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STRATEGIES FOR ACHIEVING A DOUBLY GREEN REVOLUTION IN AGRICULTURE

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Thank you very much, Dr. Brady, for these kind words. As was mentioned by Dr. Monty Jones, one thing, rice grows in a wide variety of habitats. In my own country below sea level to the high altitudes the Himalayas, and therefore if many of the predictions of global warming and its consequential impact on temperature changes, precipitation changes and sea level rice will happen.

In my view, rice is going to be even more important because it has got this wide amplitude availability. That is why the IRRI gene bank, the International Rice Research Institute gene bank has over a hundred thousand strains of rice. That itself represents the wide variety of conditions under which rice is grown. So from uplands to highlands and to lowlands, you have enormous opportunity here that also poses a great challenge to scientists in terms of improving the farming systems under diverse ecosystem; the rice farming systems are very diverse.

It was already mentioned that we have had tremendous progress in the last 50 years in particular, although rice cultivation is one of great antiquity. Monty Jones mentioned about 3,500 years of rice cultivation in West Africa. In Asia over 10,000 years of rice cultivation have been documented. Pollen people that also study pollen, they say it has been cultivation for 3,000 years.

And the major improvement started with simple selection and simple hybridization, then. And then this architecture, the change in architecture, the hybrid rice and super hybrid rice which Professor Yuan mentioned and Dr. Gurdev Khush has been working on it. IRRI has been working on it. The last columns, although from the last lecture of Professor Yuan, he has mentioned that 13 to 14 tons have already been achieved with super hybrid rices.

Many of them also require biotechnological inputs in terms of enlarging the base of diversity, bringing in genes from diverse sources. You saw in Monty Jones' presentation how anteculture embryo rescue techniques help to bring, enlarge the gene pool. You can just, there's a more positioned breeding, not necessarily to combine the whole genomes, but you can bring in the precise ones. But there are problems there.

Well, when I first met Yuan Longping, he took me in the Hunan Province, a number of hybrid rice seed plots. One of the rice seed plots which I first visited, the farmer himself producing the seed – it was very interesting. You know, they used to go with a sort of a rope to see the pollen. It was the starting point of the new chapter, the exploitation of hybrid vigor. After the semi-dwarf lines, this was an important one, and now we have further improvements over it. This morning Secretary Lorenzo mentioned that in the Philippines and elsewhere in South Asia, wherever rice is a staple, more than 20% of the food budget goes to rice alone. In other words then the rice price is stable or even comes down. You see the great benefit to the people who are rice eaters. One has to find a balance between farmers' income and the cost to consumers.

But the work of the International Rice Research Institute and almost all national research systems put together has ensured that the actual rice price has remained stable, as, as you will see here, it has come down very steadily from about 1980 onwards, the real price of rice has come down. I know when I was in the Philippines, the Philippine Nutritional Institute in Manila, they found that as a result of the cost of rice being stable and even lower than normal, 30-40% of the malnutrition in the Philippines could be addressed because of the reasonable price of the staple. This is a very important one.

Now, the current challenges which we face, there are very many in which today our panelists, I hope some of them will address new methods of approaching them. One is, we want to raise the ceiling to yield. Professor Yuan mentioned the one method of how to increase it, super hybrids. As he said, we want more stability of production and sustainability of production, both ecological sustainability and stability over a period of time. We need improvement of grain quality. There was an excellent session yesterday afternoon on various aspects of grain quality, including the golden rice of INGER and others, bridging the yield gap, it would even now with current levels of technology, technologies available on the shelf. There's a very big difference between average yield and the potential yield. This has to be addressed through public policy, improved knowledge and systems like extension and so on.

Adding value to biomass. Twenty-five rice farmers from all over Asia were chosen for recognition in 1985 on the occasion of the 25th anniversary. And those insights were present in the form of a book. If you see the book, you will find that most of the farmers said, "From rice alone, we can't make a living," because they're all small farmers, not very large farmers. And therefore we must have additional income, nonfarm employment, or value addition to the rice biomass – the straw, the bran, the husk and even the grain itself. Dr. McCouch might talk to you in the afternoon about the different kinds of rice products which we certainly make. In fact, we have established a rice bio-park, as we call it near ... Madras, where I live, to demonstrate the new opportunities available from biomass. Then to meeting the challenges of climate change, particularly sea level rise and temperature changes.

Today in relation to the controversy about genetic modification and molecular breeding and so on, one thing is very clear. With modern mapping of chromosomes, the similarity, what we call the synchrony that the genes occurring in the same order, and chromosomes have different species. In this particular case, maize, millet, sorghum and sugar cane, rice – how much of the order is the same in many cases? I think many people talking about taking genes from other species must remember this. And this is why we have started in my center what we call geno-clubs in schools, geno-clubs in village schools, in order to introduce people... young

scholars to the rice genome, the human genome. I think a large amount of genome literacy is important if you want to overcome the fear of genetic modification. And synchrony is a very powerful tool of education of what is happening.

The International Rice Genome Sequencing Initiative is an outstanding exercise in international cooperation. In fact, Dr. Nyle Brady mentioned, the earlier laureate, Dr. Robert Chandler, the founder of the International Rice Research Institute, wrote a beautiful book. It's called *Adventure in Science*. Those who are not ready I would commend it to you. The title is *Adventure in Science*, Chandler's book, the whole adventure in institution building, mobilizing science for society. It is a remarkable book.

