Ichihashi, H., et al. (1992). Rare earth elements (REEs) in naturally grown plants in relation to their variation in soils. Environ. Pollut. 76(2):157-162.

Inoue, H. and K. Saeki (2004). Removal of Cd from actual soils polluted with Cd and Zn and Cd-added soils by *Brassica juncea* and *Zea mays*. Journal of the Faculty of Agriculture, Kyushu University. H. Inoue. 49: 195. We have alternated the 3-week cultivation of maize (*Zea mays*) and that of Indian mustard (*Brassica juncea*) in a pot with the sequential rotation, maize-Indian mustard-maize-Indian mustard, to remove Cd from two actual paddy soils from Japan polluted with Cd and Zn, one (low Cd polluted (LP)) containing 6.5 mg Cd kg-1 and 715 mg Zn kg-1 and another (high Cd polluted (HP)) with 13.6 mg Cd kg-1 and 836 mg Zn kg-1. Fertilizer applications to soil in a rotational cropping inhibit the decrease in the phytoextraction efficiency. As the total of the all cultivations, the Cd removal from the soils was 2.1% of the total soil Cd amount in the LP and 1.0% in the HP, whereas the Zn removal was lower than that of Cd, 0.57% in the LP and 0.17% in the HP, respectively. The Cd absorptions by both plants were significantly greater in the metal-added soils than in the actual polluted soils in all cultivations ($p < 0.05$). This would be caused by the high concentrations of exchangeable Cd in the added soils. Results indicated that the use of metal-added soils is likely to overestimate the efficiency of some plants in phytoextraction experiments involving actual polluted soils with its variation by the experimental conditions.

Inoue, H., K. Saeki, et al. (2003). Effect of EDTA on phytoremediation of copper-polluted soils. Journal of the Faculty of Agriculture Kyushu University 47(2): 243-250. Efficiency of additive agents was studied to remove copper from Cu-mixed soils by *Brassica juncea* and *Zea mays* L. The plants were grown in decomposed granite soil (Regosol) and volcanic ash soil (Andosol) for 3 weeks. To simulate actually-contaminated soil, copper contents of 25mug Cu g(-1) and 250mug Cu g(-1) were prepared for Regosol and Andosol, respectively. EDTA was found to be an excellent additive agent to raise the availability of Cu in soils. The effect of EDTA on Cu absorption by plants was limited in Regosol. On the other hand, in Andosol the Cu accumulation in shoot of *Z. mays* for the 100 ram EDTA treatment were 3.7 times larger than that for the 0 mM EDTA treatment. The Cu absorption by *B. juncea* was not affected by the EDTA addition to Andosol. These results suggest that the effect of EDTA on the Cu absorption by plants significantly changes with the additive concentration and with the types of soil and plant.

Inoue, H., K. Saeki, et al. (2003). Effect of EDTA on phytoremediation of copper-polluted soils. Japanese Journal of Soil Science and Plant Nutrition. 74: 169. The efficiency of additive agents to remove copper from Cu-mixed soils by *Brassica juncea* and *Zea mays* was studied. The plants were grown in decomposed granite soil (Regosol) and volcanic ash soil (Andosol) for 3 weeks. To simulate actually contaminated soil, copper contents of 25 and 250 microg Cu g-1 were prepared for Regosol and Andosol, respectively. EDTA was found to be an excellent additive agent to raise the availability of Cu in soils. The effect of EDTA on Cu absorption by plants was limited in Regosol. On the other hand, in Andosol the Cu accumulation in the shoots of *Z. mays* for the 100 mM EDTA treatment was 3.7 times larger than that for the 0 mM EDTA treatment. The Cu absorption by *B. juncea* was not affected by the EDTA addition to Andosol. It was observed that the effect of EDTA on Cu absorption into the vegetable parts fluctuated not only with EDTA concentration, but also with plant species.

