Session 3

Takeshi Kano: Good afternoon ladies and gentlemen. We would like to start the afternoon session. I am Takeshi Kano, Program Director of JIRCAS Stable Food Production and he is Dr. Seiji Yanagihara. He is a rice breeding and genetic scientist and he is a sub-project leader of JIRCAS Africa Rice Project.
Title of this session is 'Researches for Environmentally Friendly Rice Production in Asia.' Now, we are going to move on to the first presentation. I would like to introduce the first speaker, Dr. Qian. He is from China National Rice Research Institute. His presentation title is 'High-Yielding Technologies in China.' Would you start please?

Qian Qian: Thank you. My name is Qian Qian. I am from China National Rice Research Institute. Before my presentation, I want to say thanks to JIRCAS because our institute started collaboration with JIRCAS more than 20 years ago, so JIRCAS sends a lot of famous scientists to my institute, such as Dr. Yano and lots of them.
In China, I think JIRCAS has made a big contribution to rice breeding and modern rice breeding system.

My title is 'High-Yield Technologies in China.' But I think I should focus on rice breeding. Why rice breeding? Everybody knows the food crisis always exists. Rice plays a key role in food security, so improving the rice yield has great meaning. In recent years, China living level increased, so people more and more are eating rice, I don't know why. Rice is very important in China.

My contents are in three parts. First part is progress of rice breeding in China. In 1994, an American, Dr. Brown asked a question, who will feed China? China is a very big country. We think Chinese shall be fed by Chinese. From that time, our country began a lot of high-yield rice, corn, wheat, and soy. Food production must be further improved in China.

In China, rice breeding has three stages. First is Green Revolution. In 1950s, rice yield was above 2 ton to 4 ton for 1 hectare. In 1970s, Dr. Yuan Longping started hybrid rice in China, so yield increased 4 ton to 6 ton. From 1996, China has started super hybrid rice project, so the yield became more.

In China, breeders will do two main things, one is for super rice and the other is ideal-type breeding, as IRRI launched in 1989, Dr. Khush said few tiller and big panicle and strong stem are the three main points. Also, if you use this new plant type in hybrid rice you can improve yield potential.
Super rice strategy began from 1996, which is， I think， a three-step strategy. In 2000 we shall reach 10.5 ton per hectare, 12 ton per hectare in2005, in 2015 we will have 13.5 ton per hectare, but also we must find some new genes and also use molecular breeding and breeding by gene design.

This year in October, I have been talking to Professor Yuan Longping. This year his hybrid new variety really in rice average yield over 15.2 ton/hectare in small area, about 7 hectares. The variety holds very big panicle, above 1000 grains in one panicle.
In China, there is the challenge of planting area with only 300 million hectares but we must improve the other side of rice.

This strategy made in 1996, said in the last year, where we shall be, we should reach 217.5 million tons of total output. Compared to 1983, shall we increase 30% yield. China production demand increased year by year. This is a lot of increase really because this year our country had 208 million tons, so it's much more need, more and more yield in China.
This is again why Dr. Yuan Longping's material has so high yield, so we must find some elite genes.

Firstly, in 1995, I found a new plant type IPA1. This mutant has very few tillers and very big panicles. We used map-based cloning and found this gene located on chromosome 8. On cloning this gene, we found OsSPL14 is the gene responsible for ideal new plant type IPA1. This year we also found an IRRI new plant type. This is the same as that I found this type above. We used isogenic lines and found that this gene contained a lot of characteristics like big panicles and strong stem, just like a lot of plants had grain weight always bigger than that of small grain plants.

I made an isogenic line, Xiushui 11-*IPA1*, Xiushui 11 is wild plant in Chinese variety. The line can increase yield about 10% than that of its wild type, also we have a lot of data showed here.

The second one I want to present to you is another gene *DEP1*, dense and erect panicle. We found it in North China variety but the South China japonica varieties all have this critical gene. This also is very big gene for rice yield. I just mentioned Dr. Yuan Longping hybridized the gene, too. This gene also has a big panicle. Compared between the two genes *IPA1* and *DEP1*, the *IPA1* panicle became bigger.

The third one is GW2. This one was cloned by Dr. Ling Hongxuan. He found this gene in Guangdong Province variety. This gene has been more used in hybrid rice.

GIF1 gene: GIF1 gene, grain-filing has become better. This one, Shanghai Institute in collaboration with my institute cloned this gene. Through comparing the gene of Indica and Japonica, wild-type materials, they found this gene is very useful in filing grain and increasing yield.

Also GS3: GS3, Dr. Zhang, he found this gene. This one is Indica variety, long grain, and a lot of Chinese have transferred this gene to Japonica rice, have made Japonica varieties. They increase yield above 10%, also can improve rice quality.

Ghd7: Ghd7 controls multi-traits of grains number, plant height, and heading date. In recent years, I found a same QTL with root activity. This gene can control a lot of different traits. This gene also used in China hybrid rice breeding is an important gene.

The third Part is how to breed super rice in China. *DEP1*, we have transferred this DEP1 to Indica variety. This one, a donor parent Shengnong265, is a very high yield variety, a Japonica super rice with *DEP1* gene.
The second is IPA1. IPA1, we have bred a lot of materials in China. We have also tested in Anhui Province, Yangtze River area, this variety with *IPA1* gene shall be used broadly in near future, I think, IPA1 has a commercializing prospect in China, we believe this.

Also, just I mentioned, we have made isogenic line with *IPA1* from 9311. This is a sequenced Indica variety. We put IPA1 to 9311. The 9311 is the parents of the first super hybrid rice in China, so also in DEP1 plus this one to 9311, similarly gw7; maybe this one is like Dr. Matsuoka's IPA1 gene. We also found these genes can increase yield by pyramiding of *IPA1*, *DEP1* and *gw7*.

Then, second step I combined these two genes together. It became higher yield. Three genes combined, with 9311 background, we combined three genes also tested to increase the yield. Maybe 30.45%, if you use these three genes combined, it can reach a higher yield.
In a recent test, my group was combining these genes to one variety, like super rice.
This one DEP1 is really high yield, five genes have been used in Zhejiang Province, even have this type of gene, my group has done.

