THE POTENTIAL IMPACT OF QUALITY MAIZE AT THE GLOBAL LEVEL

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I am delighted to participate in this symposium on Quality Protein Maize (QPM). It has been more than 31 years since the nutritional importance of the Opaque-2 gene was discovered at Purdue University, never-the-less, the benefits of this discovery are only now--three decades later--disgustingly and belatedly beginning to reach commercial production in several countries. The purpose of this symposium, as I understand it, is two-fold: firstly, to determine the present status of QPM. as a crop in different countries of the world and, secondly, to design strategies to accelerate the increase in production of QPM, especially in Third World developing countries where maize is a basic food.

This implies we must explore the reasons for the long lag-time between the time of initiation of the breeding programs designed to develop commercially acceptable QPM varieties and hybrids, and the time of release and wide-spread commercial utilization of QPM varieties and hybrid.

At the outset, I must warn you that I am an impatient scientist that loathes complacency, apathy, indecisions and bureaucratic procedures that slow research progress and/or unnecessarily delay the application of its findings to alleviate hunger and misery. In particular, I see no good or acceptable reason why it has taken three decades since the discovery of the nutritional value of the Opaque-2 gene to produce commercially acceptable and competitive QPM varieties and hybrids. Even more inexcusable, it has taken 15 years since it became apparent--to any imaginative visionary aggressive plant breeder--that the genetic variability and methods were available to convert the inferior-yielding soft Opaque-2 type endosperm to dent and flint grain types, and while doing this, increase grain yield and disease and insect resistance to the levels of the best conventional varieties and hybrids. These comments do not imply that the only reason for the slow development of commercially acceptable varieties and hybrids lies primarily with the plant breeders. On the contrary, in the next few minutes as I will point out, there is ample blame to share among directors of research, nutritionists, economists and policy makers, with members of the boards of trustees, and director generals of both the national and international research organizations in both developed and developing nations.

Out of fairness, I must warn you that my direct experience in maize breeding is limited to one year--my first year in Mexico, more that a half a century ago--when I was privileged to work with Dr. E. J. Wellhausen in the Mexican government--Rockerfeller Foundation Maize Breeding Program. During my second year in Mexico, I was shifted to the Wheat Research and

Production Program. I spent all of my research career until my retirement from the CIMMYT staff primarily working with that crop. None-the-less, throughout my career, I remained interested in the improvement of all the crops that the wheat farmers used in their rotations, which often included maize. Moreover, my interest in maize goes back to my boyhood on an Iowa farm where it was the most important crop in the oat-clover-maize rotation of that era. In addition, over the past nine years I have been involved in agricultural development programs sponsored by the Sasakawa Foundation in eight sub-Saharan African countries, where maize is the most important crops. Consequently, I have again become enthusiastically involved in maize research, extension and production problems, including QPM. However, because I have only indirectly been involved in maize research and production problems, I hope you will forgive me if some of my comments about QPM are wide of the target.

My curiosity and interest in the development of maize varieties and hybrids with improved nutritional properties dates back to the 1964 publication by Dr. E. T. Mertz and colleauges in which they clearly showed the nutritional benefits that were associated with the Opaque-2 gene. I recall the enthusiasm of that period, when maize scientists in nearly all hybrid corn companies around the world, as well as in most university programs in countries where maize is an important crop, modified their research and incorporated the Opaque-2 gene into their breeding program with the aim of increasing the levels of lysine and tryptophan. Since both lysine and tryptophan levels were known to be tightly linked and both controlled by the Opaque-2 gene, this goal appeared to be rapidly and inexpensively achievable. Unfortunately, it proved to be otherwise.

The original varieties and hybrids derived from the Opaque-2 parent had soft endosperms and yielded 15 to 20% less grain per hectare. They were much more susceptible to several foliar diseases and to ear rot and the grain was more susceptible to damage by insects in both the field and in storage. When the complexity of the breeding problem became apparent, most of the private companies and universities abandoned their high lysine and trytophan breeding programs. Moreover, about that time, a 1973 FAO/WHO report on human requirements for protein and calories substantially lowered the previous protein requirement figures. This touched off a heated debate between two groups of nutritionists which continued until 1987 when a research team drawn from three American universities reported -- and their finding became widely accepted -- that human requirements for lysine, leucine, valine and threonine were two to three times higher than proposed by FAO/WHO in the 1973 report. During this long controversy, all but three organizations terminated their lysine and tryptophan breeding programs, despite repeated feeding studies with animals, poultry, and children that showed clearly that the Opaque-2 derivities were markedly superior to normal maize. These were: the Crow Hybrid Corn Company of Milford, Illinois; Dr. H. O. Gevers at the University of Natal in the Republic of South Africa; and International Maize and Wheat Improvement Center (CIMMYT) in Mexico. Later, four other QPM breeding programs were initiated, employing primarily, CIMMYT QPM germplasm. These include: 1) the program instituted in 1978 by Professor Li Ching-Hsiung of the Chinese Academy of Agricultural Sciences in Beijing, Peoples Republic of China; 2) the program initiated in the mid 1980s at the Crop Research Institute, Kumasi, Ghana, by Dr. S. Twumasi-Afriyike and Mr. Ben Dzah with the assistance of Dr. Ernest W. Sprague Director of the CIMMYT Maize Breeding Program; 3) the program initiated in 1985 by Dr. Ricardo Magnavaca at the National Research Center for Maize and Sorghum (CNPMS), of the Brazilian Agricultural Research Corporation (EMBRAPA) at Sete Lagoas, M. G. Brazil and 4) the program initiated in 1984 at Texas A&M University, College Station, Texas by Dr. A. J. Bockholt.

