Residue-Derived Amino Sugar Formation and Its Carbon Use Efficiency

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Abstract A 21-day lab incubation experiment was carried out with arable soil and uniform ^{13}C-labeled wheat residues. Residue-derived amino sugars (AS_R) accumulated exponentially and were fitted with a first-order model $C_t = C_{Max}(1 - e^{-kt})$ well. Their maxima were 88–381 nmol g^{-1} for glucosamine ($GluN_R$), 52–105 nmol g^{-1} for galactosamine ($GalN_R$), and 107–137 nmol g^{-1} for muramic acid ($MurN_R$), respectively. Their half-lives ($T_{1/2}$) separately varied between 1.2 and 3.3 days for $GluN_R$, 1.6 and 4.7 days for $GalN_R$, and less than 0.3 day for $MurN_R$. A close relationship was observed between carbon mineralization and AS_R ($P < 0.05$), and carbon use efficiency of cumulative AS_R was calculated and compared.

Keywords Amino sugar • Carbon use efficiency • Organic residue • Carbon-13 • LC-c-IRMS

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Introduction

Though amino sugars (AS) have widely been used to investigate microbial residues and correlated organic compounds sequestration, little is known about their formation dynamics in soil (Zhang and Amelung 1996; He et al. 2011). Difficulties are probably ascribed to the definition and differentiation of varied ASs pools, substrate availability, and time scale of the study. With ^{13}C-labeled residues' incubation, LC-c-IRMS was utilized to investigate AS formation kinetics and its carbon use efficiency for the first time in this study.

Materials and Methods

0–10-cm top soil from conventional till (**CT**) and no till (**NT**) was amended with ^{13}C-labeled wheat grain (**G**), leaf (**L**), and root (**R**) at 6-mg substrate Cg^{-1} for a 21-day incubation, including six treatments: **NG** (NT + G), **NL** (NT + L), **NR** (NT + R), **CG** (CT + G), **CL** (CT + L), and **CR** (CT + R). Concentrations and δ^{13}C of AS were determined by LC-c-IRMS. Residue-derived AS ($\mathrm{AS_R}$) formation was described in $\mathrm{AS}_{\mathrm{R},t} = \mathrm{AS}_{\mathrm{R,Max}} \cdot (1 - \mathrm{e}^{-kt})$, where $\mathrm{AS}_{\mathrm{R,Max}}$ is potentially accumulative $\mathrm{AS}_{\mathrm{R},t}$, and k is $\mathrm{AS}_{\mathrm{R},t}$ the formation rate constant, and t is the incubation time.

Results and Discussion

This study showed that $T_{1/2}$ of $\mathrm{AS_R}$ formation increased as MurN ($\leq$0.3 day) $<$ GluN (1.2–3.3 days) $<$ GalN (1.6–4.7days); their maxima were 88–381 nmol g^{-1} for GluN, 52–105 nmol g^{-1} for GalN, and 107–137 nmol g^{-1} for MurN; and $\mathrm{AS}_{\mathrm{R,Max}}/\mathrm{AS}_{\mathrm{SOM},0h}$ were separately 14.9–17.8% for MurN, 5.5–13.0% for GluN, and 2.7–6.3% for GalN ($\mathrm{AS_{SOM}}$ data not shown) (Fig. 1, Table 1), which agrees with previous studies (Glaser and Gross 2005). MurN is exclusively originated from bacteria, and its faster formation suggested the important role of bacteria at the early stage of mineralization of wheat residues.

The cumulative $\mathrm{GluN_R}$ or $\mathrm{GalN_R}$ was significantly correlated to the mineralized carbon ($\mathrm{C_M}$) across all treatments throughout the whole incubation, which strongly suggests that a certain proportion of $\mathrm{C_M}$ is allocated into newly formed $\mathrm{AS_R}$ (except for $\mathrm{MurN_R}$, Fig. 2). The intercepts and slopes of linear functions between $\mathrm{GluN_R}$ and $\mathrm{C_M}$ were evidently different from their counterparts between $\mathrm{GalN_R}$ and $\mathrm{C_M}$, which clearly signifies a much higher carbon use efficiency of accumulative $\mathrm{GluN_R}$ than $\mathrm{GalN_R}$. The stoichiometric relationship between $\mathrm{C_M}$ and $\mathrm{AS_R}$ could be calculated: an increase of 0.1 μmol $\mathrm{GluN_R}$ needed 0.38 μmol $\mathrm{C_M}$, which was 13.61 lower than $\mathrm{GalN_R}$, while after 1 μmol $\mathrm{C_M}$, 0.16 μmol $\mathrm{GluN_R}$ would be synthesized, which was nearly 16 times the $\mathrm{GalN_R}$.