In future, which model is best? Sd1 green revolutionary type or Yuannan type, also this one that is genotype using 9311. This picture was taken in Yuannan. New plant type will come in. Here is a young person in my group, but this year in October we took this one. we can find these plants are almost the same plant height; very strong; not tall; we noticed it's very strong. Like biomass, it becomes bigger and bigger. This one is me, also taken in Yuannan, compared with this plant variety in Yuannan, and almost my height is at 168 cm, this one, this is very strong sturdy plant higher than me, also has big application value. I think maybe after 5 years we should use this changed China super rice for Hangzhou, we also have to be sure we have to change these old plant type using this type of new plant.

China has also used Indica and Japonica mid-type restore lines for super rice breeding. It's a very good method for high yield breeding in parents' selection. I do Indica breeding. Some people do Japonica breeding, or transferred some genes from Japonica to Indica, Indica to Japonica. Then we can know the I/J mid-type R line is best for super hybrid rice breeding.

For example, we used these QTLs for two set of markers for Japonica-Indica test, and we also did this one in these markers. This is a good feature with morphological index (MI) related to indica/japonica characters. We used Indica-Japonica population to test which one is best in rice yield according to different indica/japonica MI. Indica MI is less than 9, and japonica MI is more than 17. We found morphologically, from the Figure, here is the highest yield equal to 45 g/plant, just corresponding to indica/japonica mid-type value: 13 -15 of MI..

Also, we used *Xa* materials with the target marker segregation in breeding. We did a lot of Indica restore lines like R9308 and Zhonghui 8006, but some with Japonica Pi25 material.
This one is very, very good restore lines with multi disease tolerant genes. By the way F1 showed nearly 10% genes, so this one is Guodao1 derived from Neixiang2A and Zhonghui8006, this was broadly planned in China. This is the second big variety, very big than three others.

Conclusion, I have three. One is great success on rice production achieved via semi-dwarf gene, heterosis and super rice project. Secondly, a series of rice germplasm and yield genes, IPA1, DEP1, have been discovered and cloned. Thirdly new breeding strategies, including breeding by gene design, pyramiding breeding and mid-type restorer selection, have been used in super hybrid rice breeding

I want to say thanks to colleagues of my institute, Dr. Cheng SH, and Zeng Dali, and Cao Liyong. Also, I want to thank to China Academy of Sciences, Professor Li Jiayang to do collaboration with IPA1 and Professor Fu Xiangdong to do collaboration with DEP1. Also, I want to say thanks to Dr. Masutoka and Dr. Ashikari, this GA1 and WFP is really good genes for increased yield, especially in hybrid rice. Thanks for your attention. My English is very, very poor, also Japanese. I can see a lot of Japanese.

Takeshi Kano: Thank you very much Dr. Qian. We have used more than 20 minutes, but I would like to have only one question from the floor, somebody? Please.

Toshihiro Hasegawa: Thank you for your presentation. I have one specific question about DEP1, dense and erect panicle type, what makes this DEP yield higher than others? What's the mechanism of this dense and erect?

Qian Qian: DEP is with a secondary branch which we don't know, but DEP can enhance meristematic activity, then increase grain number, and grain yield. Also DEP, Japanese has got TN1, this gene is very strong, semi-dwarf, semi-dwarf is much better than SG1 in Japonica rice. It's very strong, it's dwarf, also bigger panicle.

Takeshi Kano: Now, we are going to the next presentation. Next speaker is Dr. Ladha. He is IRRI representative for India. His presentation title is 'Resource Use Efficient and Productive Rice-based Systems for South Asia'. Would you start please?

Jagdish Ladha: Thank you, chairperson for giving me this opportunity to share some of the work which we have been doing in South Asia. I have structured my presentation as follows:

- Food Security and Rice
- GRiSP and CSISA - New Global and Regional Concept for System Research and Delivery
- Rice-Based System – Challenges and Opportunities
- Growing Rice – New Paradigms
- Future Outlook and Likely Changes

First, I would like to talk about the Cereal Systems Initiative for South Asia in relation to this as a global and regional concept for the system research and delivery which is GRiSP. Then, I will move to my main topic which is rice-based system and finally discuss the challenges and opportunities.

Broadly, Asia can be divided in two major ecologies. One is South Asia, which includes India, Nepal, Pakistan, Bangladesh, Sri Lanka, and Bhutan where rice system is relatively more diversified such as rice-wheat rotation with other crops including pulses. Then the Southeast Asia and Pacific, where we have Philippines, Indonesia, Thailand, Japan, China, and Vietnam the rice is primarily a mono-culture with 2 to 3 crops in year. Rice-wheat rotation, a common crop rotation in the Indo-Gangetic Plains is about 13.5 million ha. There is also double crop of rice mostly in southern part of India and eastern Indo-Gangetic plains of Bangladesh and some parts of Nepal. Rice is also grown in rotation with legumes and other crops including vegetables. Also, we have cotton and wheat system mostly in Pakistan and India.

The CSISA a mega program, which is funded by the Bill & Melinda Gates Foundation and USAID with several partners including 4 CGIAR centers, NARS from the four countries, NGOs and advanced research institutions.
In South Asia, the area under cereal is declining and demand increasing. During last few decades, the crop productivity has stagnated, and also declined in some areas. There has also been tendency of increasing use of agrochemicals such as fertilizers, pesticides, herbicides with a net result of declining input use efficiency.

The soil and water resource base is going down or not maintained, and we have problems of monsoon, it was discussed yesterday as well, unpredictable rainfall pattern. The rainfall pattern is changing. That makes difficult for farmers to manage the crops. Also, night temperatures are rising resulting to yield losses.

Labor shortage. Even in countries like Bangladesh and Nepal, there is trend for labor shortage in agriculture.
Irrigation water. It's highly dependent on energy availability. If there is no electricity, no fuel, irrigation water is not available. Farmers are applying water when it's not needed because that's the time the energy is available.
The heavy uses of inputs have resulted in the increases in the cost of cultivation. Farmers are interested to reduce the cost of cultivation and increase the income. Obviously, we can't meet the food demand of future just with the current crop growth rate of 1%. The projections are that there will be 10 billion people by 2050 which will require cereal growth to be close to 1.2% to 1.5% or even higher.

