

구두발표 - 농업환경 및 토양·수질분야

OA-01

계통별 케일 내 글루코시놀레이트 함량 (Glucosinolate Contents in Lines of Kale(*Brassica oleracea* L. Var. *acephala*))

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케일(*Brassica oleracea* L. var. *acephala*) 내 기능성 성분으로 알려진 글루코시놀레이트(GSLs) 중 glucoraphanin, glucobrassicin 함량이 증대된 케일 계통을 선발하기 위하여 21계통 내 GSL 함량을 조사하였다. 케일은 배추 과 소재은행(KNRRB, 충남대학교)로부터 분양 받은 종자를 사용하였다. 각 계통의 케일은 국립원예특작과학원 온실에 파종(2012년 9월 3일)하였다. 파종 80일후 수확하여 어린 잎과 늙은 잎을 고르게 섞고 동결건조 후 분말화하여 GSL를 추출하였다. 각 GSLs는 70% 열탕 메탄올(70℃)로 추출하여 aryl sulfatase에 의한 desulfo-GSL 형태로 변환시킨 다음 HPLC-UV(227 nm, C18 칼럼)로 분석하였다. GSL 정량($\mu\text{mol g}^{-1}$ dry wt.)은 sinigrin(외부표준물질)과 각 성분의 HPLC크로마토그램 면적을 비교하여 계산하였다. 각 계통의 케일 잎의 생체중은 14~155 g(평균 84 g)로 계통 간의 큰 차이를 나타냈고, 수분함량은 평균 85%로 비슷한 경향을 나타냈다. 21 계통 케일로부터 10종류의 GSLs(glucoraphanin, sinigrin, glucoalyssin, gluconapin, 4-hydroxyglucobrassicin, glucobrassicinapin, glucobrassicin, 4-methoxyglucobrassicin, gluconasturtiin, neoglucobrassicin)가 검출되었다. 총 GSL함량 범위는 4.39-25.41 $\mu\text{mol g}^{-1}$ dry wt.(21계통 평균 12.05)로 나타났다. 주요 GSLs는 glucobrassicin(21계통 평균 6.01) > sinigrin(1.61) > 4-methoxyglucobrassicin(0.95 $\mu\text{mol g}^{-1}$ dry wt.)로 총 GSL함량 대비 50, 13, 8%이었다. 각 계통 내 glucoraphanin 함량 범위는 0.15-2.45 $\mu\text{mol g}^{-1}$ dry wt.로 28331(2.45) > 27272(1.82) = 28335(1.82) 계통 순으로 나타났다. Glucobrassicin 함량 범위는 0.38-16.99 $\mu\text{mol g}^{-1}$ dry wt.로 계통 간 큰 차이를 나타냈고, 10037(16.99) > 28335(15.01) > 28253(11.53) 계통 순으로 나타났다. 따라서 10037, 28335, 28253 계통 등은 glucoraphanin과 glucobrassicin 고함유 품종개발을 위한 육성에 이용될 수 있는 소재라 생각된다.

주제어 : Kale, Glucosinolates, Glucoraphanin, Glucobrassicin

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생육단계에 따른 메밀 품종별 페놀화합물 함량 (Phenolic Compounds of Buckwheats During Development Stages)

