Warren E. Kronstad Memorial Symposium

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As a scientist and a human being, Warren Kronstad was a giant of a man, not only for me personally, but for many others. He was the pride of Oregon State University (OSU), and a dear friend and colleague for nearly 40 years.

Warren was an outstanding agricultural research leader and distinguished professor, who contributed greatly to wheat research and production in the USA and also internationally. I dare say that he was a mentor to more foreign graduate students in wheat improvement and production than anyone of his generation. He has touched many lives around the world.

Domestic Small Grains Research and Selected Achievements

Warren's research contributions to wheat production in the Pacific Northwest are legendary. Beyond a series of important methodological contributions to plant breeding and genetics, Kronstad and his OSU research team have developed many genetically superior cultivars including the soft white winter wheats Yamhill, Hyslop, McDermid, Stephens, Hill, Malcolm, Gene, and Hoff; two winter barleys, Casbon and Adair; and two winter oats, Lane and Amity.

Through identifying and pyramiding durable resistance genes, Kronstad-developed cultivars have had extended lives. Stephens, which at one time covered 75% of the winter wheat area in the Pacific Northwest, has been a major wheat cultivar for more than two decades.

Although repeatedly recognized by the wheat producers of Oregon, perhaps the highest tribute to Warren's achievements was the establishment of the OSU Wheat Research Endowed Chair: a US$ 1,000,000 endowment funded by the Oregon wheat producers and matched by Oregon State legislature.

Turkish Wheat Research and Production Program

Warren's contributions to international research were also substantial. Together with his OSU colleague, the late Tom Jackson, Warren developed a highly successful research and technology transfer program in the late 1960s to introduce semidwarf wheats into coastal areas of Turkey, with funding from the United States Agency for International Development (USAID) and the Turkish government. Some 23,000 tons of six wheat cultivars from the CIMMYT Wheat Program were imported into Turkey in 1968. These varieties were integrated into a successful package of management practices. Twelve OSU county extension agents were sent to Turkey to work with Turkish counterparts to disseminate the high-yield wheat package. Subsequently, Warren led a team of OSU specialists in weed control, dryland management, extension, and preparation of educational materials to work with Turkish scientists to develop improved wheat management practices on the Anatolian plateau, where most wheat is grown in Turkey. The package practices, built around improved summer fallow rotation, had a significant impact on yields. The introduction of new cultivars into the coastal areas, combined with the improved crop management practices on the Anatolian plateau, led to an almost three-fold increase in Turkish wheat production between 1967 and 1977.

In addition to the work in Turkey, a graduate training program was established at OSU under Warren's direction, where 15 young Turkish scientists were trained to MSc and PhD levels in various aspects of wheat research and production. Over the years, the OSU international graduate training program has expanded beyond Turkey. Through the program, more than 100 students from over two-dozen countries, including a number of outstanding Mexican scientists, have been awarded MSc and PhD degrees.

Winter Wheat Germplasm Enhancement

Under Warren Kronstad's leadership, a highly effective international network for exchanging genetic material and information on winter and facultative wheat was developed, involving the International Maize and Wheat Improvement Center (CIMMYT), the International Centre for Research in the Dry Areas (ICARDA), and, eventually, 45 countries. The countries of the former Soviet Union and the People's Republic of China, which historically had been highly protective of their plant genetic resources, became participants in this network.

The International Winter x Spring Screening Nursery (IWSWSN) is sent annually to all major research centers where winter and facultative wheats are important. A shuttle breeding approach is employed: select F_3 lines are identified in Pendleton, Oregon, and are shuttled to CIMMYT/ICARDA-Turkey and CIMMYT-Mexico for subsequent selection. Following several cycles of selection, the most promising lines are included in IWSWSN. This system of shuttle breeding and multilocational international screening, in which segregating populations are exposed to diverse selection pressures, has led to the development of cultivars with both broad and specific adaptation and high and stable yields.