Also we need to grow rice, wheat and maize with less inputs. During the Green Revolution, our main goal was to maximize productivity. We had high-yielding varieties as well as plenty of water. The fertilizers and pesticides were liberally used. Labor was plenty and energy was not a problem.

Today our goal is of two fold. Not only yield maximization but also maximization of input use efficiency. That's why natural resource management is going to play a very important role which includes soil resource as well. Try to avoid puddling. Residue has to be a part of the whole equation, not just because it has got nutrients but also because burning causes greenhouse gas emissions.

Now, again yesterday, it was highlighted. As the consumers' income is increasing, they are demanding more nutritious food. That has to be a part of the equation. Diversification for environmental reasons, also farmers like to have cash and adaptation to climate change. These are all components of sustainable agriculture,

ecological intensification or conservation agriculture. There are three important components of sustainable agriculture which are food security, environmental quality, and economic viability.
It's not easy to balance these three. We try to do one, then we lose the attention of the second one. Now this is good for us as scientists and policy makers to think about it and conceptualize but this doesn't help farmers. The real question is: What is it for farmers? In simple terms, it is – good management practices. I am going to discuss how rice should be grown in future and what are the best management practices available for the farmers to adopt .

Leveling of the land is an entry point which improves overall farm efficiency.
Land preparation is second one. We have to go away from labor and water-intensive land preparation, and maybe minimum soil disturbance and no puddling.

Water management. Dry seeding rice under unpuddled or zero/reduced tillage saves significant amount of water. In addition, there are other smart water saving techniques like alternate wetting and drying.
Crop establishment, absolutely important. If we can establish a good dry seeding crop, I think then it is a win-win situation. We have to have right variety which yields high under direct-seeding.
Crop residue should be a part of equation and we do have good machines (for ex Happy Seeder) at least in South Asia that helps in reducing environment pollution by not burning and also improves soil health. I think if we move away from puddling, residue has to come in as mulch which results in overall benefits both on short and long-term.

Nutrient is going to be very important. We have site-specific nutrient management practices which are in place.
Pests, integrated pest and weed managements are equally important.
Diversification, wherever possible, main crop should be replaced but if it's not, then at least another crop should be integrated.

Post harvest crop management. If we can eliminate losses from post harvest, I think we can solve food production problem to some extent.
Lastly, there is a need to also link farmers to input dealers as well as market access and that will give overall farm support.

Farmers' outlook will be very positive if they make money today. A farmer probably may not care much about what happens tomorrow or in future. That's why in some circumstances some of the good management practices such as water saving does not help farmers because of lack of cash incentive. Likewise the use of residue is often not very attractive to the farmers at least in short-term. Nevertheless, as a society, we have also responsibility to make sure that ecosystem functions are not disrupted. I think all these components, one way or other way, short term or long term, will benefit the overall ecosystem functioning.

Now, the next question is important. What are the yardsticks? How do we say that a particular so called good practice is better than what farmers already doing? I probably won't be able to go in the details of this because of short of time. But we have developed a set of system monitoring indicators. Let's take an example, nitrogen-use efficiency. What farmers are doing today and what is the efficiency? We set a target of NUE with a good management practice which becomes a yardstick for farmers to achieve. Let's take example of another indicator which is biocide residue index. All the chemicals which farmers are putting in, in terms of residue index, how much is it? For rice, what farmers are doing today in conventional system, we have these numbers based on our research. If we have the targets for the various input efficiencies then we can monitor the system performance.

Now I just want to take few minutes, Mr. Chairman, to discuss the potential of dry direct seeding of rice which is likely to be popular rice culture in the future at least in South Asia. I'm not sure about in Southeast Asia with heavy clay soils. I think it is going to be a challenge in soils where rice has been puddled for a long time as a results hardpan has been created.

Puddling or wet tillage is something, an old practice which most farmers do to grow rice. I tried to go in the literature to find how it came about. I talked to several senior soil scientists in India as well as a few Japanese scientists. In India, it's believed that it came to India as a new Japanese rice culture in 1960s and later 70s. It is also believed that puddling increases the rice productivity but it takes away a lot of water, labor, and time, and about 30% of total production cost goes in puddling and transplanting.

There are many advantages of puddling and Japanese scientists have published extensively. It reduces water permeability, holds water, controls weed, and enhances soil nutrient availability. But it has some disadvantages as well. It requires more water, more labor and a longer turn-around time. Puddling also destroys soil physical condition (increases bulk density, penetration resistance, and increases cracking) which of course is not important for rice but important for the subsequent crop, if happens to be an upland crop such as wheat. However, because of labor constraint, there is a shift from puddling and transplanting to non-puddled condition or direct seeding, dry seeding, and drill seeding.
As I said, it's not going to be successful everywhere. I think in light-textured soils, which are predominantly in South Asia, it has more potential.

What are the key requirements for dry direct seeding? Precise land leveling is a prerequisite for direct seeding and to establish a good crop. If we can establish crop in the first 2 to 3 weeks, it's a win-win situation. Later, rice behaves like puddled transplanting. Seed rate is very important and we have made some really good progress in this area. If we can drop seeds in the right depth and right distance followed by a precise water management then we can expect a good direct-seeding crop of rice. Weed control is also very important but now we have a set of integrated weed management techniques perfected which allows good weed control. There are also good molecules of herbicides both pre and post emergence available which give good results. I think a suitable rice variety, which is targeted for direct seeding condition, will also help.

This is the laser machine which has been very popular among the farmers in South Asia. This technology has gone like fire. Every farmer, when sees it, wants to have it. Since a laser machine cost is high and not all the farmers can afford, custom hiring has become popular.
Conventionally, we were using these machines which were using fluted roller system and there was a heavy breakage of seeds and poor establishment and that's why farmers had to use high seed rates of up to 100 kilogram per hectare. We initially have an inclined plate type where the seed could be picked up with right precision. We moved on to more roller type which allows the use the same machine for different crops. This ensures optimum seed rate and allows priming as well.
We have now reduced the seed rate to around 15-20 kg/ha. I think this is a remarkable progress which we made in the last 10 years after working with the machine manufacturers. With a lower seed rate, the row spacing is just like transplanting and I think the key is to drop the seeds at right dept and right distance.

