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UPTAKE AND TRANSPORT CHARACTERISTICS OF ORGANIC AND INORGANIC NITROGEN IN RICE SEEDLINGS

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Abstract

The study was conducted in sterile hydroponics using isotopes tracer technique to demonstrate the posibility for rice seedlings (variety: C Liangyou 266) to directly absorb and utilize molecular organic nitrogen, transport and assimilation of organic/inorganic nitrogen. Further the activity of assimilation-related enzymes i.e Glutamic-oxaloacetic transaminase (GOT), Glutamic-pyruvic transaminase (GPT) and Glutamate dehydrogenase (GDH), in rice seedlings were also studied using isotopic tracing technique. In this regard ^{15}N-ammonium sulfate, ^{15}N-potassium nitrate and 2-^{13}C-^{15}N-glycine salts were used to analyzes the abundance of ^{13}C/^{15}N. The results suggest that the ^{15}N excess and the ratio of ^{15}N excess in shoot to root under glycine nitrogen treatment (Gly-N) were significantly higher than those under ammonium nitrogen or nitrate nitrogen treatment (p<0.05); the ^{13}C excess/^{15}N excess ratios of rice organs and the whole seedling measured at 24h after Gly-N approximated the theoretical value of 1:1, which showed gradual declines 48h and 72h later. The activities of glutamic-oxaloacetic transaminase (GOT), glutamic-pyruvic transaminase (GPT) and glutamate dehydrogenase (GDH), in rice seedlings cultured by organic nitrogen were significantly higher than those by inorganic nitrogen (p<0.05). The findings also showed that rice seedlings are capable for direct absorbing and utilizing molecular glycine nitrogen. The absorption rate of glycine nitrogen was much higher than that of ammonium nitrogen or nitrate nitrogen. The transport capabilities of organic and inorganic nitrogen in rice plants, ranked in descending order are as follows: glycine nitrogen > ammonium nitrogen > nitrate nitrogen.

Key words: Rice, ^{13}C-^{15}N-glycine, Absorption and Transport, Mechanism.

Introduction

Plants growing in special environments like the Arctic tundra (Wang *et al*., 2008; Hu *et al*., 2015) and high mountains (Paungfoo *et al*., 2008) are able to directly absorb micro-molecular organic nitrogen (e.g. amino acids) from the soil. Early-stage researches on the absorption of organic nitrogen into plants were mainly done by single labeling of ^{15}N nitrogen (Thornton *et al*., 2001). But it was very hard for ^{15}N single labeling to distinguish the directly-absorbed organic nitrogen from its decomposed products (i.e. inorganic nitrogen) or metabolites as amino acids are easily decomposed and synthesized by soil microbes (Xu *et al*., 2011). Therefore, the testing results obtained by ^{15}N single labeling could vary greatly from the actual situation. The combination of ^{13}C-^{15}N double labeling and sterile culture is a great remedy to this problem. Domestic and overseas researches evaluating the possibility of utilizing organic nitrogen directly by plants in nature mainly focused on crops like rice (Mo *et al*., 2002), wheat (Näsholm *et al*., 2009) and pakchoi cabbage (Cao *et al*., 2015) or plants in boreal forest (Xu *et al*., 2006; Gao *et al*., 2014), temperate forest, grassland (Weigelt *et al*., 2005; Scott *et al*., 2011), and subtropical forest (Kahmen *et al*., 2009; Wei *et al*., 2013). The existing studies of rice were mostly focusing on the absorption and utilization of foliar fertilizers or plant nutritional agents as well as the nutritional effects of organic nitrogen. The studies on the capacity of rice seedlings for direct absorbing, utilizing organic nitrogen as well as the transport characteristics of the absorbed organic nitrogen in these seedlings are very scarce. In the present study, 2-^{13}C-^{15}N double-labeled glycine, ^{15}N labeled ammonium sulfate and ^{15}N labeled potassium nitrate were selected as isotopic tracers under sterile hydroponics experiment was conducted to evaluate: 1) the direct absorption of organic nitrogen by rice seedlings under different nitrogen treatments (organic and inorganic nitrogen) at different time intervals; 2) the transport characteristics of the absorbed organic and inorganic nitrogen in rice plants. The findings of this research could enhance the theory of plant nutrition and provide support for further studies on the absorption and utilization of organic nitrogen by higher plants.