The International Rice Genome Sequencing Initiative, like the Human Genome Initiative, is now a partnership. But both our Chinese friends and the Japanese have already prepared genome maps, a transgenomic one in Indica, the other in Japonica, again collaborative for a very large number both of the private sector and the public sector institutions. I am amazed, because in 1984 IRRI convened the first conference, inter-center conference on mobilizing biotechnology and other crops. Since then, 1985 onwards, the Rockefeller Foundation has supported this global rice initiative and reorganized our Rice Genetics Symposium in '85. Dr. Gurdev Khush was the organizer.

Since then, the last 15-20 years, we have leapfrogged in terms of understanding. I remember in 1985 we were given controversy about nomenclature of chromosomes. Japanese called one chromosome 6, somebody else called chromosome 7 and so on. From that time onwards, the very detailed information has come.

In India itself we have under the Global Rice Genome Sequencing Initiative, allotted chromosome number 11 of rice, of certain parts of it, and the government of India committed the equivalent about \$12 million U.S. dollars, for this progress. It is making very good progress as part of the international initiative.

Clearly salinity, drought, submergence also, flooding in some cases, various forms of deficiency, phosphorous deficiency, iron toxicity, toxicity, zinc deficiency and so on. The whole series of problems are coming. There again we require new genetic traits in order to, apart from other soil health amendments, it is important to have genetic material.

This is why the integration of the best of technology, because, after all, knowledge is a continuum. Knowledge is a continuum, and every day we have progress in our knowledge of all living processes. And how do we integrate the best in Mendelian breeding. One side is the Mendelian breeding, which is still very relevant, as Dr. Borlaug reminded us yesterday. And then we have to combine all the techniques. Today's progress will take place when we don't worship any particular tool but combine the best of available tools.

And I give you one example from the work of my one colleague in my research center, what they did ten years ago. We thought we were living on a seaside, and if there is going to be sea level rise, what can we do? We require more and more varieties of crops, which are tolerant to sea water or salinity. And my colleagues started the work on identifying genes for sea water tolerance. And the mango species... marina, was used as their donor for these genes. And they

were mapped. Now it is in the second stage of field trials approved by the Department of Biotechnology. Our third stage is to go to farmers' fields. The first is the greenhouse, second is the limited field trial under controlled conditions. These have tolerated sodium chloride, and very salt tolerant. Similarly another colleague, has transferred genes for drought tolerance and it is a very tolerant one.

So there are enormous opportunities here, which will be unfolded shortly by other speakers. There's always been a quest in some areas, like Borlaug said about nitrogen fixation. Even in his Nobel Prize Award ceremony, he said we must have more nitrogen fixation by cereals, like legumes, and the other has been, a favorite theme has been converting rice from the C-3 to C-4... All the weeds attacking rice are C-4. You know, that's why they take away much of the nutrients and so on. If you don't have the weed control, the whole phenomena of puddling started both for water retention and for weed control.

So the steps in genome analysis, the title of today has been given to "Doubly Green Revolution." Environmentally sustainable advances in productivity. I called this an "Evergreen Revolution" twenty years ago. That means increasing productivity and perpetuity. You have genomics, then functional genomics, and then market-assisted selection and transgenics. It is important to mobilize all this.

I already talked about the importance of the rice biomass. In fact, the President of the Philippines, visited IRRI and found a woman making rice straw paper, and she ordered the whole Christmas cards that year from the rice straw paper. We had about ten acres called "Patty and Prosperity," making a whole series of products from the rice biomass. As a part of the International Rice Year Program in India, we had promoted this woman's rice biopox, making a whole series of products from this.

So, ladies and gentlemen, if you would now want to go to an era of bio-happiness, not bio-terrorism, I am as I said in an earlier time, I look at the bright spots, not the hotspots. Similarly, everybody talks about bio-terrorism. And our ability in my view to achieve a paradigm shift from a green to an evergreen or doubly Green Revolution, and the ability to face the challenges of global warming and you see the September issue of *National Geographic Magazine*. Those who have not read it should read it really. It's called "Global Warming," remarkable article with photographs with them.

So the ability to face the challenges of global warming and ... rice will depend upon ability to harmonize organic farming and the new genetics. I don't think we should put organic foods and GM foods, called "frankenfoods" on either side. I find increasingly the tendency growing to put one or the other. I won't take your time now, which I think it is impossible. I think we have to have a synthesis of the two. The sooner we come to an agreement that these are all part of the same pathway and all of our aim is to see that we can cause productivity and perpetuity without ecological harm.

So the new technologies will have to help us to defend the gains already made, because those gains are threatened by market forces today, price fluctuations – that is also an equally important factor of instability. You extend the gains to more farming systems, particularly upland rices and so on, like what Dr. Monty Jones explained with NERICA rices, and finally

make new gains through farming systems, diversification and value addition – because poverty will not grow only by rice cultivation. It has to be augmented with a number of multiple livelihood opportunities, nonfarm opportunities.

Now, I believe that the new technologies, whether biotechnology, genomics, bioinformatics is also a very powerful tool, and there are emerging signs of nanotechnology, which is also going to create a certain amount of controversy, particularly the bio-nanotechnology; it is an emerging field.

All of us must have one basic aim – our bottom line of our work must be the prosperity and well-being of farmers, the health safety of the consumers, and the safety of the environment. If all these three aims of keeping the farmers happy, the consumers healthy, and the environment protected, we are in for a new era of bio-happiness. Thank you very much.