RECENT RESEARCH ACTIVITIES

Structure, biosynthesis, and bioengineering of lignocellulose and phenylpropanoid metabolites for future biorefinery

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It is becoming increasingly important to establish a sustainable society by reducing our heavy reliance on fossil resources. As lignocellulosic biomass represents the most abundant renewable and carbon-neutral resources on earth, technologies to improve their utilizations are key for realizing the goal. In this context, we investigate the structure, biosynthesis and bioengineering of lignocellulose using various model plants and biomass crops. In addition, we are interested in understanding the biosynthesis of plant-derived phenylpropanoid metabolites which display various useful biological activities. Our program typically integrates research ideas and approaches based on chemistry, biochemistry, and molecular biology.

Among a wide variety of biomass feedstocks, grass biomass crops, such as *Erianthus*, *sorghum*, sugarcane, and bamboo, have attracted particular attention due to their high biomass productivity and superior environmental adaptability. To explore new breeding strategies to improve the production of useful fuels and materials from grass biomass, we seek to develop transgenic rice plants that produce biomass with improved utilization properties. Our research particularly focuses on manipulating lignin, a phenylpropanoid polymer accounting for 15-30 wt% of lignocellulosic biomass.

We have developed various rice transgenic lines in which specific genes encoding enzymes and transcription factors functioning in the lignin biosynthetic pathway are down- and/or up-regulated. Some of our developed transgenic lines appeared to display notably enhanced biomass properties that can be exploited for productions of bioenergy and biomaterials. In parallel, we are working on selective breeding of grass crop varieties, such as *Erianthus* spp. and *Sorghum* spp., with superior lignins suited for bioenergy and biomaterial productions.

In addition, aiming at biological production of useful phytochemicals, we have been characterizing plant and microbial enzymes/genes involved in formations of bioactive phenylpropanoids such as lignans and norlignans. Our recent projects include elucidation of the biosynthesis of antitumor podophyllotoxin in *Anthriscus sylvestris*, unravelling crystal structures of hinokiresinol synthases, unique enzymes responsible for the enantioselective formation of bioactive norlignans, and identification of enzymes/genes involved in the formation of estrogenic mammalian lignans (enterolignans) via human intestinal bacteria.

Selected Publications (FY2017)

[1] Takeda Y, Koshiba T, Tobimatsu Y, Suzuki S, Murakami S, Yamamura M, Rahman Md M, Takano T, Hattori T, Sakamoto M, Umezawa. Regulation of *CONIFERALDEHYDE 5-HYDROXYLASE* expression to modulate cell wall lignin structure in rice. *Planta* **246**:337-349 (2017).

[2] Lam PY, Tobimatsu Y, Takeda Y, Suzuki S, Yamamura M, Umezawa T, Lo C. Disrupting Flavone Synthase II alters lignin and improves biomass digestibility. *Plant Physiology* **174**:972-985 (2017).

[3] Tarmadi D, Yoshimura T, Tobimatsu Y, Yamamura M, Umezawa T. Effects of lignins as diet components on the physiological activities of a lower termite, *Coptotermes formosanus* Shiraki. *Journal of Insect Physiology* **103**:57-63 (2017).

[4] Tarmadi D, Yoshimura T, Tobimatsu Y, Yamamura M, Miyamoto T, Miyagawa Y, Umezawa T. The effects of various lignocelluloses and lignins on physiological responses of a lower termite, *Coptotermes formosanus*. *Journal of Wood Science* **63**:464-472 (2017).

[5] Cui S, Wada S, Tobimatsu Y, Takeda Y, Saucet S, Takano T, Umezawa T, Shirasu K, Yoshida S. Host lignin composition affects haustorium induction in the parasitic plants *Phtheirospermum japonicum* and *Striga hermonthica*. *New Phytologist* **218**:710-723 (2018).

[6] Tarmadi D, Tobimatsu Y, Yamamura M, Miyamoto T, Miyagawa Y, Umezawa T, Yoshimura T. NMR studies on lignocellulose deconstructions in the digestive system of the lower termite *Coptotermes formosanus* Shiraki. *Scientific Reports* **8**: 1290 (2018).

[7] Umezawa T. Lignin modification in planta for valorization. *Phytochemistry Reviews*, in press (2018).

[8] Miyamoto T, Yamamura M, Tobimatsu Y, Suzuki S, Kojima M, Takabe K, Terajima Y, Mihashi A, Kobayashi Y, Umezawa T. A comparative study of the biomass properties of *Erianthus* and sugarcane: lignocellulose structure, alkaline delignification rate, and enzymatic saccharification efficiency. *Bioscience Biotechnology and Biochemistry*, in press (2018).