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THE ROLE OF PLANT PATHOLOGY IN GLOBAL CEREAL PRODUCTION

by

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Mr. Chairman, Faculty members, Dr. Norman Borlaug, and family, ladies and gentlemen. First let me say how happy I am to be here today. It was a great pleasure for me to accept the kind invitation of the Faculty of the University of Minnesota, and in particular the Department of Plant Pathology, to be a guest speaker today at this dedication ceremony of the Borlaug Hall. I consider it a great honor and privilege for many reasons, and I would like to record my sincere thanks to the University of Minnesota for the opportunity to share with you, during the next 30 minutes or so, my views on the role of plant pathology in global cereal production.

You will not be surprised that I have chosen to focus my comments on a cereal crop that is almost synonymous with Minnesota, and a crop that Dr. Norman Borlaug has dedicated his life to -- wheat -- the most important food crop in the world today, with a global production of approximately 500 million tons in 1984, enough to provide annually, 3.5

billion people with their minimal caloric requirements. I would like to dedicate this presentation in recognition of the significant contributions that the University of Minnesota has made, as an Institution, to wheat pathology, and equally important the contribution that one of its most illustrious alumni, Dr. Norman Borlaug, has made to plant pathology and international agricultural research. I shall attempt to highlight what I believe to have been fundamental contributions in a global context over the past four or five decades, and then conclude by sharing with you my perceptions on future priorities.

But let me first start with some more philosophical thoughts. Throughout the annals of history, society has used the process of institutionalization to attempt to assure intellectual descent, and provide a continuum that will ensure that future generations can share the contributions that gifted individuals have made to knowledge, and the application of that knowledge to better the quality of life. It was during the Athenian era in ancient Greece that Plato, the prodigal son and pupil of Socrates, founded the institute we know today as the University, when he conducted the first ever tutorials in the Grove of Academe in Athens.Thus, the word academy is a graphic reminder of those early tutorials in Athens, which has provided a congenial environment for countless scholars in subsequent centuries, and today, institutionalized, in universities like Minnesota.

However, institutes can only become distinguished if they are served by gifted leaders, and therefore the selection of leaders is a very important process for any institution or community. Indeed, ancient Greece seemed to have had a remarkable capacity for selecting an unprecedented number of geniuses, even by today's standards, from a very small community. Aristotle, Archimedes, Pythagoras, Socrates, Plato, to name but a few. Socrates was a great philosopher, thinker, and perhaps more important, had a great ability to select gifted and motivated pupils. He was also aware of the importance of agriculture, and wheat in particular, because Greece had to import wheat from its colonies and Socrates himself recognized the importance of wheat when he said, quote "no man qualifies as a statesman who is entirely ignorant of the problems of wheat, and that one mark of a statesman was the knowledge of how much wheat was needed to feed the population of Athens" unquote. I submit that the status quo has not changed since those ancient times, except that today it is not the population of Athens that is our concern but the population of the world.

Plato, shared many of Socrates' qualities but he was also an implementor, a doer and an integrator. The University of Minnesota should be proud that it also has amongst its many illustrious alumni, its Socrates and Plato who have made fundamental contributions to wheat pathology in a global context.

Let me take you back to 1941, which is an appropriate starting point, for tracing a fascinating story about some of the colorful personalities and able professionals that practiced plant pathology in Minnesota. It was in 1941 when Dr. Stakman, then Professor of Plant Pathology at the University of Minnesota, participated in a three-man Commission that visited Mexico; the recommendations of this Commission eventually led to the initiation of the Mexican Program by the Rockefeller Foundation - the precursor of CIMMYT (The International Maize and Wheat Improvement Center) -- the organization which I have the privilege to serve.

In the early 1940s, Stakman was already making fundamental contributions to our understanding of the significance of variability in pathogens through his meticulous epidemiological studies on the most devastating disease of wheat -- stem rust. His conception and characterization of physiologic races is a milestone in the history of plant pathology. Stakman was a great ambassador for the University of Minnesota, and an eloquent spokesman for plant pathology and international agricultural research. Like Socrates he was also a great teacher, selector and motivator of future leaders. It was indeed fortuitous for Minnesota, wheat pathology and the world, that the paths of Stakman, George

Harrar and Norman Borlaug crossed on this very campus. Dr. Stakman was the principal professor for George Harrar and Norman Borlaug, who both completed Ph.Ds in plant pathology at the University of Minnesota under his supervision. Throughout history, outstanding scientists have usually attracted outstanding pupils, who became leaders in their turn. To have been accepted as a pupil and successfully trained by an outstanding worker is of itself a significant recommendation. Indeed, it is fascinating to trace the lines of descent in scientific research, linking successions of great scientists down through the generations.

