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

6.2.13 Creation of next-generation fundamental technologies for the control of biological phenomena in field-grown plants

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Overview

This area promotes research on the creation of next-generation fundamental technologies for designing, from the molecular level on up, of plants adaptable to environmental changes in the field and therefore capable of stable growth. Specifically, the relationship between phenotypes and the action of plant gene(s) would be analyzed quantitatively in both temporal and spatial terms, in order to achieve a comprehensive understanding of the physiological systems of plants adaptable to their environments. In addition, models of environmental response mechanisms would be constructed and biomarkers and the like would be identified in order to build the foundation for new plant production technologies. Technologies for the introduction of new genetic modifications would also be developed to enable the artificial design of complex genes/genotypes relating to environmental responses, with the aim of applying them in a diverse array of plants.

From the standpoint of quantitative analysis of plant environmental response mechanisms, rather than response mechanisms in single plant genes, the primary emphasis of research in this area will be on determining complex response mechanisms by means of multifactorial or quantitative trait locus (QTL) analysis. In addition, to meet the needs of analysis of, and model construction from, various types of large-scale data and the need of verification of the model constructed, we welcome the participation of individual researchers from a diverse array of fields, not only plant science but also information science, engineering and so on. In order to maximize achievements for the realization of the strategic objective, management of this research area will also be coordinated with the CREST research area "Creation of fundamental technologies contribute to the elucidation and application for the robustness in plants against environmental changes" and the PRESTO (Sakigake) research area "Innovational technical basis for cultivation in cooperation with information science".

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

Background

In the future, global temperature increases and regional irregular rainfall and droughts and so on, which are partly the result of socioeconomic activity that places a large burden on the environment, are expected to be exacerbated

worldwide. For this reason, there is concern in many parts of the world about the impact of environmental changes on crop production. As one way of dealing with these changes, there is a growing societal need for breeding technologies to create crops which can adapt to environmental changes. In order to achieve this objective, basic studies are needed to be conducted on a comprehensive analysis of the mechanisms for efficient plant growth under various environmental conditions, particularly those of adaptive responses to environmental stresses, as well as on quantitative assessments of the impacts of interactions among physicochemical and biological environmental factors in the field.

Accordingly, research in this area should be promoted with the goal of innovative technical development of environmentally adaptable plants, developed through the integration of plant science knowledge and collaboration with technologies and research achievements in the fields of information science, engineering and so on.

Innovation based on scientific and technological achievements that are not limited to the plant field will require collaboration and cooperation among researchers from different fields. With this in mind, we welcome the participation of researchers from many different fields in this research area.

Examples of Specific Research Proposals

In order to develop a quantitative understanding of molecular mechanisms relating to the diverse environmental responses of plants, we are seeking research proposals into the creation of statistical analysis technologies that show the relationship between phenotypes and the temporal and spatial manifestation patterns of gene(s), the construction of models for environmental response mechanisms, the identification of biomarkers that show growth status coordinated with environmental conditions and so on, in order to serve as the foundation for next-generation technologies to control and predict plant growth in the field.

Below are specific examples of the research anticipated. (These are mere examples of research and development; we will welcome a wide range of proposals, including those that span multiple categories and new and creative research proposals relating to environmental response other than the ones shown here.)

① Quantitative analysis of plant environmental response mechanisms

Research into the molecular systems of physiological functions relating to plant environmental responses will be pursued. The environmental factors to be studied, which affect plant growth, include the concentration of carbon dioxide, temperature, humidity, pH level and other physicochemical factors in the atomosphere and/or in the soil, in addition to biological factors. Also targeted will be biotic factors such as interactions among plants during community formation and defense reactions against disease, pests and microorganisms. In addition, based on a quantitative analysis ranging from the molecular level to the individual plant and community level, a comprehensive understanding will be provided on plant growth and metabolic mechanisms, such as photosynthetic

capability and the intake and accumulation of mineral nutrients. In each of these analyses, the main focus will be on the response network made up of multiple genes.