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메밀(*Fagopyrum* spp.)은 단백질, 비타민, 무기질과 섬유소의 함량이 쌀, 밀과 같은 다른 식량작물들보다 높으며 페놀화합물[flanonol류(rutin, quercetin), C-glycosylflavone류(orientin, isoorientin, vitexin, isovitexin)와 chlorogenic acid] 중 루틴이 많이 함유되어 있다. 따라서 모세혈관 강화, 당뇨병, 비만치료, 항고혈압, 항돌연변이 감소효과 등 효능을 가지며, 건강식품으로서의 이용 가치가 높은 작물로 인정받고 있다. 또한 메밀 산지에 따른 품질과 재배시기가 메밀 성분함량에 영향을 미친다고 보고됨에 따라 기능성 효과를 가진 페놀화합물의 정량적인 평가를 위하여 메밀 품종[한국('Dawon', 'Daegwan 3-3호'), 중국('Rice Tartary', 'Xiqiao 2호'), 일본('Kitawase', 'Hokkai T10')]별로 묘를 이식하여 2주 간격(22, 36, 50, 64, 78 days after sowing, DAS)으로 총 4번 수확하고, 50 DAS부터 잎, 줄기, 꽃 부위로 분류하여 부위별 페놀화합물 함량을 비교, 분석하였다. 동결건조 후 분말화 한 메밀 시료를 10% phosphoric acid를 함유한 MeOH(1.0 mL)로 추출한 후 HPLC-UV(350nm)로 분석하였다. 페놀화합물 함량은 대응하는 7개 외부표준물질(chlorogenic acid, orientin, isoorientin, vitexin, isovitexin, rutin, quercetin)의 HPLC peak 면적(area)과 각 성분의 면적을 비교하여 정량(mg/g dry wt.)하였다. 22 DAS에 보통메밀('Dawon', 'Xiqiao 2호', 'Kitawase')에서는 C-glycosylflavone류가 검출되었지만 쓴메밀('Daegwan 3-3호', 'Rice Tartary', 'Hokkai T10')에서는 전혀 검출되지 않았다. Rutin함량은 22 DAS와 36 DAS에서 'Hokkai T10'이 각각 42.58, 85.47 mg/g dry wt.로 가장 높았으며, 36 DAS이 22 DAS보다 약 2배 이상 높았다. 이는 'Hokkai T10'을 제외한 나머지 품종들의 평균 rutin 함량보다 각 각 약 2배, 1.8배 높았다. 50, 64, 78 DAS의 부위별(잎, 줄기, 꽃) 페놀화합물 중 rutin은 꽃, 잎, 줄기 순으로 높았으며, C-glycosylflavone류와 quercetin은 검출되지 않았다. 50 DAS에 'Xiqiao 2호'가 가장 먼저 꽃이 피었으며, rutin함량은 잎(5.02)보다 꽃(14.09)에 약 3배 높았다. 64 DAS에 chlorogenic acid는 줄기(범위 0.01-0.56)에서 소량 검출되었으며, 50 DAS에 비해 잎과 줄기의 rutin함량이 증가하였다. 'Hokkai T10' 꽃의 rutin함량은 117.47로 모든 부위 중 가장 높기 때문에 기능성성분 활용가치가 높을 것으로 생각된다. 78 DAS에 'Rice Tartary'의 잎과 줄기에서만 chlorogenic acid이 검출되었으며, rutin함량은 64 DAS에 비해 'Rice Tartary'와 'Daegwan 3-3호'의 줄기, 'Hokkai T10'과 'Dawon'의 잎과 줄기를 제외한 잎과 줄기에서 증가하였다.

주제어 : 메밀(*Fagopyrum* spp.), 생육단계, 페놀화합물, Rutin

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OA-03

Influence of Rice Cultivar on CH₄ Emission Characteristics in Paddy Soil (논 토양에서 벼 품종이 메탄 방출량에 미치는 영향)

