Session 4: Stable Supply of High Value-Added Food

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Y. Hayashi
We have four presenters today to discuss value-added food. To give an overview, Japan is working on developing several kinds of value-added crops, including tomatoes, sweet potatoes and rice, as well as sericulture. Value-added food has added nutritional value or efficiency of nutrient absorption, and can be used to enhance lifestyle in prosperous countries as well as to fill unmet needs for nutrients in poorer countries. It also offers the possibility of gaining extremely detailed genetic information about food origin to ensure transparency of the food supply.

Breeding Crops for Better Nutrition

Howarth E. Bouis
I will discuss micronutrients, malnutrition, mineral and vitamin malnutrition in developing countries and how we can use agriculture to improve the situation.

Micronutrient malnutrition, which includes iron, zinc, iodine, and vitamin A deficiencies, is a massive problem. Lack of vitamins and minerals increases sickness and morbidity levels, and these higher morbidity levels lead to higher mortality levels. Iron deficiency in children, meanwhile, reduces cognitive abilities for life, while zinc deficiency impairs the ability to grow. Iron deficiency is also associated with 40% of all deaths in childbirth. Therefore, this problem needs to be addressed.

The underlying cause behind this problem is poverty and the inability of people to afford the food that contains the nutrients they need. Since the 1960s, while cereal production has increased dramatically in line with population growth, the production of fruits, vegetables, animal products and fish has not kept pace, leading to higher prices. Poor people are spending more of their income than ever before on lower-value food.

The HarvestPlus program seeks to make these healthier foods affordable through plant breeding, by putting more minerals and vitamins in the basic staples that they eat every day in large quantities. At the same time, however, there is increasing production of crops for biofuels, which is further driving up food prices for poor people. Moreover, with global warming, CO2 levels are rising, and it has been shown that CO2 increases result in lower mineral concentrations in crops, which will further compound the micronutrient deficiency problem in developing countries.

HarvestPlus is trying to address the problem by putting more iron and zinc in rice, and putting more vitamin A in maize, for example. The advantages of a biofortification strategy are huge for public health and reducing mortality. It is also more cost-effective than supplements, which are recurring, fixed expenditures. Investing up front in agriculture, however, offers a sustainable and relatively inexpensive solution once the seeds are in the food supply. Moreover, biofortification strategies are by definition applied in rural areas where many poorer people live, and which are often neglected in supplement distribution schemes.

HarvestPlus program is administered by the Consultative Group on International Agricultural Research. The HarvestPlus Challenge Program is developing these mineral and vitamin-dense crops. This requires, in addition to breeding, such research as finding the genes that are responsible for the translation of the minerals from the soils to the plants and into the seeds. It is also necessary to work with nutritionists to test biofortified varieties to make sure that nutrition is sustained and improved throughout the preparation process. The program therefore works with a network of scientific institutions in very many disciplines in very many countries around the world to make this happen.

HarvestPlus' budget is US$66 million over 5 years, or US$14 million per year, very low in light of the high goals of the project. The program has donors from Europe, the United States, the World Bank and the Gates Foundation. It hopes that Japan will also contribute.

Whether biofortificaiton can work comes down to three questions: Can we get the breeding to work? Would biofortified foods actually improve the nutritional status of mineral-deficient people? And, can we get the farmers to adopt the high-iron rice, and for the consumers to eat it? If we can say yes to those three questions, then we are successful. The program thus far has shown some success on the first two questions, but the dissemination is harder to test, as the first two tasks must be completed before seeds can be put out into general agricultural use. However, sweet potato dissemination in Africa is underway.

There is a lot of talk at the conference about institutionalization, making this sustainable, making this happen so that we have impact and being able to measure the impact. In the past, engineered rices have been adopted in many countries, with a major proportion of Indian rice coming from a particular lab. When this strain was developed in the 1960s, however, there was not the same level of information available about mineral and vitamin deficiencies. That can be corrected this time. But it is important to note that farmers will not adopt a new crop simply because it is nutritious, but rather because it has a high yield, so achieving high-yield varieties is another key task to ensure dissemination. In fact, the increase in mineral intake will be largely invisible to the population.

In closing, often scientists do not understand the connectedness across different disciplines and understand a systems approach. In agriculture and health in developing countries, too, the people working in agriculture do not understand how their work has a huge impact on health and nutrition in their countries, and the people working in nutrition never look to agriculture as a solution. They want to do their supplements and their food fortification, and they never think about their agricultural comrades as being the main people to help them address the situation. This problem has been around for some time, and the gap needs to be bridged going forward.

Q&A/Comments

Question 1. What is the effect of global warming on crops?

H. Bouis
Higher levels of CO_2 increases the biomass of crops, which improves the yield, but actual mineral volume stays the same, which means that mineral density decreases.

Mineral Nutrient Transporters: Their Potentials for Crop Improvement

T. Fujiwara
In contrast to Dr. Bouis, I will focus on plant production and yield rather than plant quality. Plants are able to use soil for energy because they take up minerals from the soil, transport them to areas where photosynthesis occurs, and then they produce oils in seeds, which is where they become food. My research is focused on understanding the mechanism of mineral uptake and transport and modifying those processes to make plants give a better yield or better quality of food.