② Construction of mathematical models for environmental response mechanisms and development of biomarkers

Informatics research into plants using large-scale data will be pursued. The results of statistical analyses of the level of environmental factors, the expression of genes and the correlations between these and plant phenotypes will be used to construct mathematical models of environmental responses for the purpose of establishing technologies to predict phenotypes based on environmental and genetic information. Moreover, following the development of techniques for data mining and clustering and so on and theory formation, the common elements and particular characteristics of individual varieties will be determined in order to identify crucial factor(s) that provide the foundation for application development, in order to study the value of these factors as biomarkers.

③ Study of new technologies for genetic engineering and gene introduction

Research into genetic engineering technologies for use in breeding plants adaptable to environmental stresses will be pursued. In recent years, new plant breeding techniques (NBT) such as genome editing, oligonucleotide-directed mutagenesis and so on have been developed. However, the efficiency and speed of gene introduction vary depending on plant species and variety, and new technologies must be developed. In this research area, the development of elemental technologies that will form the foundation for next-generation technologies of plant genotype designing will be conducted with the aim of creating plants adaptable to environmental changes and capable of stable growth. Examples of the elemental technologies to be developed include those for the modification and introduction of many genes, those to dramatically improve operational efficiency, and those to enable gene transfer for plant species in which genetic transformation is difficult.

This research area may target--in addition to grain crops, fruits, vegetables and other economic plants--plant varieties which grow wild in field environments, as well as *Arabidopsis thaliana, Lotus japonicas,* and other model plants. In the case of research using such wild or model plants, however, the application of research achievements to economic plants should be added to the research plan to the extent possible. The locations where the research is conducted may include not only farm fields and the like but also artificial climate incubators, artificial climate chambers and other small enclosed environments with completely artificial light where a stable environment can be ensured, as well as plant factories and so on. When the research is executed entirely within such controlled environments, however, the research proposal should note the future deployment of the achievements into the field.

Management of the Research Area Following Selection

At an early stage following research plan selection in this research area, a meeting shall be set up between the research supervisor, etc. and the PRESTO researchers in order to reconsider the research plan. This will enable the smooth creation of achievements not only for individual research but for the research area as a whole. In order to achieve synergy among research areas, cooperation with the relating CREST and PRESTO research areas established at the same time in 2015 shall also be planed.

Discussion will be made on infrastructure measures for this research area in order to promote shared use of data and data analysis tools, and other open science activities. For example, when a database is compiled and made available, stating clearly the policy for database compiling and provision, a research infrastructure may be established in cooperation with the JST National Bioscience Database Center (NBDC) and other organizations.

Furthermore, there will also be active collaboration with programs being implemented by the Cabinet Office's Cross-ministerial Strategic Innovation Promotion Program (SIP) and other ministries and agencies, as well as with related international institutions. Specifically, joint workshops and symposiums will be held with these institutions in an effort to promote the achievements created in this research area.

Considerations when Submitting Proposals

When submitting research proposals, please confirm 1) and 2) below.

