Nitrogen Isotopes in Plants
Nitrogen: The Basics
Nitrogen: The Basics

Nitrogen Gas

Ammonium

Nitrate
Nitrogen Assimilation

Ammonium (NH$_4^+$)

Nitrate (NO$_3^-$)
Since nitrogen is a limiting nutrient, plants can’t be picky...

\[ \frac{{^{15}\text{N}}}{{^{14}\text{N}}} = \frac{5}{10} \]

\[ \delta^{15}\text{N} = \frac{5}{10} \]
Ammonium ($\text{NH}_4^+$) → Nitrite ($\text{NO}_2^-$) → Nitrate ($\text{NO}_3^-$)

Assimilation

Nitrification
The reactant (ammonium) contains more $^{15}\text{N}$ than the product (nitrate).

The reactant (ammonium) has a higher $\delta^{15}\text{N}$ value than the product (nitrate).
Ammonium \((\text{NH}_4^+)^+\)

Nitrate \((\text{NO}_3^-)\)

Nitrite \((\text{NO}_2^-)\)

Assimilation

Nitrification
Denitrification

Atmospheric Nitrogen ($N_2$)

Assimilation

Ammonium ($NH_4^+$)

Nitrite ($NO_2^-$)

Nitrate ($NO_3^-$)

Assimilation

Bacteria

Bacteria

Bacteria
Denitrification: Lighter Goes Faster

The reactant (nitrate) contains more $^{15}$N than the product ($N_2$).

The reactant (nitrate) has a higher $\delta^{15}$N value than the product ($N_2$).
Denitrification

- Atmospheric Nitrogen ($N_2$)
  - $\downarrow^{15}N$  
  - $\downarrow^{\delta^{15}}N$

- Ammonium ($NH_4^+$)
- Nitrite ($NO_2^-$)
- Nitrate ($NO_3^-$)

Assimilation

$\uparrow^{15}N$  
$\uparrow^{\delta^{15}}N$
Nitrogen Fixation

$\delta^{15}N = 0\%$

Atmospheric Nitrogen ($N_2$)

Assimilation

Ammonium ($NH_4^+$)

Assimilation

Nitrite ($NO_2^-$)

Assimilation

Nitrate ($NO_3^-$)
Nitrogen Fixation

On land (in soils), N\textsubscript{2} fixation is mostly done by rhizobia (a type of bacteria). In aquatic (marine and freshwater) ecosystems, it is mostly done by cyanobacteria.

Atmospheric N\textsubscript{2}  

\begin{align*}
\frac{^{15}\text{N}}{^{14}\text{N}} &= \frac{5}{10} \\
\delta^{15}\text{N} &= \frac{5}{10}
\end{align*}

Ammonium (NH\textsubscript{4}\textsuperscript{+})

\begin{align*}
\frac{^{15}\text{N}}{^{14}\text{N}} &= \frac{5}{10} \\
\delta^{15}\text{N} &= \frac{5}{10}
\end{align*}
Ammonium (NH$_4^+$)

Nitrate (NO$_3^-$)

Nitrite (NO$_2^-$)

Atmospheric Nitrogen (N$_2$)

$\delta^{15}N = 0\%$

Nitrogen Fixation

Assimilation

Assimilation
Ammonium (NH$_4^+$)

Nitrate (NO$_3^-$)

Nitrite (NO$_2^-$)

Atmospheric Nitrogen (N$_2$)

The form of inorganic nitrogen a plant uses strongly influences its $\delta^{15}$N values!
Wide Range in $\delta^{15}$N Values in New Mexican Plants and Algae!
Plant Nitrogen
Take Home Points

• Transformations between different types of inorganic nitrogen produce the largest isotopic fractionations in the nitrogen cycle

• All of these transformations are done by bacteria (microbes rule the world, and they certainly rule the nitrogen cycle)

• During chemical transformations, lighter molecules (containing $^{14}$N) move faster, resulting in lots of variation in $d^{15}$N values of both the organic and inorganic pools of nitrogen