The role of ammonia in plant physiology

Ineke Stulen, Ana Castro, and Luit J. De Kok

Laboratory of Plant Physiology
University of Groningen
The Netherlands

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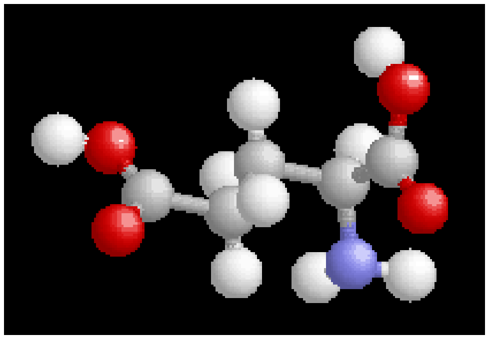
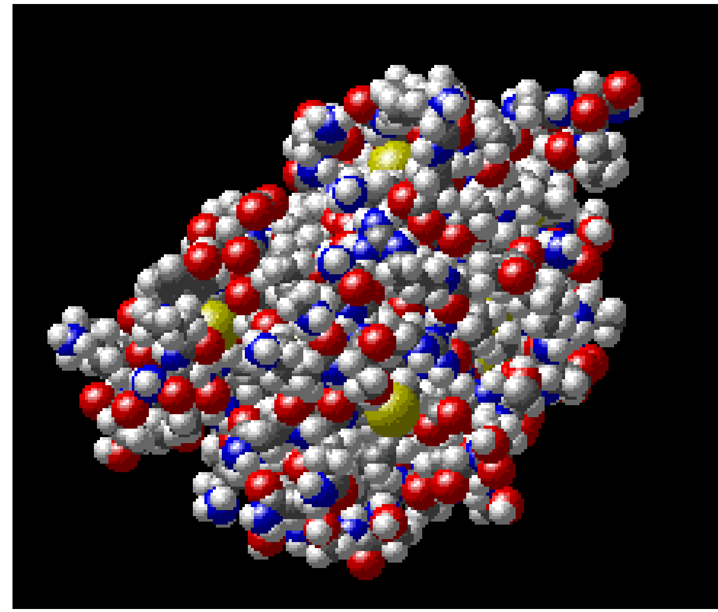
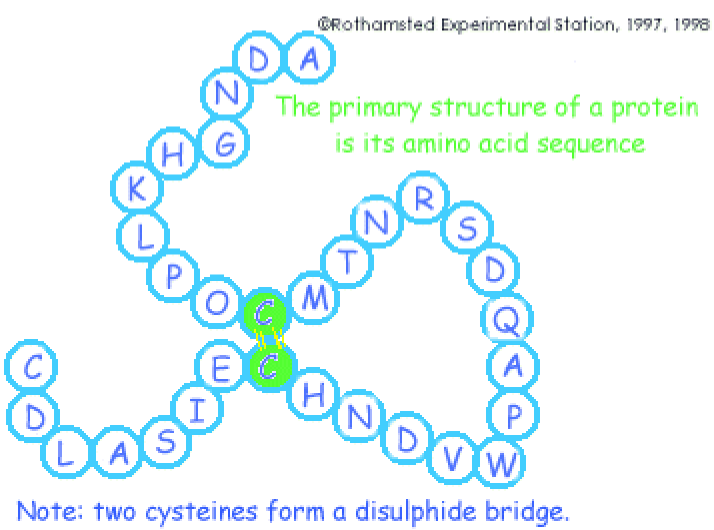
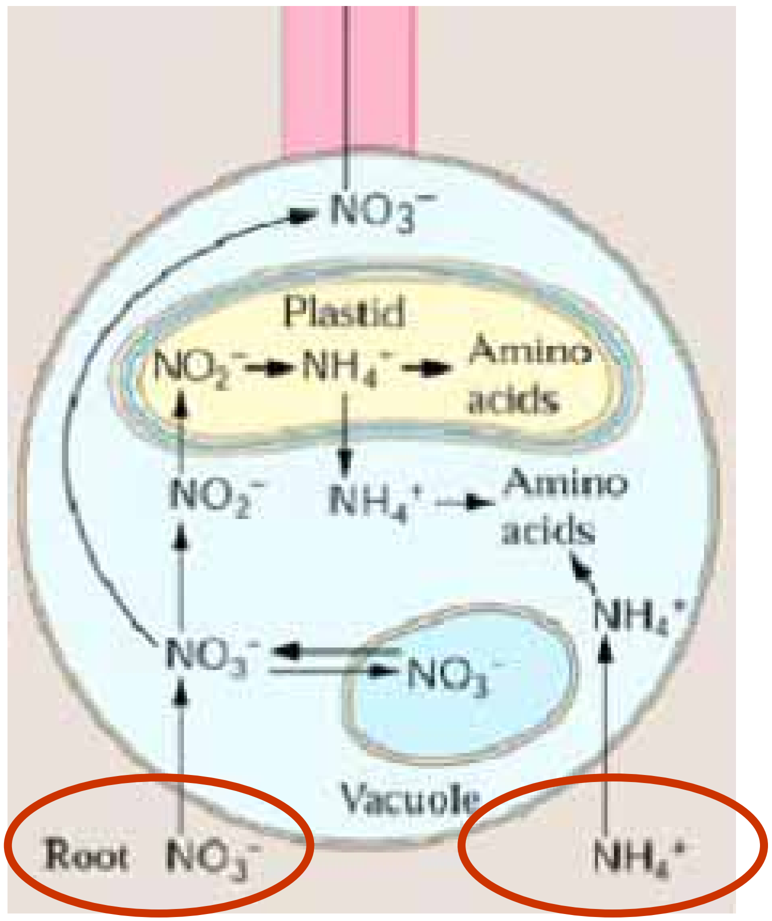
N is essential – amino acids and proteins



