Plant Research Group

Carbon-sequestration with the use of Plants and Trees

Ambient partial pressure of CO_2 (370 ppm), which is one of the main factors causing the global warming, is expected to reach its value of 1,000 ppm on A.D. 2100. IPCC set its value to 550 ppm, about half 1,000 ppm, which shows the necessity of carbon-sequestration management at the world-wide level. Now, techniques for carbon-sequestration are developed from the two aspects: CO_2-emission suppression and CO_2-fixation enhancement. CO_2-emission suppression includes the usage of alternative energy to fossil resource energy: sun, atomic, terrestrial heat etc. In addition, the utilization of biomass energy (bioenergy) is developed. As for CO_2-fixation enhancement, geological and ocean sequestrations techniques are developed, which are non-biological approaches. Contrary to these techniques, biological sequestration technique, afforestation and the expansion of its area are developed.

We, in Plant Research Group, develop the techniques for both CO_2-fixation enhancement (carbon stock formation) and CO_2-emission suppression (alternative energy formation), that is, large scale afforestation and bioenergy usage (Figure 1). In large scale afforestation, we improve trait of plants and trees, where growth and abiotic tolerance are stimulated, using molecular biological techniques with the useful genes (afforestation project and frontier soil project). These projects contribute to the enhancement of CO_2-sequestration through the formation of carbon stock. Furthermore, we develop the improvement of plants to have the ability to produce factorial materials in chloroplasts (factorial plants project). This project contributes to CO_2-emission suppression through the production of alternative energy. As follows, we report the works of three projects.

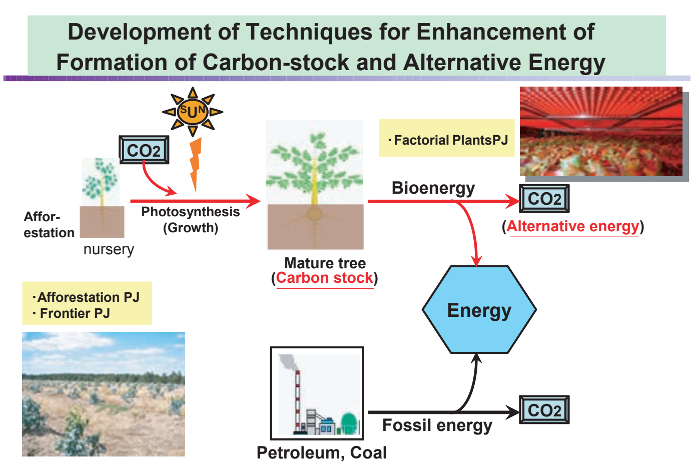

Figure 1

Afforestation Project

The purpose of this project is to develop the fundamental technologies to allow for afforestation in unsuitable area for vegetation, such as semi-arid area, to reduce atmospheric CO_2. We carry out the project in collaboration with paper companies and universities. (This project is supported by METI from FY2003 to FY2007.)

In this project, we try to develop two main techniques; (1) A technique to enhance the ability of photosynthetic CO_2 fixation or, to confer the abiotic stress tolerance on woody plants, such as Eucalyptus and Populus by genetic modification, (2) A technique to isolate the elite trees from Eucalyptus, those have superior ability of growth and stress tolerance, and produce the cloned cell lines of the elite trees.

Under combined stress with strong light and drought in semi-arid area, plants close their stomata to avoid the loss of water by transpiration. However, the close of stomata leads to decrease CO_2 influx to chloroplasts, and decline in the rate of photosynthesis. As the result, absorbed photon energy, which is usually consumed by photosynthesis, becomes excess, and the excess photon energy stimulates the production of reactive oxygen species (ROS) by reduction of dioxygen in chloroplasts. Furthermore, ROS induces oxidative damage, i.e. “sunburn”, to cellular components of plants.

RITE develops the fundamental technology for suppression of ROS production and rapid elimination of produced ROS in chloroplast by genetic modification with Arabidopsis and tobacco as model plants. By overexpression of ferredoxin gene in chloroplasts of tobacco plants, RITE has succeeded to stimulate activity of cyclic electron flow around photosystem I and to enhance the ability of heat dissipation process, in which excess photon energy is consumed as heat, in transplastomic plants (Figure 2).

In future, the application of our techniques will produce drought tolerant transgenic woody plants, and they will contribute to the afforestation in semi-arid area.

