Does nitrogen supply impact the cadmium fluxes to developing durum wheat (Triticum turgidum L. subsp. durum) grains?

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Does Nitrogen Supply Impact the Cadmium Fluxes to Developing Durum Wheat (*Triticum turgidum* L. subsp. *durum*) Grains?

INRA SCIENCE & IMPACT

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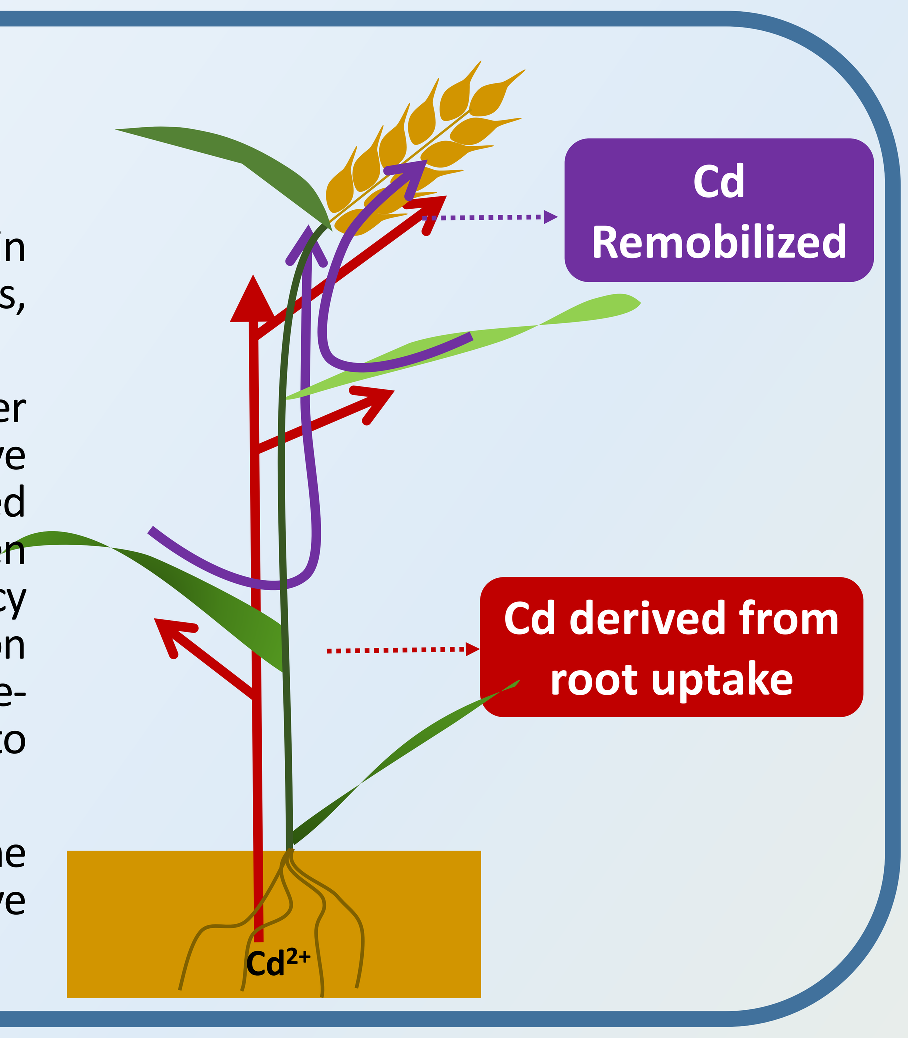
Background