Materials and Methods

Rice variety and isotope tracer: The rice seedlings (variety: C Liangyou266*C*provided by the Nuclear Agricultural Science and Aerospace Breeding Institute, Hunan Academy of Agricultural Sciences), were cultured for 21 days in sterile hydroponics. Three isotopic tracers i.e. 2-^{13}C-^{15}N-glycine (^{13}C abundance: 99%; ^{15}N abundance: 98%), ^{15}N-ammonium sulfate (abundance: 10.65%) and ^{15}N-potassium nitrate (abundance: 10.3%) supplied by China Isotope Corporation, were used.

Absorption and transport of different types of nitrogen in rice plants: The experiment was conducted in sterile hydroponics at organic nutrition laboratory of the Nuclear Agricultural Science and Aerospace Breeding Institute (Hunan Academy of Agricultural Sciences) according to the sterile culture method for plant organic nutrition as proposed by Wu *et al*., (2000). Trace method was designed in line with the isotopic tracing method of

Näsholm *et al*., (2001) and Wei *et al*., (2013). The nutrient solution of rice cultivation contains a lot of elements (N, P, K, Ca, Mg) and micronutrient (Mn, Mo, B, Zn, Cu, Fe). Three isotopic treatments were used in nutrient solution as the nitrogen source at a concentration of 10mg/L i.e. (1). 2-^{13}C-^{15}N-glycine (^{13}C abundance: 99%; ^{15}N abundance: 98%), (2) ^{15}N-ammonium sulfate (abundance: 10.65%) and (3) ^{15}N-potassium nitrate (abundance: 10.3%) along with control (distilled water). There were 9 replications for each treatment in random block arrangement.

The experiment was conducted pots using graduated cylinder (volume: 2000 mL) filled with 300g of quartz sand to each pot. The pots were sealed with glass paper in order to ensure light transmittance and proper humidity. Healthy rice seedlings were transplanted in graduated cylinders (one plant in each cylinder). Approximately 40mL of respected treatment solution was added to each graduated cylinder and bacterial test was conducted at each sampling. The seedlings were kept in the light for 10h (intensity: 30,000 lux) and in darkness for 14h every day; The day /night temperature was adjusted at 30°C. Sample the root, stem, and leaf 24h, 48h, and 72h after the nitrogen treatment. Root samples were washed with 0.5mmol/L $CaCl_2$ solution for four times to remove the isotopic tracer adhering on the surface of the root; then, the roots were rinsed with distilled water to remove $CaCl_2$, The collected samples were dried at the temperature of 50-60°C for 0.5 h after being defrosted at 90°C; dried samples were grinded into fine powder with a micro plant grinding machine (refrain from cross contamination of isotopes from different treatments). Plant samples (root, stem, and leaf) were subjected to isotopic analyses using isotope spectrometer (DELTA V Advantage, America) and elemental analyzer (Flash 2000 HT, Thermo Fisher Scientific, America) to determine the total C, N content, ^{13}C abundance, and^{15}N abundance of each organ under different treatments.

The excess ^{15}N and ^{13}C were calculated by the following equations as suggested by (Wei *et al*., 2013; Taylor *et al*., 2004):

$$X_c=[C_T[\%]/12\times(^{13}C_T\text{atom}\%-^{13}C_c\text{atom}\%)\times f]\times10^6$$

$$X_N=[N_T[\%]/14\times(^{15}N_T\text{atom}\%-^{15}C_c\text{atom}\%)\times f]\times10^6$$

where X_c and X_N denotes the ^{13}C excess ^{15}N excess (µmoL/g, DW) in each gram of dried samples; C_T and N_T are the total C and total N of rice samples; $^{13}C_T$atom% and $^{15}N_T$atom% represent the ^{13}C and ^{15}N abundance of the samples treated by nitrogen and labeled by isotopes, respectively; $^{13}C_c$atom% and $^{15}N_c$atom% refer to the ^{13}C and ^{15}N abundance of the control samples, respectively; *f* is the enrichment coefficient (or enrichment factor) of isotopic tracers.