Since representatives of all of these organizations are present at this symposium, and will be making presentations concerning their programs, I will confine my remarks to observations and conclusions I have gleaned from close, but indirect, association with the CIMMYT QPM program.

As the complexities and difficulties of incorporating the Opaque-2 gene into commercially viable varieties and hybrids became apparent, Dr. Ernest Sprague, with financial support from United Nations Development Fund (UNDF) organized an interdisciplinary team, consisting of Dr. Surinder K. Vasal, geneticist/breeder, and Dr. Evagalina Villegas, biochemist, to cope with the problems. I became fascinated by the close team work and creative methodology that was developed by this team to overcome the many defects that were encountered in the original soft endosperm derivatives. Gradually, over more than fifteen years they were able:

1. To convert the soft floury endosperm of the original Opaque-2 phenotype to dent and flint types while making certain the Opaque-2 gene was not lost during the conversion. Thousands of chemical analysis were conducted each breeding generation to make certain the Opaque-2 gene was not lost because of "masking" while the genes that modified the endosperm texture were being accumulated;
2. To accumulate genes that restored the potential grain yield of Opaque-2 derivites to the level of the best normal varieties and hybrids of the same

maturity class;

3. To develop QPM varieties, inbreds and hybrids similar to the best normal varieties, inbreds and hybrids for resistance to the major disease and insect pests present in Mexico;

4. To demonstrate that the defects of lower grain yield, soft endosperm, slower drying (dry-down at ripening), greater susceptibility to disease and insect pest all could be corrected by conventional breeding procedures. In other words, the current data indicate that QPM varieties and hybrids can be developed that are equal to the best normal varieties or hybrids in grain yield, agronomic type and in resistance to diseases and insects and which without additional production costs provide superior nutrition.

Unfortunately, after Dr. Ernest Sprague left the directorship of the CIMMYT Maize Program in 1983 while the heated debate between nutritionists still raged -- the CIMMYT QPM program support began to weaken and erode and finally ended 1993.

Sadly, because of breakdown in collaboration between the maize research program of CIMMYT and the Mexican National Institute of Forestry, Agriculture, and Animal Research (INIFAP)---in a large part because of repeated changes in program leadership in both institutions---the CIMMYT

QPM materials were never evaluated on farms in Mexico. This CIMMYT germplasm, however, recently has been made available to many other maize breeding programs.

The Ghanaian QPM program for the past five years has been evaluating much of the CIMMYT germplasm and is incorporating resistance to streak virus into the best adapted inbred lines and varieties.

THE CHALLENGE:

Spectacular progress has been made during the past three decades in increasing, both yield per hectare, and total and per capita production of the principal cereals (wheat, rice, maize) in the developed nations as well as in many developing nations. Meanwhile, per capita production of grain legumes/pulses--in both the developing nations and in the world--continues to decline. This decline is especially disastrous in developing nations where animal products are both in short supply and expensive. Thus, the majority of the population must utilize diets based primarily on cereals and grain legumes/pulses to meet their protein needs.

For these reasons it is now an opportune time to launch an aggressive QPM production program to off-set the continuing decline in per capita production of grain legumes/pulses.

It appears to me that the maize breeders, biochemists, nutritionists, agronomists, entomologists, plant pathologists, food technologists and policy makers assembled here should aggressively accept the challenge to utilize the wealth of information and the QPM materials that have been developed over the past three decades and put them into large-scale commercial production to improve both human nutrition and animal production, especially in developing countries where animal proteins are scarce and expensive. We must remember, we are few in number--at best 10 to 20 scientists--while those working on the genetic improvement of conventional maize hybrids and varieties number in the several hundreds and more probably indirectly in the thousands. To compensate for the handicap or unevenness of the playing field (budget and personnel), we must organize ourselves effectively and attack the challenge enthusiastically. As we progress in this endeavor more funds and personnel will be forthcoming.

