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Fakultät für Naturwissenschaften und Technik
Facoltà di Scienze e Tecnologie
Faculty of Science and Technology

# Nitrogen fertilization in pome fruit trees

## La fertilización nitrogenada en frutales de pepita

*Massimo Tagliavini*

**16ª Reunión RUENA**
**Madrid, 24.04.2018**

# Contents

1. The reference frame/the main challenges
2. Special features of fruit trees affecting N nutrition
3. Tree responses to changes in N availability
4. Tree N fluxes: internal cycling, uptake…
5. N fluxes at orchard level
6. Management of the N supply
7. Final remarks

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# Growers‘ expectations

- Income
  - Low production costs
  - High yields
  - High fruit quality
  - Adequate prices for the produce
- Good working conditions/Quality of life

# Society‘s and Consumers‘ expectations

- Healthy and accessible food (fruits)
- Null/Low impact of the production cycle on the environment

# *Environmental Performances* concept includes

- Efficient use of limited or not-renewable resources
- Null/low transfer of polluting molecules to air and water-bodies
- Maintenance/enhancement of soil fertility

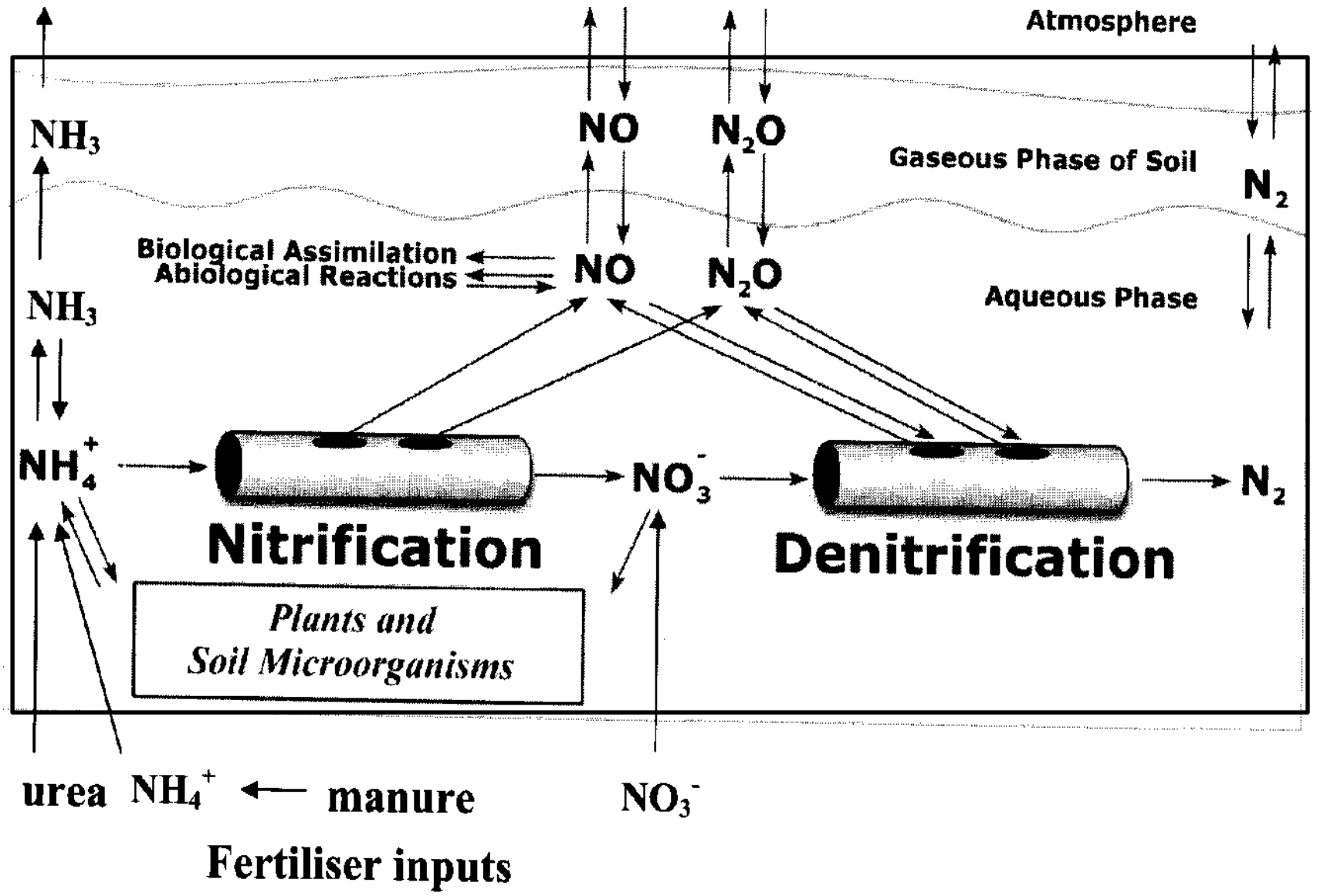
# *Environmental Performance* concept includes

- **Efficient use of limited or not-renewable resources**
- Null/low transfer of polluting molecules to air and water-bodies
- Maintenance/enhancement of soil fertility

The carbon footprint *(0.9-1.8 kg CE/kg N), due to* the amount of energy *(approx. 76 MJ/kg N)* involved in the life cycle of synthetic N fertilizers has some impact on the GHG emissions and fossil fuel sources

# *Environmental Performance* concept includes

- Efficient use of limited or not-renewable resources
- **Null/low transfer of polluting molecules to air and water-bodies**
- Maintenance/enhancement of soil fertility




The “Hole-in-the-Pipe” conceptual model from Fireston and Davidson (1989) and Davidson (2000)

# The main challenge

**How to reconcile tree productivity and environmental issues**

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# Features of fruit trees affecting N nutrition and N supply

1. **Orchard perennial life cycle**
2. Orchard design allows the permanent/temporary presence of other herbaceous species (plants' interactions, beneficial effects or competition for N)
3. The same variety can be grafted on rootstocks differing in root growth and specific nutrient uptake ability.
4. Rather limited amounts of N annually removed with the fruits as compared to other horticultural and field crops

# Orchard perennial life cycle

- Internal tree N cycle

- N nutrition in one year is affected by the N status the previous year(s)

# Features of fruit trees affecting N nutrition and N supply

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40

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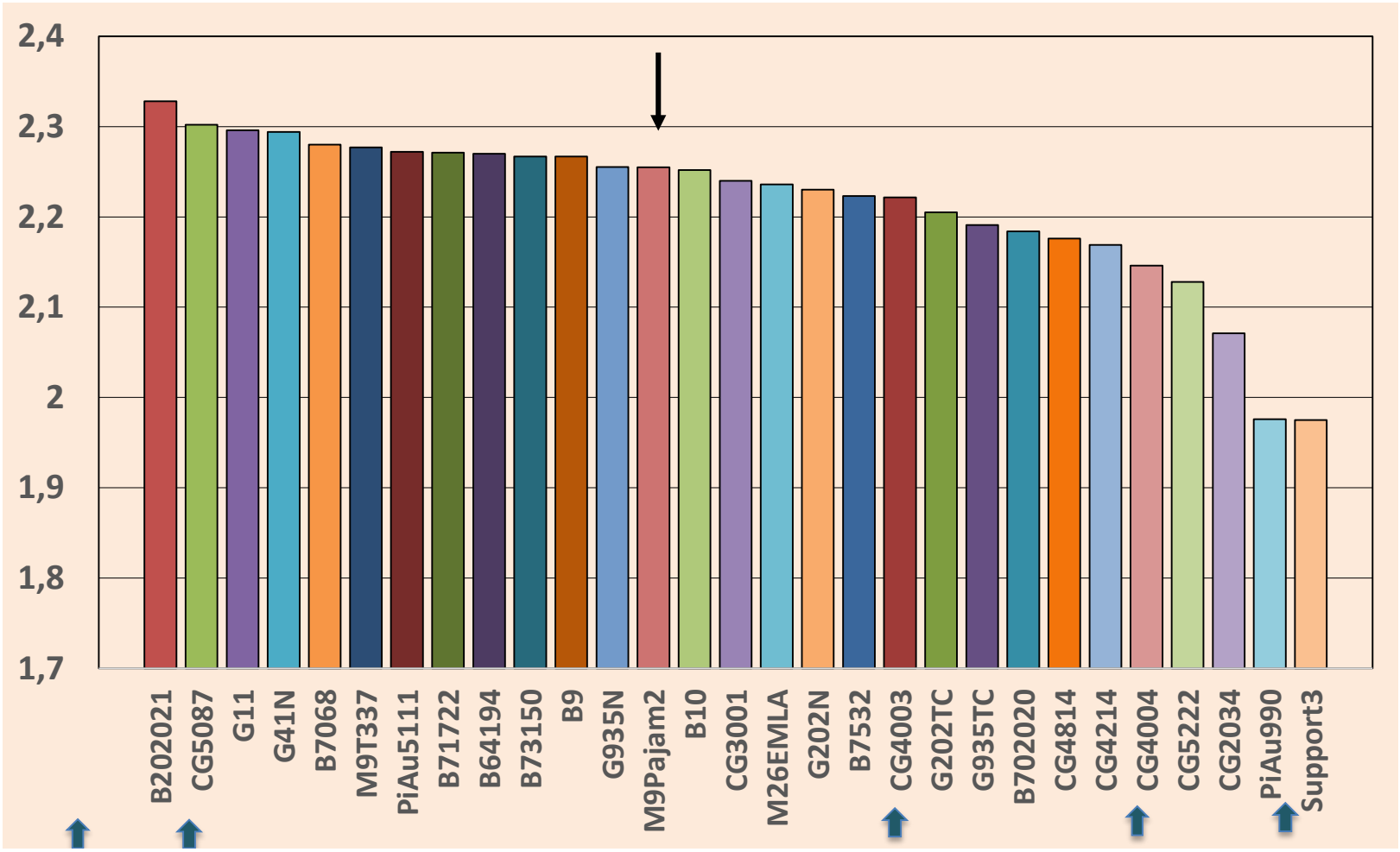
# Average Leaf N (% DW) in 'Aztec Fuji' on Various Rootstocks average 2012-2014