Assimilation mechanism of amino acid nitrogen in rice seedlings: Effects of organic and inorganic nitrogen sources on the activity of assimilation-related enzymes were studied in rice seedlings. The study was conducted using three equivalent-nitrogen treatments of isotopic salts i.e. (1) Gly-N; (2) NH_4^+-N (3) NO_3^--N nutrient solutions @ 10mg/L with three replicates arranged in randomized manner. The nutrient solutions were prepared according to the formula for rice as suggested by the International Rice Research Institute (IRRI). The triangular flasks (volume: 1000mL) were taken for pot experiment; filled with 200g of quartz sand in each flask and covered with 20×200mm test tube to provide a moist environment that allows the seedling to grow upward. Approximately 40mL of nutrient solution was added to each flask and one seedling in each flask was planted. Twenty one days old seedlings were grown for 7 days and then the samples collected to conduct bacterial test for nutrient solution; in each sample. Fresh weight of root, stem, and leaf was measured enzymatic activities (GOT, GPT and GDH) were determined. and difference of activity percentage D (%) of rice in root, stem, and leaf) under three different nitrogen treatments (i.e. Gly-N, NH_4^+-N, and NO_3^--N) were calculated according to following equation:

$$D(\%)=[(A-B)/B]\times100.$$

where, A, B, and C denote GOT, GPT, or GDH activity of rice root, stem, or leaf under Gly-N, NH_4^+-N, and NO_3^--N treatments.

Effect of various amino acid nitrogen sources on the activity of assimilation-related enzymes: This experiment was divided into three equivalent-nitrogen (10mg/L) treatments: (1) Gly-N nutrient solution; (2) Glu-N nutrient solution; (3) NH_4^+-N nutrient solution; three replications for each treatment and random arrangement; one seeding in each pot; the seedlings were 21-day-old; the experimental method was the same as the above. Cultivate the seedlings for 7 days and take the samples; determine the GOT, GPT and GDH activity of the whole plant.

Data analysis: The experimental data were analyze statistically to study the significance of difference (LSD method); t-test was used to evaluate the difference between the ratio of ^{13}C excess/^{15}N excess in rice treated by isotopic 2-^{13}C-^{15}N-glycine and the theoretical ratio (1:1) and data is presented in diagrams by Excel 2007; DPSv14.50.

Results

Variance of ^{15}N excess: The ^{15}N excess in rice root, stem, leaf and whole seedling increased with time under all nitrogen treatments (Fig. 1). For root samples collected from Gly-N treatment, the ^{15}N excess measured after 48h and 72h of treatment were 2.42 and 8.93 times higher than amount of that measured at 24h after the treatment. while for root samples collected from ammonical nitrogen treatment, the ^{15}N excess was 2.12 (48h) and 6.87 (72h) times higher than the amount that measured at 24h after the treatment; Similarly for root samples collected from nitrate nitrogen treatment, the ^{15}N excess was 2.21 (48h) and 6.91 (72h) times higher the amount of that measured 24h after the treatment. The differences in ^{15}N excess of roots under different nitrogen treatments were detected were highly significant @ $p<0.01$).