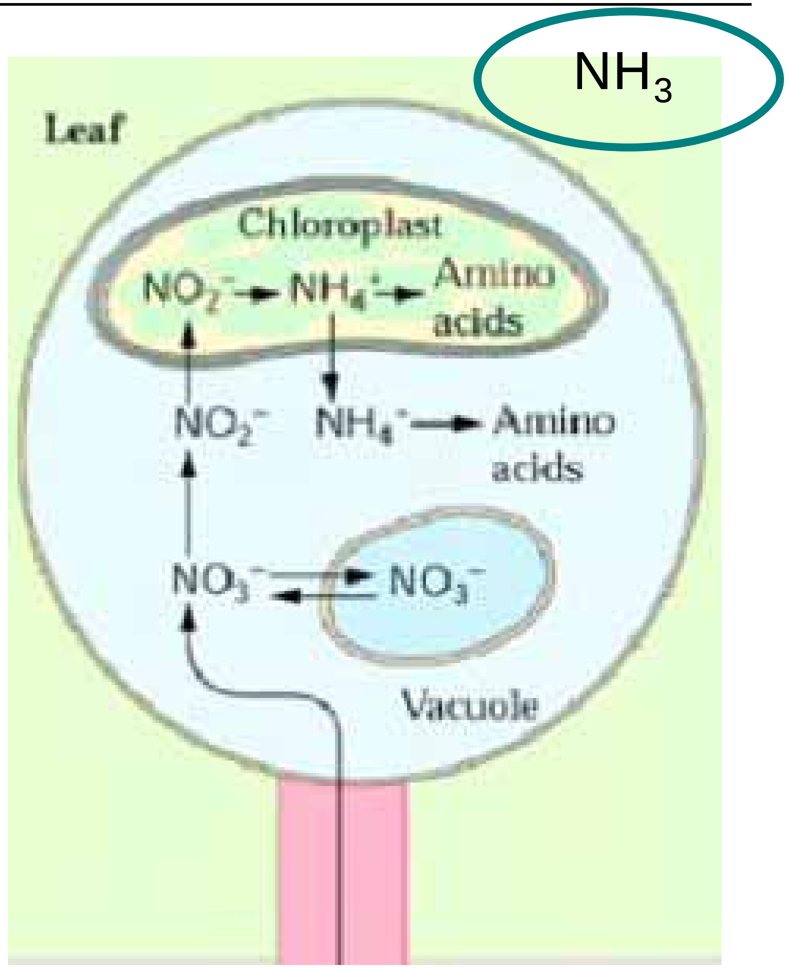




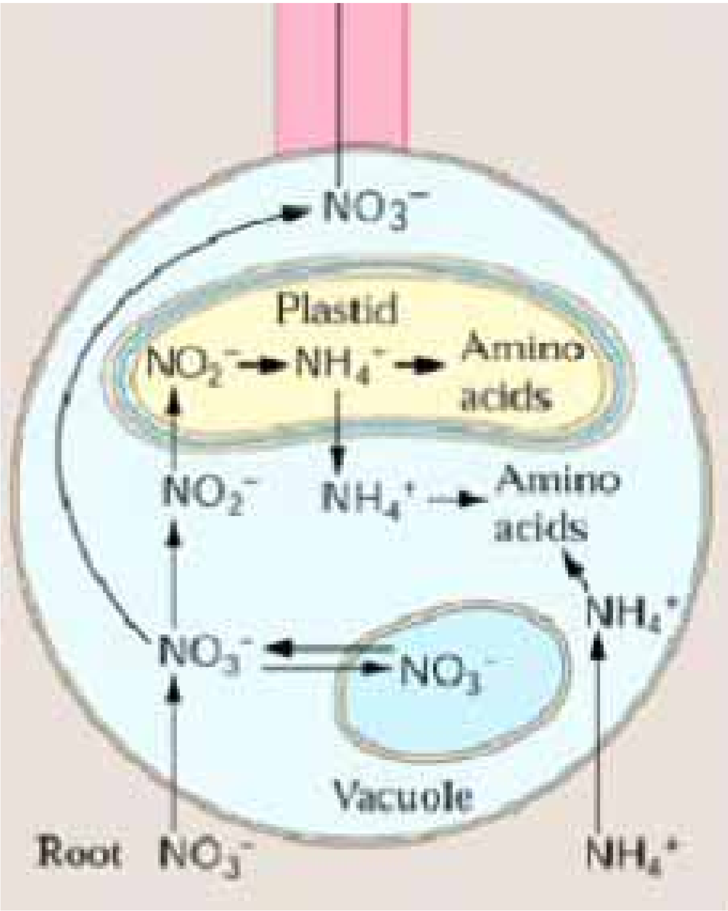
N uptake and assimilation



nitrate ammonium



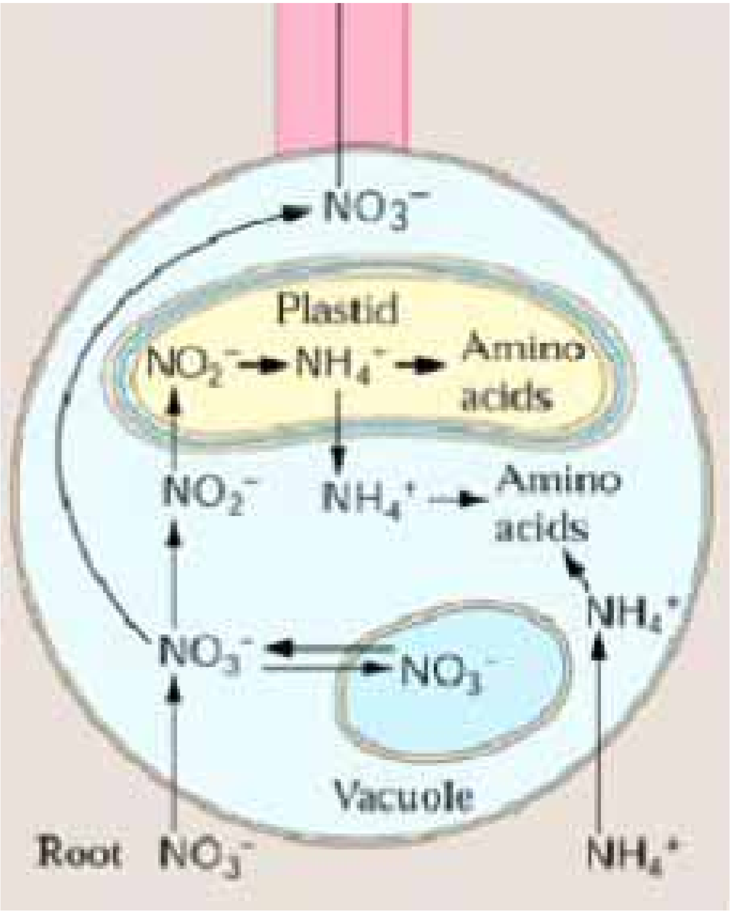
N assimilation - root



nitrate ammonium

- NO_3^- and NH_4^+ actively taken up by transporters

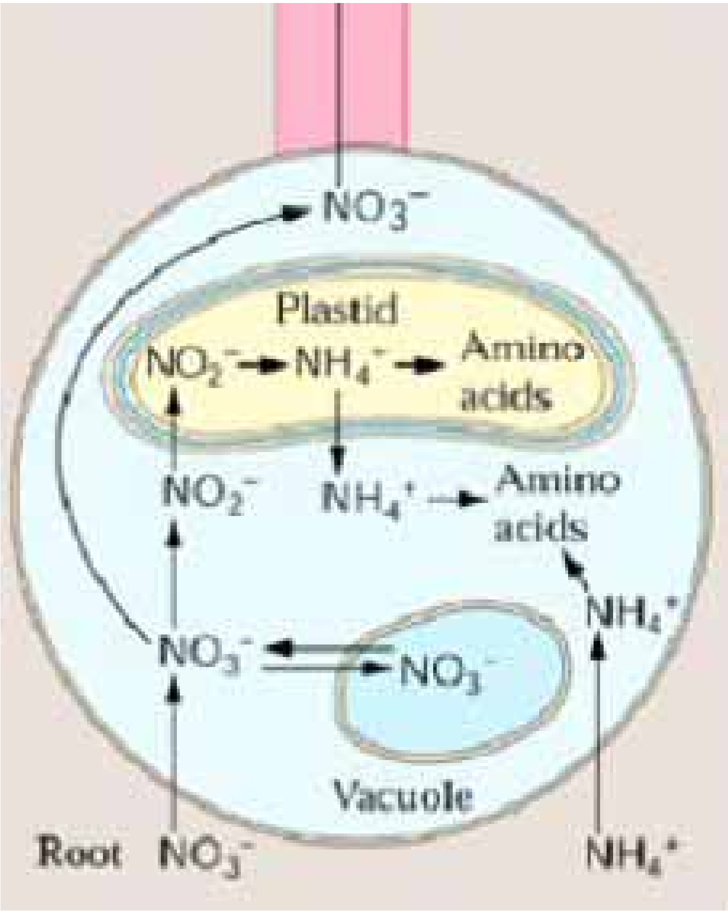