Inoue, H., K. Saeki, et al. (2003). Effect of temperature on copper accumulation of *Brassica juncea* Coss. and *Zea mays* L. grown in copper-contaminated soils. Environment Control in Biology. H. 41: 183. The effect of temperature on copper (Cu) extraction in two types of plants, *B. juncea* and *Z. mays*, was investigated in Japan. These plants were grown in Cu-amended decomposed granite soil (DG soil, 29 microg Cu g-1) and volcanic ash soil (Andosol, 292 microg Cu g-1) under 15, 20, 25 and 30degreesC for 3 weeks in the phytotron. For *Z. mays*, the amount of Cu extraction was the same in both DG soil and Andosol, while that for *B. juncea* was more in the DG soil than in the Andosol. This suggests the difference in the Cu-accumulation ability between these plants. The highest Cu accumulation was achieved by *Z. mays* grown in the Andosol at 30degreesC. In lower temperature conditions, *B. juncea* did not exceed *Z. mays* in terms of Cu accumulation for both soils. Since *B. juncea* had more crop density in field, the Cu accumulation per unit area was higher in *B. juncea* than in *Z. mays* at low temperature conditions. For the more effective extraction of Cu from polluted soils, it is necessary to select the optimum plant that conforms to the temperature during cultivation.

Inouhe, M. (2005). Phytochelatins. Brazilian Journal of Plant Physiology 17(1): 65-78. Phytochelatins (PCs) were first discovered as Cd-binding Cadystins A and B in a fission yeast and then in many plants as the major components of Cd-binding complexes. PCs have the general structure of (gamma-glutamyl-cysteinyl)n-glycine (n=2-11) and the variants with the repeated gamma-glutamyl-cysteinyl units are formed in some plants and yeast. They are capable of binding to various metals including Cd, Cu, Zn or As via the sulfhydryl and carboxyl residues, but their biosyntheses are controlled preferentially by the metal Cd or metalloid As. PCs are synthesized from glutathione (gamma-glutamyl-cysteinyl-glycine) in steps mediated by PC synthase. Genes (CAD1, PCS1) of the enzyme have been isolated from plants, fission yeast and some animals. Inhibition studies of PC biosynthesis via glutathione have demonstrated their fundamental roles in the metal detoxification in yeast and fungi, green algae and some aquatic plants, and also in the suspension-cultured cells and intact tissues in higher plants. Over-expression of PC synthase genes increases the Cd-tolerance in yeast and bacteria efficiently but not always ill higher plant tissues especially in metal-accumulating species. Hyperaccumulators of Cd, Zn, Ni or As in terrestrial plants have a common feature where massive metal transport to shoots prevails, besides the ability of their roots to form PCs. This suggests that PC-based metal detoxification might be an ancient type of defense mechanism established in micro-algae or micro-fungi, and the additional PC-independent mechanism via vascular transport system became established later in higher plants. Readjustment of the PC-dependent and independent mechanisms at the metal-binding sites in the symplast and apoplast of shoots can be effective for further improvement of the metal detoxification activities and the tolerance characteristics of higher plants under various conditions.

Institute for Land Rehabilitation. (1979). Selection, propagation, and field establishment of native plant species on disturbed arid lands. Bull. 500. Utah Agric. Exp. Stn., Logan, UT.

Interdisciplinary Plant Group. (1995). Will plants have a role in bioremediation?. Proceedings/Abstracts of the Fourteenth Annual Symposium, 1995, Current Topics in Plant Biochemistry, Physiology and Molecular Biology, April 19-22, 1995, University of Missouri-Columbia, Columbia, MO.

Inui, H. and H. Ohkawa (2005). Herbicide resistance in transgenic plants with mammalian P450 monooxygenase genes. Pest Management Science 61(3): 286-291. Transgenic potato and rice plants were generated by the introduction of human P450 species, CYP1A1, CYP2B6, CYP2C9 and CYP2C19, which metabolized a number of herbicides, insecticides and industrial chemicals. The transgenic potato plant T1977 co-expressing CYP1A1, CYP2B6 and CYP2C19 genes showed remarkable cross-resistance to several herbicides with different structures and modes of action due to metabolism of these herbicides by the P450 species expressed. The transgenic rice plant 2C9-57R(2) expressing CYP2C9 gene showed resistance to sulfonylureas, and the transgenic rice plant 2C19-12R(1) expressing CYP2C19 gene showed cross-resistance to certain herbicides with different structures and modes of action. These transgenic plants appear to be useful for herbicide resistance as well as phytoremediation of environmental contaminants. (C) 2005 Society of Chemical Industry.