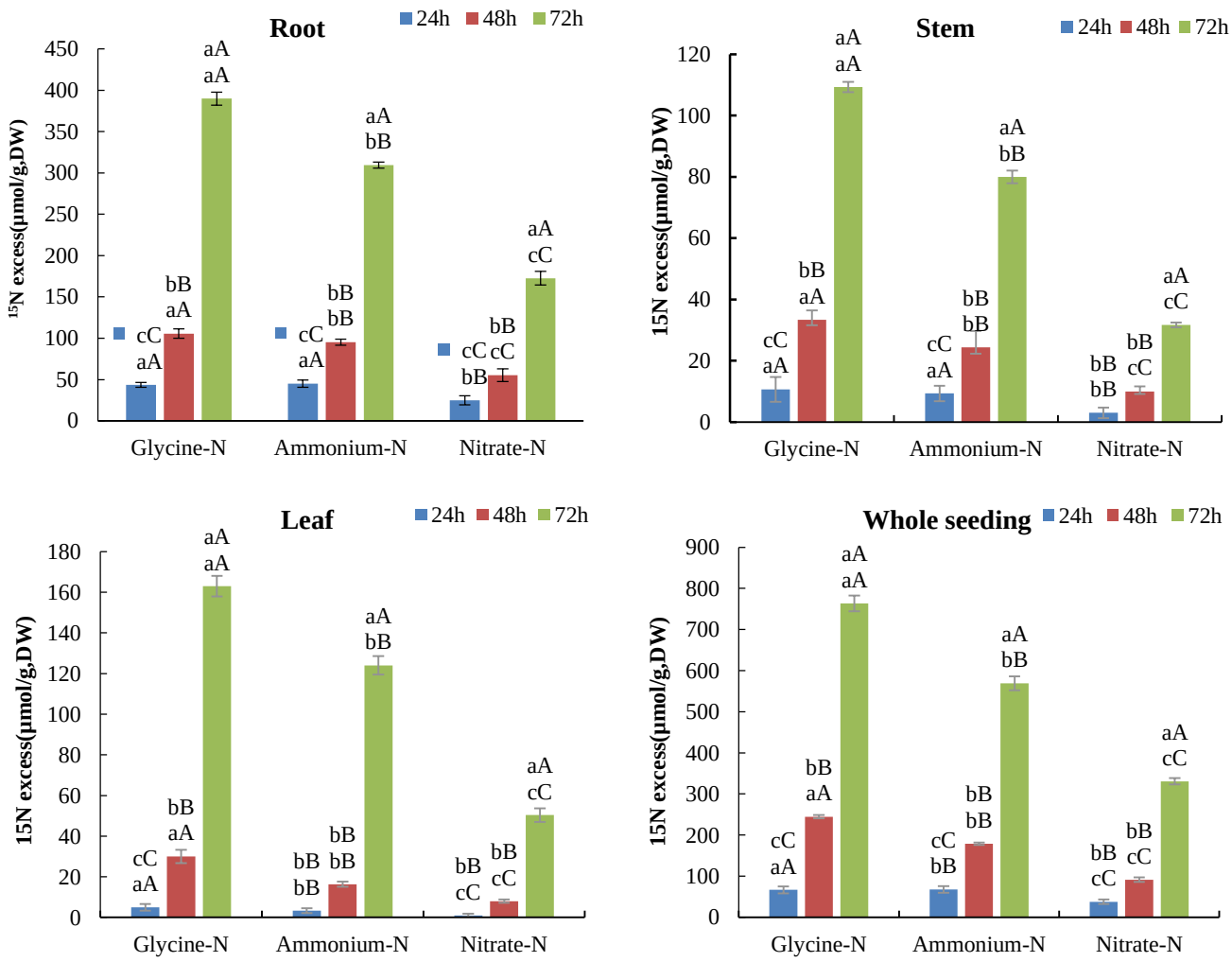

Fig. 1. ^{15}N excess in rice root, stem, leaf and whole seedling at different time points after various N isotope treatments.
Note: Different small and capital letters at the top indicate significant differences in ^{15}N excess at various time points under the same isotope treatment at the 0.05 and 0.01 levels, while those at the bottom indicate significant differences in ^{15}N excess at the same time point under various isotope treatment at the 0.05 and 0.01 levels.

For stem samples collected from Gly-N treatment, the ^{15}N excess measured 48h and 72h after the treatment was also 2.23 and 8.85 times higher than amount of that measured 24h after the treatment. The stem samples analysed for ^{15}N excess from ammonium nitrogen treatment were also 3.29 (48h) and 2.61 (72h) times more than the amount that measured after 24h of treatment;

On the other hand the stem samples collected for ^{15}N excess measurement from nitrate nitrogen treatment, showed 10.56 (48h) and 3.33 (72h) times more than the amount that measured 24h after the treatment. The differences in ^{15}N excess of stems under three nitrogen treatments were also highly significant" (p<0.01).

For leaf samples collected from Gly-N treatment, the ^{15}N excess was 6 and 32.6 times higher than measured after 48h and 72h of treatment as compared to the amount measured after 24h of treatment. The differences in ^{15}N excesses at three intervals were extremely significant (p<0.01). Similar trend was observed in case of ammonium and nitrate nitrogen treatment. The ^{15}N excesses in leaf samples collected 72h after were much higher than those collected 24h and 48h after the treatment. Specifically, for leaf samples collected from ammonium nitrogen treatment, the ^{15}N excess measured 72h after the treatment was 4.90 and 37.24 times high than the amount of those measured 24h and 48h after the treatment respectively; the ^{15}N excess measured 72h after nitrate nitrogen treatment was 8 and 50.67 times of those measured 24h and 48h after the treatment. The variances of ^{15}N excesses in whole plants at different time points (24h, 48h and 72h) under three nitrogen treatments showed a similar tendency to those found in rice roots.