N assimilation - root



nitrate ammonium

- NO_3^- and NH_4^+ actively taken up by transporters
- NO_3^- reduced, and transported

N assimilation - root



nitrate ammonium

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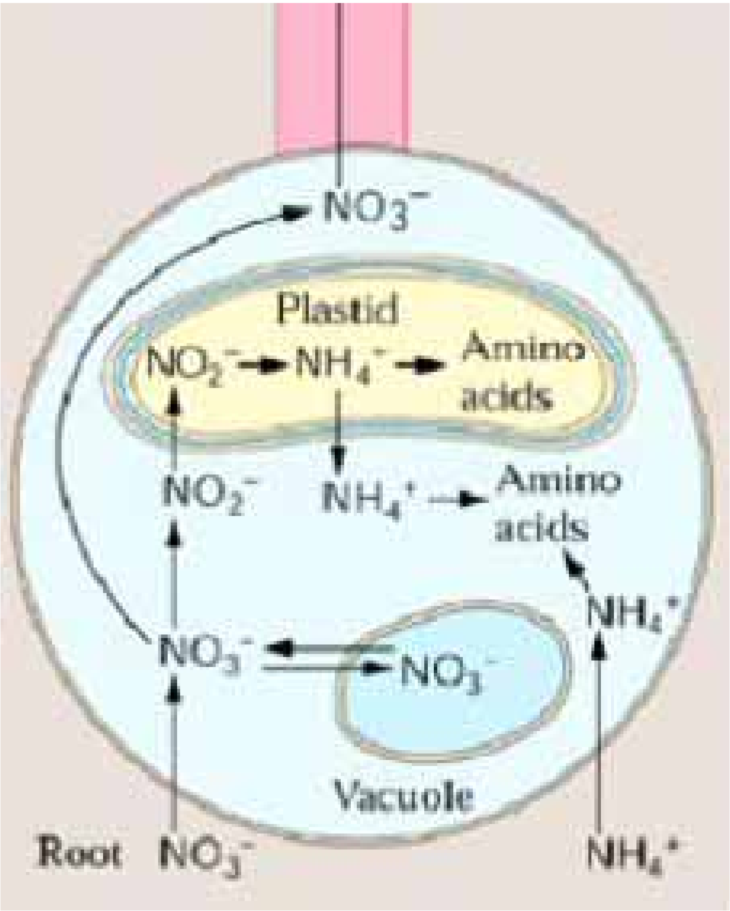
N assimilation - root

