Plans and Results for Research Projects with External Competitive Funding

Starting in FY 2013

1. How climate change will affect agriculture in Japan: assessments in high spatial resolution

Influence of climate change, especially of temperature rise, on agriculture has been apparent in Japan in the twenty-first century. For instance, heat stress in maturing stage has been deteriorating quality of rice in southwestern Japan, and various types of high temperature injuries of apples, grapes and mikans have also been apparent in a wide area of Japan. On the other hand, increased concentration of atmospheric carbon dioxide is generally expected to enhance crop photosynthesis, while temperature rise in the last four decades changed taste of apples sweeter. These influences of climate change on agriculture will be serious with progress of the global warming. To assess impacts of climate change on agriculture in Japan in the middle of the twenty-first century and the effects of probable adaptation measures to minimize the negative impacts, we started a five-year contract research with the Ministry of Agriculture, Forestry and Fisheries of Japan. About 70 experts in National Institute for Agro-Environmental Sciences (NIAES), National Agriculture and Food Research Organization (NARO), Forestry and Forest Products Research Institute (FFPRI) and prefectural research organizations participate in the project. The targets of the impact assessment include cereal crops (rice, soybean, and wheat), fruits, forage crops and water resources for agriculture. In the project, we are investigating mechanism of various impacts of climate change on each crop by field and laboratory experiments and database analysis, and are improving numerical models to estimate impacts of climate change. In the field experiments, we are utilizing specially designed experimental facilities such as rice FACE (Free-Atmosphere CO_2 Enrichment) and TGC (Temperature Gradient Chamber). By using the numerical models combined with the latest down-scaled climate scenarios, we will assess impacts of climate change on agriculture in Japan on a fine spatial resolution (1 km).

2. Technology development for circulatory food production systems responsive to climate change: Development of mitigation option for greenhouse gases emissions from agricultural lands in Asia

This five-year research project entitled "MIRSA-2" has been launched since September 2013 entrusted by the Secretariat of the Agriculture, Forestry and Fisheries Research Council of the Ministry of Agriculture, Forestry and Fisheries of Japan. Water management in irrigated rice paddies is the most promising option to reduce a potent greenhouse gas (GHG), methane (CH_4), emitted from the paddies. Alternate Wetting and Drying (AWD) was developed by International Rice Research Institute (IRRI), Philippines, to save the usage of irrigation water and is being disseminated to Asian countries. The objective of this project is to develop the improved water management based on AWD that can always reduce soil-derived emissions of CH_4 and nitrous oxide (N_2O) during a rice growing season from irrigated rice paddies in Asian countries by 30% as carbon dioxide equivalent compared to the conventional practice (i.e., continuous flooding). Six research institutes located in Asian countries participate in this project: Hue University of Agriculture and Forestry, Vietnam; Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Thailand; Philippine Rice Research Institute, Philippines; Indonesian Agricultural Environment Research Institute, Indonesia; IRRI; and NIAES. To achieve the objective, the project implements "field demonstration of AWD effect on reducing GHG emissions" by means of measuring the emissions from rice paddies in the four countries for multiple years, and "development of the guidelines for implementing Measurement, Reporting and Verification (MRV)", which will be the basis for the near-future application of AWD as a GHG reduction activity to a carbon credit scheme.

3. Research project for improving food safety and animal health – Development of cultivation management for mitigating arsenic contamination risk in rice –

Cadmium (Cd) is toxic to humans at concentrations lower than those at which it is toxic to plants because its effects on humans are cumulative. Although flooding of paddy fields effectively reduces grain levels of Cd, anaerobic conditions in paddy soil lead to arsenic (As) mobilization which could consequently increase the uptake of As by rice.

The Ministry of Agriculture, Forestry, and Fisheries (MAFF) of Japan analyzed the As content of staple crops in Japan and found that an average value of total As and inorganic As concentration in polished rice were 0.14 mg kg^{-1} and 0.12 mg kg^{-1}, respectively (2014). As concentration in most other agricultural products was below the detection limit. Although sea food is a common source of total As, most of As in sea food are organic form which is less toxic than inorganic As. A market-basket survey, with As-speciation analysis, indicated that

rice is a major source of dietary intake of inorganic As in the Japanese population. The intake of inorganic As in rice carries a significant risk for cancer in populations for whom rice is a staple food. A ML for inorganic As (0.2 mg kg^{-1}) in polished rice has been adopted by the 37th Session of the Codex Alimentarius Commission (2014).

This project has the following four study components:

1) Development of simultaneous mitigation technologies for arsenic and Cd in rice by using the low accumulating traits of rice cultivars
2) Development of simultaneous mitigation technologies for As and Cd in rice by using water management and adsorbent materials.
3) Development of prediction methods for As contamination risk in rice.
4) Development of simple and quick analytical methods for As concentration in rice and paddy soil

The project began in FY 2013 and is scheduled to end in FY 2017. This research project is supported by a grant from the MAFF and conducted by 13 organizations. The results obtained in this project will be useful for making management measures for the code of practice for the prevention and reduction of As contamination in rice which will be developed by the Codex Alimentarius Commission.