The ratio of ^{15}N excess in shoot (stem and leaf) to that in root: The ratio of ^{15}N excess in shoot to root under all isotope nitrogen treatments tended to increase with time (see Fig. 2). There were significant differences among the ratios of ^{15}N excess in shoot to root under different nitrogen treatments at 24h and 48h later. The ratio of ^{15}N excess in shoot to root under Gly-N treatment was 35.7% and 153.23% higher than those under ammonium nitrogen and nitrate nitrogen treatments respectively. Similarly the ratio of ^{15}N excess at 72h after treatment under Gly-N treatment was 9.87% and 36.54% higher than those under ammonium nitrogen and nitrate nitrogen treatments respectively. This indicates that more isotope-labeled nitrogen was transported from roots to shoots with the increase of time under each treatment.

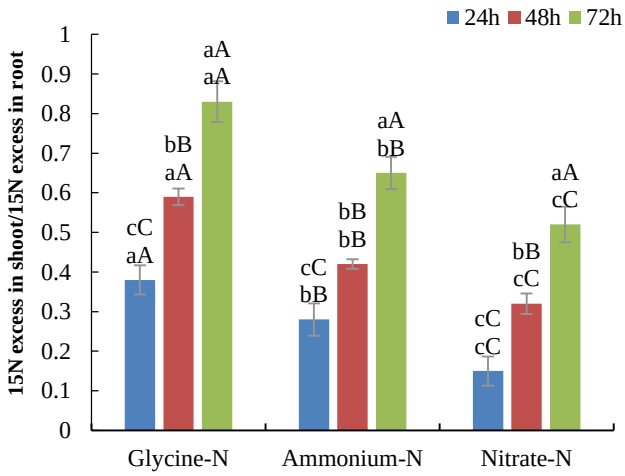

Fig. 2. The ratio of ^{15}N excess in shoot to root of rice seedling at different time points after various N isotope treatments.
Note: Different small and capital letters at the top indicate significant differences in the ratio of ^{15}N excess in shoot to root at various time points under the same isotope treatment at the 0.05 and 0.01 levels, while those at the bottom indicate significant differences in the ratio of ^{15}N excess in shoot to root among various isotope treatments at the same time point at the 0.05 and 0.01 levels.

^{13}C and ^{15}N excess in rice seedlings: The ^{13}C excess was detected in the root, stem, and leaf of the rice seeding at 24 h after the application of Gly-N (Table 1). The ^{13}C excess of the whole seedling had a tendency to increase with time. At 72h later, the ^{13}C excess increased by 43.68% and 25.39% compared to those at 24h and 48 h respectively, indicating extremely significant differences among the ^{13}C excess measured at these three time intervals (p<0.01).

There were no significant differences between the ^{13}C excess and ^{15}N excess of the root, stem, leaf and whole seeding 24h under various nitrogen treatments, and the measured ^{13}C and ^{15}N excess approximated the theoretical value (namely, 1:1). According to the results of T-test, there were no significant differences between the theoretical ^{13}C excess/^{15}N excess ratio and the actual ^{13}C excess/^{15}N excess ratios measured in the rice root, stem, leaf, and whole seeding 24h after nitrogen treatments. In contrast, 48h and 72h after the nitrogen treatments, the ^{13}C excess/^{15}N excess ratios of rice root, stem, leaf, and whole seeding declined sharply; there were significant differences between the theoretical ^{13}C excess/^{15}N excess ratio and the actual ^{13}C excess/^{15}N excess ratio (p<0.01).

Effects of organic and inorganic nitrogen sources on the activity of assimilation-related enzymes: As shown in Table 2, Glutamic-oxaloacetic transaminase (GOT), Glutamic-pyruvic transaminase (GPT) and Glutamate dehydrogenase (GDH), activity of the whole seedling under Gly-N treatment were higher than those under NH_4^+-N treatment. The GOT, GPT, and GDH activity of rice parts cultured by these two nitrogen sources followed the order of "leaf > root > stem". However, the enzyme activity of the same part varied greatly according to the type of nitrogen source (p<0.05). The percent difference (%) between the GOT activity of root, stem and leaf was 32.7%, 29.5%, and 1.9% respectively. The GOT activity was maximum in root i.e. 21.5µmolg^{-1}h^{-1}. The difference percentage D (%) between the GPT activity of root, stem and leaf was 93.4%, 26.1%, and 2.0% respectively. Similarly GPT activity was also found at peak in roots i.e. 99.8µmolg^{-1}h^{-1}. The difference percentage D (%) (%) between the GDH activity of root, stem and leaf was -19.3%, 24.1%, and 89.2% respectively. In contrast to this the GDH activity was on its peaked in leaf i.e. 256.6µmolg^{-1}h^{-1}.