Integrated weed management is crucial, we cannot just depend on herbicides only, if you learn from the experiences of Malaysia, Sri Lanka, and also US for example. Herbicide resistance can be a severe problem. Wherever it's possible, stale seed bed technique which works well should be recommended. Also zero tillage with residue as mulch solves wed infestation by about 50%. Of course, herbicides will continue to be important component of integrated weed management.

Now I will just take 1 or 2 minutes, Mr. Chairman, to summarize the large on-station and on-farm data during the last few years. We analyzed the data using the meta-analysis and mixed model analysis. Instead of showing the detailed results, I would like to give you a summary. Here are the data of the yield change.
In dry direct seeding, there is a tendency of lower yield but we have also got many trials where we got high yields as high as puddled transplanting, suggesting the potential is there. There is a tendency of more nitrogen use which is linked to lower initial supply of N from soil mineralization. Therefore a basal dose of N helps in dry direct-seeding. Definitely farmers have to invest more in herbicide but saves in labor by not doing hand-weeding.
Greenhouse gas emission is very important. In dry direct seeding, methane emission is reduced on an average by 47% but nitrous oxide is increased to about 270%. However, the global warming potential is still on the positive side, 20%-40%.

There is a saving of $30 to $80 per ha per crop. Also a direct seeded crop is harvested about 7 to 14 days earlier which allows timely planting of the next crop.
I have got the last slide, Mr. Chairman. What's going to happen in the future? I think more and more machines will be used for establish and harvesting crops. I remember Dr. Masa-san, when he was in South Asia, many times he said 'tillage revolution' and I think that's what is happening and I think with tillage now, mechanization revolution is going to happen.

I think agrochemical use, especially herbicide, is probably likely to increase. Land consolidation, probably likely to happen. Private sector is coming in more picture and they are playing role and we will have to see how much positive role they will play. Access to market and inputs is going to be very important. We have to have these best management practices for productivity growth, for 1.2% to 1.5% growth rate. Diversification and more hybrids are going to come in if we have to increase the yields and farming is going to be more attractive. If you want to retain farmers on farm at least in the developing countries, I think it's important that farming more attractive for them.
Thank you very much, Mr. Chairman.

Takeshi Kano: Thank you very much, Dr. Ladha. I think you have some questions and comments but we have used the time. I would like to have question and answer in the last general discussion part. Thank you very much again.
We would like to move to the next presentation, Dr. Toshihiro Hasegawa. He is a senior researcher of National Institute for Agro-Environmental Sciences, Japan, and his presentation title is 'Rice Production Technologies for Climate Change'. Please start.

Toshihiro Hasegawa: Thank you, Mr. Chairman. I'd like to thank the organizers of this meeting. I really appreciate this opportunity to give this premier talk. My topic is about climate change. It's a very large subject, and an amount 20 minutes' talk just can't cover all the aspects. I will try to focus on some of the aspects. But I would like to emphasize that the research on this climate change field needs basically four components. One, a good understanding of historical change in climate; the other one is climate change, what the climate is going to be, including some of the downscaling, what's going to happen in a specific place.

Some other important mechanism we're understanding using some of the field experiments, chamber experiments, what the crop response is going to be, and good modeling work including some of the important aspects of crop responses and soil responses. That's something we need to work on but also we have to look at the different aspects of the climate change. From the upstream of the climate change, we have change in climates.

But change in climate means basically two components; one, a gradual change in climate. CO2 is gradually changing. Temperature base is going up. But at the same time, the variability is also changing; water, temperature, heat, etcetera. These are the things we have to look at, and not in the same way but in different ways. From the downstream of the climate change impacts point of view, the gradual change in climate can be an opportunity, for instance, better access to the climate resources. Climatic variability, on the other hand, can be a risk component, where, the yield and quality losses that may take place. These are the things we have to look in terms of climate change research.

In today's topic, I will mostly focus on some of the risk assessment here under climate change. Particularly temperature responses, already JK-san mentioned about it. Temperature response, we need some better understanding for the increasing gradual shift in temperature. Day and night temperature works differently and we need better understanding on this. Also, other part is the extreme heat that frequently happens in the recent years. What's going to happen under extreme heat? For rice, mostly the reproductive phase is very vulnerable. That's where we see some of the emerging problems like chalks in the grains and some of the cracks in the grains although the temperature is not the sole cause of this.

Future threat, as Kato-san has already mentioned in his last talk, the spikelet sterility. This is very sensitive to temperature. The chamber experiment shows that if you have temperature higher than 35 degree C at the time of anthesis flowering, anther dehiscence is disturbed and many of the pollen do not reach the stigma. The sterility increased by 16% by 1 degree increase above 34-35 degrees, so that's substantial. If we have 40 degrees around flowering time, most of the spikelets become sterile. This is a future threat but we need to look at the field conditions whether this is really going to happen under the field conditions.

This is one lesson from Japan in 2007. We had a record-high temperature recorded near Tokyo and also Nagoya area, more than 40 degrees in midsummer. According to the chamber results, this should result in some substantial increase in spikelet sterility or decrease in grain set. Actually we did a survey of these areas to look at the sterility, how much sterility took place. We have a 2007 hot summer here and a normal summer here. On the X-axis is the sterility percentage as the classes and this is the frequencies of paddy fields. About 130 paddy fields were investigated. Apparently, compared to the normal summer, the sterility already increased as a result of hot conditions.

This is the temperature response in the chamber. Above 35 degree C, sterility increases sharply. But if you have seen, these are the temperature classes of the paddy field in 2007. These are the sterility classes. If you predict the sterility under these conditions, the expected sterility is something like this. This means the actual condition of sterility is not as high in this case as we expected from the chamber result. We need to fill this gap between the chamber and the field.