When plants are deprived of or exposed to excessive amounts of certain key nutrients, it greatly affects their growth. Plants can be genetically modified and bred to respond better to these conditions.

For example, there are many semi-arid regions where boron concentration in the soil is high, which usually stunts plant growth. We were able to identify a gene responsible for boron transportation. Overexpression of this genotype does not have a negative impact on plant growth when boron concentrations are medium or high, but the plant is tolerant of low-boron conditions. It is impossible to remove boron from the soil, but by overexpressing this gene in a plant, it is possible to make plants more tolerant to these high concentrations. It is also possible to create a crop for boron-deficient soils in the same way, eliminating the need to use boron fortifiers in fields. These would have a major effect on crop productivity in areas like Australia, with high boron concentration.

Although my research as in the field of rice, the same technology is feasible for other crops, and an analogous gene has already been found in barley and wheat in Australia. To summarize, nutrient transporters are useful at generating plant nutrients, leading to better production of crops in sub-optimal soils.

Q&A/Comments

H. Bouis
Did the study look at the amount of boron in the seed or the part that a person would eat?

T. Fujiwara
Boron was measured in roots and shoots, but not in seeds. Human beings take in boric acid mainly from plant sources such as vegetables, not much from cereals. There is a positive correlation between boric acid intake and health risks. When you take up a substantial amount of boric acid, but not too much, there is reduced risk of cancer. However, it is not thus far considered as an essential nutrient for health of humans. The concentration of boron in seeds is relatively low. It tends to remain in leaves.

Question 2. It is reported that 10 to 30% of potential crops are lost as a result of plant disease, plant pests or weeds, despite improvements in end technology and seed technology. The goal of clinical plant science is to develop technologies for plant protection, and work on topics related to the potential functions of plants. Clinical plant science is technologically integrated, and includes plant pathology, pest biology, weed science, pesticide science and physical pathology as Dr. Fujiwara presented, as well as pollutant science or integrated pest management, genetic engineering and genetic breeding.

Aspects of Breeding for Jasmine Rice

Apichart Vanavichit
My team aims to make jasmine rice adaptable to flooding stresses. In the era of global warming it was thought that drought was the biggest problem, but in Thailand flooding has become more frequent, and no germ plasma today in rice can withstand long stagnation resulting from flash flooding.

The green revolution benefits farmers. Fertilizers are very expensive today. The green revolution idea emphasizes breeding for sustainable agriculture, which fits well with the rice environment in Thailand, where farmers grow rice in non-irrigated areas, and face a lot of stresses like drought and flooding.

Jasmine rice provides the biggest income for farmers. Aromatic rice takes up about US$5 billion in the world rice market. Jasmine rice adapts to low fertility because it is tall and has a weak stem that cannot withstand high nitrogen fertilizers. Less nitrogen also gives it better aroma and cooking quality. Increasing aroma was another objective. Also, as people are talking more about low glycemic index, with jasmine rice this and other micronutrient densities must be examined. There is also the question of market acceptability, as Thailand exports rice all over the world, and many countries will not accept genetically modified rice. Therefore Thailand has developed a program for non-GM biotechnology, with the added advantage of low start-up costs.

Molecular breeding requires integration of classical breeding, pathology and entomology, and utilization of local genetic variations in an effective way. The steps in selection are to first identify the applications, then develop effective DNA markers as close to the QTL as possible, and then design a gene-specific marker if possible to make it more functional. Then, if possible, combine all the QTLs into one rice variety. It is also necessary to consider the extreme environments that the high yielding varieties will come to face in the future. In 2005 the first flooding-resistant jasmine rice was released, and farmers were impressed at its ability to withstand flooding. The next threat to be tackled is insects. More difficult is drought.

This is the whole 10 year project. We started in 2002 making isogenic lines based on jasmine rice. Then in 2006 we accomplished two QTL combined, and now in 2008 we have three QTL submersions. In 2012, we hope to combine salt tolerance and drought tolerance into jasmine rice. We hope that jasmine rice will stay with us forever, even if we are going to have extreme environments in the future.

Is it possible to make rice more aromatic? The team tried to find the gene for aroma to figure out the biosynthetic pathway of that aromatic compound and design metabolic engineering to make the rice more aromatic. All aromatic rices in the world contain one important aromatic compound, found most in brown rice and rice bran. Notably, new rice varieties yield more than jasmine rice, but they lack the aroma. However, the team has even created an aromatic version of koshihikari rice. Does aroma make rice more nutritious? One goal is to produce jasmine rice with added iron and high anti-oxidants. A jasmine rice higher in iron was successfully produced, and there is also the rice berry, which is a version of rice that has very high antioxidants, and a low glycemic index jasmine rice. Now the task is to appeal to consumers both based on high bioavailability of micronutrients and low glycemic index; these two properties are often inversely proportionate, however. If there is a way to genetically improve the bioavailability of, for example, iron, then it would be possible to incorporate brown rice into everyday cuisine.