Two of the first steps, that I feel are important in launching a successful QPM production program include:

1. The development of a set of three cooperative International QPM Yield Nurseries to be grown at many locations in the cooperating countries. In these yield tests the best QPM. varieties and hybrids should be compared to the best conventional varieties and hybrids from more or less the same

latitudes and elevations (hence three different nurseries);

2. Establishment of an intensive three-to-five month "hands-on" apprenticeship training for young graduates of colleges of agriculture (at one location) where an integrated crop management course will be taught. Part of the hands-on training course should involve analyzing the previous year's International QPM Yield Nurseries' data and also in preparing the next year's International QPM Yield Nurseries.

In Mexico (at CIMMYT) in the 1960s, similar exercises and training programs played an important role in preparing many young wheat scientists from Asian, African, and Latin American countries for participating in the transfer of new wheat technology when they returned to their own countries. They played key roles in developing the so-called Green Revolution during the 1965-1975 period in Asian and South American countries.

I hope, and strongly recommend, that cooperative action will be taken at this symposium, within the next three days, to organize such activities.

My experience in working with agricultural development programs in many Latin American, Asian and African countries over the past fifty years tells me that the struggle to convert large areas of commercial maize production to QPM production in the developing nations will be long, frustrating and arduous.

I am convinced it can be done if there is the proper dedication and scientific and political will.

THE WILL TO WIN THE BATTLE OF QPM:

As I consider the challenges and obstacles ahead that must be circumvented to successfully launch significant QPM production programs in a number of African, Asian and Latin American countries, my thoughts go back to the hectic years of the middle 1960's---to the hurdles, struggles and battles we had to endure while transferring the "Quiet" Mexican Wheat Revolution to food short and famine plagued Pakistan and India, where it gave rise to the so-called "Green Revolution."

Among the most important of the many obstacles that had to be maneuvered were the following:

1. Gaining the whole-hearted enthusiastic support of millions of small farmers---who according to most senior scientists, economists, planners and other top-level bureaucrats were said to be ultra conservative and unreceptive to new technology. Several thousand half-acre demonstration plots installed on farms--employing a package of improved crop production technology, including use of the high-yielding dwarf Mexican varieties, sown at the proper date and with the appropriate rate of seeding,

appropriately fertilized, and opportunely weeded and irrigated--generally yielded three to five-fold the yield of conventional methods. The farmers, seeing the contrast in yield, destroyed the myth of their non-receptivity to new technology. Many farmer's field days were organized at demonstration sites to explain the improved production technology which converted them into activist groups, clamoring and pressuring government for changes in policies on availability of fertilizer, seed, and credit, while also demanding international prices for their grain, rather than half the world price that they previously were forced to accept. This new enthusiastic, aggressive attitude and pressure at the grass-root level was instrumental in forcing governments to adopt more realistic policies which facilitated the widespread use of the new technology, which in turn revolutionized wheat production.

2. With few exceptions, senior scientists--be they plant breeders, agronomists, entomologists, plant pathologists or economists--were afraid to take significant risks. They were satisfied with status quo, for they had reached the pinnacle in the civil service power structure and in their pay scale. Consequently, they feared the unknown risks of change for two reasons: firstly, the new technology might fail and result in a crop failure

for which they would be blamed; secondly, a spectacular success might raise the question from superiors, "So, if it was so easy to achieve, why didn't you do it before?" Moreover, most senior scientists knew they would not be blamed for low stagnant crop yields, that result in worsening per capita food shortages caused by explosive population growth---so why risk change?

Nor are all of the conservative senior scientists that are fearful of change located in developing countries. I have encountered them in affluent developed countries as well, including the U.S.A. In the late 1950's, when we were busily at work trying to incorporate the Japanese Norin dwarfing genes into our best tall Mexican wheat varieties. We encountered many defects in the progeny, including low grain yield, floret sterility, shriveled grain, low flour yield, poor baking quality and extreme susceptibility to half a dozen diseases--problems quite similar to those encountered in the early years in trying to develop acceptable high yield Opaque-2 derivatives of maize. One of the most prominent European wheat breeders of that period, pleaded with me to quit wasting my professional life on such a hopeless cause. Nevertheless, a decade later this work had produced the so called "Green Revolution" that spectacularly increased wheat production in Asia and eventually contributed to feeding of hundreds of millions of people around the world. During the same period, several well-respected senior wheat scientists in the USA insisted that while semidwarf wheat varieties were effective in raising yield under irrigation in Mexico they would never be successful under rainfed conditions. They were wrong! Before they re-organized their breeding program--less than a decade later--about 33% of the spring wheat region of the USA was sown to "renegade" Mexican semidwarf wheat varieties.

3. The Disasters of Parastatal Seed Organizations:

Incompetent, bureaucratic, politicized seed organizations are the bane of agricultural development. We will undoubtedly have to deal with them as we promote the development of QPM in many African countries, at least until farmer cooperative seed organizations can be developed or until the private sector develops effective seed multiplication and distribution systems.