The one reason that could possibly explain why this occurs is the air temperature is different from the panicle temperature. The panicle temperature is a sensitive organ. It's very different from air, given the conditions like wind speed, humidity, and solar radiation. This is the way our cartoon shows the model that we are working on to estimate the panicle temperature but, in fact, we need to do something to measure the actual microclimate in the canopy. This is something we started after 2007. We need to measure what really the temperature is around.
We started this multi-network, including Japan, Philippines, Taiwan, India, Sri Lanka, Myanmar, US, all those countries. What we did is to measure climate in paddy fields. That is not a fancy instrument but we just used the canopy measurement sensor. We call it MINCER, Micrometeorological Instrument for Near Canopy Environment of Rice. It looks something like this. It's a stand-alone.

We don't need a power supply. We don't need a big battery on this. This is a solar panel on top of it. It looks like a mincing machine. We call it MINCER. But unlike a mincing machine the meat comes out of this place, the other side. The air comes in from this side. The forced ventilation is very important to understand this canopy climate. We have distributed this to eight countries, in Asia also. This is the example installed in one of the experimental stations in Taiwan. We visited last month and a MINCER was installed in the field.

The preliminary results are presented in this side. White one is the above canopy temperature and green one is the inside canopy temperature and the red line is above canopy and inside canopy temperature differences. Here are the eight countries. For instance, this is the dry season in Philippines. The canopy temperature is much lower than air whereas like in Taiwan and inland China, this difference is very small. This means like even if we have same temperature level, your panicle fields have different temperature levels. This can have very damaging effect.

This is one example taken in China in Jing Zhou, Hubei Province, 1 day measurement of temperature, panicle, and air. In this case, the panicle temperature is much warmer than air by about 4 degrees. As a consequence, at the time of flowering, different varieties have different responses to this very extremely high temperature.

The seed set rate and also the different varieties, many of hybrid rice in China and some of the varieties showed very high seed set, not very high but over 80%. Some goes down to 50%. This is one of the reasons why we see the different response to the air temperature but also the varieties are very diverse in terms of the response to the temperature. These are the things we need to figure out on how we can take advantage of this difference in terms of seed tolerance variety.

Another lesson from 2007 Japan is that management also changed the spikelet sterility. These are the different timings of planting dates and then they are exposed to different temperature around flowering time. This plot shows the relation between the nitrogen application rate versus spikelet sterility. We see 37 degrees gives the higher spikelet sterility but it depends on the nitrogen. Nitrogen level in some way reduces the associability to heat. This is another region where we have to work on why this occurs in addition to the variety differences.
This is about temperature as well as heat events. There are a number of other issues but we have to focus on that.

I will slightly touch upon the story about the long-term change in CO2. CO2 is the main substrate for photosynthesis. This has been studied for many years but still we need to have some better understandings.
Nitrogen interaction under field conditions. Yes, there is also some down-regulation or acclimation takes place under higher CO2 if the rice is exposed for a longer period of time. We have genotypic differences. One is as shown by Shimono and the other one by Yang in China. There is also temperature interaction. In this case, the lower temperature showed a lower yield enhancement under CO2.

Now, I'm moving on to the experiment that has somehow warmer than the original CO2 experiment here. This is the challenge for the open field experiment for CO2 exposure. We call it the free-air CO2 enrichment abbreviated as FACE. The rice FACE first initiated in Shizukuishi, northern part of Japan, in Iwate.
From last year, 2010, we started a new FACE experiment in Tsukuba-mirai City, near Tsukuba. We have set octagonal-shaped rings, each size being 17 meter across about 240 square meter. We fumigate CO2 from the windward edge of this ring to give the highest CO2 targeted at 200 PPM above the ambient. Also, we included different varieties, soil and water warming treatment, different nitrogen treatments, etcetera inside the FACE rice. These are nested in the CO2 treatment. We have four of these rings each for CO2 and ambient CO2 without fugumigation.

The preliminary results showed That there was no variety that showed the lower yield in the high CO2 than in the ambient. All the varieties showed positive response but there was a large variation in the yield enhancement: the lowest enhancement last year was 3%, whereas the highest response was 36%. There is a huge window for change in the CO2 responsiveness and can be an opportunity for adaptation.

Yesterday Kato-san told us that the rain yield target of the brown rice is about 1 ton per hectare but inside of this Takanari reached 1 ton. You could say that's cheating or doping but still the yield target can be dependent on the environment. This may be a better variety that is suited for an elevated CO2. That's another challenge to look at in this FACE ring.

In our FACE study, another challenge is to look at the carbon cycle in the field. We had CO2 and also warming treatments inside of this from Shizukuishi site also. The treatment warmed soil and water by 2 degrees C. That resulted in about 44% increase in methane emission and CO2 equivalent is about 6 or 7. 'Also CO2 enhances this methane emission. A combined effect of CO2 plus 2 degrees resulted in about an 80% increase in methane emission. That's huge.

The methane is from the soil organic materials and also from the plant substrate. Our carbon isotopes experiment shows about a half of the methane is from the current photosynthates. This plant response is immensely important in this field. What we have to do in the future is to develop a better carbon flow management through plant management under high CO2 and temperature. That should give us a better adaptation and mitigation strategy as a win-win situation.

A short outlook of climate change study, we need to move forward toward effective international cooperation. Agricultural practices are specific to regions and also the impacts of climate are very specific. Climate change takes place all over the world. This is a common problem but adaptation and mitigation should be site-dependent, locally specific. There is no single one super technology that can solve all the problems and the solutions have to be tailor-made depending on the regions.

To facilitate this tailoring technology in the different sectors, we need to have a good database. We need to have good climate, soil, agricultural practices, some of the better mechanistic understandings of the climate change impacts, and also not the biological seeds but the seeds of the technology, of adaptation options, etcetera.

These are the things we need to work on internationally. This is something we think that's important in the future. One is the monitoring. Many excellent networks already exist like Global Research Alliance and Flux net. Let me also add MINCER net to those. That is also another important network for monitoring what is happening as a climate change or is there any sign of change taking place.

The other one is open-field environmental manipulation like FACE. This is another global issue. FACE is an expensive experiment. You can't do everywhere in the world but we need to have a really good teamwork to address the CO2 issue. Let me introduce a map of global FACE site network. It's not a strong network but like a consortium. There are currently, as far as I know, 13 big FACE experiments going on in the world. The red circled ones, are the crop FACEs. Rice is here and in China. Mostly wheat and soybean, maize, and the field crops like wheat, barley, sugar beet, etcetera.