People eat foods other than rice, but rice could be a good model to make products. On the value chain, farmers may get higher prices because rice has a better genetic background and is more nutritious. The team also experimented with low glycemic rice, using properties of bran. It is possible that this could be used to treat diabetes in the future as well. Nutritionists can help plant breeders create optimum crops.

Q&A/Comments

An unidentified speaker asked about the prospect of Thailand using genetically modified rice from Japan

A. Vanavichit
I must reiterate that there are major acceptance issues for GM rice in Thailand, and therefore Thailand will not produce GM rice. When golden rice was introduced, people were not interested in eating it. Thai people get nutrients from many foods other than rice, and so they do not need to have all their nutrients in this one food. Something that can be improved is reducing the anti-absorption factor of rice to help make the nutrients in foods eaten with rice more bioavailable.

Agricultural Problems of Pakistan

Khurram Bashir
Wheat is the major food crop in Pakistan, while cotton is the lifeline of the economy. Agriculture accounts for 26% of the GDP, and about 55% of the labor force is engaged in agriculture. Immediate problems are salinity, drought, insect pests, and rice and cotton diseases—blight, leaf curl. Wheat is affected to a lesser extent.

Pakistan has the technology needed for gene transformation, but economically cannot afford to produce genetically modified rice, as it would prevent export to certain areas of the world. However, the pesticides currently used to keep insects away are building up in fields, and are quite toxic. Genetically modified cotton, however, could be acceptable. However, because regulation is not very thorough, introducing and genetically modified crops could result in uncontrolled spread as farmers illegally use the seeds. A major cotton pest was introduced to Pakistan 20 years ago as a result of illegal importation of seeds from the United States. Therefore, Pakistan has been carrying out chromosome variation, and has released some varieties identified by this method, as well as hybridization, especially for rice. However, this has not proved effective for insect resistance yet. None of the 30,000 rice varieties available in Pakistan showed significant insect resistance. The idea of GM for this purpose was dropped a year ago due to concerns about exports.

Q&A/Comments

Question 1: Much of the germ plasm in Thailand comes from Pakistan, so I thought that Pakistan had more resistant rice genes available.

K. Bashir
It may be that the insects have adapted over time to the

Pakistani rice, as currently the rice lacked resistance.

Question 2. Cloned genes will suppress natural genetic variation, and therefore investment in research should be more on finding natural genetic variation first. Marker selection is less expensive than cloning.

K. Bashir
I agree, but policies on research are led by the government, and Pakistan still lacks detailed genomics.

Molecular breeding for enhancing tolerance to low iron availability in calcareous soils

Naoka Nishizawa
The uptake and translocation of mineral nutrients in plants is essential for plant growth. Since plants are a source of food for humans the nutritional value of plants is of central importance to human health. One of the widest ranging abiotic stresses in world agriculture arises from problem soils. In calcareous soils, agricultural productivity is severely affected by high soil pH, where metal ions, especially iron, are not available to plants, a major problem for optimum crop production.

Rice plants possess a ferrous iron transport system and have low levels of endogenous activity. Consequently, rice plants are extremely susceptible to low iron availability in calcareous soils. To enhance tolerance in rice plants to iron deficiency in calcareous soils, we introduced mutational reconstructed genes selected for better performance at a high pH into rice. The expression of this gene was markedly induced by iron deficiency. When cultured in calcareous soil, lines overexpressing this gene showed enhanced tolerance to low iron availability in calcareous soil.

The study successfully showed that a transgenic approach to increasing the tolerance of rice to low iron availability is a practical way to improve agricultural productivity in calcareous soils. This strategy may also apply to other graminaceous plants such as maize, sugarcane and sorghum. In these plants, in addition to tolerance to low iron availability in the calcareous soils, iron and zinc concentrations of material seeds increased in the transgenic rice lines with enhanced secretion of phytosiderophores. Iron deficiency-tolerant rice was crossed with other rice to obtain a transgenic rice with a closed flower and no dispersion of pollen, to prevent unwanted spreading of GMO strains.

Q&A/Comments

Question 1. Could you please confirm the relative uptake of zinc and iron?

N. Nishizawa
In endosperm cultured in soil where pH is medium, uptake of iron and zinc is increased and transport is also increased. Nicotianamine and deoxymugineic acid in the seed may have some role in the accumulation of zinc or iron.

H. Bouis
Why zinc is spread in the endosperm while iron stays on the outside?

N. Nishizawa
Zinc is easily transported inside the endosperm, in part because more of it is needed than iron.

Question 3. Did you analyze ferritin?

N. Nishizawa
The subject of our study was wild-type, non-transformant rice seed, and so therefore we did not analyze ferritin.

Question 4: Is it possible that some unknown factor could move iron into the endosperm? This would be a major breakthrough for creating high-iron rice.

N. Nishizawa
It is our hope that this factor is either nicotianamine or deoxymugineic acid could accomplish this.