Courtesy Fallahi, 2017

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4. **Rather limited amounts of N annually absorbed and removed by the fruits as compared to other horticultural and field crops**

# Indicative amounts of absorbed-N and N removed by the crop

| | Yields T/ha | Total N uptake Kg/ha | N removed by produce Kg/ha (% of total) |
|---|---|---|---|
| Cauliflower | 40 (curds) | 380 | 115 (30%) |
| Wheat | 7-10 (grain) | 203-300 | 160-230 (78%) |
| Apple | 40-70 (fruits) | 61-103 | 22-32 (31-36%) |
| Pear | 40 (fruits) | 58 | 18 (31%) |

Internal data and selected literature

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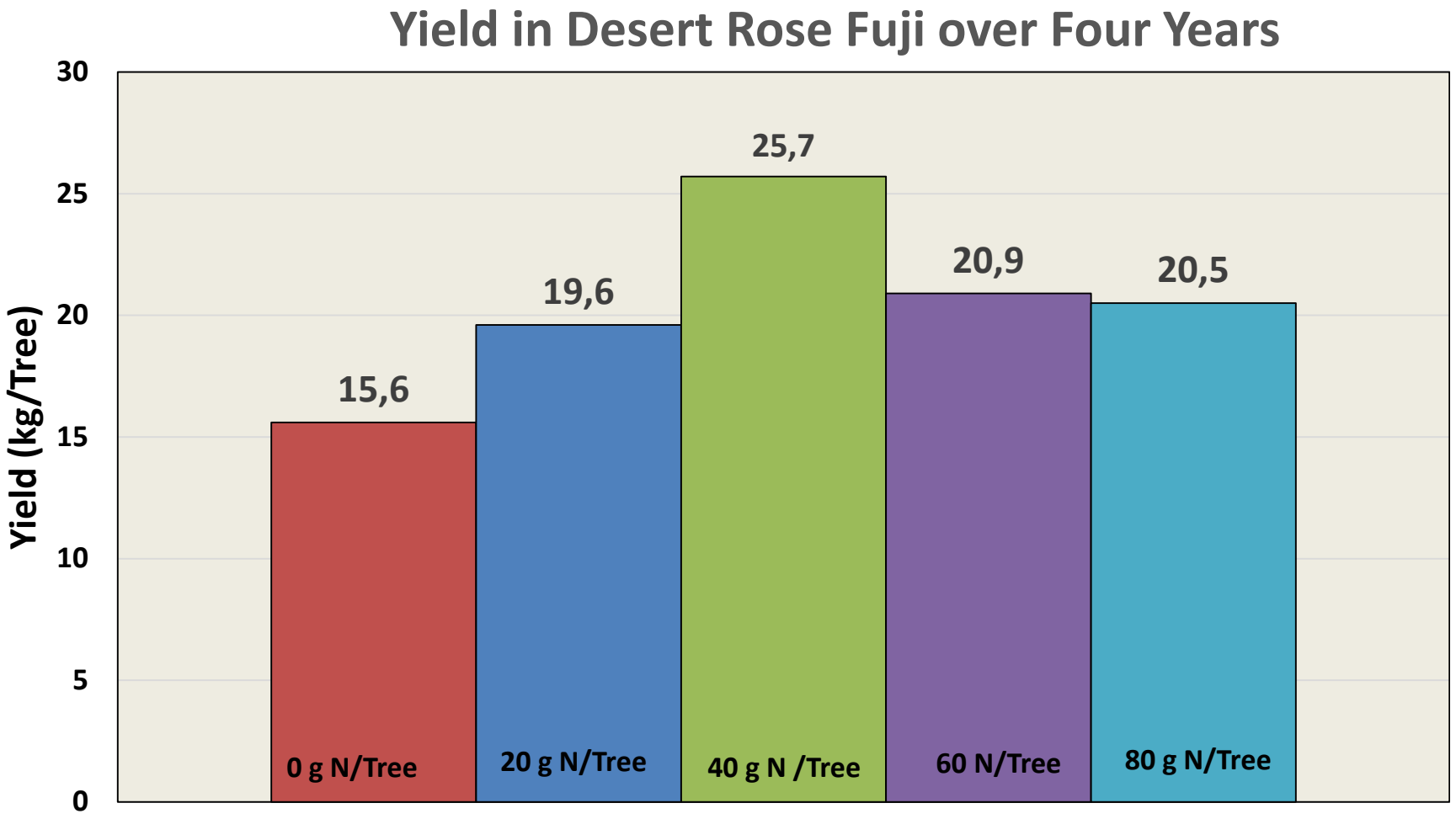
# Effects of N on apple and pear trees

Within a relative wide range of N availability, shoot growth increases at increasing soil N

| N supply level | Apple Shoot growth | Apple Root biomass |
|---|---|---|
| | (cm/tree) | (g/tree) |
| **N1** | **41** | **56** |
| **N2** | **96** | **49** |
| **N3** | **103** | **61** |

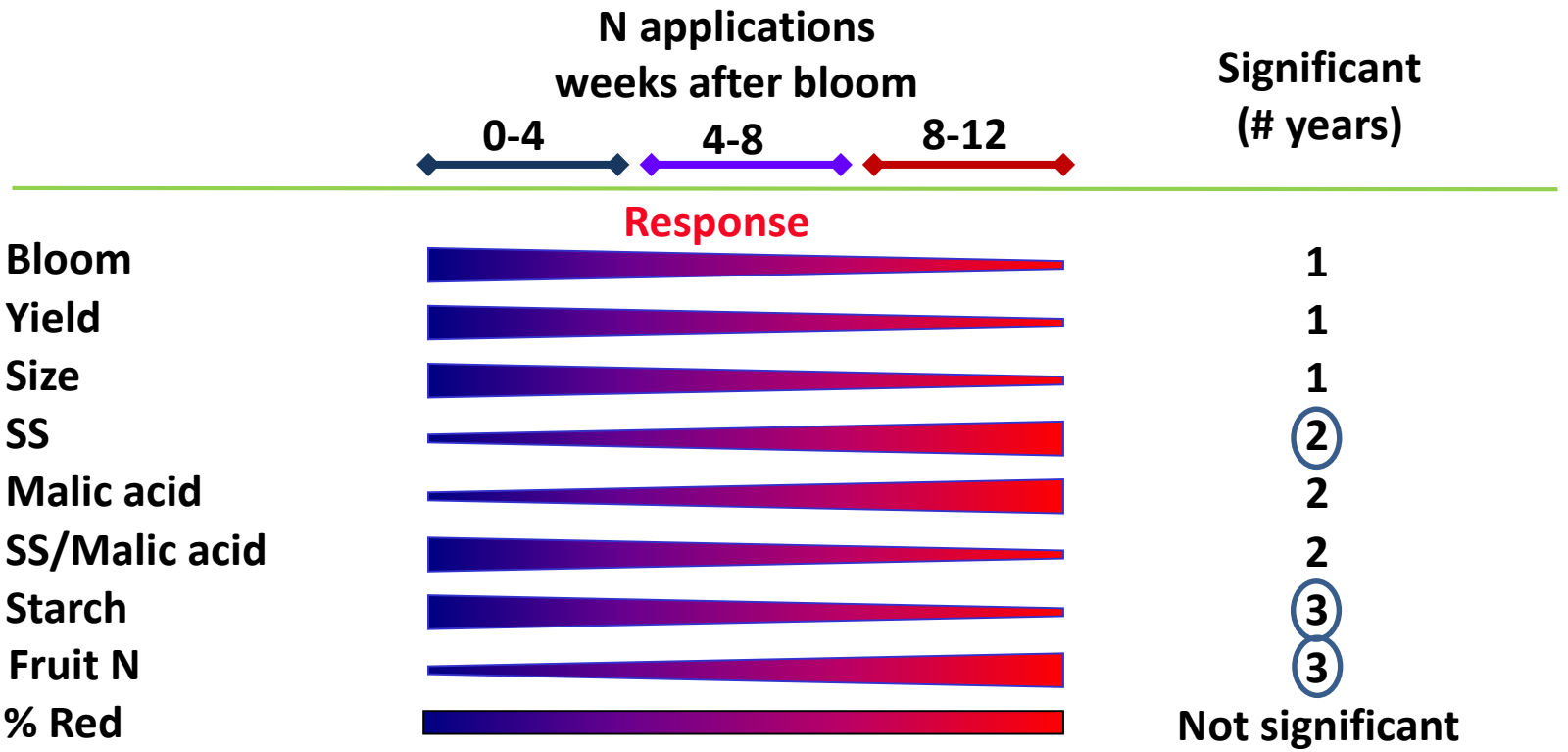
Zanotelli personal communication




Courtesy Fallahi and Neilsen, 2017

# Effect of timing of N applications on Gala/M.9 over 3 years

(Neilsen personal communication 2017)




- Late N applications accelerated maturity (starch content, SS)
- High fruit N concentrations at harvest potentially detrimental to storage

# Fruit quality

- Excessive tree N uptake
  - poorly colored fruits (potential problem for apples) due to a shading effect (vigorous shoot growth) and a higher fruit N (retarded chlorophyll degradation). *Shading could also help reducing sun-burn risks!*