These are the only five spots we have at the moment. We need to work on to collaborate, not just as a meta-analysis but we need to look at why the response is similar and why response is different depending on the species, depending on the conditions. That's something we need. So far, there is no tropical FACE existing yet but hopefully in the very near future.

The third one is modeling exercises. Many of the climate modelers, they have long been worked together do domany ensembles of the climate model results. The agricultural models have just started their work on ensemble a collaborative work since last year. The rice team has also started headed by Bas Bouman and others. We have already determined four benchmarks or sentinel sites to test whether your crop models are performing good or not, what are the needs for the future improvement, also the future impact assessment.

These are the things we are working on. The number of collaborators is very huge. Not just our institute, but many others including overseas institutions. Researchers on rice, FACE and models from different groups and countries work to adapt to climate change GRiSP is an part of this, and I hope that this work keeps on going under the good umbrella of GRiSP. With that, I would like to conclude my presentation. Thank you for your attention.

Takeshi Kano: Thank you very much, Dr. Hasegawa. We would like to have questions from the floor. If you have, please raise your hand. No questions? Okay, we would like to have more questions in the general discussion. Thank you very much.
We would like to move to the fourth presentation. Dr. Kazunobu Toriyama, he is Director of Crop, Livestock, and Environment Division, JIRCAS. His presentation title is 'Recent Developments in Yield Increasing Theory Focusing on Nitrogen Use Efficiency'. Could you please start?

Kazunobu Toriyama: Thank you for your kind introduction. This work has been done with a close collaboration between rice geneticists and soil scientists and also rice physiologists. I myself am a soil scientist and have a strong interest in rice growth and nitrogen uptake. Today, I will focus on nitrogen-use efficiency because it is a very important factor to keep the rice production in a more environment-friendly way.

To solve the problems of rice cultivation in developing countries, it is not successful without an innovation of rice production through research collaboration in breeding and crop management together with new concepts. There could be two strategies to cope with the rice production problems. One is to meet a pressing demand from developing countries such as from Africa. Others are measures for long term demands for the future.
For both purposes, increase of nitrogen-use efficiency is the key research target. For urgent pressing demand, use of conventional techniques, well adapted to the specific places and updated, are necessary. However, for long-term measures, innovation based on technology breakthrough is more important, and I will refer to this topic today.

There are three topics in my presentation. Firstly, introduction of JIRCAS's Rice Innovation Project. Secondly, strategy to improve nitrogen-use efficiency. Lastly, a goal of my presentation will be a breakthrough concept, nitrate hypothesis.

Rice Innovation Project is an ambitious JIRCAS's project abbreviated from Rice Innovation for Environmentally Sustainable Production Systems. This project consists of three research themes. One is a resistant rice to blast disease, and the second is a high productive rice cultivation under limited nitrogen fertilizers and the third is to increase the adaptability to environmental stresses such as P and Zn deficiencies.

There are two ways to improve nitrogen-use efficiency. One is called agronomic nitrogen-use efficiency. It is defined as a yield divided by applied nitrogen. The other is a physiological nitrogen-use efficiency. It is defined as a yield divided by absorbed nitrogen.

It is important to improve both factors. We can take three strategies for this: breeding high yield variety and proper adjustment of fertilizer application by plant and soil diagnosis. For example, breeding of root traits which leads to a larger rhizosphere volume can contribute to improve this factor. Discovering the phenomena showing a high physiological nitrogen-use efficiency and elucidate the physiological mechanism and genetic basis in it are needed with close collaboration between different disciplines. I will show you how important this is.

At first, I will introduce Dr. Obara's result. This is related to the root morphology. His group discovered the QTLs for root elongation in response to exogenous ammonium nitrogen concentration. They were mapped and verified, and the candidate genes responsible for them were estimated by comparative mapping with genes for ammonium uptake and also nitrogen metabolism.

I will show you two slides to explain *Glaberrima* variety showing long seminal roots which grow very vigorously in early growth stage. They show high agronomic nitrogen-use efficiency. From the analysis, they determined root length traits on some chromosomes.

Now, I'm moving on to the second topic: Strategy to improve nitrogen-use efficiency from crop management aspects. One important thing is a nutritional diagnosis for nitrogen. We sometimes use leaf color charts for proper nitrogen application. It increases the nitrogen-use efficiency and also enable a site-specific management of nitrogen. It means we can get high crop yield with less nitrogen application.

However, recently aerobic soil management with little water stress could be an another option to increase nitrogen-use efficiency. I will explain about this by using our research results. We used 31 rice varieties from Indica, Japonica, and landrace and improved ones. These were water-cultured in different nitrogen concentrations. The relative dry weight was measured and analyzed by cluster analysis.

You can see there are five variety groups and some relationships between variety types and the relative dry weight response of rice. Very interestingly, those groups showing different responses to dry weight production as well as the physiological nitrogen-use efficiency.
Varieties in the fifth group are improved varieties. They showed lower physiological nitrogen-use efficiency, although they are said to be improved. On the other hand, most of the third groups are landrace varieties which showed a rather high performance.

Then, as the former experiments were carried out by using the mixture of ammonium and nitrate, we conducted the experiment by using only ammonium, nitrate, and compared with those by mixture of nitrogen. Also, relative dry weight was measured and the vigorous growth in the ammonium and nitrate mixture plot was observed.
Ammonium is abundant in flooded soil. It might be the reason why varieties' response to sole ammonium is relatively similar. However, for nitrate, used varieties showed very different responses and it is same in a mixture of ammonium and nitrate. Interestingly, the mixture of ammonium and nitrate shows a better dry weight than sole application of each nitrogen source. Less nitrate was taken up by all rice varieties than ammonium plot. You can see old variety groups showed a better nitrogen uptake and also better nitrogen-use efficiency.