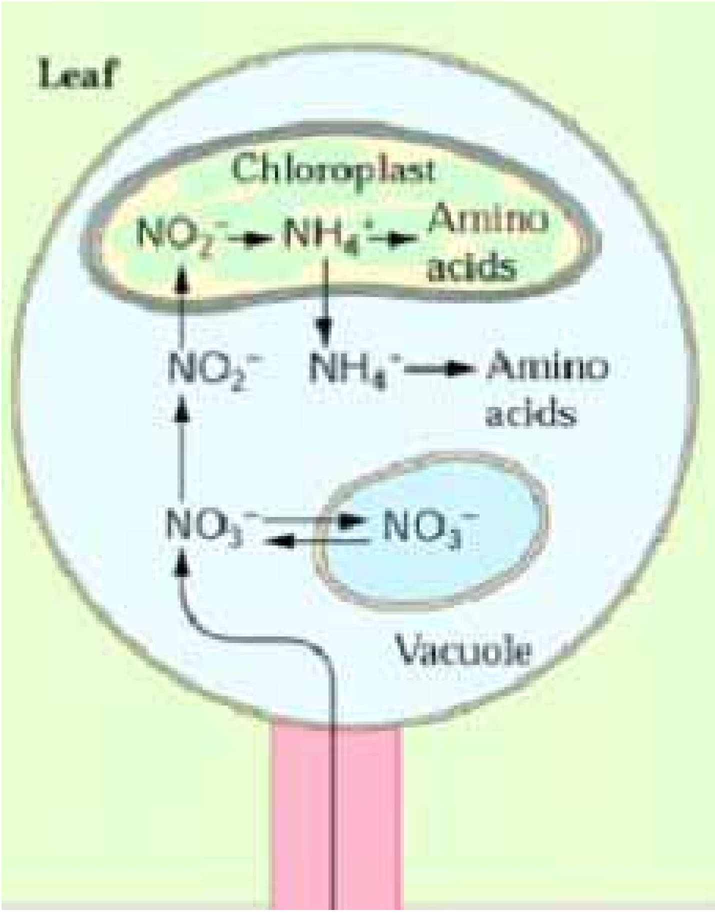


nitrate ammonium

- NO_3^- and NH_4^+ actively taken up by transporters
- NO_3^- reduced, and transported
- NH_4^+ attached to a C skeleton (GS)
- amino acids formed
- used in protein synthesis

N assimilation - leaf

- NO_3^- reduced
- NH_4^+ attached to a C skeleton



N assimilation - leaf

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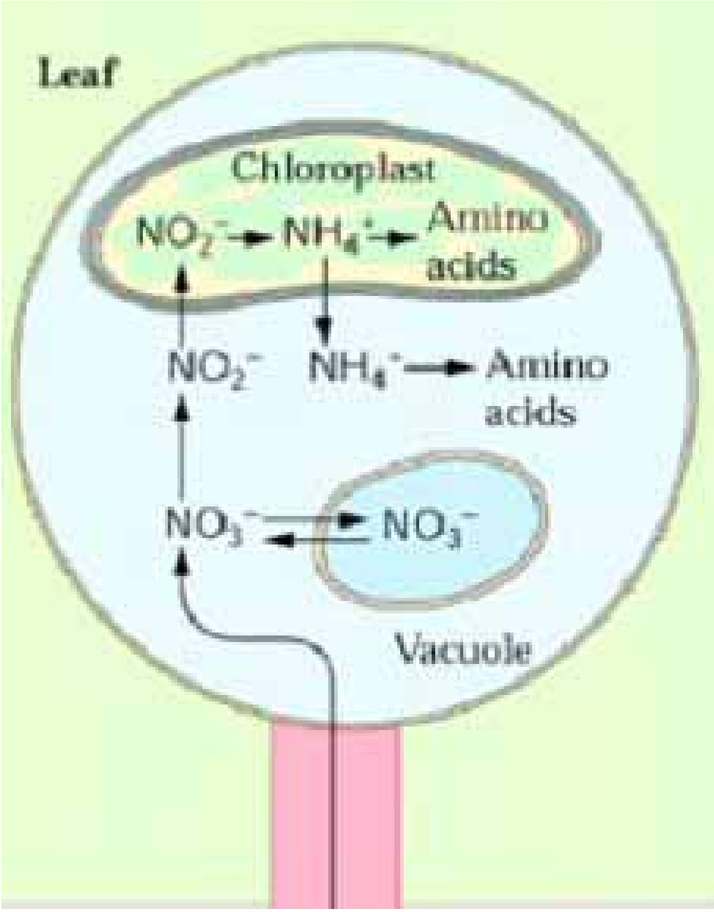
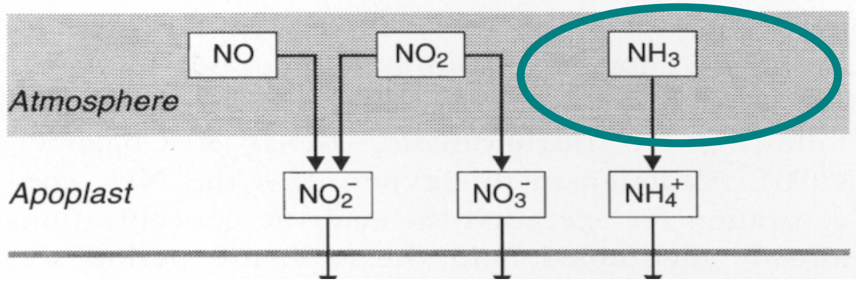