Stakman was probably also instrumental in nominating Dr. George Harrar to be the leader of the Mexican Program in 1943 and Norman Borlaug as a pathologist in 1944. Thus the troika of Stakman, Harrar and Borlaug, all plant pathologists trained at the University of Minnesota, had a profound effect on the international wheat research conducted in Mexico, from its very genesis. The University of Minnesota through Stakman also trained many of the world's leading pathologists and almost all of the leading pathologists on wheat stem rust. Stakman viewed his alumni as a family and an anecdote can best describe his familial feelings. The current principal bread wheat breeder in CIMMYT is Dr. Sanjaya Rajaram, a pathologist who trained with Dr. Watson in Australia who, in turn, was a student of Dr. Stakman. When Stakman first met Dr. Rajaram in Mexico he greeted him with the statement "If you trained with Watson then you are my grandson" and thus the lineage of the Minnesota Stakman/Borlaug/family remains intact in CIMMYT today and includes three international staff, Drs. Prescott, Renfro and Saari all of whom graduated in plant pathology at the University of Minnesota. In addition CIMMYT staff have the privilege of working with countless colleagues from the Third World who have also been trained in plant pathology at Minnesota.

During Dr. Stakman's last visit to Mexico in April 1977. Norm Borlaug made the following statement, "I have imagined that the difference between the teachings of Socrates in ancient Greece and those of Professor Stakman in Minnesota is one of surroundings. Socrates and his pupils walked among the olive trees, and "Stak" and his students walked among the wheat fields looking for rust. Both teachers transcended the limits of one discipline to give their students a profound perception of humanity and its problems."

If Stakman is the Socrates of Plant Pathology in Minnesota, then only one man can be its Plato, and he is Dr. Norman Borlaug, the pragmatist and practitioner, the integrator and the implementor. Norman Borlaug's greatest contribution to the advancement of science is probably his unique ability to integrate plant pathology with all other disciplines in the quest of that elusive but ultimately most important target of all - increased wheat productivity. Borlaug has never forgotten the devastation that can be caused by stem rust of wheat. Along with Stakman and others, he helped, conceptualize and organize, in 1952, the first international stem rust nursery. This work would not have been possible without the support of the USDA Cooperative Rust Laboratory at the University of Minnesota which conducted all the race analyses. Indeed, it is very satisfying to see the staff at the USDA rust lab and the faculty and students all working so closely together towards a mutual objective.

Borlaug was first successful in incorporating stem rust resistance into the tall wheats, from a variety with a very appropriate name. The variety was called Hope and this resistance was stabilized by 1950. Starting in 1955 he introduced the dwarfing genes and combined good agronomic traits with stem rust resistance. The first international yield tests were initiated in 1959 and by 1962 the first semidwarfs were released in Mexico. Borlaug's training as a plant pathologist led him to explore in 1958 the yet-to-be realized tremendous potential of multilines -- a concept that I am sure has more important implications for the future, whether as multilines or mixtures.

The decade 1962 to 1972 bore the most important fruits of the long wheat improvement campaign, in which Borlaug continuously maintained a very high priority for maintenance research on stem rust but also gave increasing importance to leaf rust, stripe rust and Septoria. The first semidwarfs were used in India in 1965 when 300 tons of seed were shipped in the fall of that year. These were literally the seeds of the Green Revolution which led to the award in 1970 of the Nobel Peace Prize to Norman Borlaug, humanitarian, statesman and pathologist.

Today, approximately 45 million hectares of the developing country wheat area are planted to semidwarf wheat cultivars that carry Mexican germplasm in their pedigrees; in other words they occupy almost 50 percent of the 100 million hectares of wheat in the developing world. In addition 25% of the wheat in the USA and 50% of the wheat in Australia are planted to cultivars with CIMMYT germplasm in their pedigrees. A conservative estimate of the yield contribution to increased developing country production, made by these cultivars alone is 200 kg/ha per annum, which can be converted to 9 million tons of increased annual production - sufficient to provide 60 million people in the developing world with 65 percent of their annual caloric consumption. Much of this increased productivity is due to the incorporation of increased resistance to the major diseases in the semidwarf wheats.