I will show you some supporting data from several research papers. Kronzucker and Kirk who worked at IRRI demonstrated that co-provision of ammonium and nitrate increased total nitrogen uptake. Also, Duan and his group from Nanjing Agricultural University in China showed that mixture of ammonium and nitrate enhanced the uptake of ammonium. Duan showed that an addition of nitrate to ammonium increased the ammonium uptake rate. They analyzed by Michaelis-Menten's analysis and showed that the transporter for nitrate has been enhanced by the addition of ammonium. In addition, their group showed that ammonium transporter gene expression was enhanced by nitrate addition.

Nitrate effect is very interesting. There are some physiological meanings in nitrate, I think. Barlaan and Ichii of Kagawa University presented that there was a positive correlation between nitrate reductase activity in rice plant and biomass production. They used many rice varieties and showed that nitrate could be stored in vacuole of shoot tissue. This is also shown by Nanjing Agriculture University's group. They estimated that the nitrate can move to leaf tissue when nitrate was depleted in the leaf tissue. It could be a possible physiological basis of improved nitrogen-use efficiency.

In Japan, a field experiment regarding the use of nitrate was done by Yamamuro in Hokuriku Nat. Agr. Expt. Station. Normally, nitrate fertilizer was not used in paddy field because it is very easy to be denitrified. However, he dared to use it to see the effect of nitrate on rice growth. He suggested the delayed biomass increase after vegetative stage compared to ammonium applied plot. This may be also related to nitrate storage.

IRRI researchers also showed that hybrid rice varieties with higher nitrogen-use efficiency contained more nitrate in shoots than conventional cultivars between late tillering and heading stage. So far, I presented the data showing the positive effect of nitrate on nitrogen uptake and biomass production. The problem is that nitrate is not always used as nitrogen fertilizer in the field because of its denitrification drawbacks. If nitrate is very effective in increasing nitrogen-use efficiency, it is important to supply them from soil itself.

There are three possible sites where nitrate could be produced in paddy soil eco-system. One is surface oxidized layer of soil and also irrigation water. Rhizosphere is also a site where ammonium oxidizing bacteria are living and they do nitrification there. However, if soil is aerated, I mean if upland or aerobic soil management is done, surface soil and bulk soil, both can be a good supplier of nitrate to rice plant as well.

Recently, Kato from the University of Tokyo and Katsura from Kyoto University collaborated and found in field experiment that upland condition without severe water stress could be more appropriate to show the potential productivity of rice plants than grown in flooded conditions. They showed significantly higher radiation use efficiency as well as higher fraction of radiation intercepted which suggest the contribution of canopy structure improvement. Based on these data and reports, I will show you a nitrate hypothesis as shown in the slide.

By using aerobic soil management without water stress it can make enhanced nitrification. There are two possible ways which leads to the higher biomass production. One is that an aerobic condition enhanced the root development at early growth stage which could give a better canopy structure. This is related to the increased radiation intercepted and also nitrification. It means nitrate can be supplied together with ammonium which in turn increased the radiation use efficiency. These two factors can contribute to increase dry matter production. Recently, Auxin, which is a phytohormone suggested to be released in the root by the signal of nitrate. If it is also true for this improved nitrogen use system, it is very interesting. I hope somebody verifies this hypothesis.

This is the last slide, showing the future research to be addressed for improving nitrogen use efficiencies. To seek for the optimum conditions under aerobic soil culture for the increased nitrogen uptake may be a key to realize the nitrate effect to rice growth. To write it is easy, however, to achieve this is very difficult. Aerobic condition without water stress is worthy to be explored. From my experience, it is very difficult but it’s a challenging thing.

Clarify the physiological mechanism and the genetic basis for the increased physiological nitrogen use efficiency and the nitrate uptake is also a good target of innovation in rice cultivation. If there is any positive effect of nitrate uptake on photosynthesis, it’s also a very interesting hypothesis. However, I have no evidence for this yet.
Of course, the goal could be achieved both by a genetic improvement of nitrogen use efficiency and the development of a suitable crop management. Thank you very much for your kind attention.

Takeshi Kano: Thank you very much, Dr. Toriyama. We would like questions for his presentation in the general discussion. Thank you very much.
We are going to the time of general discussion. I would like to divide two phases of general discussion time. First, we would like to accept direct questions and comments to the four presentations. Then, after that, we would like to have a comment on the future research subject in the area of this session and we would like to know what kind of research framework is necessary for conducting such future research subjects effectively. Such comment will contribute to the next panel discussion.
I would like to have first direct questions and comments to the four presentations. Please raise your hand. Please.

Achim Dobermann: I have two comments. One is just as an additional information to Dr. Hasegawa’s presentation. He will be coming to IRRI in about 2 weeks where we want to have a brainstorming workshop on how we can design a new kind of FACE system, one that we can exclusively use for rapid screening of large numbers of germplasm with regard to CO_2 responsiveness.
That will be the next challenge. Because from the studies conducted so far, it seems that there are significant variations among genotypes that would make it valuable to look into genetic diversities, we got the CO_2 responsiveness and we need to design a system for that and we need to do this under tropical conditions so that we can run three or four batches of crops through that in a year.

But that requires a new kind of FACE system. One that also consumes less CO_2, I hope. I think it’s a very exciting work that has been done and also in the new FACE site that I have visited last year, if I remember right, and we now need to take that to a step where we can also, from our point of view, make use of this in gene discovery and ultimately breeding.

Then I wanted to congratulate Dr. Toriyama for his very interesting presentation on the nitrogen use efficiency and nutrition. I just wanted to add a comment on that that in the late 1990s, I did some research on similar hypothesis with Dr. Kirk and Professor Young in southern China. We never published the results because for one reason or another we all left for other jobs after that but I still have all the data. That work was in farmer’s fields and we were testing the hypothesis whether a mixed nutrition with nitrate and ammonium could significantly increase the nutritional status and yield of hybrid rice versus inbred. We could clearly confirm your finding there.

That hybrid, in particular, responded very well to mixed nitrate application. Inbred was much less. In our hypothesis, a wonderful explanation for this was that hybrids, at least under that management situation, there was alternate wetting and drying, developed much stronger surface route systems that were able to absorb nitrogen very quickly and particularly nitrate. But there is a lot, I think, that supports this idea and I think this is becoming increasingly relevant now again when we are talking more about direct seeded rice, aerobic rice. Systems, where we don’t have flooding anymore and where we basically grow rice almost like a well-irrigated upland crop.

