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Rare earth elements and bacterial C1 metabolic system

MINAMISAWA, Kiwamu[1*] ; SEKI, Kenjiro[1] ; ZHIHUA, Bao[1] ; SUGAWARA, Masayuki[1] ; SHINODA, Ryo[1] ; TANI, Akio[2] ; MASUDA, Sachiko[2] ; MITSUI, Ryoji[3]

[1]Graduate School of Life Sciences, Tohoku University, [2]Institute of Plant Science and Resources, Okayama University, [3]Department of Biochemistry, Faculty of Science, Okayama University of Science

The rare earth elements (REEs) include lanthanum (La) and cerium (Ce) as light REEs. La and Ce are very low abundant in the universe, but relatively higher abundant in the earth crust including soils. Recently, it has been reported that the product of xoxF gene in Methylobacterium. extorquens AM1 is La- and Ce-dependent methanol dehydrogenase (MDH) (Nakagawa et al. 2012), which is different from classical Ca-dependent MDH encoded by mxaF gene. Although bradyrhizobia are ubiquitous bacterial in the environments, they are often associated with legume and non-legume plants. In the present work, we examine the effects of La and Ce on C1 metabolism (methanol oxidation) of these bradyrhiozbia. We used six strains of Bradyrhizobium oligotrophicum S58, Bradyrhizobium sp. BTAi1, Bradyrhizobium sp. ORS278, Bradyrhizobium sp. RP5, Bradyrhizobium sp. RP7, and Bradyrhizobium sp. WD16. The former three strains formed root nodules of an aquatic legume plant (Aeschynomene indica), while the latter three strains are endophytes in paddy rice roots. They are also able to survive in oligotrophic environments such as soils (Okubo et al. 2013). BLASTN search were conducted on the genomes of six strains by the DNA sequences of xoxF and mxaF gene in M. extorquens AM1. As a result, the former three strains of the aquatic legume plant (A. indica symbionts) have xoxF gene that presumably encodes La- and Ce-dependent methanol dehydrogenase (MDH), while the latter three strains of rice endophytes have both xoxF and mxaF gene. Culture experiments supported these results: The cell growth of B. oligotrophicum S58, Bradyrhizobium sp. BTAi1 and Bradyrhizobium sp. ORS278 (A. indica symbionts) was enhanced by La or Ce in HM medium containing methanol as a sole carbon source. They utilized methanol in the medium. On the other hand, the growth enhancement of bradyrhizobial rice endophytes (Bradyrhizobium sp. RP5, Bradyrhizobium sp. RP7, and Bradyrhizobium sp. WD16) by La or Ce additions were not observed in the same culture condition, probably because the existence of classical Ca-dependent MDH encoded by mxaF gene. We constructed two types of xoxF mutants, xoxF::omega and delta xoxF of B. oligotrophicum S58 by using omega cassette and sac markerless system, respectively. In the presence of La or Ce in HM medium supplemented with methanol, the growth of xoxF::omega mutant decreased as compared with that of wild-type strain of B. oligotrophicum S58. On the other hand, the growth of delta xoxF mutant increased as compared with that of wild-type strain S58. This apparent discrepancy indicates two suggestions in methanol catabolism in B. oligotrophicum S58. Firstly, the polar effect of omega cassette probably induced the repression of gene for formaldehyde catabolism, which located on downstream of the xoxF gene in xoxF::omega mutant. Secondly, there are other xoxF genes for La- or Ce- dependent MDHs. Indeed, we found redundant xoxF gene candidates on the genome of B. oligotrophicum S58 by extensive survey. Finally, we want to discuss the geobiological significance of light REEs in environmental bacteria.

Keywords: Rare earth elements, Bacteria, C1 compound metabolism, Bradyrhizobium, Methanol, Methanol dehydrogenase