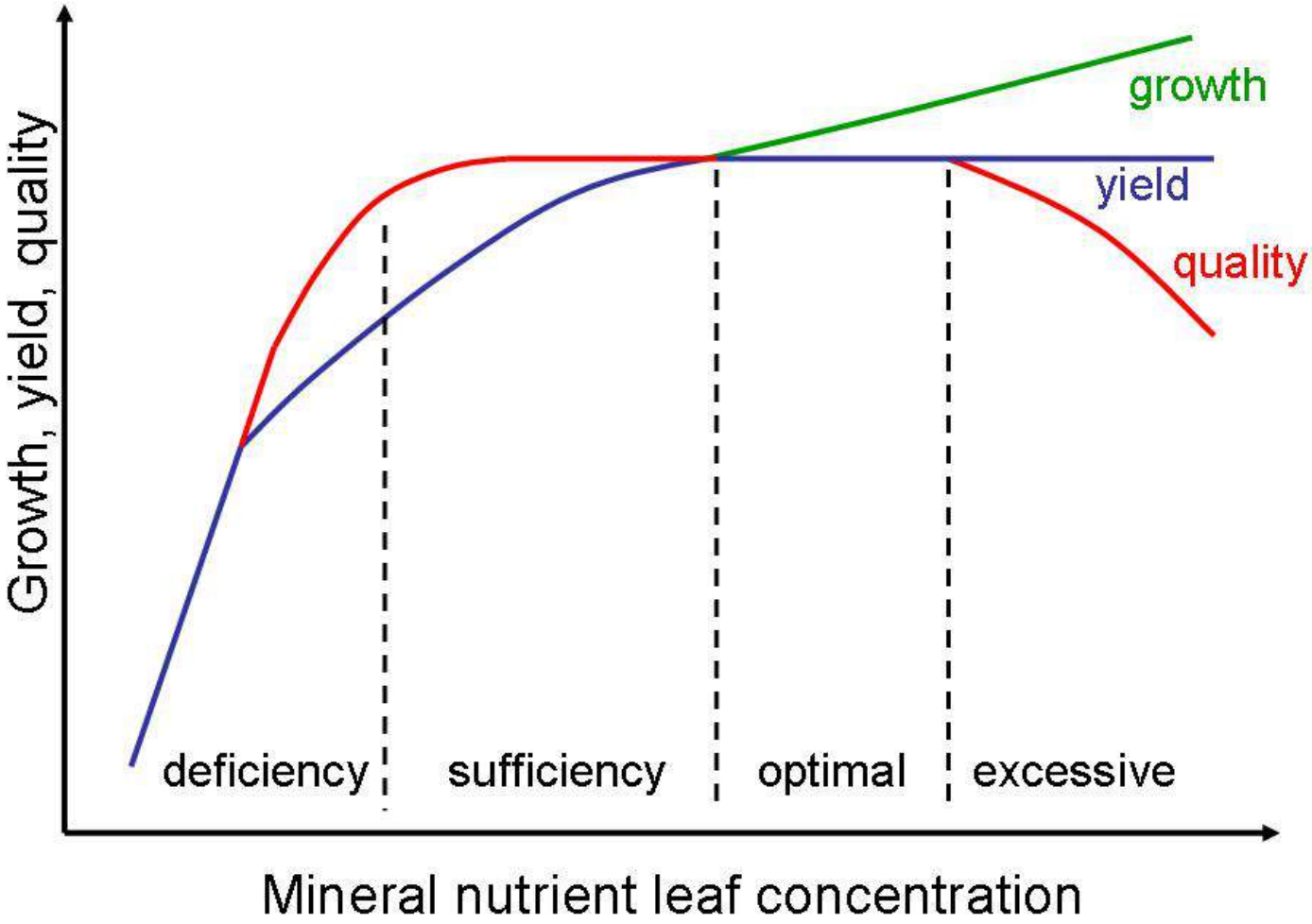
# Fruit quality

- Excessive tree N uptake
  - poorly colored fruits (potential problem for apples) due to shade and higher fruit N (retarded chlorophyll degradation). *Shade could also help reducing sun-burn risks!*
  - Effects on timing of fruit maturity apparently different in apple and pear (delayed) and not-consistent
  - Fruits more prone to physiological disorders (bitterpit, corkspot, internal breakdown)
  - Fruit/tree more susceptible to pathogens (es. *Erwinia* a. and *Penicillium* e.) and parasites (es. *Cacopsylla* p.)

# To sum up

- Increasing soil N availability increases shoot growth/less marked effect for foliar N supply
- Late N availability delays leaf senescence and might depress shoot hardening
- Yields increase at increasing N supply up to an optimum, then might decrease
- At increasing soil N availabilities, fruit quality decreases before yields start decreasing

# Summary of the response to N




Tagliavini, Failla and Xiloyannis, 2012

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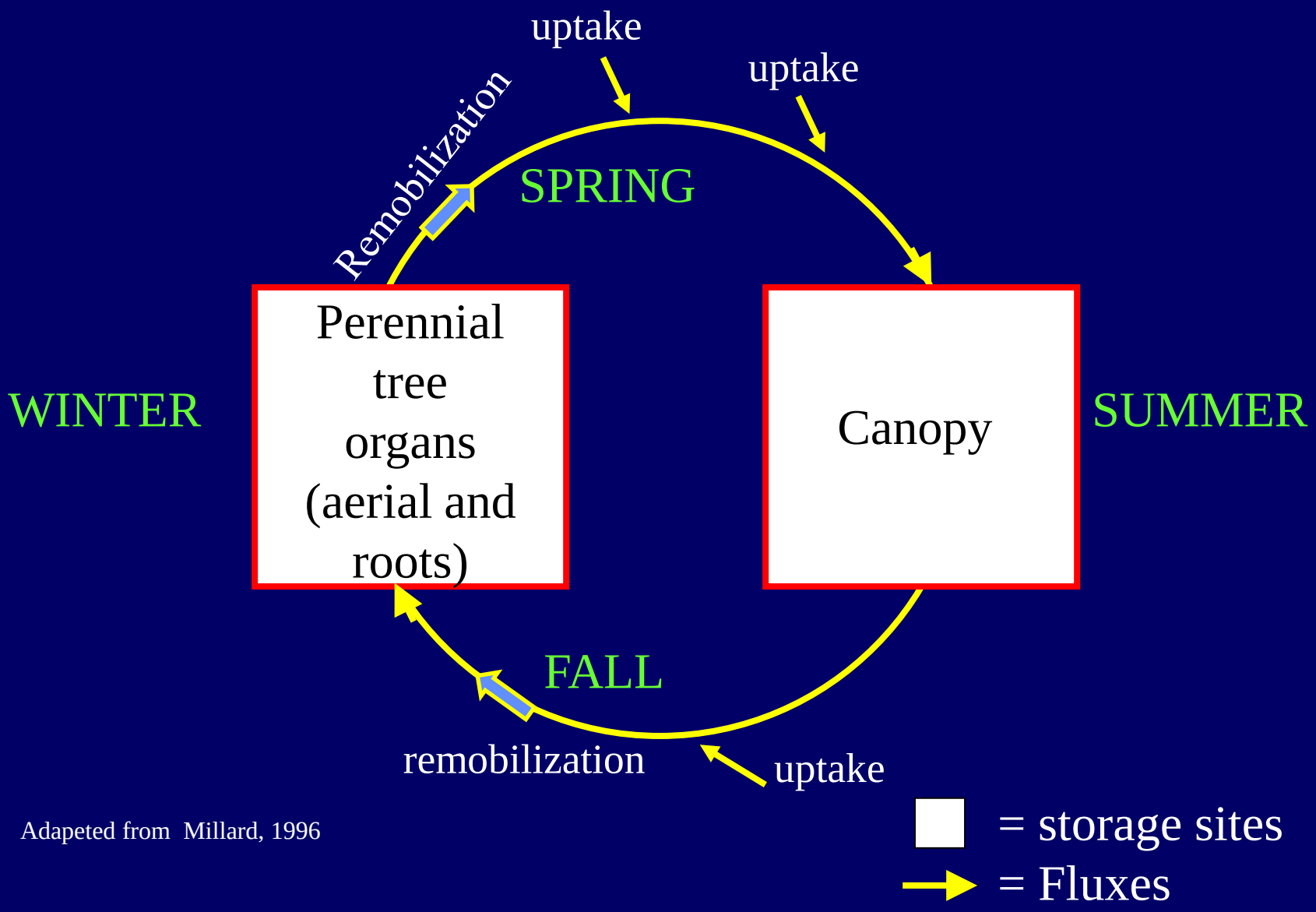
# SOURCES OF NITROGEN IN DECIDUOUS TREES




Adapeted from Millard, 1996

**NITROGEN WITHDRAWAL FROM SENESCENT APPLE LEAVES :**

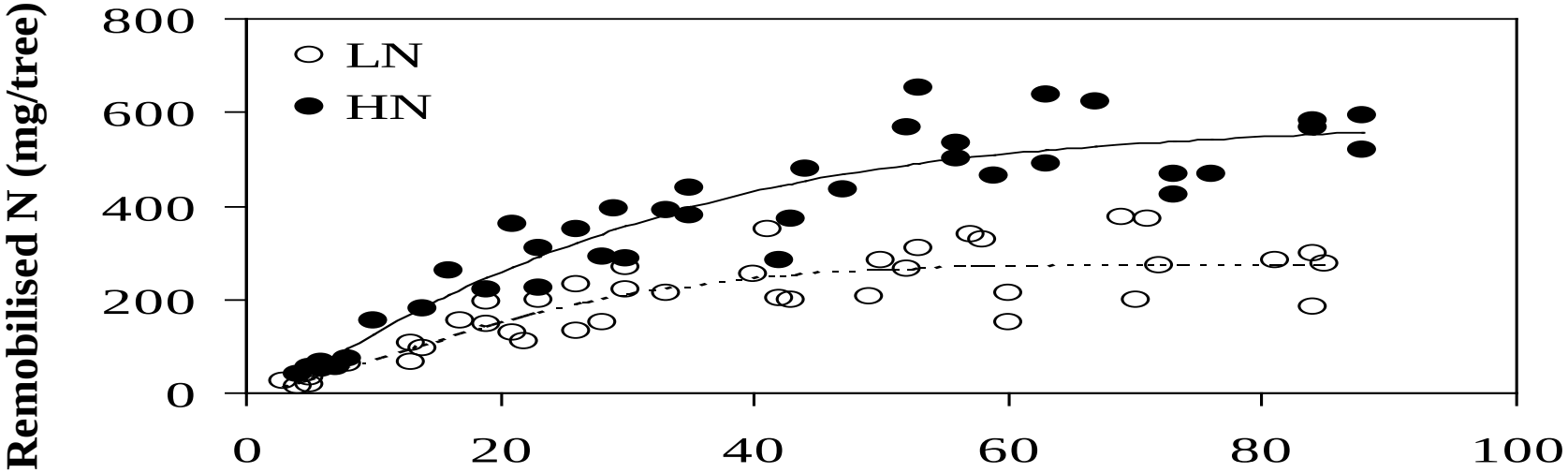
**around 20 kg/ha**

**At full boom, some 90-95 % of leaf and flower N derives from remobilization of stored N (Neilsen et al. 1997)**

- The amounts of N reserves in one year affects the initial N status of the tree the following year