Atmospheric NH_3 deposition

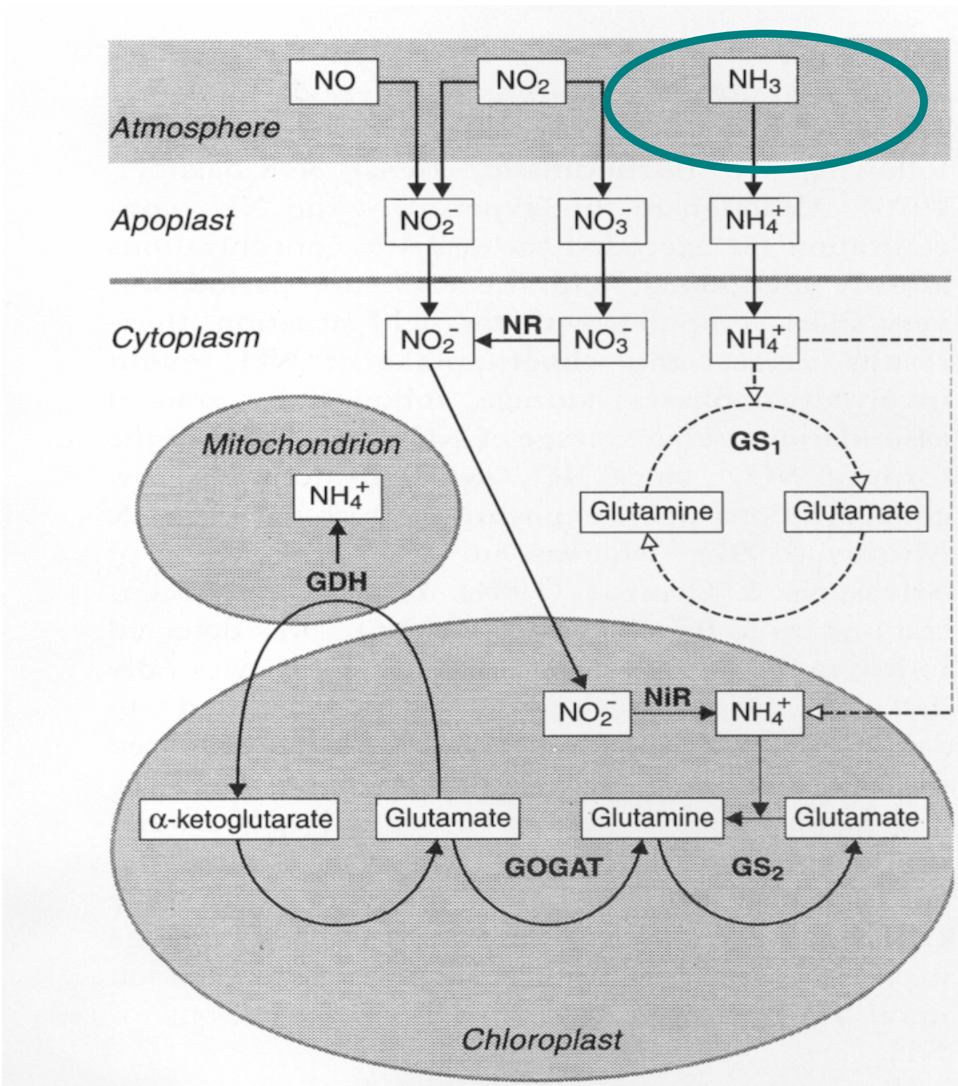


NH_3 taken up

dissolved in apoplast

NH_4^+ formed

Atmospheric NH_3 deposition



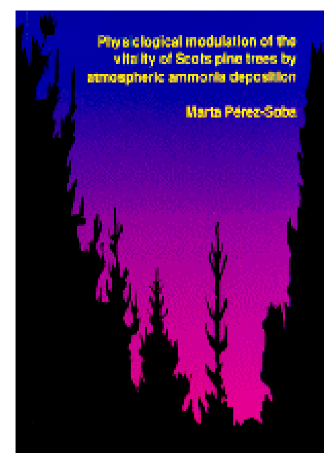
NH_3 taken up

dissolved in apoplast

NH_4^+ formed

NH_4^+ assimilated by

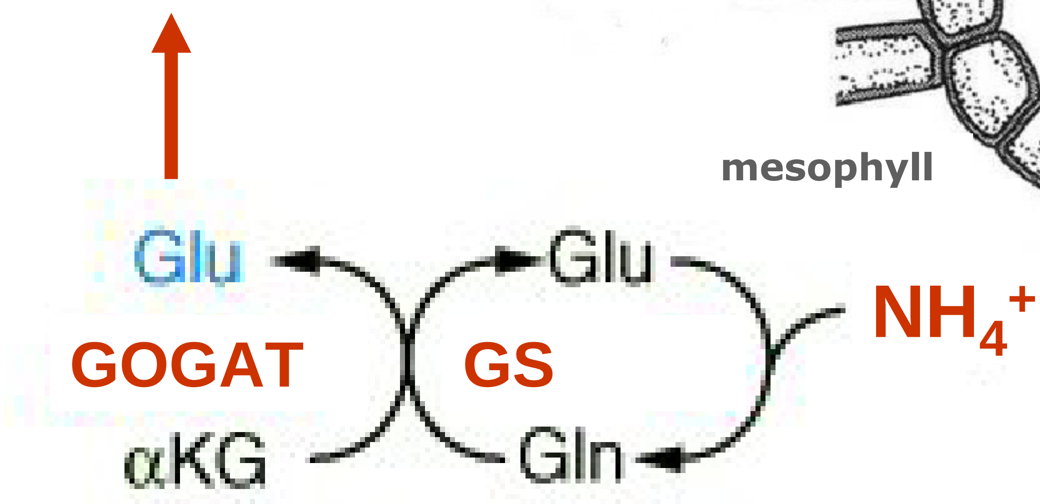
glutamine synthetase(s)