Table 1. ^{13}C excess and ^{13}C excess/^{15}N excess of rice seedling under 2-^{13}C-^{15}N-glycine treatment.

Rice seedling	^{13}Cexcess (µmol/g, DW)			^{13}C excess/^{15}N excess		
	24h	48h	72h	24h	48h	72h
Root	42.80 ± 5.2cC	47.55 ± 3.5bB	58.50 ± 4.6aA	0.98 ± 0.01aA	0.45 ± 0.06bB	0.15 ± 0.02cC
Stem	8.56 ± 1.3cC	10.33 ± 1.5bB	13.12 ± 2.1aA	0.98 ± 0.01aA	0.31 ± 0.03bB	0.12 ± 0.03cC
Leaf	6.43 ± 0.8cC	8.34 ± 1.0bB	11.41 ± 1.3aA	0.99 ± 0.01aA	0.29 ± 0.04bB	0.07 ± 0.01cC
Whole seedling	57.79 ± 6.8cC	66.22 ± 5.6bB	83.03 ± 5.2aA	0.98 ± 0.01aA	0.40 ± 0.07bB	0.11 ± 0.02cC

Note: Lowercase and capital letters indicate significant differences of ^{13}C excess or ^{13}C excess/^{15}N excess among different time points under 2-^{13}C-^{15}N-glycine treatment at the 0.05 and 0.01 levels, respectively

Table 2. GOT, GPT, and GDH activity of rice plants cultured in Gly-N and NH_4^+-N hydroponic solution for 7 days.

Position	N-sources	Enzyme activity		
		GOT (µmolg^{-1}h^{-1})	GPT (µmolg^{-1}h^{-1})	GDH (µmolg^{-1}h^{-1})
Leaf	Gly-N	42.4 ± 8.2aA	148.5 ± 14.5aA	485.5 ± 25.8aA
	NH_4^+-N	41.6 ± 4.6bB	145.6 ± 10.6bB	256.6 ± 32bB
Stem	Gly-N	13.6 ± 2.3aA	48.3 ± 3.9aA	65.4 ± 8.3aA
	NH_4^+-N	10.5 ± 1.2bB	38.3 ± 4.1bB	52.7 ± 10.6bB
Root	Gly-N	21.5 ± 2.5aA	99.8 ± 11.4aA	76.8 ± 13.5bB
	NH_4^+-N	16.2 ± 1.8bB	51.6 ± 3.2bB	95.2 ± 14.6aA
Whole seedling	Gly-N	20.8 ± 4.6aA	75.6 ± 5.8aA	135.4 ± 13.4aA
	NH_4^+-N	18.9 ± 3.1bB	50.4 ± 3.7bB	114.9 ± 18.9bB

Note: The activity of GOT and GPT was expressed in the pyruvate micromol produced by one gram of fresh plant sample during the reaction in an hour; the activity of GDH was expressed in the variation of optical density in one minute caused by each gram of fresh plant sample in the reaction system, and a variation of 0.001 was taken as a unit (U) for calculation (the same as below). Small and capital letters indicate significant differences of 0.05 and 0.01 levels in enzyme activity of different rice organs (or the whole seedling) under various nitrogen treatments