- Length of remobilization in spring

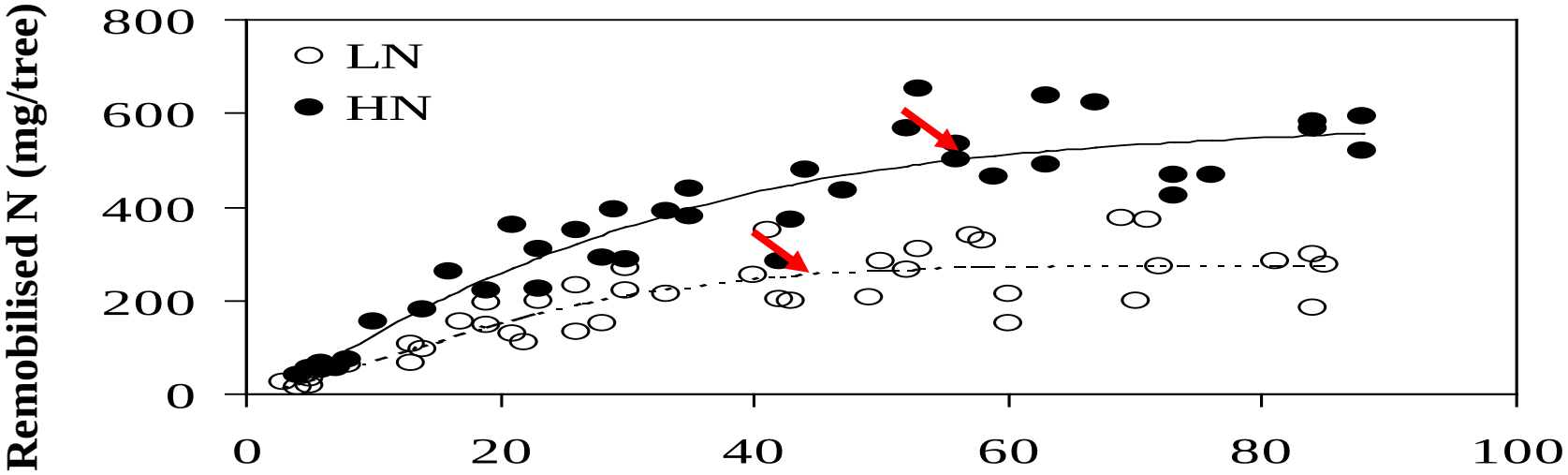
- ***N remobilization as affected by the N supply the previous year (Grassi et al., 2002, PCE)***



- The amounts of N reserves in one year affects the initial N status of the tree the following year

- Length of remobilization in spring

- ***Dynamics of N remobilization as affected by the N supply the previous year (Grassi et al., 2002, PCE)***



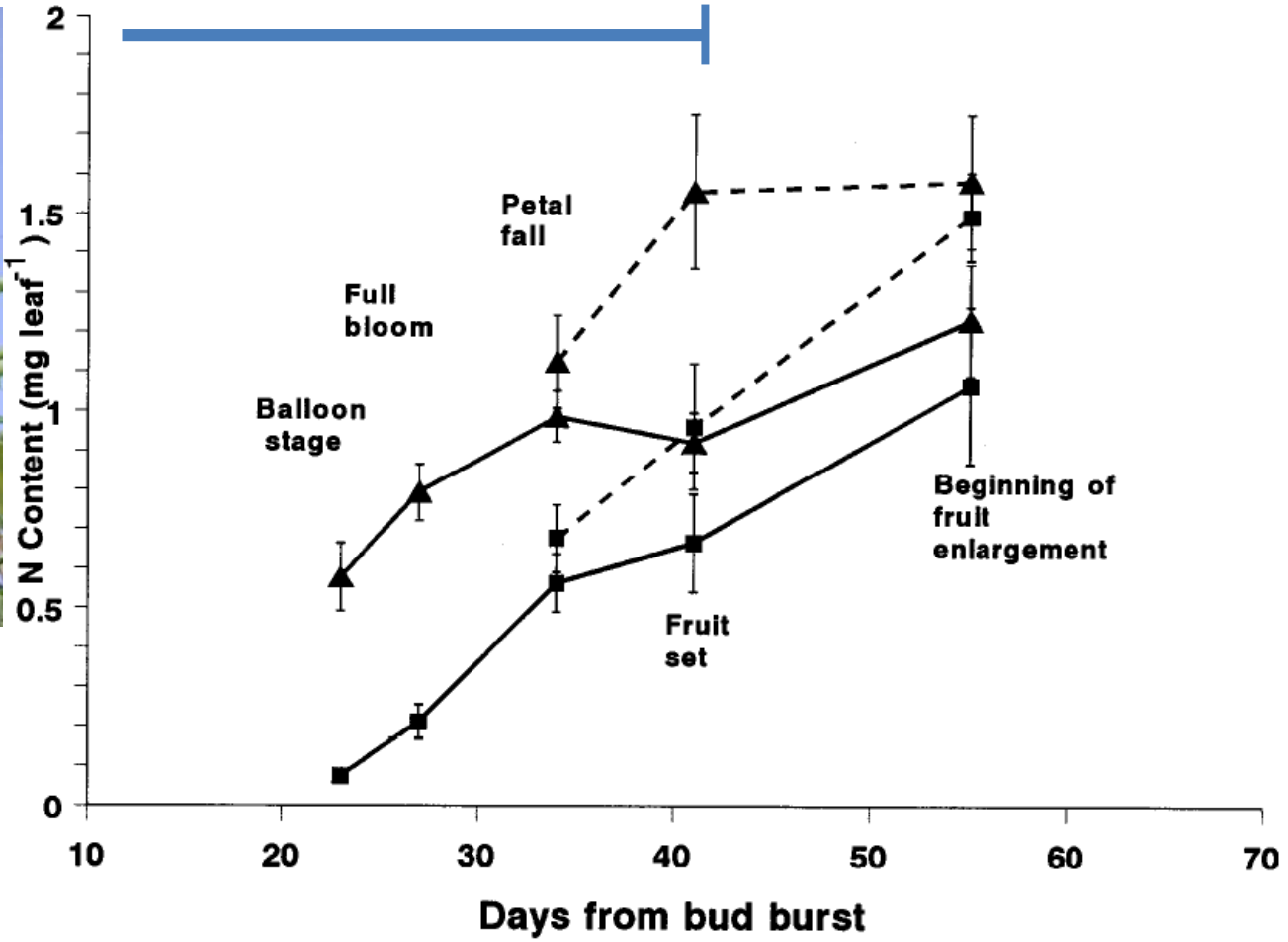



*Figure 3.* The amount of N remobilised (▲) and taken up from fertiliser (■) found in spur (solid line) and shoot (dashed line)

Tagliavini et al., 1997

# Consequences on N management

The amounts of N reserves in one year affects the initial N status of the tree the following year

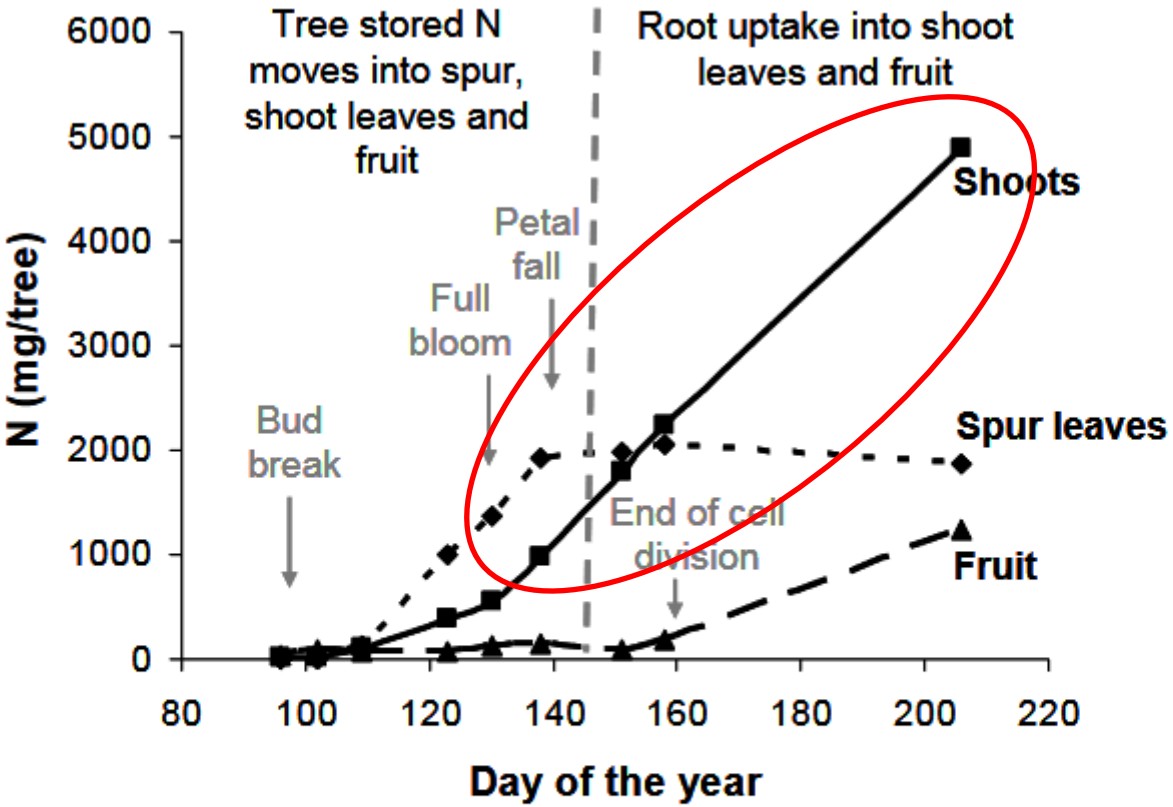
***How to build proper amounts of reserve N?***

Length of remobilization in spring

***Suggests optimal periods for starting the soil N supply***

# Dynamics of N uptake along the season

# Apple cv. Fuji




Relationship between N supplied via remobilization or root uptake in the spring in relation to phenology. Adapted from Guak et al. (2003) and Neilsen et al. (2006a).