4. Development of impact assessment and management on biodiversity correspondable to novel genetically modified organisms

Genetically modified organisms (GMOs) have been utilized worldwide, from closed system to open field. Commercially cultivated crop area and countries of GM crop have been increasing year by year, and the total area was ca. 175 M ha, and 27 countries in 2013. And the area in the developing counties was dramatically increased, e.g. Brazil, Argentina, China, and India. The Convention on Biological Diversity (CBD) was opened for signature at the Earth Summit in Rio de Janeiro on 5 June 1992, and Cartagena Protocol on Biodiversity to CBD was adopted and entered into force in 2000's. The protocol is aimed at protecting biodiversity from the adverse impact of GMOs by using modern biotechnology.

This project is one in a sequence of twelve known collectively as the "Research project for genomics-based technology for agricultural improvement", which is supported by the Ministry of Agriculture, Forestry and Fisheries of Japan. The objective of the sequential project is to develop DNA markers on the specific traits of crops, e.g. small grain cereals, soybean, vegetable, to establish the crop breeding system by using the makers, to develop novel breeding technologies towards the next generation by using genomic information in order to improve the vital crop traits such as yield and so forth.

The targets of GMO here introduce fitness improvement, such as environmental stress tolerance and pest resistance (e.g. *Bacillus thuringiensis* (Bt) protein), and we focus on soybean, canola, rice, silkworm, and fishes (Atlantic salmon, killifish "Medaka" and carp) and their wild relatives. New Plant Breeding Techniques (NBT) is also one of the targets. This project has the following two study components. One is to develop impact assessment techniques for GMOs in viewpoints of adverse effect on biodiversity and modified gene detection. The other is to develop risk management technologies for GMOs in viewpoint of adverse effect on biodiversity and coexistence between GMOs and none-GMOs (e.g. cleistogamy).

This project is composed by 21 action plans as a whole, and they are conducted by about 45 researchers from 16 organizations. The project began in FY 2013 and is scheduled to end in FY 2017. The participants are not only NIAES, but also other non-designated independent administrative institutions, universities, and the private sector.

Ending FY2013

1. Development of 'Health checkup based Soilborne disease management (HeSoDiM)

This project was started in 2011 by financial support of Ministry of Agriculture, Forestry and Fisheries (MAFF). In general, the prediction model is a powerful tool for airborne diseases but is not applicable to soilborne diseases due to the difficulty of accurate prediction. This indicates the need for an alternative decision-making system. For this reason, Tsushima and Yoshida (2011) proposed a new system that does not rely on prediction, i.e., HeSoDiM. HeSoDiM consists of the three steps described below.

1) First step: Completion of a "health checklist" for each of farmer's fields.

In this step, a checklist for each of farmer's fields including diagnostic items such as variety name, disease severity in the previous crop, and PCR-DGGE and DRC (dose-response curve) data is filled out by the farmer before cultivation. All checklists are stored in the database.

2) Second step: Estimation of the "D-potential level"

In this step, the D-potential level of a field is assessed based on the checklist obtained in both the current and past years.

3) Third step: Selection of appropriate control measures according to the D-potential level

In this step, appropriate control measures are selected economically according to the D-potential level (e.g., levels 1–3).

Finally, the manual of HeSoDiM was constructed in FY2013. The usefulness of HeSoDiM is now tested for control of various soilborne diseases in some prefectural agricultural experiment stations.

2. Development of new biopesticides and methods for their applications toward low input farming

Pesticides containing microorganisms which have inhibitory effects against plant pathogens as the active ingredient are generally called as biopesticides. Because interests have been growing on environmentally friendly agriculture and food safety by farmers and consumers, as well as governmental back up based on agri-environmental policies, use of biopesticides is assumed to become more popular in agricultural practices. However, owing to difficulties to exert stable inhibitory effects, microbial pesticides or even chemicals against soil-borne diseases, which cause serious damages on crop production, are still less developed. Under such background, we are carrying out a research project funded by Ministry of Agriculture, Forestry and Fisheries from 2011 fiscal year to develop novel microbial agents which can lead to biopesticides, and methods for application of the microbes against significant diseases of Solanaceae, such as bacterial wilt, Fusarium wilt, and Fusarium crown and root rot. For the selection of microbes, emphasis was placed on *Bacillus* spp., plant growth promoting rhizobacteria or fungi, and arbuscular mycorrhizal fungi, etc. Several members of these microbes have been known to cause induced systemic resistance (ISR) against various plant pathogens in plants; the mode of action appears to be suitable for controlling soil born disease more efficiently. Our study revealed that *Bacillus thuringiensis* serovars *sotto* and *fukuokaensis* caused ISR induction to tomato plants, and showed superior inhibitory effects against bacterial wilt and Fusarium wilt of tomato, respectively, in pot and field experiments. Since *B. thuringiensis* has already been used as an effective bioinsecticide, we propose the species is useful as ‘dual control agent’ effective to the both of insect pests and plant diseases. In addition, against Fusarium crown and root rot disease of tomato, we found two *Paenibacillus* strains isolated from tomato phyllosphere showed significant inhibitory effects in field experiments. They are also promising microbial candidates for novel biopesticides against the disease. Further experimental studies using the verified candidates are ongoing with agrochemical companies to develop commercial biopesticides.