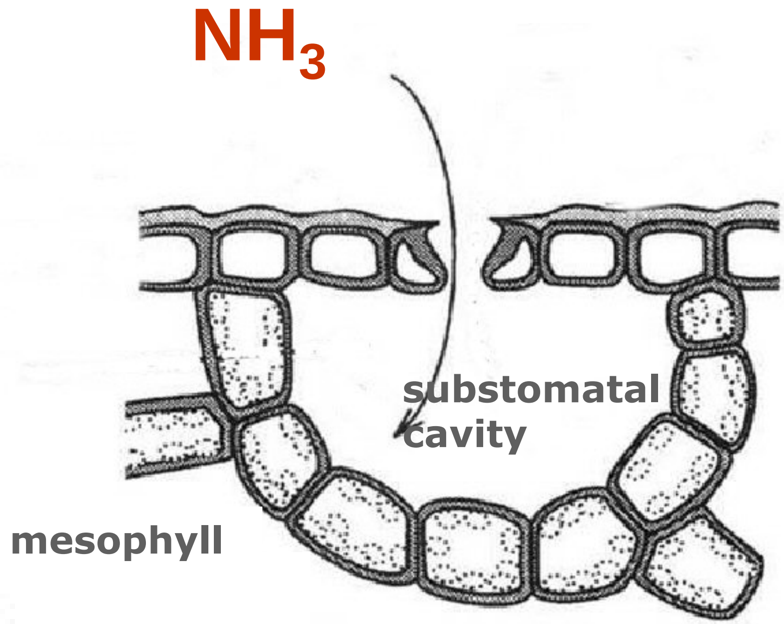


M. Pérez-Soba, 1995

Atmospheric NH_3 as N source

proteins
amino acids





GS - glutamine synthetase – high affinity for NH_4^+

Atmospheric NH_3 as N source
underlying physiological processes

series of experiments with *Brassica oleracea* (curly kale)

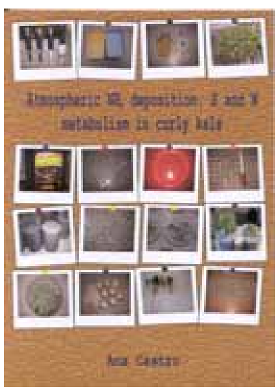
exposed to a range of NH_3 concentrations (0 - 8 µl l^{-1}) for one week

controlled environmental conditions

in nutrient solution, with and without nitrate

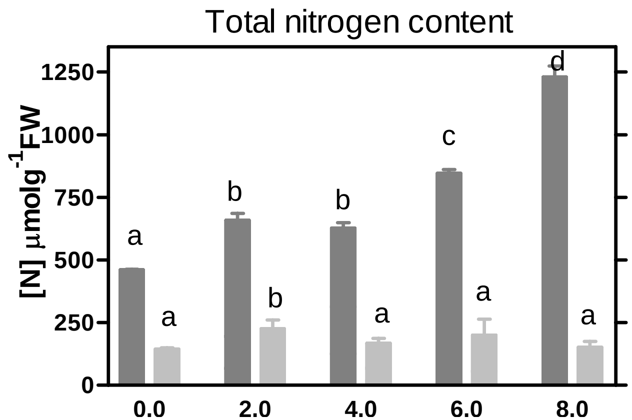
Atmospheric NH_3 as N source
underlying physiological processes

- contribution to the N requirement for growth?
- effect on root NO_3^+ uptake ?



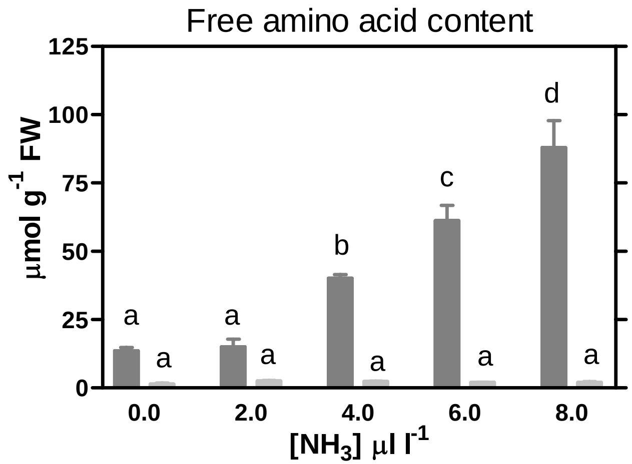
A. Castro, 2006

Atmospheric NH_3 as N source
underlying physiological processes



Increase in total N and amino acids up to the highest [NH_3]

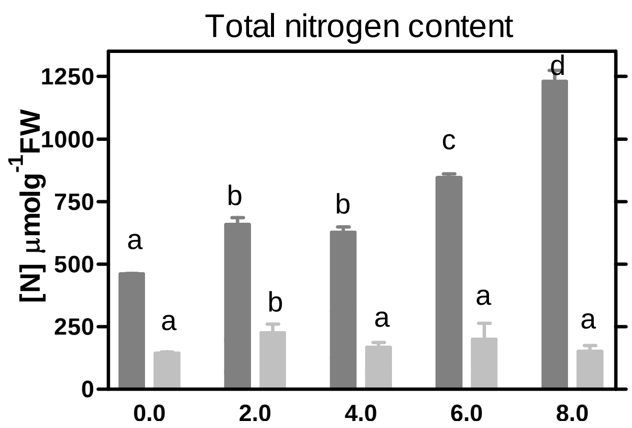
Plants grown with nitrate in the nutrient solution