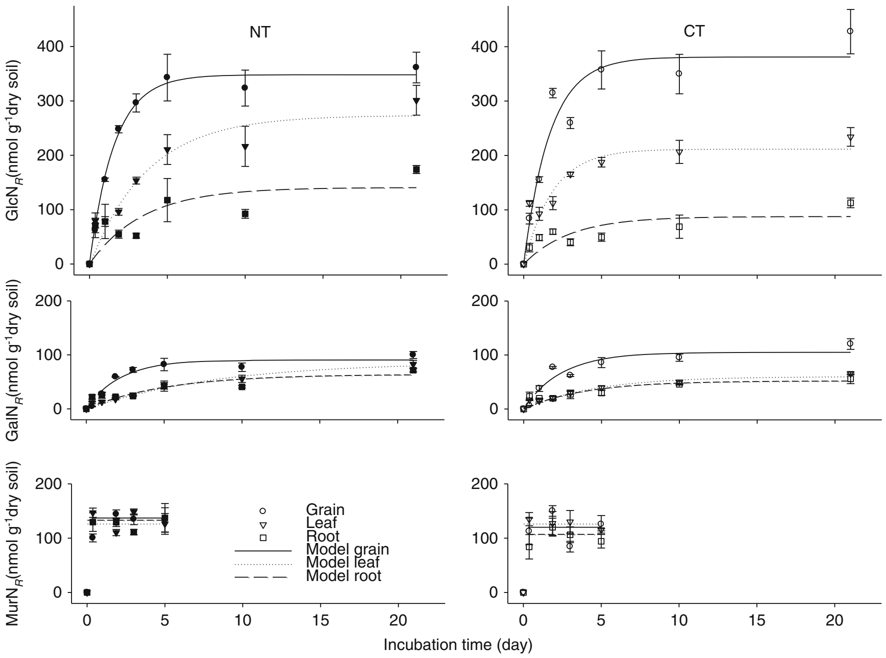

Fig. 1 Modeled and measured residue-derived amino sugar concentration ($AS_{R,t}$) as a function of time

Table 1 Parameters description of AS_R formation

AS_R	Treats	$AS_{R,max}$ (nmol g^{-1})	k (day^{-1})	$T_{1/2}$ (day)	R^2
GluN$_R$	NG	348 ± 13a	0.5 ± 0.0a	1.3 ± 0.1c	≥0.967
	NL	274 ± 20b	0.3 ± 0.0b	2.4 ± 0.4b	≥0.852
	NR	141 ± 22bc	0.6 ± 0.0a	1.3 ± 0.1c	≥0.474
	CG	381 ± 19a	0.6 ± 0.0a	1.2 ± 0.1c	≥0.900
	CL	212 ± 13bc	0.5 ± 0.0a	1.5 ± 0.1c	≥0.820
	CR	88 ± 11c	0.2 ± 0.0c	3.3 ± 0.4a	≥0.849
GalN$_R$	NG	90 ± 5a	0.4 ± 0.0a	1.6 ± 0.1c	≥0.917
	NL	87 ± 7b	0.2 ± 0.0c	4.3 ± 0.0a	≥0.922
	NR	64 ± 7b	0.2 ± 0.0c	4.7 ± 1.2a	≥0.734
	CG	105 ± 6a	0.4 ± 0.0a	1.7 ± 0.0c	≥0.903
	CL	61 ± 3b	0.2 ± 0.0c	4.0 ± 0.5a	≥0.924
	CR	52 ± 6c	0.3 ± 0.0b	2.7 ± 0.1b	≥0.670
MurN$_R$	NG	137 ± 6a	2.7 ± 0.7	0.3 ± 0.1	≥0.875
	NL	133 ± 40a	–	–	–
	NR	127 ± 45a	–	–	–
	CG	120 ± 11a	–	–	–
	CL	127 ± 43a	–	–	–
	CR	107 ± 8a	–	–	–