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We assessed the effect of eight Japonica rice (*Oryza sativa* L.) cultivars on CH₄ emission in typical mono-rice paddy soil based on our hypothesis that the CH₄ flux may differ significantly among rice cultivars because each rice cultivar has different physiological and anatomical characteristics and may differently affect the microbial abundance involved in the CH₄ dynamics in paddy soil. The rice cultivation experiment was conducted over 3 years (2010-2012) at the Duryang Experimental Station, Gyeongsang National University, Sacheon, South Korea. Eight cultivars selected included the late-maturing (135 days) such as *Chuchung*, *Dongjin*, *Ilmi*, *Junam*, *Nampyeong*, *Samkwang*, and early-maturing like *Odae* and *Woonkwang* cultivars. A closed chamber method (Ali et al., 2009) was used to estimate CH₄ fluxes for the entire cropping periods. For determining CH₄ production potentials, methanogens abundance and activity, total carbohydrates and dissolved organic C in soil and organic acids in solution solutions were analyzed. Methanotrophs abundance and activity in soil, dissolved CH₄ and CO₂ in soil solution as well as root oxidation area were investigated by rhizobox and digital image analysis experiment for characterizing CH₄ consumption capacity. The overall patterns of CH₄ emission rates were similar among the cultivars for each year. A typical CH₄ emission pattern was observed, in which, CH₄ emission rates were lower at the initial vegetative stage, rapidly increased with the developing anaerobic soil condition and plant growth, and peaked at the maximum heading stage of the rice plant. The CH₄ emissions then rapidly returned to background levels at harvesting stage. The mean CH₄ emission rates (0.15-0.37 g m⁻²day⁻¹) and total CH₄ fluxes (20.0-50.0 g m⁻²) varied significantly among the cultivars (P<0.05). Methane fluxes were directly affected by the substrate-producing potential and gas transport capacity of each cultivar rather than the external plant growth variables. With regards to CH₄ production, methanogen abundances, carbohydrates and dissolved organic C in soil and total organic acids in soil solution differed significantly among the cultivars. While with regards to CH₄ consumption, dissolved[CH₄] and [CO₂] in soil solution as well as root oxidation area differed significantly among cultivars. Methane fluxes were highly positively correlated with methanogen abundances, soil carbohydrates and dissolved organic Cs, and total organic acids in soil

solutions while negatively correlated with methanotrophs abundance in soil, $[\text{CO}_2]\text{-C}/[\text{CO}_2 + \text{CH}_4]\text{-C}$ in soil solution and root oxidized area, but not with any of the apparent plant growth parameters. Rice cultivar and growth stage did not have an influence on the community structures of methanogens and methanotrophs. In conclusion, the selection and development of a cultivar with lower CH_4 flux may be an effective countermeasure for decreasing CH_4 emissions from rice paddy soil.

Key words : CH_4 production and Consumption potentials, CH_4 emission, Organic substrate production, Rice cultivar, Root oxidation, Paddy soil

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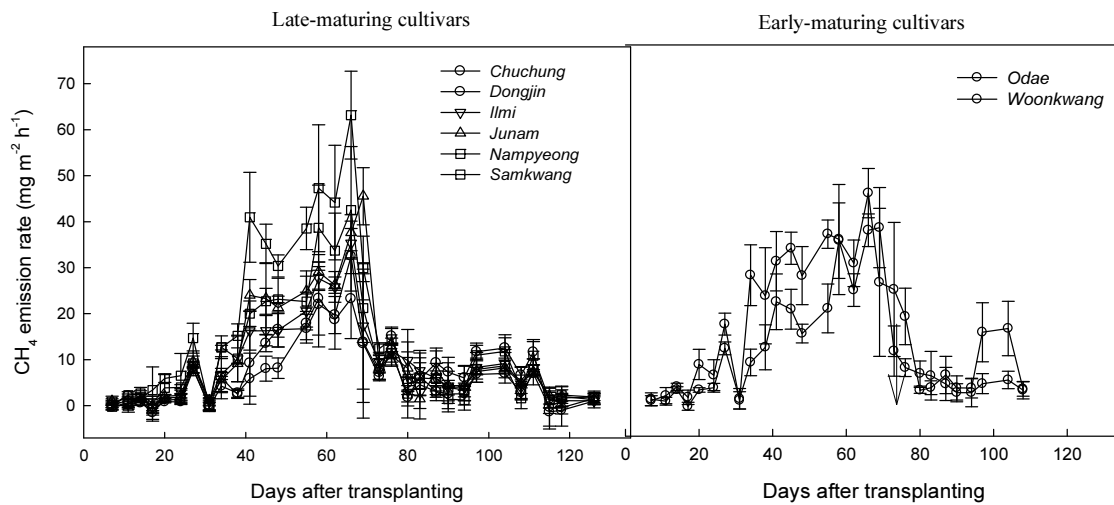


Fig. 1. Changes in CH_4 emission rates during rice cultivation in 2010.

Gutierrez, J., Kim, S.Y., Kim, P.J., 2013. Effect of rice cultivar on CH_4 emissions and productivity in Korean paddy soil. *Field Crops Research* 146: 16-24.

