

Research area in Strategic Objective “Establishment of environmentally-adaptive-plant design systems for stable food supply in the age of climate change”

6.1.11 Creation of fundamental technologies contribute to the elucidation and application for the robustness in plants against environmental changes

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Overview

This area promote research on establishment of the technology for designing useful plants from the molecular level on up, based on a comprehensive understanding of the environmental response mechanism of plants in the field. Specifically, the properties of plants responding robustly to environmental fluctuations will be quantitatively determined, and then new technologies enabling artificial control of growth and functions will be established. From the standpoint of exit strategies, the primary emphasis is on economic plants as experimental material, and efforts will be focused on identifying functional markers, DNA markers and other biomarkers for developing new plants.

Specific research and development activities should keep in mind the ultimate aim of applying the knowledge gained at the molecular level up to the level of field environments. Activities will be conducted in the following three categories:

- 1) Highly precise quantitative analysis of the environmental response mechanisms of plants
- 2) Modeling of plant environmental response mechanisms
- 3) Evaluation of the plant characters modified by sophisticated reconstruction of genes or genotype

The promotion of research in this area will require making a quantitative understanding of the diverse functions of plants, analyzing large-scale data of different types, and building and verifying models. Accordingly, we encourage the participation of researchers in many fields in addition to plant physiology, such as breeding, ecology, statistics, information science and engineering. In addition, collaboration among different fields will be promoted through comprehensive management of the research area that encompasses these fields. Furthermore, in order to maximize achievements in accordance with the strategic objective, the management of this research area will also be coordinated with the PRESTO (Sakigake) “Creation of Next-generation fundamental technologies for the control of biological phenomena in field-grown plants” and “Innovational technical basis for cultivation in cooperation with information science” research areas.

Research Supervisor's Policy on Call for Application, Selection, and Management of the Research Area

Background

Plant science is playing a more and more important role in the effort to find solutions to food supply issues resulting from global climate change. Despite the very high level of plant science research in Japan and the highly regard in which it is held throughout the world, however, these strengths have not led to applications or commercial development. One of the reasons for this is the complexity of the environmental response mechanisms of the plants themselves. For many species, scientists do not yet have an adequate understanding of response mechanisms at the molecular level in farm fields and other field environments in particular. Moreover, large volumes of omics data are being collected due to advances in measurement and analysis instruments in recent years, such as next-generation sequencers, mass spectrometers, high-speed computers and so on, and these are expected to make a major contribution to breeding, but the fact that the data are a mixture of both wheat and chaff is a major barrier to the effort to link the achievements of basic plant research to the development of new useful plants. There is also the issue of differences in the perception of value of the achievements between basic and applied researchers — specifically, the different perspectives of researchers who want to get their research into high-impact journals and researchers who want to achieve specific breeding objectives.

In this research area, we will keep the need to deal with these issues in mind while working to build an organization to promote research that is not bound by conventional thinking. In doing so, we will work to make new discoveries and create new technologies and develop the basic technologies that will lead to new plant varieties, thereby helping to resolve the food supply issues faced not only by Japan but by the entire world.

Necessary Research & Development and Research Organization

There are three research and development categories in this research area. When submitting proposals, please ensure that two or more of the following categories are involved in the proposal.

1) Highly precise quantitative analysis of the environmental response mechanisms of plants

Conducting a more precise quantitative analysis of the gene(s) of plants grown in field environments and the behavior of metabolic product and the like (changes in temporal and spatial expression patterns, etc.), and their relationship to phenotypes, will enable understanding of the interconnectedness among environmental factors, gene(s), phenotypes and so on. Moreover, for the basic necessary tools, research into simple, efficient and precise methods for analysis of the behavior of relevant gene(s) in a field environment, ones for measurement and evaluation of phenotypes, and ones for measurement of environmental factors will be conducted, in addition to the development of technologies and equipment. (The following are mere examples of research and development; we welcome creative proposals based on new concepts.).

- (a) Methods for highly precise omics analysis of plants in the field
- (b) Methods for highly precise character evaluation of plants in the field
- (c) Association analysis of highly precise omics data and highly precise phenotype data

- (d) Development of technologies, tools, equipment etc. for conducting (a) - (c)

2) Modeling of plant environmental response mechanisms based on actual measurement data

Statistical analysis and mathematical modeling will be performed for the interconnectedness of environmental factors, gene(s), genotypes and phenotypes. This will make it possible to establish technologies for predicting phenotypes based on environmental data and genetic data. (The following are mere examples of research and development; we welcome creative proposals based on new concepts.) We also welcome proposals that do not simply build mathematical models but also allow verification of the constructed models by means of observations based on actual data, or that resolve problems with existing models.

- (a) Construction of mathematical models relating to environmental response mechanisms of economic plants
- (b) Development of technologies for creating new models associating gene loci and phenotypes based on probability theory
- (c) Construction of models that associate genetic information and phenotypes and then incorporate the effect of field environments

3) Evaluation of the plant characters realized by sophisticated reconstruction of genes or genotype predicted by models

Based on identification of the combination of genes needed to produce a desired phenotype in a certain environment, these genes will be introduced and constructed artificially through genetic engineering, cross-breeding and so on, and then cultivated in specified isolation chambers, isolated farm fields or ordinary fields. This will make it possible to confirm the validity and repeatability of the identified factors. (The following are mere examples of research and development; we welcome creative proposals based on new concepts.)

