Effects of rice species, germanium application method and soil texture on germanium uptake and growth of rice plants with germanium

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Abstract
The growth characteristics, Ge absorption and grain quality of rice plants were investigated for different rice cultivars, Ge application method and soil textures in order to select the optimum rice cultivars, germanium (Ge) application method and soil texture for production of functional rice with Ge. The rice yield for soil application was higher in the order of Hopyungbyeo = Junambyeo > Ilmeebyeo >> Dongjinbyeo. On the other hand, the rice yield for foliar spray was higher in the order of Junambyeo > Ilmeebyeo= Hopyungbyeo >> Dongjinbyeo. The rice yield for soil application was higher than that for foliar spray regardless of rice cultivars. For soil application, the Ge absorption in various parts of the rice was higher in the order of rice bran > brown rice > polished rice regardless of rice cultivars. The Ge absorption of brown rice in Hopyungbyeo, Ilmeebyeo, Dongjinbyeo and Junambyeo by soil application was 14.5, 8.0, 11.6 and 10.4 mg/kg, respectively. In leaf, stem and root, Ge absorption for foliar spray was higher than that for soil application, whereas, in rice bran, brown rice and polished rice, the Ge absorption for soil application was higher than that for foliar spray. The growth status of rice plant was similar in all soil textures, and rice yield was higher in the order of silt loam > clay loam > loam > sandy loam. In rice bran, the Ge uptake for silt loam, clay loam, loam and sandy loam were 980, 868, 754 and 803 μg/pot, respectively. The Ge uptake of brown rice and polish rice were greater in the order of silt loam > sandy loam > clay loam > loam. In silt loam, the Ge uptake rates of leaf, stem, root, rice bran and brown rice were 19.7, 2.3, 0.03, 3.1 and 0.44%, respectively. Therefore, the optimum rice cultivars, Ge application method and soil texture were Hopyungbyeo, soil application and silt loam, respectively, provide suitable conditions for production of functional rice with Ge.

Key Words
Germanium, rice cultivars, germanium application method, soil texture, functional rice with Ge.

Introduction
Germanium, a metal element with an atomic number of 32, is well known to be a constituent of semiconductors such as diodes. On the other hand, it is said that organic germanium shows therapeutic efficacy. Organic germanium is used mainly as a therapeutic agent and additive for health food. Organic germanium was reported as antitumor, which induces interferon, antivirus, antiathritic activity and an immunological modifier. Recently, effective organic germanium is produced by the use of microbes or algae. Objectives of this study were to investigate the effects of rice cultivars, germanium application method and soil texture on germanium uptake and growth in rice plant with germanium.

Methods
In order to obtain the optimum rice cultivars and germanium (Ge) application method for production of functional rice with Ge, the growth characteristics, Ge absorption and grain quality of rice plant were investigated under different rice cultivars (Hopyungbyeo, Junambyeo, Ilmeebyeo and Dongjinbyeo), Ge application method (soil application and foliar spray) and soil textures (clay loam, silt loam, loam and sandy loam). This study was carried out in Wagner pots. Ge concentration in soils (clay loam, silt loam, loam and sandy loam) for rice plant cultivation was at 8 mg/kg.

Results
The Ge absorption of brown rice in Hopyungbyeo, Ilmeebyeo, Dongjinbyeo and Junambyeo for soil application was 14.5, 8.0, 11.6 and 10.4 mg/kg, respectively (Table 1). In leaf, stem and root, the Ge

Table 1. Rice yield and Ge contents of brown rice for different rice cultivars.

Rice cultivars	Yield (g/pot)			Ge content (mg/kg)		
	Control	Soil Application	Foliar spray	Control	Soil Application	Foliar spray
Hopyung	11.7±0.4	9.7±0.4	6.3±0.4	0.8±0.2	14.5±1.4	14.5±1.2
Junam	11.9±0.7	9.4±1.1	8.4±0.7	0.6±0.3	8.0±1.2	11.8±2.6
Ilmee	10.3±1.5	7.9±1.0	6.6±0.7	1.1±0.3	11.6±3.2	11.8±3.6
Dongjin	11.5±0.6	8.3±1.1	8.0±1.1	0.6±0.3	10.4±2.6	12.9±2.8

Data represent mean ± SD (n = 6).

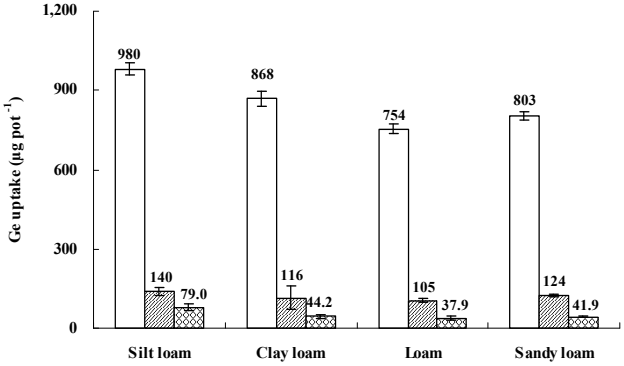

Figure 1. Ge uptake of rice grain under different soil texture. (□: Rice bran, ▨: Brown rice, ▩: Polished rice).

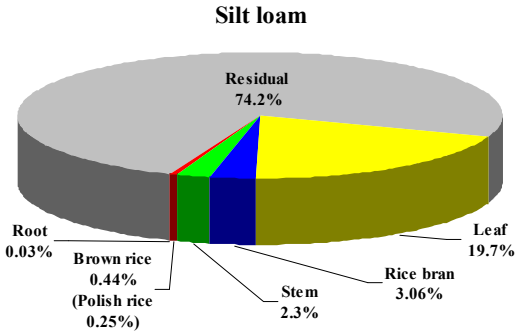

Figure 2. Ge absorption rate of rice plant in silt loam.

absorption for foliar spray was higher than that for soil application, whereas, in rice bran, brown rice and polished rice, the Ge absorption for soil application was higher than that for foliar spray. In rice bran, the Ge uptakes for silt loam, clay loam, loam and sandy loam was 980, 868, 754 and 803 μg/pot, respectively (Figure 1). The Ge uptakes of brown rice and polish rice was greater in the order of silt loam > sandy loam > clay loam > loam. In silt loam, the Ge uptake rates of leaf, stem, root, rice bran and brown rice were 19.7, 2.3, 0.03, 3.1 and 0.44%, respectively (Figure 2).

Conclusion

The optimum rice cultivars and Ge application method were demonstrated to be Hopyungbyeo and soil application, respectively, which provided suitable conditions for production of functional rice with Ge. In addition, under the given experimental condition the optimum soil texture for production of functional rice with Ge was a silt loam.

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