I think we need to really rethink our theories in terms of nitrogen nutrition but you’ve presented that as hypothesis, to me it makes a lot of sense. Hopefully, it can be confirmed and I would also like to suggest that if we can find ways to collaborate on this research we have an experimental side in IRRI now where this would be extremely relevant. What I showed yesterday, large fields that we manage with sprinkler irrigation but we don't know yet how to manage nitrogen very well. If you want to consider collaborating with us, then please let us know.

Takeshi Kano: Thank you. Additional comment from Dr. Hasegawa or Dr. Toriyama? No comments?

Toshihiro Hasegawa: I am just very excited to visit IRRI in 2 weeks' time. This is a wonderful workshop. It will be a big challenge for many FACEs in the world. Nobody has done the next generation FACE yet. Nobody has done that in the tropical area. This will really be a major challenge. I am really looking forward to that. Thank you.

Takeshi Kano: Thank you. Any other questions? For example, we don't have enough time to have a question for Dr. Ladha. Please raise your hands. How about for Dr. Qian? In this session, we have four different viewpoints. One is breeding varieties, and the second is cropping system, and the third one is the climate change, and the last one is nitrogen fertilizer use efficiency. Our session covers a broad range of research, I think. Do you have any comments or questions? Please Dr. Hasegawa?

Toshihiro Hasegawa: I have another question for Qian-san. In your talk, many of the targets for the high yielding in China, it looks like it's mostly about the sink formation, panicle structure. You don't have to worry about source capacity like photosynthesis for getting about 13 tons of rice. If you have a big panicle or a large sink, you automatically get a bigger source ability. That's what you are aiming at or do you have any specific target to increase the photosynthesis ability as well?

Qian Qian: Yes, we really need to have very strong stigma and bigger, also there can be use of more yield, effectively use nitrogen, this is new plant type. Also, if possible, we would also want to join IRRI and JIRCAS international activity for breeding. We would like JIRCAS to organize such activity because compared to 10 years ago China also has some plans for breeding and other activity, so please if IRRI and JIRCAS have some kind of – and also we welcome to China to see breeding effect. Thanks, maybe I'm not understanding your question.

Toshihiro Hasegawa: I think I have the same question to Kato-san. I think in Japan that should be okay or not or…?

Hiroshi Kato: Now, we don't have a huge material for improving the photosynthetic ability itself. If you have such kind of material, we want to use, please inform. Maybe C4 is good but it needs genetic engineering, so it's difficult to use.

Takeshi Kano: Thank you very much. I would like to have a more general discussion. Now, in our sessions, we don't have enough information about disease and pest control. I would like to have some comments about disease and pest control in the future. Can I ask Dr. Fukuta? As you know, he is carrying out rice blast network in Asia, and in the future such work will contribute to African rice production also, I think. Please.

Yoshimichi Fukuta: I want to use the first slide of Dr. Toriyama. I would like to explain regarding this issue. I would like to explain at first my project. Can I use Toriyama-san's presentation? Because my project, Rice Innovation Project is focused on the three issues. First one is the blast network. The second one is improvement or adaptability for the problem soil and the abiotic stress. The third one is the improvement of nitrogen efficiency of rice and development of some cultivation system. It means in this concept we don't like to use so much fertilizer. We don't like to use so much pesticide because our target farmer is really a poor person. They cannot buy enough fertilizer and pesticide.

In the future, we need like a focus to save this chemical control or something like that. We are focusing the low fertilizer system and more adaptability improvement and focusing on no-pesticide cultivation system. Regarding the blast resistance, we are finally focusing on developing the multiline variety. Multiline variety is a very unique material. It also introduces some resistance gene. Different resistance gene, each background, we developed the isogenic line. These isogenic lines are combined and cultivated. We can avoid the risk of infection by blast fungus. It means no need to use pesticide in the cultivation system. We are recommending to develop the multiline variety in here.

At the same time, if you want to develop the multiline variety, you need some differential system to identify the blast fungus to know the resistance gene or resistance variety. It's a minimum tool. Two steps, differential system development and improvement of genetic background or rice variety. My concept of JIRCAS Project, but this one is an important point.

Everybody understands the design and agrees with themselves and developed by themselves. The important point; maintained themselves and improved themselves. JIRCAS cannot continuously support this work. In the initial time, we would like to provide some starting point to each collaborator. The point is we would like to collaborate with the CGIAR Center and NARS people. It's okay.

Takeshi Kano: Thank you very much. Do you have any comments? We would like to have one or two comments. Please, Dr. Koyama.

Osamu Koyama: The purpose of this session is to discuss about the future of rice in Asia. That's very important for us to know. In Japan, somebody already talked that the consumption is declining. In China also, consumption is already plateaued. What we have to do is to raise the value of rice in order to utilize our land and also climate which are very suitable for rice cultivation other than other crops.

There are many kinds of values of rice, rice for other food products like bread and so on. But sustainability may be most important value to pursue for us. Because the sustainability and environmental values, such as the value of clean water, the value of river stream, those things are very important to conserve. These kinds of studies are very relevant for us for the future of Asian people. That's my comment. Thank you very much.

Takeshi Kano: Thank you very much. We have used enough time. At the end of this session, I would like to ask Dr. Yanagihara to summarize.

Seiji Yanagihara: Suddenly you gave such an important job to me but – well, in this session, the title was 'Researches for Environmentally Friendly Rice Production in Asia'. In this session, we learnt strategic breeding system from China. We had introduction of case study in India: Intensive crop and resource management. Then also, Dr. Hasegawa introduced to us change of climate and its risk and advantage.
Finally Dr. Toriyama suggested a new potential of nitrogen use efficiency. Dr. Hasegawa's presentation and Dr. Ladha's presentation, this kind of package is necessary in each region. To develop such regionally-suitable package, we need collaboration and also database gathering all those information. For that purpose, probably we need a collaboration network to accumulate all those information. I hope in the next panel discussion, panelists could discuss about organizing of this network system. Thank you very much. Good afternoon to you all.

Takeshi Kano: Thank you, Dr. Yanagihara. We would like to close this session. At the end of the session, again please give the speakers a big hand.