Following a review of the levels of resistance to the major diseases, incorporated by Borlaug, it can be stated that the semidwarfs are more resistant than the local landraces and other improved cultivars to stem rust, leaf rust, and powdery mildew. More effort is being devoted to increasing the resistance to *Fusarium* head scab, *Helminthosporium* and *Septoria*, since the current semidwarf germplasm is less resistant than other local or nationally improved tall cultivars. However, the new semidwarf Veery lines are as resistant to *Septoria* as other improved lines, and even better levels of resistance have already been identified in materials currently under consideration for release. For stripe rust, the current level of resistance in the semidwarfs is almost as good as in other improved cultivars, and considerably better than the local landraces. Indeed, the new Veery semidwarf lines appear to carry a slightly higher general level of resistance to diseases than other improved cultivars and excellent sources of resistance have been identified in materials currently under consideration for release.

The resistance to the major diseases in the semidwarfs was achieved by Borlaug and his colleagues by utilizing a great range of genetic sources, including local landraces, to build more stable and long-term resistance. Multilocational testing has been, and must continue to be, an important system for identifying more stable forms of resistance. Multilocational testing, in conjunction with trap nurseries to monitor virulence changes in the pathogens, can provide a very effective strategy for identifying stable resources of resistance within the context of a global system, which can deploy resistant genes in an efficient and responsible way.

But how about the future? Reviewing past successes is an easier task than setting future priorities, nevertheless this is the most important challenge facing us today.

One legacy of the Green Revolution is the perception that wheat research focuses only on the kinds of dramatic breakthroughs in crop performance through improvement research achieved by Borlaug during the late 1960s and early 1970s. There is much less awareness of the substantial and continuous effort that Borlaug made in maintenance research, which is required to sustain the productivity gains that have already been achieved Maintenance research can be defined as the effort required to prevent yield decline and to protect the yield gains that have already been achieved due to the introduction of resistance or tolerance to pathogens, pests and other stresses. It is very important to recognize the distinction between maintenance research, which is required to maintain yields at current levels, and improvement research which is required, not to maintain, but to increase yields above their current levels.

Maintenance research represents a critically important component of any wheat research program, including the CIMMYT wheat program. Contrary to common belief, maintenance research cannot be effective unless it incorporates the most innovative/recent technological developments. In practice, maintenance and improvement research are fully integrated within a breeding program so that no clear division is visible, nor indeed justifiable, because both types of research are required to ensure stable productivity and adequate wheat supplies for the future.

The need for a maintenance research program will increase:

- as yield increases, due to greater resistance to one or more pathogens/pests;
- when pathogens have high plasticity, i.e., the ability to generate new virulent forms capable of infecting cultivars that were previously resistant, e.g. leaf rust;
- for obligate parasites, which have greater capability (compared to facultative parasites) to generate new virulent strains of the pathogen;
- when resistance is monogenic/specific as opposed to multigenic/non-specific or durable resistance;

- when crops are grown as monocultures on large acreages and under intensive production systems.

Failure to conduct adequate maintenance research can result in an immediate change in the status of resistance to a particular pathogen, which can subsequently and quickly result in significant losses in yield. Not only could such a situation result in serious losses, but perhaps more important it could also erode the confidence in, and long-term support for agricultural research.

To quantify the relative importance of maintenance research, it must be compared to improvement research efforts that lead to an increase in yield, The importance of maintenance research can be estimated by comparing the annual increase in yield due to crop improvement research with the potential loss in yield that could occur if maintenance research is not adequate. To make a realistic comparison it is estimated that during the last decade the CIMMYT wheat program increased wheat yields by 1% per year; equivalent to 780,000 tons/year on the 45 million ha of the semidwarfs grown in the developing world. However, in the event that the most popular CIMMYT based variety Sonalika, which now occupies 8 of those 45 million ha, became susceptible to only one of the major diseases because of inadequate maintenance research, the losses could be enormous. Estimates based on a range of loss measurements during actual past epidemics suggest that losses due to a moderate-to-severe epidemic on the 8 million ha could be up to 9 million tons for stem rust, 2 to 5 million tons for leaf rust, up to 4 million tons for Septoria, and from 2 to 3 million tons for stripe rust. It is important for both scientists and research administrators to recognize that unless maintenance research is supported adequately the potential loss from any one of the major pathogens can be significantly greater than the annual gain in yield due to improvement research. Maintenance research must be implemented in a preventive mode; it would be unfortunate for everyone if disaster had to strike before adequate resources are provided.