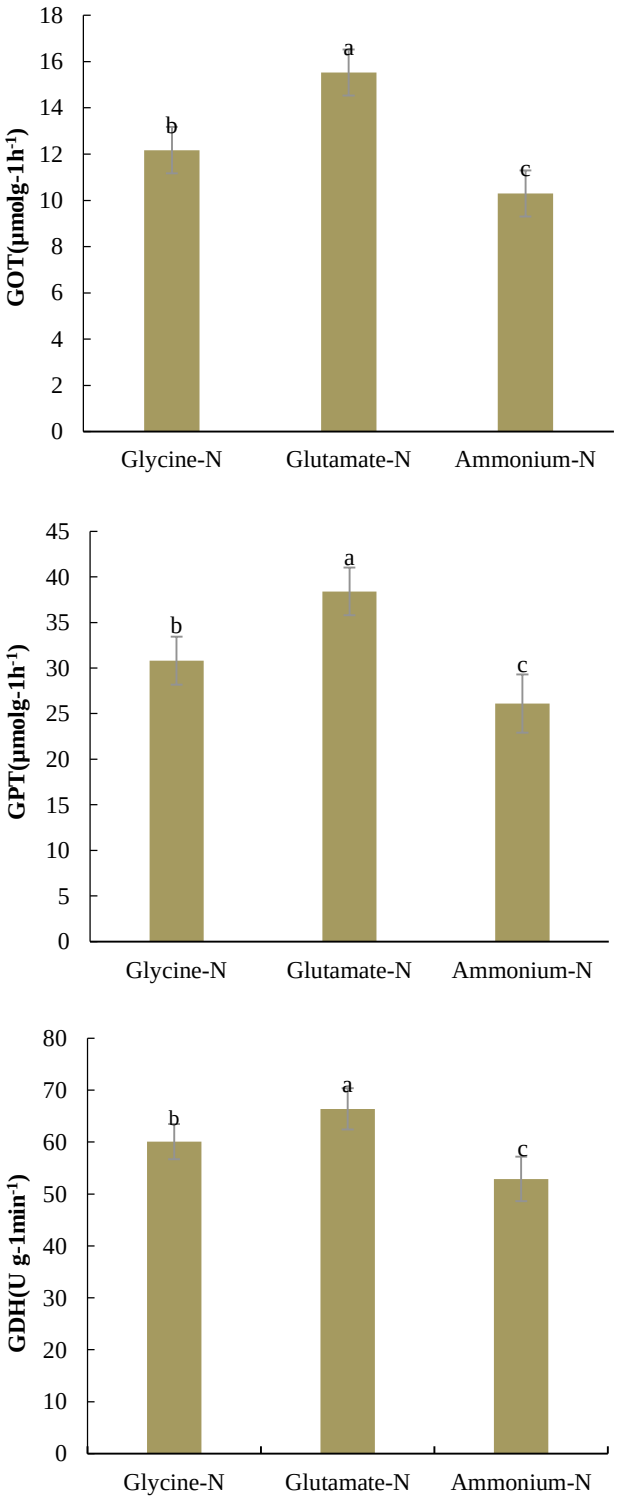

Fig. 3. GOT, GPT and GDH activity of rice plants cultured in Gly-N and NH_4^+-N hydroponic solution for 7 days.

Effects of various amino acid nitrogen sources on the activity of assimilation-related enzymes: As shown in Fig. 3, there is a close connection between the type of nitrogen source and the activity of GOT, GPT and GDH. Specifically, the activity of GOT, GPT and GDH peaked in rice seedlings cultured by Glu-N nutrient solution, followed by Gly-N, and then NH_4^+-N. The GOT activity in rice seeding cultured by Glu-N was 1.28 and 1.52 times of those by Gly-N and NH_4^+-N, respectively; the GPT activity in rice seeding cultured by Glu-N was 1.25 and 1.47 times of those by Gly-N and NH_4^+-N, respectively; the GDH activity in rice seeding cultured by Glu-N was 1.11 and 1.26 times of those by Gly-N and NH_4^+-N, respectively. This means amino acid nitrogen source could stimulate the transaminase and dehydrogenase of amino acids in rice seedlings.

Discussion

More than 90% of the total nitrogen in the soil is formed by organic nitrogen, while amino acid nitrogen, a hydrolysate of organic nitrogen, accounts for 13.3-52.0% of the total nitrogen (Nie *et al.*, 2011; Jones *et al.*, 2005). Glycine, one of the dominant amino acids in soils and fertilizers, has a simple structure and low molecular weight, which is therefore regarded as an ideal nitrogen source for evaluating the effects of amino acid nitrogen on plant nutrition (Adamczyk *et al.*, 2008). In the present research, 2-^{13}C-^{15}N-glycine was chosen as organic nitrogen source. The results suggest that there were ^{13}C and ^{15}N excess in all rice organs at different time intervals under 2-^{13}C-^{15}N-glycine treatment, and the ratio of ^{13}C excess/^{15}N excess (measured 24h after the treatment) approximated the theoretical value of 1:1. This means the ^{13}C of 2-^{13}C-^{15}N-glycine has been transported into the root system due to the absorption of molecular glycine by rice seedlings, which proves the capacity of rice seedlings to absorb complete glycine molecules from the solution. It is well reported that the glycine in the sterile hydroponics can be directly absorbed into the root system instead of undergoing enzymolysis before the absorption (Wu *et al.*, 1999). The findings of the present research work have also proved that amino acids can be taken in and utilized by rice roots and transported to stems and leaves. It was also observed that ^{13}C excess was significantly lower than ^{15}N excess, mainly because acarboxylic carbon labeled by 2-^{13}C-^{15}N-glycine can effectively reduce the decarboxylation of amino acids in plants and therefore less ^{13}C losses, but there were still ^{13}C losses due to the respiration of acarboxylic carbon through deamination and tricarboxylic acid cycle (Näsholm *et al.*, 2001). Consequently, the measured value of ^{13}C in rice seedlings would be lower than the actual absorption value because of respiration and metabolism.