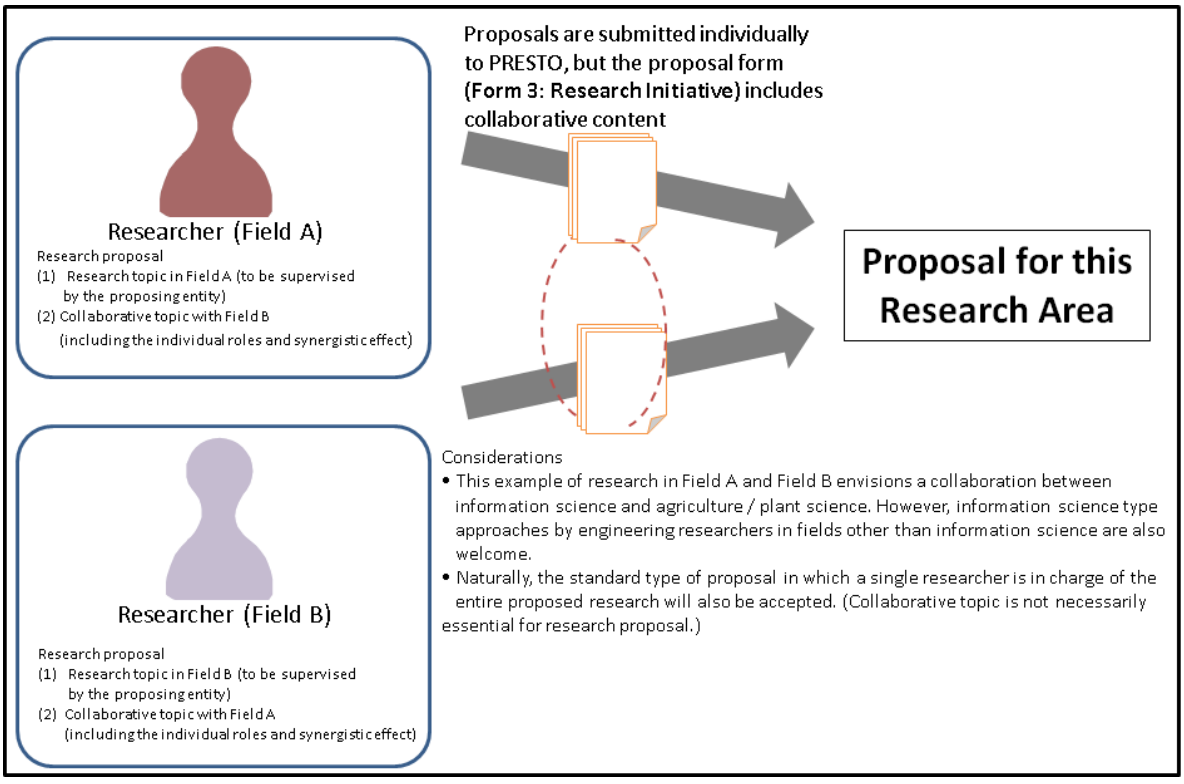
1) Differences from the researches to be pursued in the PRESTO research area "Innovational technical basis for cultivation in cooperation with information science"

JST has established the present research area and the "Innovational technical basis for cultivation in cooperation with information science" research area as independent PRESTO research areas, based on the strategic objective of "Establishment of an environmentally adaptive plant design system to achieve a stable food supply in the age of climate change." The present PRESTO research area is established in the field of life innovation, and involves a quantitative exploration of the physiological (and genetic) functions of plants as responses to the environment. This would aid in the effective (molecular) design of plants with the desired traits. In contrast, the other PRESTO research area is established in the field of information science, and instead of focusing on the physiological functions, its primary emphasis is on recognizing the "black box" nature of the topic and extracting the ideal environmental conditions for plant growth. This would help in creating the infrastructure for the design of sustainable agricultural production.

2) Collaborative research proposals

PRESTO research programs are designed to bring out the ideas and capabilities of individual researchers thoroughly and free them from organizational limitations. However, in this research area, a high level of collaboration is needed between different fields including plant science and information science. Accordingly, in addition to the standard type of proposals (from individual researchers), collaborative proposals involving two or more PRESTO proposal researchers will be accepted.

Specifically, when it is difficult for the researcher proposing the research topic to conduct the research alone, an information science researcher, for example, may discuss the possibility of collaboration with another researcher in plant science or other fields in advance. Then each researcher may submit a separate proposal in this research area, noting their individual roles and the anticipated synergistic effect in their proposals (see figure below). Even in such cases, however, each researcher will be considered to be an independent "PRESTO researcher," and each research proposal must include its own creative ideas. Note that proposals that involve collaboration with other research areas are not allowed. When submitting collaborative proposals, please describe (in Form 3: Research Initiative) your personal and collaborative research contents separately, as well as the present status of coordination with the collaborative researcher. In the case of a pair of collaborative proposals, it is possible that only one of the research proposals will be selected depending on the quality of the personal research contents. In fact, no collaborative research proposals were selected as a pair in this PRESTO area, either in 2015 or in 2016. Please ensure that each research proposal satisfies the requirements of novelty and challenge worthiness of PRESTO.



Collaborative Proposal

Note:

For more information, please visit the following website: http://senryaku.jst.go.jp/teian/top/setsumeikai.html, from where you can obtain the explanatory material presented in the briefing session that was conducted during the call for proposals for this research area in 2016. No briefing session will be held for this research area in 2017.