The wheat revolutions in Pakistan and India were derailed and nearly aborted because of poor quality seed first imported from the Mexican parastatal seed organization. In August 1965, 350 tons and 300 tons of Mexican semidwarf wheat seed were shipped from Los Angeles to Pakistan and India, respectively, on the last freighter that could deliver the seed to the two countries for timely sowing. A series of unfortunate events nearly destroyed the operation, including a four-day delay at the border of the fleet of trucks transporting the seed from Mexicali, Mexico to Los Angeles--resulting from inexplicable and unnecessary red tape fabricated by bureaucrats of both the Mexican and American breeds. The day the trucks were finally cleared at the border coincided with outbreak of the race riots in Los Angeles, and resulted in further delays, as the National Guard detained traffic into the Los Angeles area. As a result of these events, we were forced to pay several days demurrage, from our anemic budget, for delaying departure of the freighter.

The freighter carrying the seed for both countries finally shipped out from Los Angeles on an early Sunday morning in August, to my relief and delight. But that same Sunday afternoon, the war between Pakistan and India erupted. The seed for the two countries was separated and transhipped from Singapore arriving at the ports of Bombay and Karachi a month late for planting. There were further delays in the ports and shortage of railroad freight cars, because of military traffic, which further delayed the arrival of the seed at the planting sites. Because of the late arrival of the seed, germination tests were dispensed with to plant as soon as possible. A week later it was apparent germination was faulty. Seeding rates were doubled, the war continued, criticism was lavish, and frustrations were tremendous. I shuttled from Pakistan--by way of neighboring neutral countries--to India, trying to salvage something from this disaster.

An inspection made by the government of Mexico of seed in the warehouse in Mexico, from which the Pakistani and Indian seed had been shipped, established that improper fumigation had reduced germination of the seed to 30%.

Astute handling of supplementary fertilizer and irrigation on the thin stands of seedlings in both Pakistan and India induced prolific tillering. Happily, at harvest, the crop was good and the Lady of Serendipity smiled enough to convince Minister of Agriculture C. Subramianium to import 18,000 tons of Mexican wheat seed. With this decision the "Green Revolution" was back on track. This purchase, as well as subsequent seed purchases in 1967 of 42,000, 23,000, 5,000 and 3,000 tons by Pakistan, Turkey, China, and Brazil, respectively, were made directly from Mexican farmer cooperatives and arrived with germination of 96% or better.

During my lifetime, I have experienced at least six similar disasters with seed, all of them involving parastatal organizations. During the past three years, the Sasakawa-Global 2000 program has been involved in assisting in the development of a network of small-scale private seed growers in Ghana, which are now functioning reasonably well. Although I would very much like to see private seed companies take over the major responsibility of multiplication and distribution of improved seed, this is not likely to happen in most African nations within the next two decades because of limitations in infrastructure and the economic and political uncertainties for private investments.

It is interesting that Dr. Cicily Williams (1896-1992). a public health officer and nutritionist in Ghana (Gold Coast) during colonial period used the Ghanaian term "Kwashiorkor" to describe the protein malnutrition (deficiency) condition (more specifically attributable today to inadequate levels and balance of essential amino acids in diets), especially common among infants and children in many parts of the country. Currently, somewhere between 10 to 15% of the maize area in Ghana is now sown to the QPM variety Obatanpa, which will contribute greatly to correcting Kwashiorkor among infants and children in that country. There was hope that the QPM variety Obatanpa would become the dominate maize during Dr. William's lifetime so that she would have been able to see a practical solution to the malnutrition problem she described. Unfortunately, the QPM production campaign came about five years too late for her to enjoy it--but belatedly it must be made to happen throughout Ghana in the next five years.

In closing, I want to congratulate and thank EMBRAPA/CNPMS and the organizing committee of this Symposium on Protein Quality Maize, and especially the chairman, Dr. Edilson Paiva, for bringing together this interdisciplinary group of scientists who are determined to establish QPM as a commercial crop to improve human nutrition. I also especially want to congratulate Drs. Ricardo Bressani, George Graham and Nevin Schrimshaw for the tireless and thankless role they have played in defense of QPM as a crop for improving human nutrition, especially among low income people in the developing nations, during the long rather nasty debate with other nutritionist over the past 20 years.

Finally, the long lag-time between the discovery of the nutritional importance of the Opaque-2 gene and its utilization to alleviate malnutrition (especially in the developing nations) has been deplorable and inexcusable. We, who are convinced that this goal is scientifically and economically achievable are few in number, and it will take great determination, dedication and leadership to make it happen. Let us all cooperatively unite with the goal of converting the potential nutritional benefits of Q.P.M. to reality within the next five years. That is the challenge--we must make it happen--we must not fail--we can make it happen <u>if we have the will</u>!

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