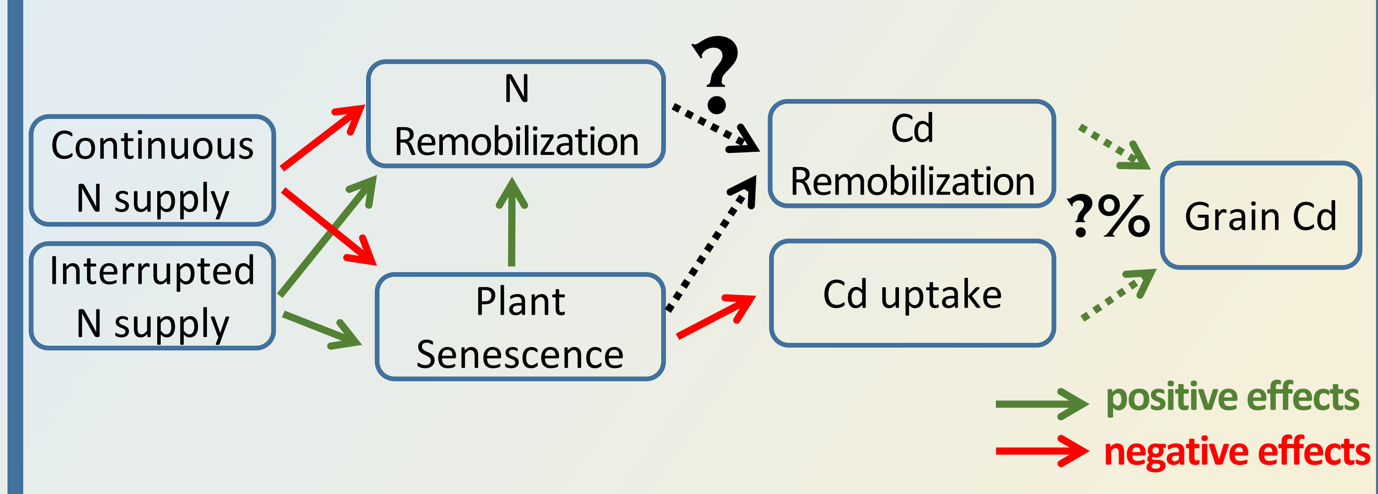
Cadmium is a toxic, non-essential element. It can be accumulated in durum wheat grain to levels exceeding the international trade standards, which is threatening human health.

Cd imported into developing durum wheat grains originates from either direct uptake of Cd by roots or remobilization of Cd stored in vegetative organs. The remobilization of Cd has been shown to be quite limited when hydroponic plants are continuously well-supplied with nitrogen [1], while the availability of N is often low in field soils. N deficiency accelerates leaf senescence which often induces the remobilization processes [2]. So it is possible that, if Cd remobilization is a senescence-dependent process, the level of N supply might affect the fluxes of Cd to developing grains by its impact on plant senescence.

Consequently, it is necessary to quantify the relative contribution of the two pathways for grain Cd loading and to assess how their relative contributions may be impacted by the levels of N supply.