Isermann, K. (1977). A method to reduce contamination and uptake of lead by plants from car exhaust gases. Environ. Pollut. 12(3):199-204.

Ishikawa, S. (2005). Promising technologies for reducing cadmium contamination in rice. Rice is life: scientific perspectives for the 21st century. Proceedings of the World Rice Research Conference held in Tsukuba, Japan, 4-7 November 2004. International Rice Research Institute (IRRI): 381. This paper discusses the current ameliorating techniques (soil dressing, water management, application of soil amendments) being applied in Cd-polluted paddy fields and promising techniques (phytoremediation, and introduction of low Cd-accumulating rice varieties) for reducing Cd contamination in rice (*Oryza sativa*).

Ishikawa, S., N. Ae, et al. (2006). Is *Brassica juncea* a suitable plant for phytoremediation of cadmium in soils with moderately low cadmium contamination? Possibility of using other plant species for Cd-phytoextractio. Soil Science and Plant Nutrition 52(1): 32-42. We evaluated the ability of *Brassica juncea* (L.), which has already been recognized as a plant suitable for metal phytoremediation, and of several other plant species (maize, rice and sugar beet) to extract cadmium (Cd) from soils with moderately low

levels of Cd contamination. Two of the 56 cultivars of *B. juncea* were preliminarily screened as high-Cd accumulators using a hydroponic culture solution containing a high level of external Cd (1 mg L-1). Thereafter, 7 cultivars within 4 plant species (maize, *B. juncea* [2 cultivars], rice [3 cultivars with different subspecies] and sugar beet) were grown in a hydroponic culture solution containing a low Cd level (0.05 rng Cd L-1) or in pots filled with 2 types of contaminated soils containing moderately low Cd levels under upland conditions. The 2 soils consisted of a Fluvisol and an Andosol and contained 1.82 and 4.01 mg Cd kg(-1) on a dry soil weight basis, respectively, determined using 0.1 mol L-1 HCl-extraction. The results indicated that *B. juncea* was less able to accumulate Cd in shoots compared with hydroponically cultured rice and sugar beet, and was even less effective when grown in soil culture. Rice and sugar beet displayed a higher accumulation not only of Cd but also of other heavy metals (Cu, Fe, Mn and Zn) in their shoots than *B. juncea* when they were grown in the two Cd-contaminated soils. Maize displayed the lowest metal accumulation among the plant species tested. Growing the rice cultivars in both soil types led to the most significant decrease in soil Cd concentration determined using extraction with 0.1 mol L-1 HCl. In contrast, we did not observe any significant decrease in soil Cd concentration in *B. juncea*. Sequential Cd extraction of soil revealed that rice was more effective than *B. juncea* in phytoextracting Cd from less-soluble fractions in soils. Based on the plant and soil analyses, it was suggested that *B. juncea* does not offer much promise for phytoextraction of Cd from soils with relatively low contamination, and that rice may be an eligible plant for metal phytoremediation of such soils.