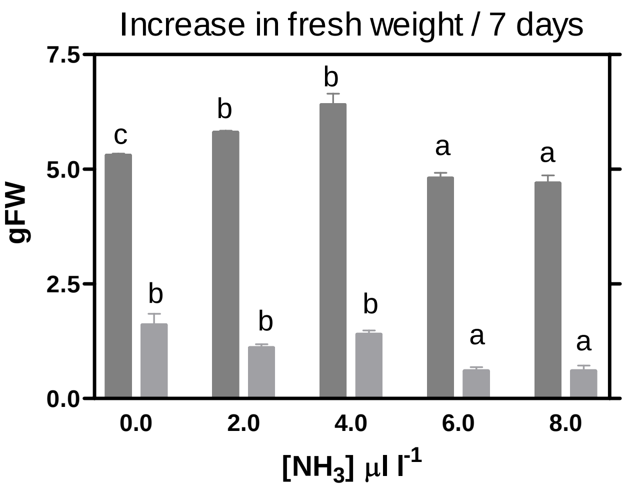


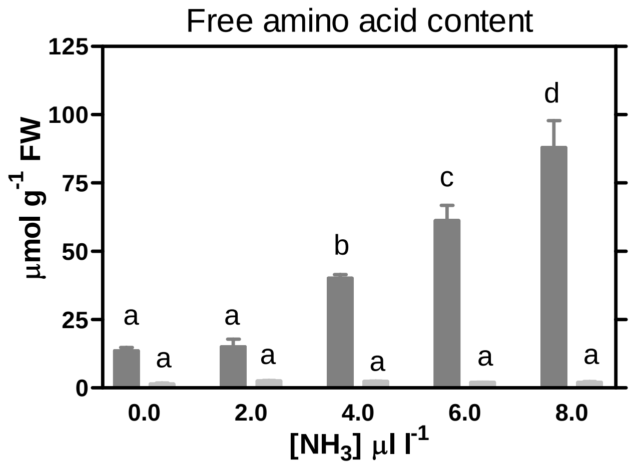
"Metabolic detoxification" – capacity of the GS/GOGAT system to assimilate NH_4^+ -

is high over the whole range

Atmospheric NH_3 as N source
underlying physiological processes







growth (increase in fresh weight) is reduced at 6 and 8 µl l^{-1} NH_3

although "detoxification" is still possible, shoot and root growth are reduced!

Atmospheric NH_3 as N source
contribution to N nutrition

	Control		4 µl l^{-1} NH_3	
	+ NO_3^-	- NO_3^-	+ NO_3^-	- NO_3^-
Biomass S	1.19^{c}	0.29^{a}	1.17^{bc}	1.03^{c}
Biomass R	0.24^{b}	0.35^{cd}	0.10^{a}	0.35^{abcd}
DW % S	8.9^{a}	17^{d}	12^{bc}	12^{a}
Total N S	618^{c}	414^{a}	917^{e}	803^{d}
AA S	14^{b}	9^{a}	73^{d}	64^{d}
Total N R	317^{c}	202^{a}	348^{c}	339^{c}
AA R	11^{a}	13^{a}	24^{c}	25^{c}

Experiments with *B. oleracea,* grown in nutrient solution, + and – NO_3^-, fumigated with 4 µl l^{-1} NH_3 (Castro, 2006)

S shoot; R root; biomass production in g; N and amino acids (AA) in µmol g^{-1} FW

Plants can grow well with NH_4^+ as sole N source

Atmospheric NH_3 as N source
contribution to N requirement for growth

N requirement for growth can be defined as

$N_{requirement} = (RGR) \times N_{content}$

in which RGR is the relative growth rate

$g\ g^{-1}\ day^{-1}$

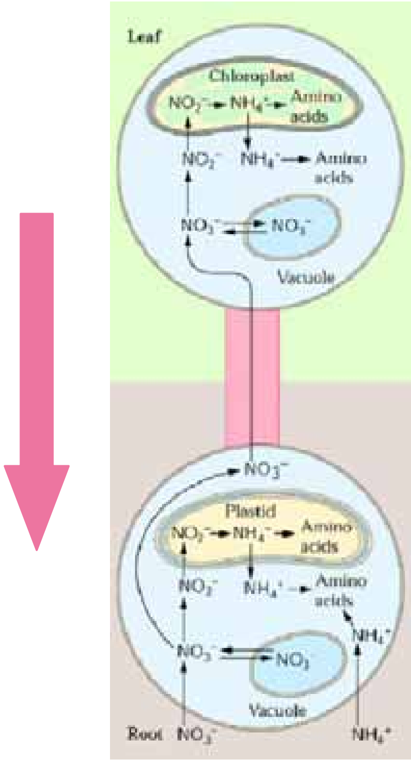
4 $\mu l\ l^{-1}$ NH_3 as sole N source can contribute considerably (70-80%) to the N requirement for growth

in agreement with theoretical calculations (Stulen *et al*, 1998) and Raven (1998)

Atmospheric NH_3 as N source
effect on root uptake

Does fumigation with 4 µl l^{-1} NH_3 reduce root NO_3^- uptake?