- (a) Reconfiguration and character evaluation of gene loci and genotypes derived from model analysis
- (b) Quantitative assessment of various in-cell omics indicators in a field environment of plants with genes derived from model analysis

In this call for application, we particularly welcome proposals that contain following research item(s) in relation to the categories mentioned above;

1) Highly precise quantitative analysis of the environmental response mechanisms of plants

- Development of novel or uniquely improved methods for highly precise omics analysis of plants in the field
- Development of novel or uniquely improved methods for highly precise evaluation of plant traits in the field
- Development of novel and uniquely improved technologies for association analysis of highly precise omics phenotype data

2) Modeling of plant environmental response mechanisms based on actual measurement data

- Development of novel modeling technologies

Also, we need proposals in which various economic plants such as Solanaceae, Brassicaceae, Fabaceae or Poaceae are used as major target materials or challenging proposals that include development of versatile models and technologies applicable to wide range of plant species.

In this research area, we put emphases on creation of new concept and methodologies toward elucidation of plant robustness and its application to economic plants, as well as development of new technologies for this purpose. In the selection, priorities are given to applications that meet following requirements;

- (a) The proposal is advanced basic and fundamental research which contributes to establishment of the technology for designing plants from the molecular level on up, based on a comprehensive understanding of the environmental response mechanism of plants in the field
- (b) The proposal has a concrete plan or intention to develop practical technologies within or after the research period
- (c) The proposal works to acquire highly precise or previously unavailable data by development of novel data acquisition and analysis technologies
- (d) Two or more of the three categories mentioned above are involved in the proposal

In general, the research will be conducted in the field. However, research in artificial climate incubators, artificial climate chambers and other small, enclosed environments or plant factories with completely artificial light or the like where a stable environment can be ensured may be conducted as long as the objective is to deploy the achievements in the farm field and so on in the future.

Moreover, in order to address global food supply issues, field research may include the use of overseas farm fields. Studies should be conducted in compliance with the laws and regulations of the region where the field research is conducted, and with due approaches to the local community (for persuasion and to ask for cooperation, etc.).

The research organization will need to conduct a quantitative analysis of plant functions from various perspectives. For this reason, it is recommended that the organization include participation by

- researchers in the areas of molecular physiology, molecular breeding, population genetics, field crop physiology, ecophysiology and so on;
- plant-related researchers from the molecular level to the field level;
- statistical scientists and computer scientists who conduct genome analysis, computer processing and modeling;
- agricultural researchers in the areas of agriculture, breeding, agronomy and so on; and
- engineering researchers who develop the measurement technologies and instruments, etc., that are used in the field.

Moreover, depending on the location where the research is conducted, collaboration with national and local governments, national and prefectural research institutions, private companies and so on may also be considered.

Collaboration Inside and Outside the Research Area

We are actively seeking proposals from research teams with the farm fields that will be the hub for collaboration both inside and outside the research area, as well as ones from research teams with database support functions. For

example, we will provide active support to efforts to provide farm fields for joint use by researchers in this CREST and the relating PRESTO research areas. We also welcome such teams that can install a common database for this research area that would make it possible to register the data obtained by each team and provide the data to researchers in this CREST and the relating PRESTO research areas, and such teams that possess data analysis, model-building and other support functions.

Activities in the Research Area Following Selection

At an early stage following selection in this research area, a meeting shall be set up between the research supervisor, the research director and the lead joint researchers and so on, in order to formulate a research plan together with the research director to ensure the smooth creation of achievements. This research area will be managed while bearing collaboration with PRESTO research areas inaugurated in 2015 in mind. Through this research area management, joint research will be encouraged if it is possible that, as a result of this collaboration, multiple CREST research and PRESTO research projects will be able to develop their topics using the same approach.

Moreover, in order to promote collaboration within the research area, we also plan to consider the possibility of limiting the target plant species so that, in the event that there is a call for proposals in the next and subsequent fiscal years, different research and development efforts can be compared using the same species or varieties.

In addition, a discussion encompassing the entire area will be conducted to determine what contribution in this research area can make to the shared use of data and data analysis tools, and to other open science initiatives. For example, when a database is compiled and made available, stating clearly the policy for database compiling and provision, cooperation in providing the data to the JST National Bioscience Database Center (NBDC) may be requested.

Furthermore, there will also be collaboration with other CREST and PRESTO research areas, as well as with programs being implemented by the Cabinet Office's Cross-ministerial Strategic Innovation Promotion Program (SIP) and other ministries and agencies. In addition, workshops and symposiums in collaboration with international institutions will be held in order to promote the achievements created in this research area.

Considerations when Submitting Proposals

When submitting proposals for this research area, please clearly indicate the following three items:

- (1) Objectives to be achieved three years and five years after selection
- (2) Development following the conclusion of the CREST program, and
- (3) The basis for the proposal as regards the aforementioned items.

Please provide a specific research plan in the proposal. The upper limit for total research expenses will be 500 million yen (except overhead expense). For proposals that exceed 300 million yen (except overhead expense), please clearly indicate the reason of the expenses in the proposal (Note in Form 6). Also note that research expenses will be revised for each fiscal year, and expenses may increase or decrease in accordance with the progress of research.

Note: The briefing sessions for the call for proposals in this research area WILL NOT be held in this fiscal year.