Issam, N., W. B. Ammar, et al. (2006). Comparative study of cadmium effects on membrane lipid composition of *Brassica juncea* and *Brassica napus* leaves. Plant Science. 170: 511. The term phytoremediation is used to describe the clean-up of heavy metals from contaminated soils by plants. In this study, we examined cadmium (Cd) accumulation by *Brassica napus* in comparison with the known Cd-hyperaccumulator *Brassica juncea*, in a hydroponic medium. Cd treatment was applied as a concentration series between 0 and 50 microM for 15 days. Most of the Cd taken up was retained in roots in both species, however, *B. juncea* accumulated more Cd in the shoots compared to B. *napus*. Excess metal supply resulted in an increase in the lipid content of *B. juncea* leaves grown under cadmium treatment, but did not affect fatty acids composition. In contrast, an alteration in the lipid composition of *B. napus* leaves was observed together with a decrease in the lipid contents. The amounts of chloroplastic lipids: monogalactosyldiacylglycerol (MGDG), digalactosyldiacylglycerol (DGDG), sulfolipids (SL) and phosphatidylglycerol (PG) decreased drastically under the effect of metallic treatments. Whereas, amounts of extrachloroplastic lipids: phosphatidylcholine (PC) and phosphatidylethanolamine (PE) were significantly increased. The latter finding suggested that PC and PE synthesis was enhanced by metal application. Moreover, the levels of polyunsaturated fatty acids mainly linolenic acid (C18:3) and hexadecatrienoic acid (C16:3) and that of trans palmitoleic acid (C16:1t) from PG declined. So, cadmium seems to affect preferentially chloroplastic lipids containing higher levels of polyunsaturated fatty acids. Lipid changes in *B. juncea*, the well known Cd-hyperaccumulator specie, revealed a more stability of its cellular membranes to cadmium-stress as compared to Cd-sensitive specie, *B. napus*.

Issoufi, I., R. L. Rhykerd, et al. (2006). Seedling growth of agronomic crops in crude oil contaminated soil. Journal of Agronomy and Crop Science 192(4): 310-317. Phytoremediation of hydrocarbon-contaminated soil shows promise as a low-cost alternative to most remediation methods. This study evaluated seedling growth of six crop species in crude oil contaminated soils. The experiments were conducted in a greenhouse. Weathered crude oil was added to an Ipava silt loam soil at the rate of 0 (control), 10, 50 and 100 g of crude oil kg(-1) of soil, which was then placed into pots. Irrigation was used to maintain soil moisture at approximately field capacity. Five seeds of *Zea mays*, *Meticago sativa*, *Lolium perenne*, *Triticum aestivum*, *Glycine max* or *Vicia villosa* were sown per pot. The experimental design was completely randomized with five replications per treatment. Germination and seedling height data were recorded on day 7, 14, 21 and 28. Plants were harvested on day 28, separated into shoots and roots and dried to measure biomass. Analysis of variance was used to determine treatment significance. Significant treatment mean values were separated using Tukey's Honestly Significant Difference Test. Based upon percent emergence and plant biomass production in contaminated soil, *Z. mays* and *G. max* seedlings show the greatest potential to enhance remediation.

Itouga, M., Y. Kato, et al. (2005). Phytoremediation using bryophytes, 1. - Characterization of copper accumulation and remediation of lead from fry ash using *Scopelophila cataractae* (Mitt.). Hikobia 14(3): 263-271. We have estimated remediation effects of toxic metals in heterogeneous wastewater with redundant Ca2+ such as ash funded by a grant for a Leading Project (a project to design sustainable management and recycling systems for biomass, general, and industrial wastes) from the Ministry of Education, Culture, Sports, Science and Technology of the Japanese Government. In this project, we have examined phytoremediation effects using bryohytes in a method called 'bryofiltration'. To estimate the remediation effects of lead (Pb) from wastewater using the moss *Scopelophila cataractae* (Mitt.) Broth., we analyzed gametophytes of this moss using X-ray Analytical Microscope (HORIBA XGT-5000), and the metal nutrients in the gametophytes were quantified using inductively coupled plasma mass spectrometry (ICP-MS; Perkin Elmer Elan6100DRC). Usefulness of bryofiltration to remove Cu, Co, Pb, and Zn from wastewater was demonstrated, and especially remediation of lead from fry ash was shown by this Study. Two kinds of heavy metal accumulation sites in Scopelophila cataractae were identified based on the extraction patterns for HCl with different pH values.

Izosimova, A. amd I. Alekseev. (1998). Competition of the plants for the reducing of heavy metals uptake by crops on contaminated lands. Fourth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe, Sept. 15-17, 1998.