OA-04

Selection of Mix-Seeding Ratio of Hairy Vetch and Barley as a Green Manure on Considering Nutrient Production and Greenhouse Gas Emission in Rice Paddy Soil (벼 논에서 양분생산력과 온실가스 배출량을 고려한 녹비작물 헤어리베치와 보리의 합리적 혼파 비율 산정)

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The utilization of green manures as alternatives to reduce the use of mineral fertilizers is considered a good agricultural practice. Green manures, often known as cover crops, are plants which are grown to improve the structure and nutrient content of the soil. There are largely two types of green manure and legumes and non-legumes which have different characteristics. Adopting mixtures between legumes and non-legumes can be an efficient tool to merge the advantages of the single species in the cover crop practice achieving both environmental and agronomic benefits. In order to evaluate the effect of green manures which have different combination of leguminous and non-leguminous cover crop on rice productivity and environment, two cover crops, barley and hairy vetch, were seeded with different combination rates; barley100%, barley75%+hairy vetch25%, barley50%+hairy vetch50%, barley25%+hairy vetch75%, hairy vetch100%. And biomass productivities and nutrient values were evaluated during the fallow season. The whole biomass was incorporated as a green manure to substitute chemical fertilizers, and its application effects on rice productivity and environmental impact, in particular greenhouse gases emission, were evaluated in rice paddy soil during cultivation.

Mixed seeding of barley and hairy vetch affected significantly increasing cover crop biomass productivity of green manure and natural nutrient supply. It turned out that mixed cover biomass of barley and hairy vetch was very effective as a substitute of chemical fertilizer on increasing rice productivity and soil organic matter content. However, its application as a green manure largely increased GHGs emission ca. 3 times higher than that in NPK treatment. Therefore, soil management which can reduce GHGs emission during rice cultivation should be introduced simultaneously under cover crop application

Key words : Green manure, Paddy soil, CH₄, N₂O, Rice productivity, Nutrient supply

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Oxidizing Potential of Rice Root as an Uptake Regulator of Ions Influenced by Soil Redox Changes (토양 산화환원 전위 변화에 따른 벼의 철 흡수 조절인자로서 근권산화력 평가)

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Phosphorus is an essential macronutrient commonly precipitated with Fe, Ca and Al. Generally applied chemical amendments such as of FeCl₃, CaCO₃ and Al were known to effectively reduce soluble P in soil solutions. However, in the paddy fields with permanent reduced soil conditions, Fe solubility as well as the availability or solubility of P increase as these elements are reduced and converted into more soluble forms. Similar effects can be observed in Fe and Mn which are essential micronutrients whose dynamics can be affected by the redox condition of the soil. Iron and Mn are required by plants in trace amounts however, with the developing reduced condition in paddy soils, their solubility increase which may lead to subsequent toxicity effects of the excessive uptake of these micronutrients by plants. It has been reported that roots can oxidize various compounds present in the soil which serves as a defense mechanism of rice against toxic substances such as Fe²⁺, hydrogen sulfide (H₂S) and others. This study hypothesized that the oxidizing potential of rice roots may act as a regulator of ions influenced by soil redox changes. A mini rhizotron experiment was conducted to evaluate the oxidizing potential of six rice cultivars (*Chuchung*, *Dongjin*, *Junam*, *Ilmi*, *Nampyeong* & *Samkwang*). The root oxidized area was obtained through digital image analysis using Adobe Photoshop CS5 and image analyzer (<http://mkwak.org/imgarea/analysis.php>). Iron, P and Mn contents were determined by chemical and ICP analyses. Cultivars with high root oxidize area showed higher Fe content on the surface of the roots (Fe plaque). Iron plaque has a positive correlation with the external P and Mn contents of the roots and a negative correlation with the inner root P and Mn. Conclusively, root oxidizing potential of rice enhances the formation of Fe plaque on the surface of the roots. The Fe plaques served as a reservoir of P and Mn for plant uptake however in higher amounts, it serves as a barrier on the root surface to prevent excessive uptake of toxic elements from the soil.

Key words : Root oxidizing potential, Digital image analysis, Fe plaque, Soils redox, Solubility, Toxicity

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