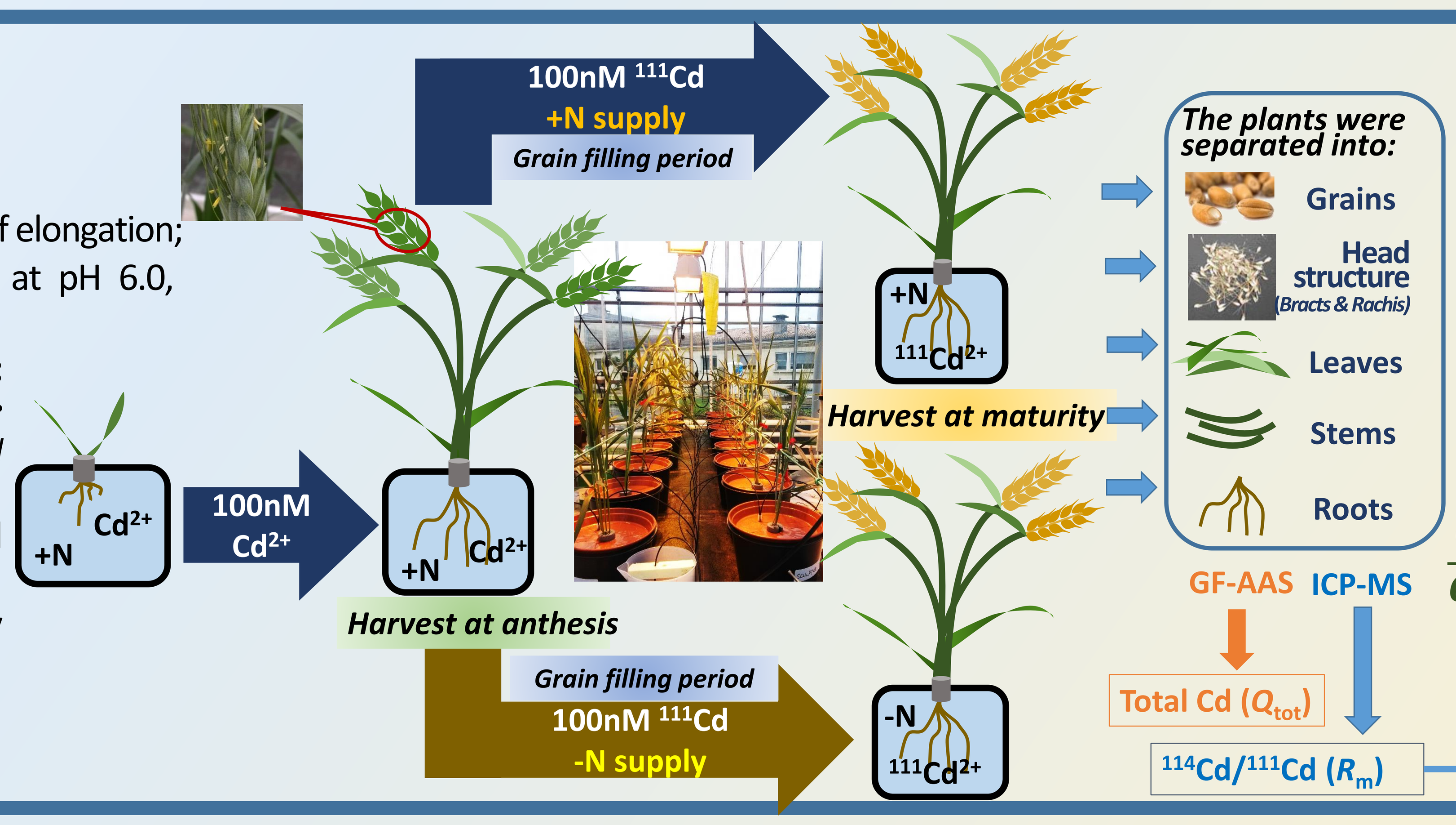
Hypothesis & Objectives



- To determine the quantitative importance of the two origins of the grain Cd by using Cd isotopic tracing.
- To determine whether the supply of N during grain filling has an impact on the Cd remobilization and the level of Cd in the grains.

Materials

- **Durum wheat Cultivar**: *Sculptur*;
- Plants were trained to develop **4 tillers** from the start of elongation;
- **Hydroponics**: modified Hoagland's nutrient solution at pH 6.0, refreshed automatically;
- **Cd^{2+} was supplied after transplanting at low dose**: non-toxic, fixed at **100 nM**, *p*(Cd^{2+}) = 10.78 (*to reproduce the level of exposure to Cd found in pore water of contaminated agricultural soils [3]*);
- ^{111}Cd-enriched **isotope labeling** after anthesis until maturity;
- **Two treatments**: continuous or interrupted N supply after anthesis until maturity;
- **Harvest 2 times**: at anthesis, at maturity;
- **Five repetitions.**



The amount of Cd remobilized

$$Q_s = Q_{tot} - Q_{ei}$$

The amount of Cd derived from root uptake

$$Q_{ei} = \frac{1}{1 + Q_s/Q_{ei}} \times Q_{tot}$$

$$\frac{Q_s}{Q_{ei}} = \left(\frac{M_s}{M_{ei}}\right) \cdot \left(\frac{A_{ei}^{111}}{A_s^{114}}\right) \cdot \left(\frac{R_m - R_{ei(114/111)}}{1 - R_m \times R_{s(111/114)}}\right)$$

M_s and M_{ei}: the molar weights of natural standard (*s*) Cd and enriched (*ei*) ^{111}Cd isotope, respectively;
A_{ei}^{111} and A_s^{114}: the abundance of ^{111}Cd in the labeled nutrient solution and is the natural abundance of ^{114}Cd, respectively;
R_m and $R_{ei(114/111)}$: the $^{114}Cd/^{111}Cd$ ratio measured in the plant sample and in the labeled nutrient solution, respectively
$R_{s(111/114)}$: the natural ratio of $^{114}Cd/^{111}Cd$.