reduced N compound



Root NO_3^- uptake

Atmospheric NH_3 as N source

effect on root uptake

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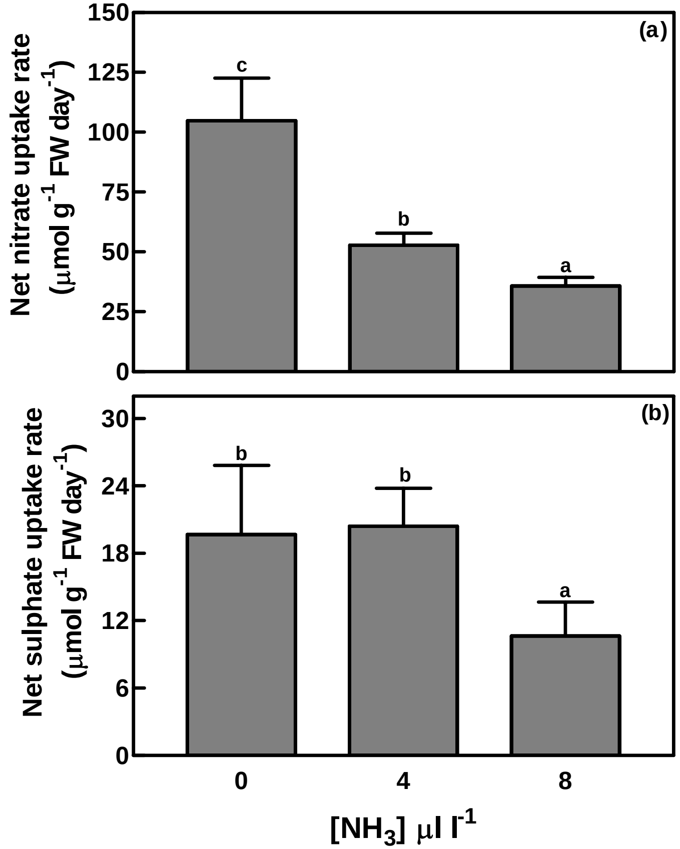
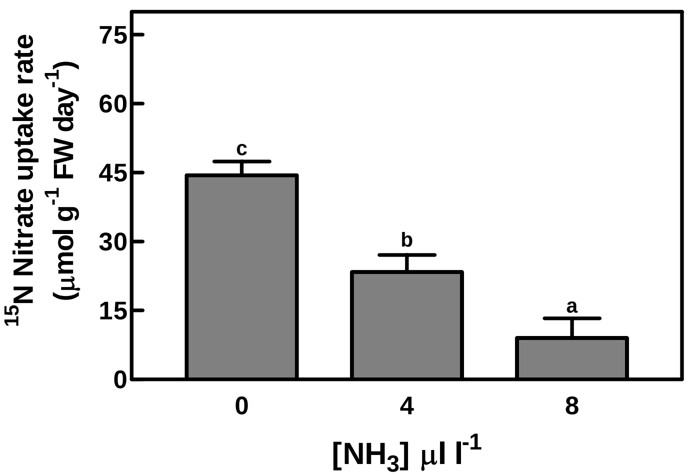




signal – specific AA

Atmospheric NH_3 as N source
underlying physiological processes

- contribution to the N requirement √
- effect on root uptake √

- nutrient *vs* toxin? both
- mechanisms of NH_4^+ toxicity?

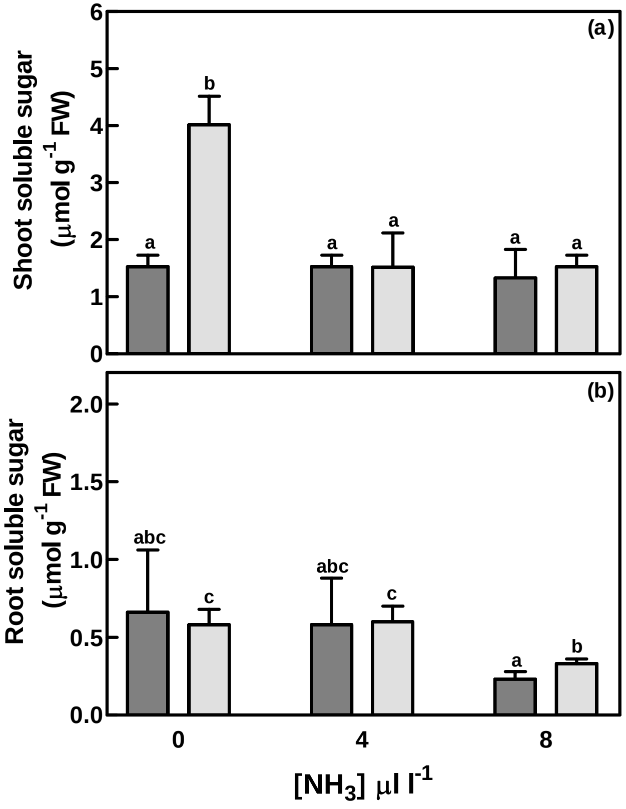
Atmospheric NH_3

proposed mechanisms of toxicity – evidence?

1. Insufficient "detoxification" capacity
   – no evidence

2. Shortage of sugars?

Atmospheric NH_3
shortage of sugars?



The impact of NH_3 on soluble sugar content in shoot (a) and roots (b). + NO_3^- and – NO_3^- treatments are given in dark and light-grey bars, respectively.

2. "Shortage of sugars? – no evidence

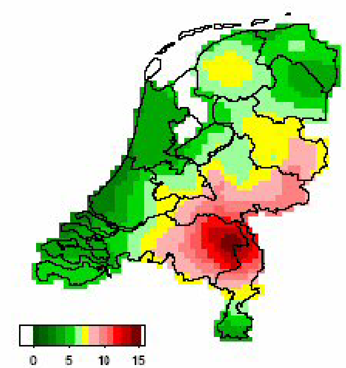
Atmospheric NH_3

proposed mechanisms of toxicity

1. Insufficient "detoxification" capacity no evidence
2. Lack of sugars for the assimilation of NH_4^+ no evidence
3. Cation imbalances – impaired root uptake ?
4. Ethylene response

experiments in nutrient solution
$[NH_3]$ 0 – 8 µl l^{-1}

yearly average concentration:
6.6 µg m^3 – 9.3 nl l^{-1}
5.1 µg m^3 – 8.0 nl l^{-1}
peak concentrations:
> 2 µl l^{-1}



soil/root compartment

Atmospheric NH_3 – nutrient or toxin?

nutrient

detoxification

inhibition of growth

toxin

gradual - depending on plant species

The role of NH_3 in plant functioning

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There is no clear-cut transition in the level of metabolism of the absorbed atmospheric NH_3 and its phytotoxicity.

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The physiological basis of the phytotoxicity of atmospheric NH_3 is still largely unknown.

There is no clear-cut transition in the level of metabolism of the absorbed atmospheric NH_3 and its phytotoxicity.

The effect of atmospheric NH_3 on plants might be strongly dependent on the soil nutrient status.