the Mexican maize and wheat began to appear, requests were made to the Rockefeller Foundation by many other countries for similar assistance in agricultural research and training programs. Then, similar programs were established in Colombia (1950), Chile (1955), and a maize-breeding program in India in 1956. In 1958, the Rockefeller Foundation and Ford Foundation, under the leadership of Drs. J.G. Harrar and F.F. Hill, jointly established the International Rice Research Institute (IRRI), the first of the IARCs.

Training of Wheat Scientists from the Near and Middle East Countries in Mexico

In 1960, an exploratory trip, sponsored jointly by FAO and the Rockefeller Foundation, was made across North Africa and Near and Middle East countries to determine whether any of the wheat research information and improved varieties developed in Mexico might be of value in these countries. As a first step, a "hands-on" interdisciplinary training program for young wheat scientists from that vast region was initiated in Mexico in 1961. As part of this training and research program, an International Spring Wheat Yield Nursery was established. Included in this nursery were the best of the new Mexican semidwarf varieties as well as the best commercial spring wheat varieties of Canada, the U.S., Mexico, Argentina, Chile, Egypt, Pakistan, and India. The International Yield Nursery was soon being grown at more than 100 locations around the world. Within 3 years, it clearly had established the superiority of the Mexican varieties in many countries, including Pakistan and India.

As the food shortages in South Asia worsened in 1963, 200 kilograms of seed of the best varieties were sent by air to Pakistan and India for testing on small plots on many farms. As a result of very positive results, in 1965, 300 tons of seed were imported into Pakistan and India. Despite many problems (including the Pakistan-Indian war), the results again were excellent in both countries. Then, with famine worsening–in 1966 India imported 18,000 tons of seed and in 1967 Pakistan imported 42,000 tons, and Turkey 21,000 tons. From this seed, improved agronomic practices, including use of right kind and amounts of fertilizer and with a change in policy to stimulate the adoption of the new technology, the so-called Green Revolution was born.

To give you an idea of the impact, wheat production in India rose from 12 million (metric) tons in 1965, to 68 million tons in 1998, and from 4.5 million tons in Pakistan to 18 million tons. Major impacts also were achieved in China, Turkey, Chile, Argentina, and many other developing countries.

These successes led to the creation of the CGIAR and the expansion to 16 IARCs. Today, there is an international system of agricultural research involving the public and private universities, and national and international research institutes. This system, though currently suffering budgetary problems and the effects of the "bureaucracy" virus, still is the best hope for keeping world food production increasing faster than population growth, and for reducing the humiliating and degrading poverty that haunts too many in this world of ours.

In summary, Dr. Kronstad for the past 3 decades has been both an inspirational counselor and mentor to our CIMMYT staff and to many hundreds of young agricultural scientists studying in Mexico. He has kept us attuned to the important new scientific developments in academia from around the world. In addition, he has kept us informed about new developments in his efficiently well-organized wheat-breeding program at Oregon State University, which in addition to developing new better wheat varieties for farmers in the Pacific Northwest, *also is producing a new generation of outstanding wheat scientists for the world.*

I wish him well in his well-earned retirement. I hope that from time to time we will be able to induce him to come out of retirement for short periods, so that his expertise can be utilized as a special consultant to solve problems in developing African and Asian nations.