Neilsen et al., 2010

# Seasonal N accumulation in apple shoots and fruits

Biomass increase and N influx into bourse shoots (including one fruit) from blossom to harvest (average of Golden *del* and *Nicoter)*.

| Periods (days from full bloom) | Biomass increase mg/day | N influx mg/day |
|---|---|---|
| 0-36 | 90 | 1.90 |
| 37- 81 | 280 | 2.45 |
| 82-117 | 320 | 1.52 |
| 118-158 | 260 | 0.88 |

End of fruit cell division

Zanotelli et al., 2015

# To sum up

- After bloom, N uptake rate initially increases, peaks and then decreases approaching harvest
- Fruit N almost entirely derives from root uptake and its accumulation starts after fruit cell division

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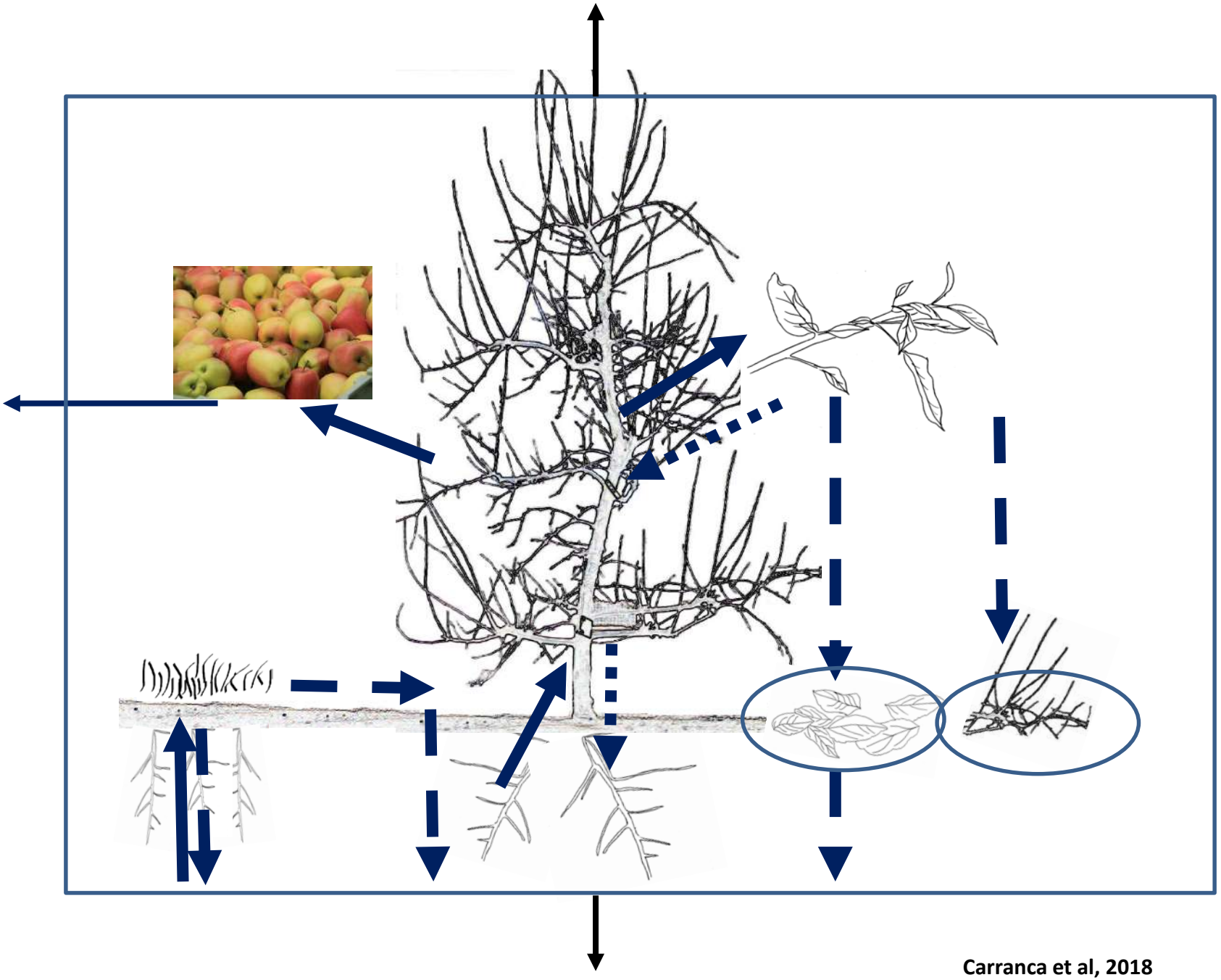
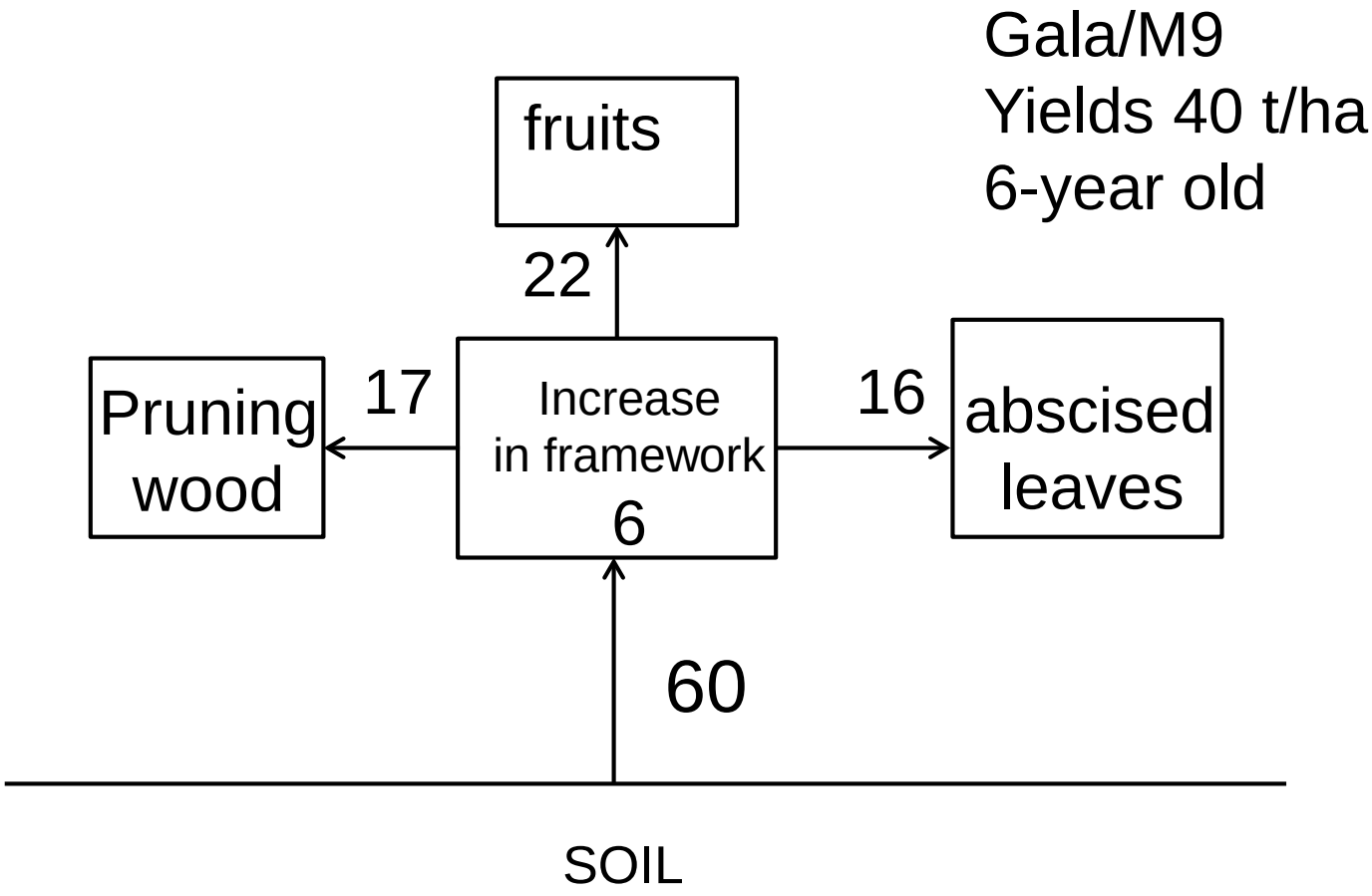