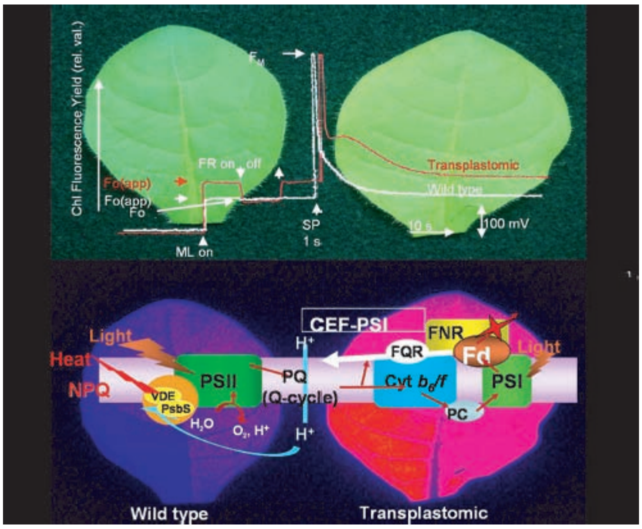

Figure 2

Frontier Soil Project

In semi-dry areas, soils are poor in nutrients and water. In cooperation with Saitama University, Kohchi University, the General Environmental Technos Co. Ltd., and Forest Products Commission in Australia, we tackle the development of a soil-improving technology using microbes and plants (Figure 3). We try to improve soils with nutrients provided from mycorrhizal fungi and nitrogen-fixing microbes including cyanobacteria and root-nodule bacteria symbiotically alive in Acacia roots. Frontier project is developing a cyanobacteria having high nitrogen-fixation capacity by a genetically engineering technique, and also searching for a mycorrhizal fungi having high absorption capacity of phosphate ions. Moringa oleifera, which survives in semi-dry areas, has water storage roots. We also evaluate the water storage capacity in the soils. Based on searching for useful microbes and useful plants and improving those physiological functions by a genetically engineering technique, our goal is applying this technology to afforestation in semi-dry areas.

Fundamental Technology for Controlling the Material Production Process of Plant Chloroplasts (Factorial Plants Project)

The development of bioprocess represents an important issue in the creation of a fossil resource-independent recycling-oriented society. To address this issue, it is necessary to develop fundamental technology for the production of industrial materials or other useful substances in plants. Gene-recombination technology succeeded in conferring resistance to herbicide or insect on transgenic plants. The purpose of this project is to improve the basic technology to produce the industrial material by functions of substance production in plants.

Photosynthetic organella, chloroplast converts CO_2 to various substances such as sugars, lipids and amino acids etc. by using light energy. We are engaged in the analysis and control of material production processes in chloroplast by using already established chloroplast transformation technology (Figure 4). The integration of transgene into chloroplast genome offers an advantage that transgene flow via pollen is absent due to maternal inheritance of the chloroplast genome.

Since plants have their own metabolic control systems, it is necessary to identify the substance production processes and to regulate key metabolic pathway. We demonstrated the enhanced productivity of isoprenoid that is of industrial importance as additives, organic materials, vitamins and ingredients in medicine by engineering chloroplast metabolic pathway. Based on the results of the analysis of the transgenic plants, we will identify a rate-controlling step in chloroplast metabolism. For the purpose of improving the chloroplast transformation technology, we will develop an artificial system that regulates the level and tissue of transgene expression.

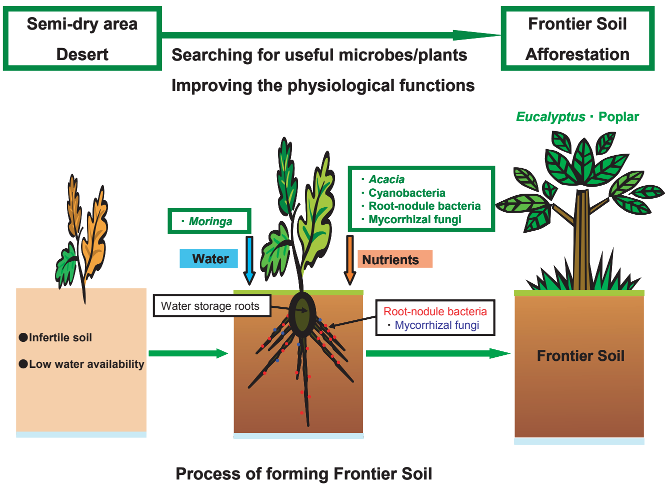

Figure 3

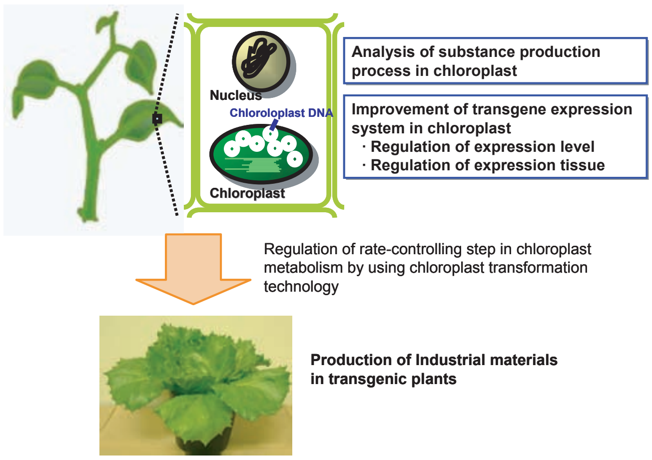

Figure 4