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# Aluminium resistant, plant growth promoting bacteria induce overexpression of Aluminium stress related genes in *Arabidopsis thaliana* and increase the ginseng tolerance against Aluminium stress

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ABSTRACT

*Panax ginseng* is an important cash crop in the Asian countries due to its pharmaceutical effects, however the plant is exposed to various abiotic stresses, lead to reduction of its quality. One of them is the Aluminum (Al) accumulation. Plant growth promoting bacteria which able to tolerate heavy metals has been considered as a new trend for supporting the growth of many crops in heavy metal occupied areas. In this study, twelve bacteria strains were isolated from rhizosphere of diseased Korean ginseng roots located in Gochang province, Republic of Korea and tested for their ability to grow in Al-embedded broth media. Out of them, four strains (*Pseudomonas simiae* N3, *Pseudomonas fragi* N8, *Chryseobacterium polytrichastri* N10, and *Burkholderia ginsengiterrae* N11-2) were able to grow. The strains could also show other plant growth promoting activities *e.g.* auxins and siderophores production and phosphate solubilization. *P. simiae* N3, *C. polytrichastri* N10, and *B. ginsengiterrae* N11-2 strains were able to support the growth of *Arabidopsis thaliana* stressed by Al while *P. fragi* N8 could not. Plants inoculated with *P. simiae* N3, *C. polytrichastri* N10, and *B. ginsengiterrae* N11-2 showed higher expression level of Al-stress related genes, *AtAIP*, *AtALS3* and *AtALMT1*, compared to non-bacterized plants. Expression profiles of the genes reveal the induction of external mechanism of Al resistance by *P. simiae* N3 and *B. ginsengiterrae* N11-2 and internal mechanism by *C. polytrichastri* N10. Korean ginseng seedlings treated with these strains showed higher biomass, particularly the foliar part, higher chlorophyll content than non-bacterized Al-stressed seedlings. According to the present results, these strains can be used in the future for the cultivation of ginseng in Al-persisted locations.

## 1. Introduction

Many of Agricultural soil area are contaminated with many of heavy metals (Ghnaya et al., 2010) and Aluminum (Al) is considered one of them (Goodwin and Sutter, 2009). Although Al is required for plant growth, it has toxic effects on the plant development in the acidic soil (Ezaki et al., 2004) which represent around 30% of the total earth's lands and as much as 50% of the total arable lands. Most of acidic soil in the tropical and subtropical regions are extensively used for agricultural purpose, therefore Al toxicity in these regions represent a serious threat (Von Uexküll and Mutert, 1995). The toxicity of Al affects the crop productivity by limiting the root elongation, which accordingly reduces the uptake of the nutrient and water from the soil, leading to the reduction of the growth of the whole plant (Kochian, 1995; Goodwin and Sutter, 2009; Ma et al., 2012). Many physiological mechanisms have been reported by which the plant tolerates the toxicity of Al. They are divided into external and internal tolerance. External tolerance is accomplished by the production of organic acids from the roots cell to the rhizosphere in order to chelate surround Al ions and make it unavailable to the plant (Magalhaes et al., 2007; Ryan et al., 2011; Delhaize et al., 2012). The internal tolerance occurs by the dragging of Al ions and trapped in plant cell walls or plasma membrane or inside the plant cell in the vacuoles away from sensitive tissues (Kochian, 1995; Ramgareeb et al., 2004). Al-tolerant related genes have been characterized as summarized in Fig. 1; *ALMT1* (Aluminum-activated maleate transporter 1) is a gene which encodes malate transporter which participated in the tolerance of the plant against Al stress by transporting the organic acid, malate out of the plant cell to chelate rhizospheric $Al^{3+}$ and make it unavailable to the plant uptaking (Ryan et al., 1995; Raman et al., 2005; Ryan et al., 2011; Delhaize et al., 2012;

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