Carranca et al, 2018

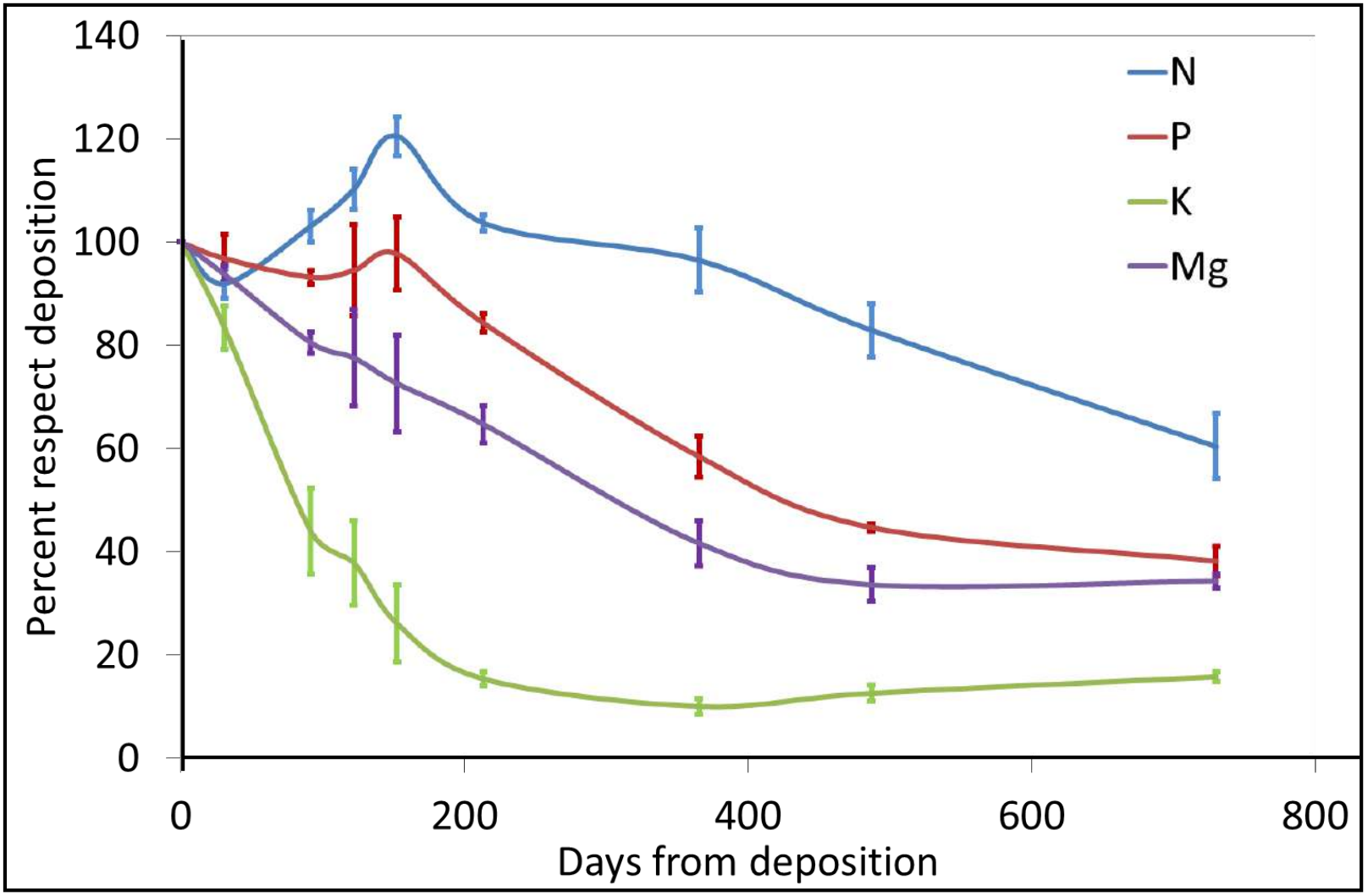
# Annual Nitrogen uptake and partitioning in apple (kg/ha)



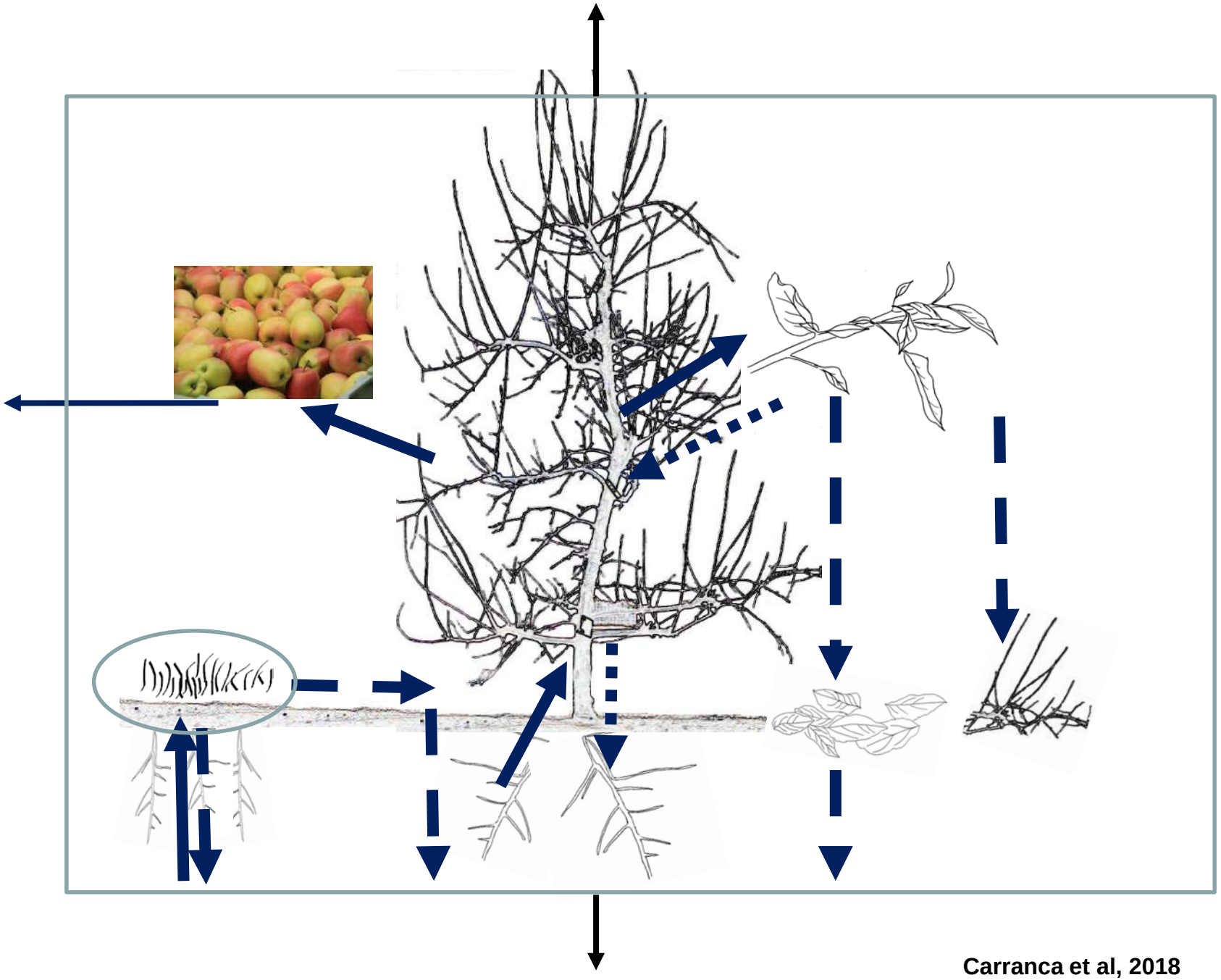

Scandellari et al., 2010


What’s the fate of nutrients contained in decomposing leaves?

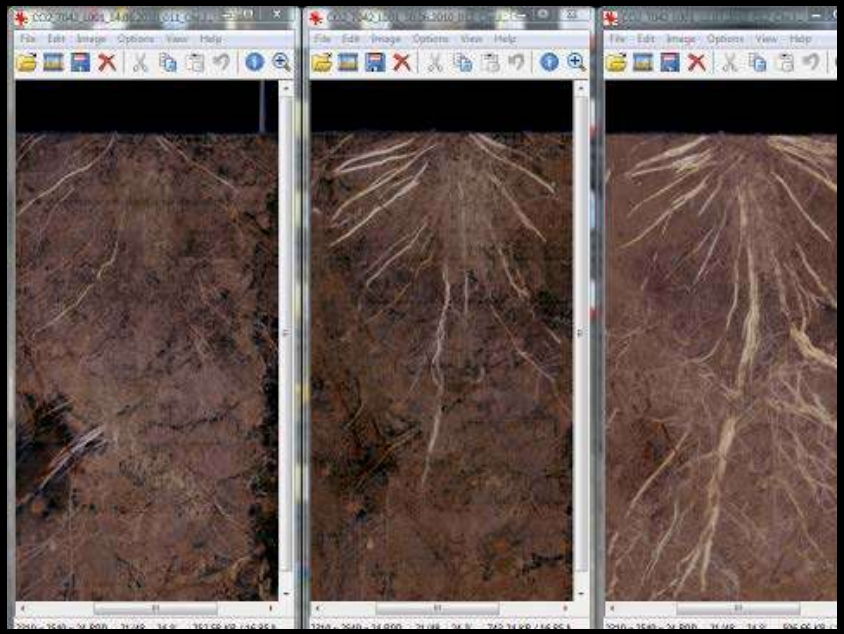
# Percent variation of initial nutrient contents of apple leaves during decomposition (T0=100%)