For the agricultural research services of the USA as a whole, it is estimated that 40% of total research resources is devoted to maintenance research; in the case of sugar cane research in Hawaii, between 90 and 95% is maintenance research. (Plucknett and Smith, Nature 1984). We estimate that up to two-thirds or approximately 66%, of the total effort in wheat improvement at CIMMYT is devoted to maintenance research, which is primarily but not exclusively, focused on disease resistance. Furthermore, for the future, the role of maintenance will be greater as yield levels are increased and the frequency of cropping is raised.

Within the context of maintenance research I believe that we should take urgent steps to revitalize our global efforts on disease surveillance with emphasis on the monitoring of virulence rather than race identification which tends to relate only to the major genes. In recent years, some of the international activities on disease surveillance and virulence monitoring have been reduced or even terminated. This is an area of expertise for which Minnesota has an international reputation, particularly for stem rust, and I believe it is a high priority research thrust. This offers a unique opportunity for the USDA Cooperative Rust Laboratory and the Department of Plant Pathology at the University of Minnesota to develop an international collaborative research project which CIMMYT would be happy to facilitate within the context of an international network. It would allow for the characterization of resistance and the monitoring of virulence patterns which, in turn, would facilitate a more effective and responsible deployment of resistant genes within a global context.

An ancillary international program on epidemiology and the estimation of economic losses due to diseases is also required. Epidemiology and economic losses due to diseases were topics of great interest to Stakman, Borlaug and others, and I am happy to see that today, Minnesota maintains that international leadership through the program led by Dr. Paul Teng. The extension of this program at the international level would greatly improve the effectiveness of the relatively few resources currently devoted to this endeavor. The application of quantitative methods coupled with mathematical analysis and modelling has markedly increased our capability to produce useful results in this area.

The use of multilines or mixtures should also be further explored since the use of genetically diverse cultivars distributed in space and time could provide a very effective mechanism against the build-up of a serious disease epidemic. This approach has been called a multilineal complex of cultivars. The genetic analysis of disease resistance and studies on mechanisms of resistance should also receive much greater attention in the future because basic research is always a prerequisite for an effective, applied research program.

Recognizing that there is no single solution to disease control, an evolving strategy must be developed to integrate disease management within a more holistic scheme of integrated crop protection. As wheat production becomes more intensive, there will be more need to combine all forms of disease resistance with effective chemical and biological control methods. As we are forced to bring more marginal areas under production, there will be a need for a better understanding of diseases on wheat in these more marginal lands and non-traditional growing areas.

Biotechnology through tissue culture techniques already allows more effective selection of wheats resistant to toxin producing pathogens. The development of DNA probes as diagnostic tools for virus detection may for the first time allow us to accurately survey and assess the economic impact of virus diseases in wheat. I believe that more attention must be given to viruses in general, and especially the ubiquitous viruses such as barley yellow dwarf, as well as some of the bacterial diseases that are becoming more prevalent and difficult to control.

In the field of international agricultural research and development USA is particularly privileged to have, at the helm, the Senior Deputy Administrator of USAID, Dr. Nyle Brady, who will address us later. Dr. Brady is a scientist of international repute who not only knows the theories of international research but has been a very able and skilled practitioner. Few nations enjoy the privilege of such research leadership in international aid and development, and you should not fail to take advantage of the opportunities it offers.

In closing, may I, as a non-American guest representing an international agricultural research community, and CIMMYT in particular, offer a warm and sincere vote of thanks to the United States of America, the University of Minnesota, particularly the Department of Plant Pathology, the USDA Cooperative Rust Lab and last, but certainly not least, to Dr. Norman Borlaug, a statesman, humaritarian, fellow pathologist and friend, for all that you have done to advance the cause of wheat pathology and agricultural science. Let the Norman Borlaug Hall that is being generously dedicated today stand as a mark of respect and honor for a distinguished alumnus, and be a constant reminder of the importance of international agricultural research, and the need for interdisciplinary research in the interest of science, global security and quality of life in tomorrow's world.