Importance of International Germplasm Exchange and Testing

Many in this roomplant scientists may not know that organized international germplasm testing only began about 50 years ago in response to a disease epidemic of enormous proportions. In 1950, a devastating stem rust epidemic (race 15b) threatened all commercial wheat varieties in the USA and Canada. In response, the United States Department of Agriculture (USDA) appealed to eight countries—Mexico, Colombia, Ecuador, Peru, China, Brazil, Argentina, and Canada—to join in testing 1,000 wheat lines selected from the US World Wheat Collection, as well as advanced generation lines from several of the breeding programs in these countries, especially Mexico.

The results of the USDA's First International Stem Rust Nursery exceeded expectations in identifying stem rust resistant parents, and, today, much of the stem rust resistance in commercial wheat can be traced to the breeding materials identified from those early nurseries.

There were other benefits from this international cooperative effort of even greater importance than the identification of germplasm with resistance to race 15b of stem rust. A new mechanism for widespread international testing of germplasm—first in wheat and later in many other food crops—was in the process of formation.

CIMMYT's predecessor organization, the Office of Special Studies, an agricultural program of the Mexican Government and the Rockefeller Foundation, was a major contributor of advanced lines to the USDA's First International Stem Rust Nursery and to subsequent versions of this nursery. In addition, by 1962 a Rockefeller-FAO program for the Near East was sponsoring a regional wheat yield trial, and Rockefeller-Mexico also assembled a spring wheat yield trial for the Americas. In 1964, these were merged to become the International Spring Wheat Yield Trial (ISWYN), which CIMMYT prepared and distributed annually to hundreds of locations worldwide over the next 30 years. This nursery permitted breeders from around the world to test their best varieties over a broad range of geographic locations. The resulting data was invaluable in the development of the broadly adapted, high-yielding semidwarf wheat varieties with resistance to stem rust and other diseases, first in Mexico and later in many countries around the world.

International testing helped to break down psychological barriers that had separated the efforts of plant breeders in different organizations. Before the USDA's First International Stem Rust Nursery, many breeders were reluctant to release advanced lines from their breeding programs to fellow scientists for fear that the new varieties would be named and released without proper recognition of the breeder or organization. Early-generation segregating materials were rarely distributed to other scientists, largely for the same reason.

It became accepted policy that any line tested internationally could be used by collaborating scientists for breeding purposes or for distribution as a commercial variety, provided the source of the material was acknowledged. Not only did international testing introduce new genetic variability into national breeding efforts, it also provided individual breeders with the opportunity to simultaneously evaluate the adaptation and disease stability of their promising new materials in many different environments worldwide.

I believe it is fair to say that the advent of international testing marked the beginning of the modern era of plant breeding. It also gave rise to the Green Revolution, which saved untold millions from starvation in the 1960s and 1970s.

Through multilocational testing over a range of elevations and latitudes, we have been able to develop wheat germplasm with broad adaptation and general (race-nonspecific) disease resistance. Stable resistance to stem rust (*Puccinia graminis tritici*) has existed for more than 40 years. Moderate resistance to leaf rust (*P. recondita tritici*) exists, but the stability is still inadequate. Prior to 1960, devastating epidemics of these diseases, particularly stem rust, commonly occurred at least once every decade in many parts of both the developing and developed world.

Intellectual property rights (IPR), so important for mobilizing private capital for agricultural research, is a complicated issue and goes beyond the scope of this paper. However, I have concerns—along the same lines as obsolete plant quarantine regulations—about the potential of IPRs to disrupt the international flow of germplasm among scientific institutions. While it is not clear whether public sector institutions will generate significant revenue from biological patents, the potential for this to happen can affect the willingness of breeders to share germplasm for fear of jeopardizing future royalty income. Genetic conservation efforts may also be seriously hampered by the fear that the collecting agencies stand to gain from patenting economically useful genes.

Somehow we must find a way to keep international germplasm exchange and testing networks relatively free, open, and unfettered. A publicly funded germplasm system can and should complement proprietary research programs. However, the public program should also remain as an alternative provider of improved germplasm, both to maintain a "counterweight" to proprietary research and to serve nations where private research interest and activity is lacking.

These were matters of great concern to Warren Kronstad, and this symposium is an excellent opportunity for us to reflect on how best we can keep international cooperation and international germplasm exchange and testing alive and prospering.