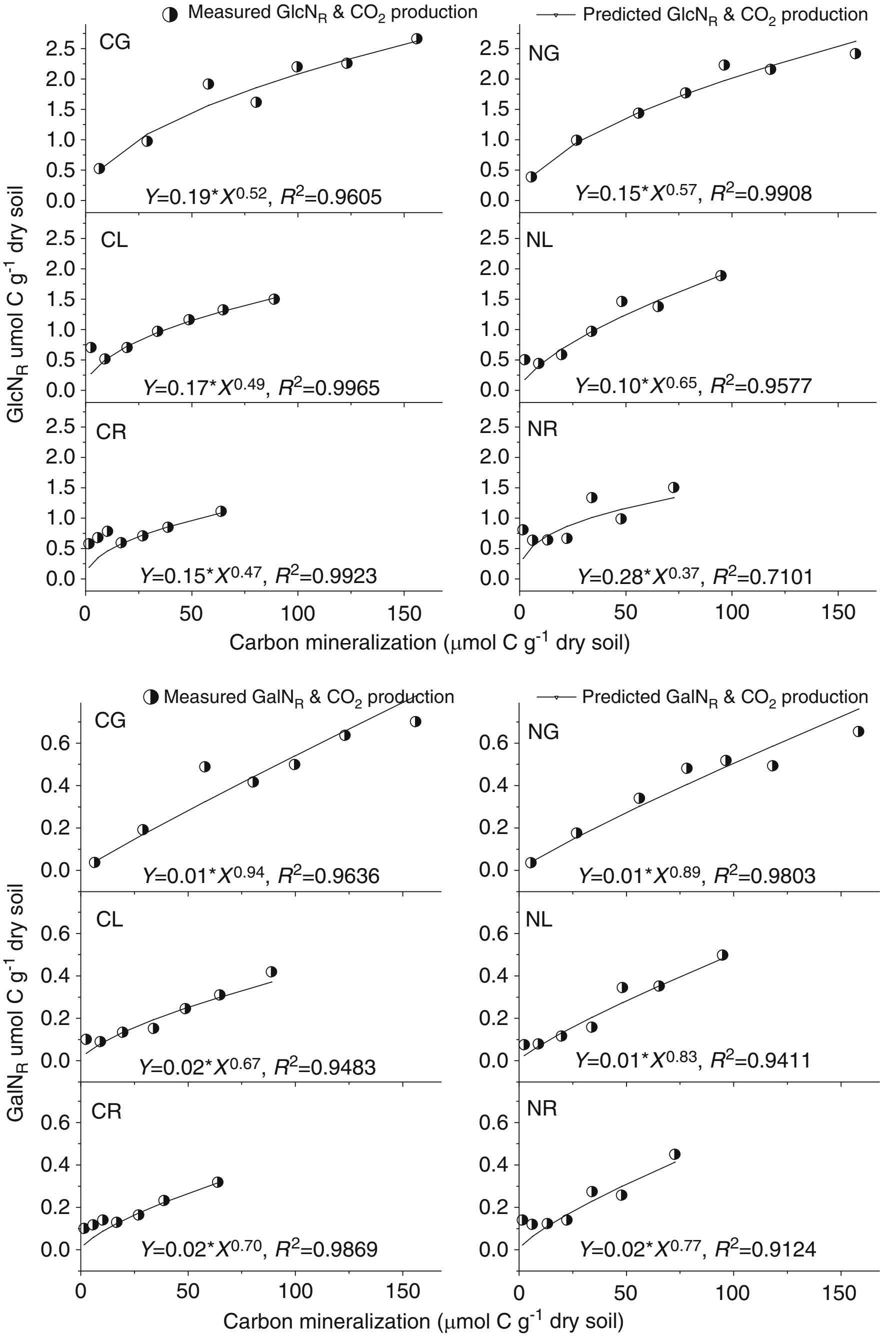

Fig. 2 Correlation between C mineralization and AS$_R$

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