Results

Cd fluxes in plant under *continuous N supply* during grain filling

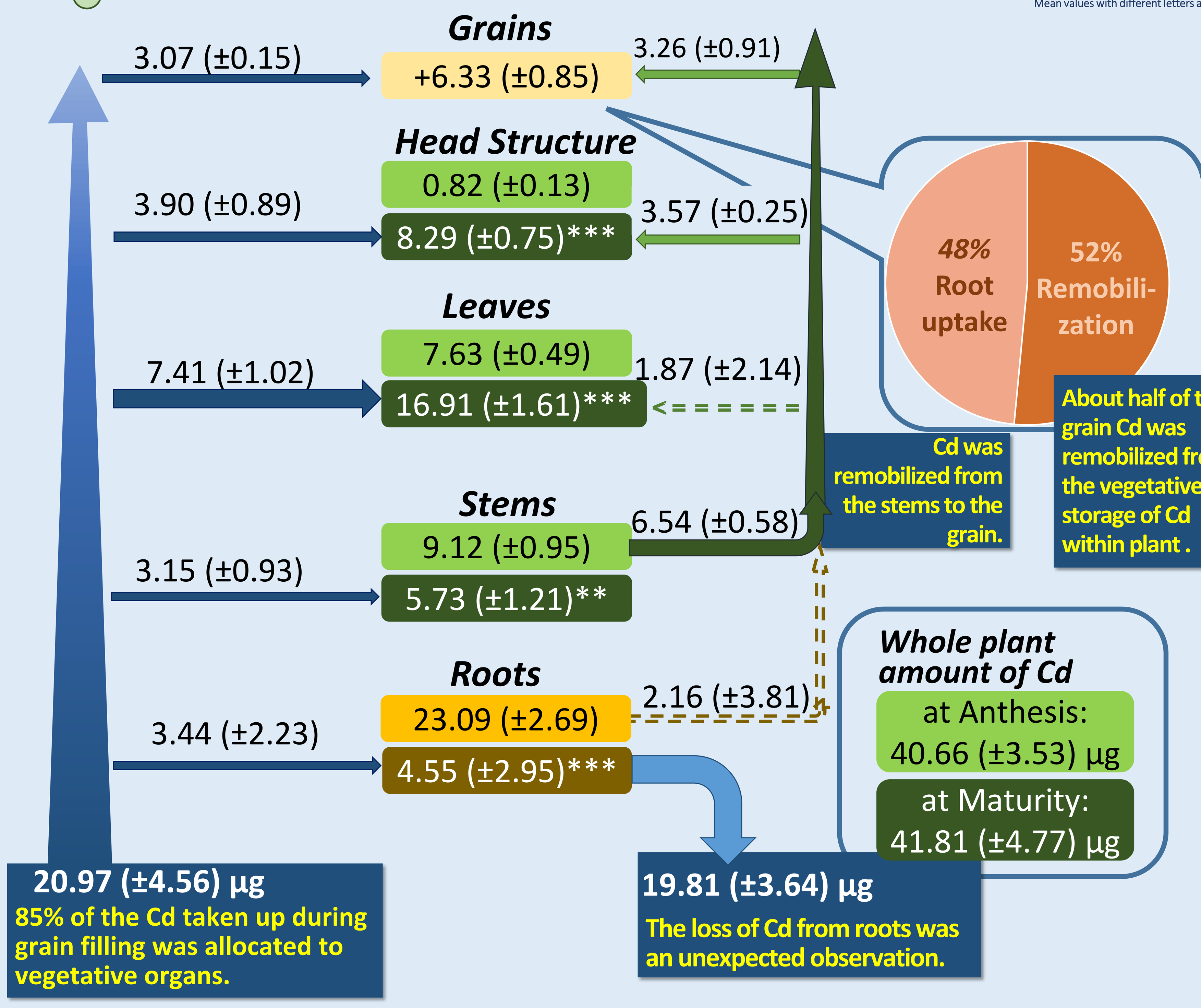
57% of the grain N derived from remobilization

Grain Elements conc.	High N supply	Low N supply
N (%)	4.1a	4.4a
Cd (µg/g)	1.3a	1.2a

Mean values with different letters are significantly different ($P < 0.05$)