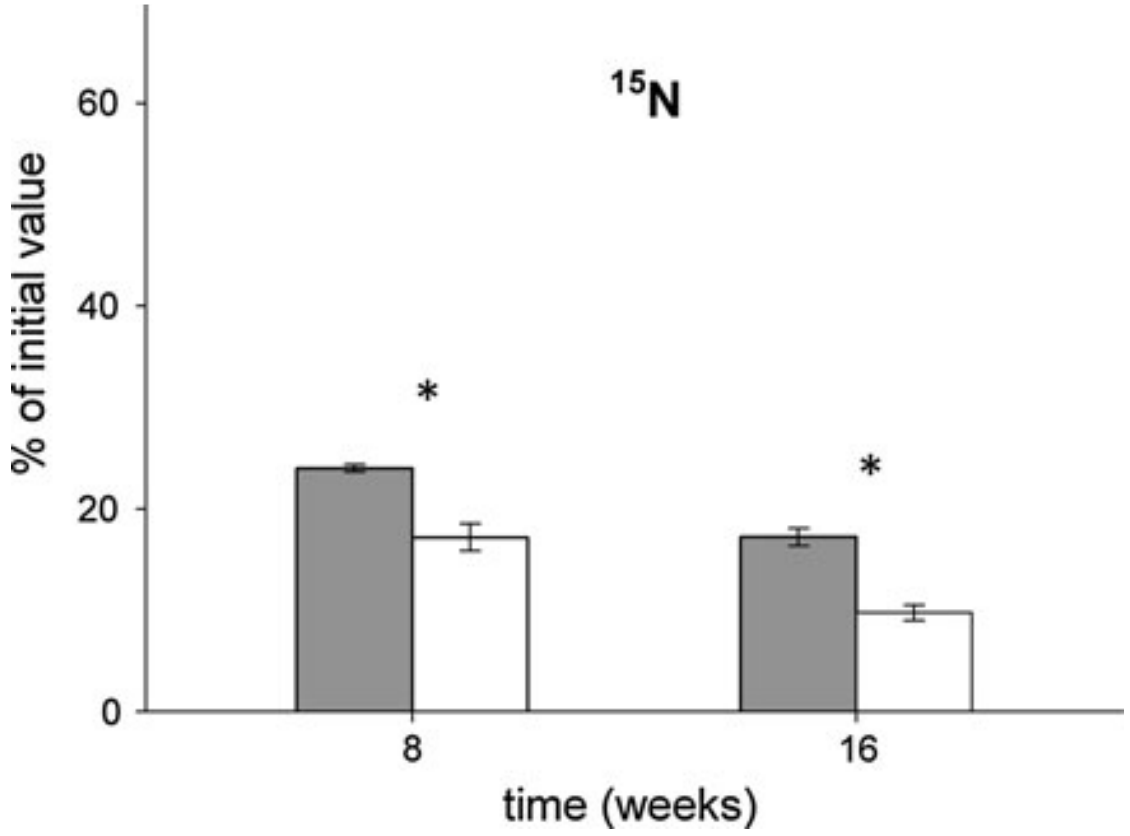

Tagliavini et al., 2007



Carranca et al, 2018



# Rapid release of N from mowed *Lolium p.*(solid bars) and *Trifolium r.* (open bars) on the soil surface (Brunetto et al., 2011)



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# How to match soil N availability with root N uptake needs

1. Tree N needs

# N budgets

- **At orchard level (output – input)**

where outputs (**net removals**) are

***N*** *in the annually removed* ***fruits*** *+*

***N*** *stored in* ***perennial organs*** *(or N in pruning wood if trees are adult) +*

***N*** *in the* ***abscised leaves*** *(only in the first years after transplanting)*

# **Net removals** per unit of fruit yield (kg/t fruit)

| | | | | | |
|---|---|---|---|---|---|
| | N | P | K | Ca | Mg |
| APPLE | 0.9 | 0.2 | 1.3 | 0.5 | 0.2 |
| PEAR | 1.7 | 0.2 | 2.4 | 1.6 | 0.3 |

Tagliavini et al., 2016

# N budgets

- **Soil system budget (uptake - availability)**

*How to monitor soil N availablity*

1. *Models*
2. *In situ-measurements*

# How to match soil N availability with root N uptake needs

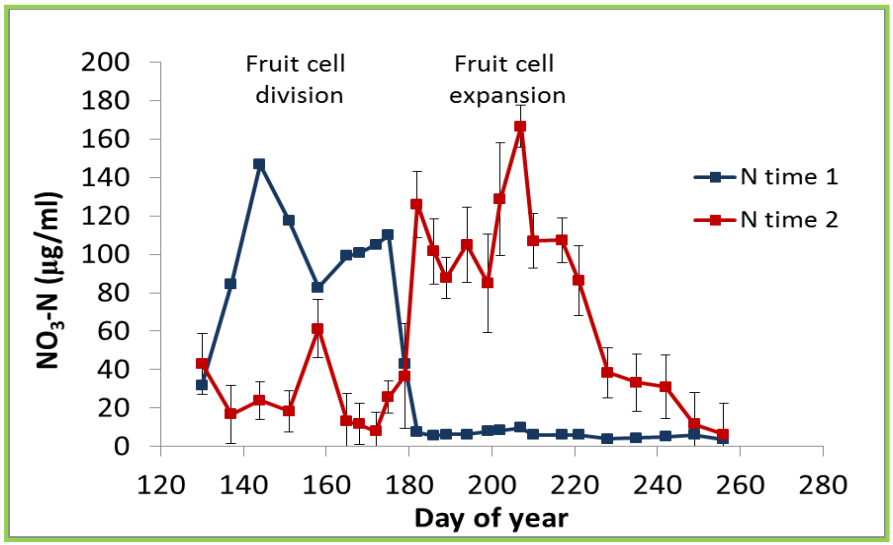
1. Tree N needs
2. N-supply technology

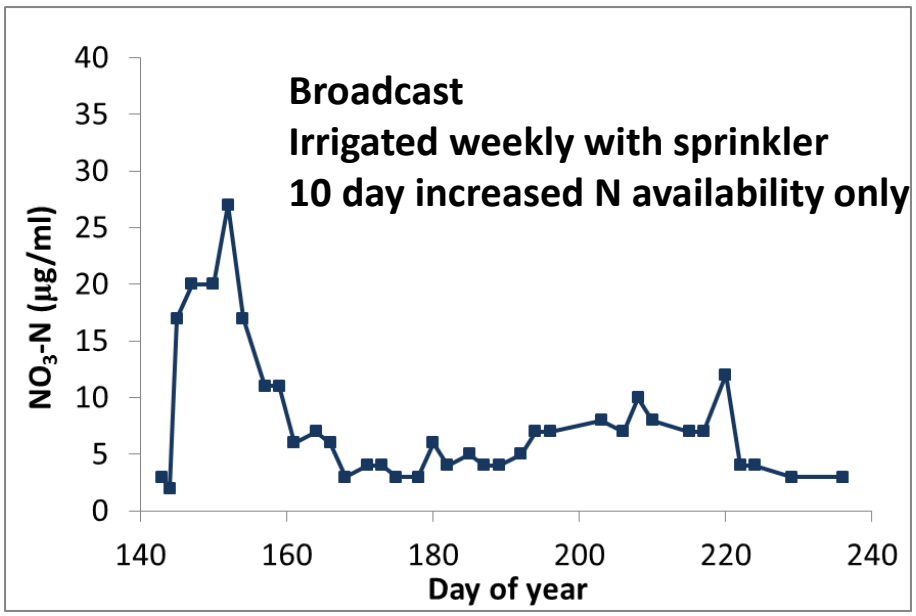
# Supply technology

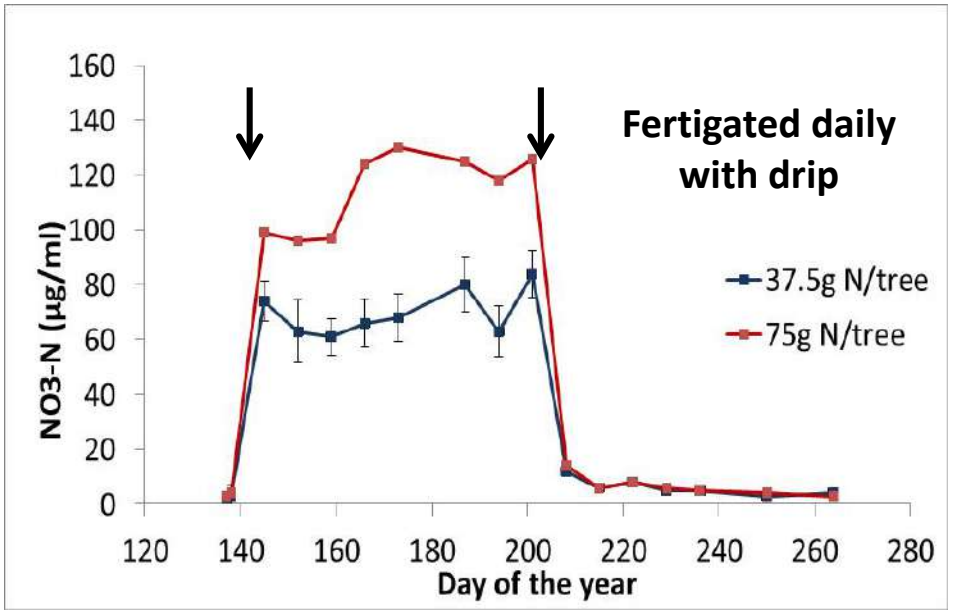
- Fertigation

# Nitrogen fertigation can control N availability

**Soil solution nitrate concentrations at 30cm depth measured after irrigation ends (within 1 hr)**




Neilsen et al. 1998 JASHS 123

# Supply technology

- Fertigation
- Foliar supply

# Foliar N supply

- Urea among the most effective N sources
- Absorption rates >50% (up to 90%)
- Most N absorbed within 48-72 hrs from supply
- Urea increases penetration rates of other salts (P, Mg, S, Fe)