It is known that the ^{13}C of 2-^{13}C-^{15}N-glycine taken in by plants, decompose and decrease in amounts due to respiration and metabolism (Näsholm *et al.*, 2001). For this reason，Therefore, it is more reliable and logical to use the measured value of ^{15}N as an indicator of the quantity of molecular glycine, absorbed directly in and utilized by plants. According to the findings of Näsholm *et al.*, 2001, the variation of ^{15}N excess is a good index of a plant's capability to directly take in and utilize molecular glycine. In the present work, the ^{15}N excess in rice organs and the whole seedling under glycine nitrogen was significantly higher than those under ammonium and nitrate nitrogen treatments, which means rice seedlings are capable of directly absorbing and utilizing glycine nitrogen, and the absorbed amount of glycine was much higher than those of ammonium and nitrate nitrogen, this may possibly be related to the genetic characteristics

(Inthapanya *et al*., 2000), development stages (Mo *et al*., 2011), and growth environment (Wang *et al*., 2010; Zhao *et al*., 2013) of rice. This indicates that plants are selective about what source of nitrogen is to take in from the environment, and the amount of nitrogen absorbed into plants would vary with the type of nitrogen source. It was reported earlier that plants are capable of actively absorbing amino acids through the specific carrier protein on their plasmalemmas (Yuan *et al*., 2009), and amino acid transporters exist on the surface of plant roots (Rentsch *et al*., 2007; Paungfoo *et al*., 2010), including the transport system for basic amino acids and the one for neutral or acidic amino acids (Tegeder *et al*., 2010). Conversely the absorption of ammonium nitrogen and nitrate nitrogen into plants was regulated by two different transport systems: the high-affinity transport system and the low-affinity transport system (Li *et al*., 2009). Thus it is concluded that the absorption of glycine nitrogen into rice seedlings is connected with the activity of the neutral amino acid transporters, however, further studies on the absorption mechanism are needed.

Organic nitrogen (e.g. glycine) absorbed into plants is assimilated through deamination, transamination and other reactions (Ma *et al*., 2004). In this research work, the activity of GOT and GPT in rice root under Gly-N treatment was much higher than under NH_4^+-N treatment, and the activity of GDH in rice leaf under Gly-N treatment was significantly higher than that of NH_4^+-N treatment. This indicates that most of the amino acids transamitted and assimilated in root system, and root is the major organ of rice seedling for amino acid transmination. Fraction of the amino acids absorbed into roots was transported to the leaves for deamination, which might be the cause of increased GDH activity in leaves. Thus rice leaves may be the major organ for amino acids deamination and assimilation. In contrast to this, the GDH activity in root under NH_4^+-N treatment was higher than that under Gly-N treatment, possibly because the deamination of glutamic acids is reversible when catalyzed by GDH. This reaction could stimulate the conversion of NH_4^+-N into glutamic acids in roots, which would then be transported to other organs to adjust the metabolic process and stimulate the smooth growth of rice plants. However, further investigation is needed to find out the exact cause of this phenomenon. As shown in Fig. 3, the activity of GOT, GPT, and GDH is subject to the type of nitrogen source; Glu-N and Gly-N can better motivate the activity of GOT, GPT and GDH in rice seedlings, revealing that amino acid nitrogen could facilitate the activity of amino acid transaminase and dehydrogenase.

Conclusion

The findings proves that rice seedlings are capable of directly absorbing and utilizing molecular glycine nitrogen; the amount of glycine nitrogen absorbed into rice seedlings was significantly higher than that of ammonium nitrogen and nitrate nitrogen ($p<0.05$). The amino acid nitrogen absorbed into the root system was transported to stems and leaves in the form of molecules; rice seedling's capability to absorb and transport nitrogen varies with the type of nitrogen source, and follows the order of glycine nitrogen > ammonium nitrogen > nitrate nitrogen. The glycine absorbed into rice plants was assimilated in roots, stems, and leaves by transamination and deamination to provide amino acids, proteins, and energy; the absorbing of organic nitrogen into rice plants would effectively improve the activity of GOT, GPT, and GDH, and the degree of activity is connected with the type of nitrogen source.

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