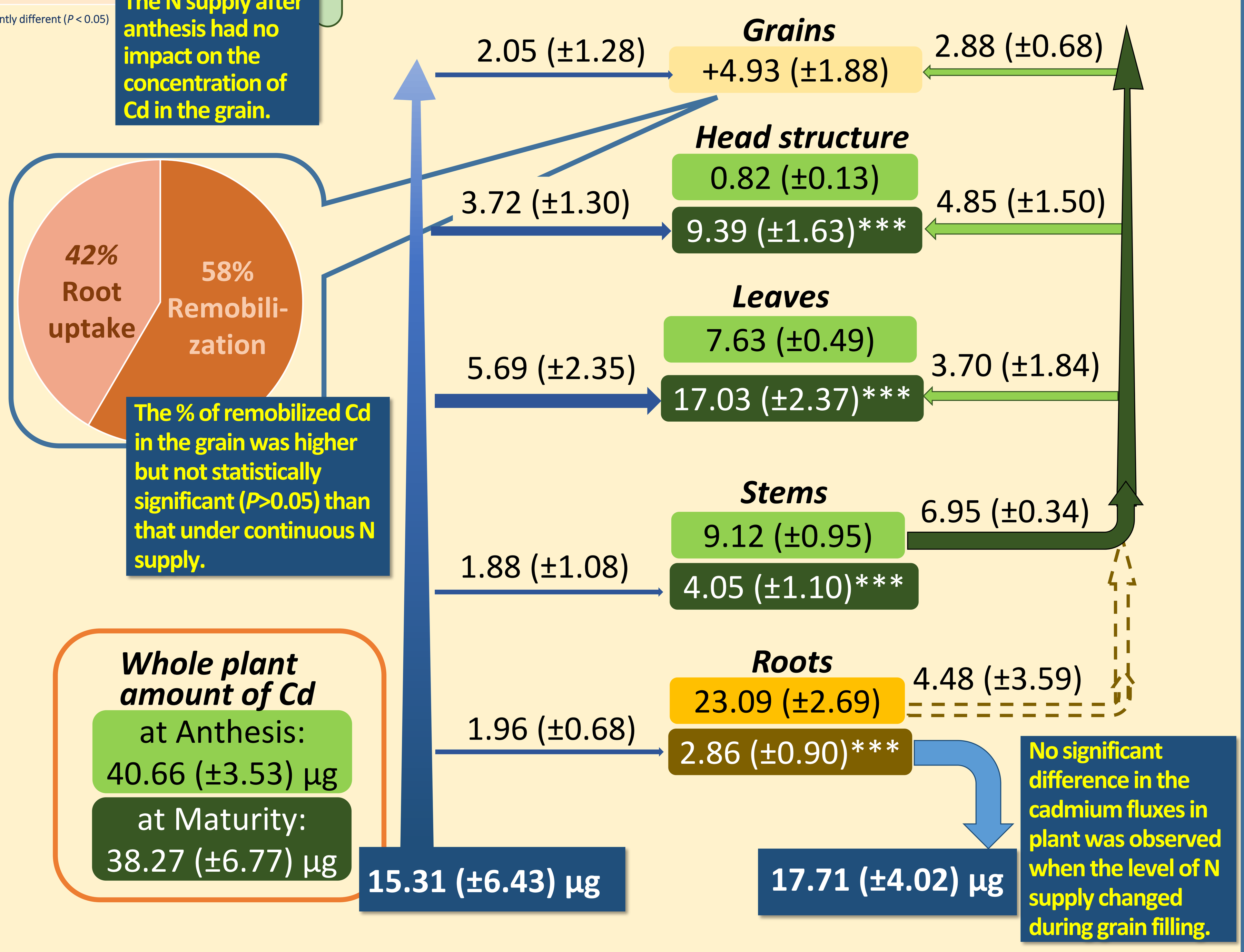
The level of grain N wasn't impacted by the interrupted N supply during grain filling thanks to the high efficiency of N remobilization.

The N supply after anthesis had no impact on the concentration of Cd in the grain.



Cd fluxes in plant under *interrupted N supply* during grain filling

100% of the grain N derived from remobilization



Conclusions

- The remobilization process accounts for about half (50-60%) of the Cd in durum wheat grains.
- The N supply after anthesis had no impact on the Cd fluxes into developing grains. Cd remobilization may thus be a senescence-independent process.
- The low availability of N during grain filling period in the field may not affect the accumulation of Cd in durum wheat grain.

[1] Harris, N. S. et al. *BMC Plant Biology* (2013) 13:103;
[2] Maillard, A et al. *Frontiers in plant science* (2015) 6;
[3] Nolan, A. L. et al. *Environmental science & technology* (2003) *37*(1), pp. 90-98.

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