# Supply technology

1. Fertigation
2. Foliar supply
3. Organic N sources

# Effects of the organic management of N supply on soil parameters after 6 years

| Treatment | Organic matter % | Total soil N ‰ | Microbial biomass mg C $g^{-1}$ |
|---|---|---|---|
| Compost/tillage | 4.8 | 2.9 | 439 |
| Alfalfa mulch | 7.1 | 3.7 | 606 |
| Conventional | 2.3 | 1.5 | 230 |

Treatments applied yearly
Soil effects always significant
Yields and leaf N levels unaffected

Neilsen et al., 2013

**The effectiveness of organic N sources strongly depends on biological reactions**

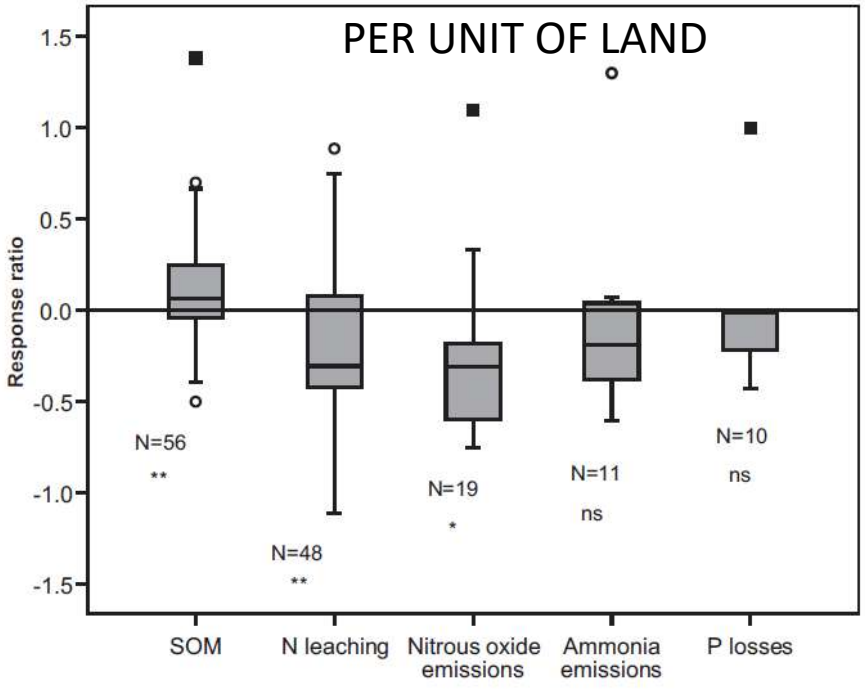
**and**

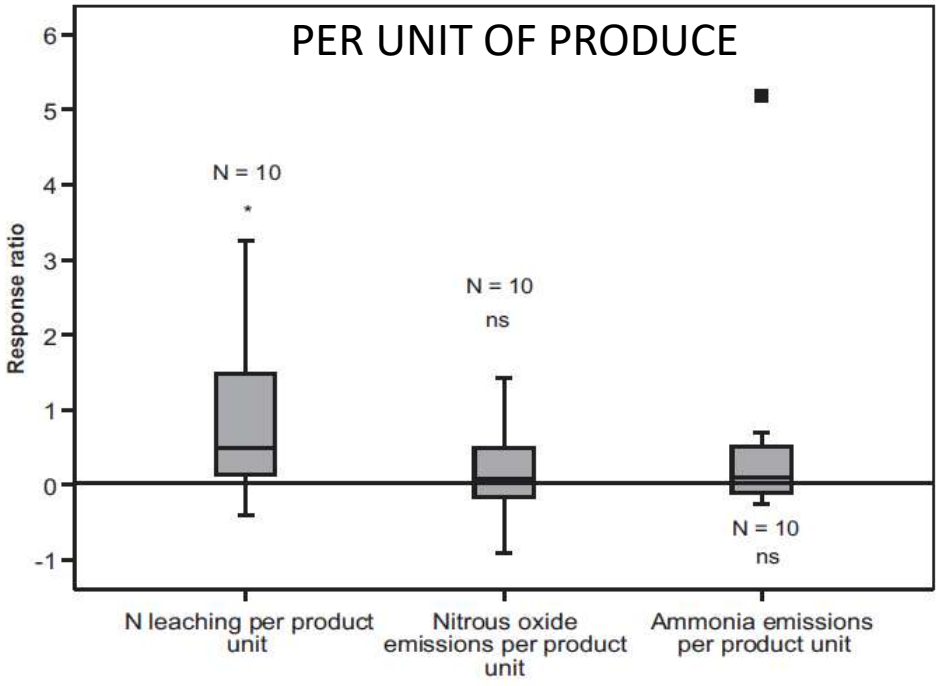
**there is a need to study how**

**to better match N mineralization of different N sources (with different C/N) and tree N needs**

# Not only synthetic-, but also organic-fertilizers can be responsible for environment pollution

Comparison between organic and integrate/conventional farming as far as the effects on the Environmental Performances are concerned (summary of >70 plots across UE)




Negative values indicate lower effect of the organic farming as compared to Integrated/conventional in relation to a given parameter; positive values indicate the opposite

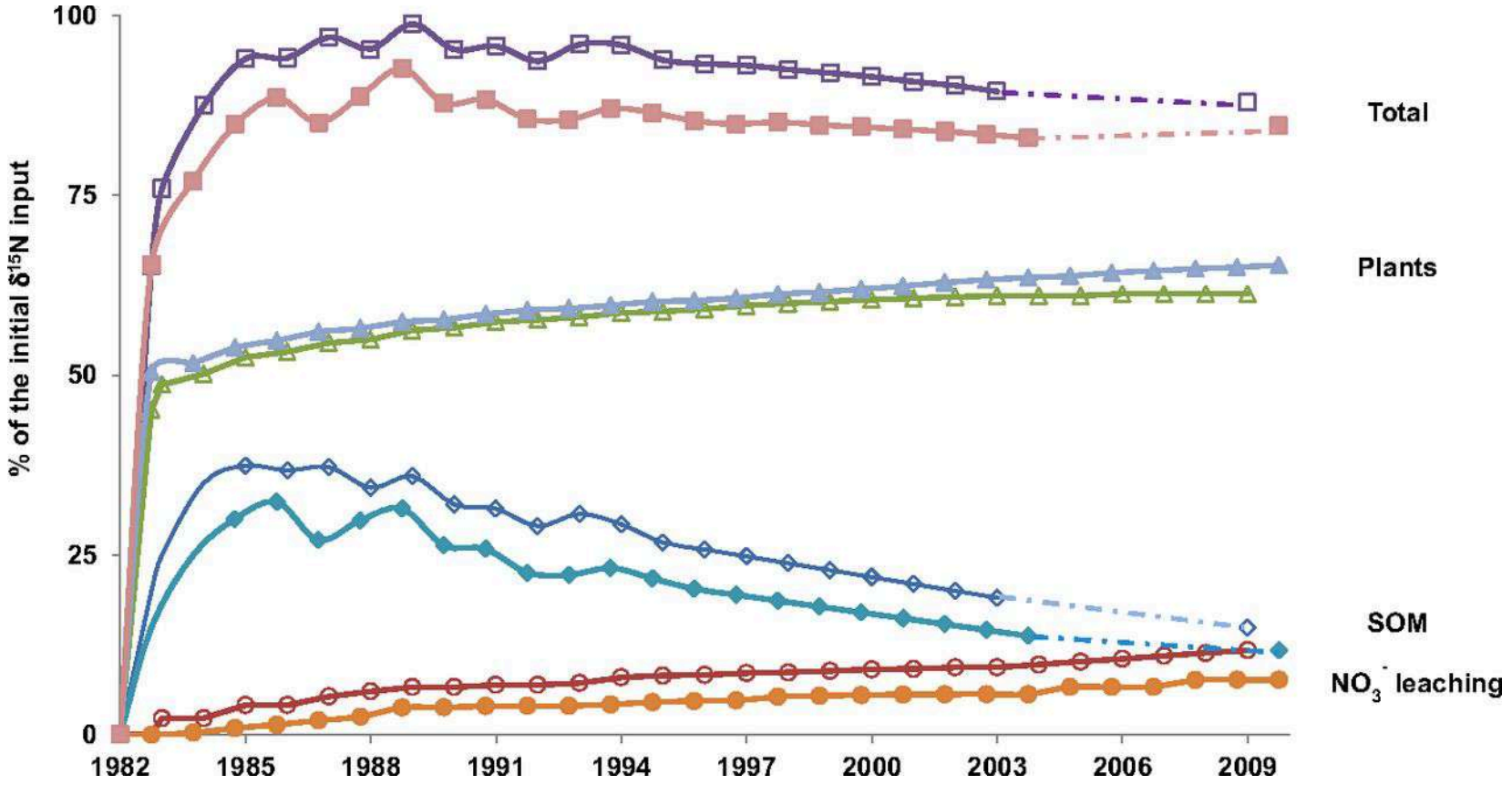
*Source: Tuomisto et al. (2012)*

# Final Remarks

- Low fertiliser N use efficiency in fruit trees often recorded (< 30%)
  - even in container trials and with split applications
  - *N rates too high, low root density, N losses?*

- Recovery rates recorded after one year

**Cumulative budget of 15N-labeled fertilizer nitrogen based on mass and isotope balances for plants, soil organic matter (SOM), and nitrate in lysimeter outflows for Lys S (full symbols) and Lys W (empty symbols).**




Mathieu Sebilo et al. PNAS 2013;110:45:18185-18189

PNAS

# How to enhance fertiliser NUE over time?

- *…Soil organic matter management is crucially important for maximizing the long-term benefit of fertilizer applications for (crop) yields and for minimizing nitrate export to the hydrosphere…(Sebilo et al., 2013)*
- Water supply based on needs
- Cover crops
- …

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Grazie dell'attenzione!

Danke für Ihre Aufmerksamkeit!

Thanks for your attention!