# Modelling N uptake in B. napus plants in the field conditions: estimation of active roots involved in nitrate uptake by a synthetic parameter, the integrated root system age (IRSA)

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# Modelling N uptake in *B. napus* plants in the field conditions: estimation of active roots involved in nitrate uptake by a synthetic parameter, the integrated root system age (IRSA)

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## Introduction

A mechanistic structure–function model was developed to predict nitrogen (N) uptake throughout the growth cycle by a winter oilseed rape (*B. napus*) under field conditions. Because of the overestimations of N taken up regarding both influx rates measured with $^{15}N$ tracer and total root length measured under field conditions [1], a parameter called ARB (Active Root Biomass) was developed in order to estimate the active root absorbing biomass [2]. It was based on an other synthetic parameter called IRSA (Integrated Root System Age) that accounts for changes in root uptake properties with root age [3]. Although the effect of root ageing on the nitrate influx rate is very strong (Fig. 1), it is hardly ever introduced into N uptake agronomic models [1,3].

## Methods

Oilseed rape plants fed on a wide range of external nitrate concentrations showed a continuous decrease in the nitrate uptake rate with plant age under field and hydroponic conditions (Fig.1). However, increasing external concentrations of nitrate extend the functioning of the roots and their capacity for nitrate uptake (Fig.1B). A synthetic IRSA parameter takes into account this specific root behaviour [3,4].

***Integrate Root System Age parameter (IRSA)***
IRSA parameter (in °Cday) is defined as the sum of the average age of the root segments in °Cday relative to the final sampling date [3]:

$$IRSA_{ti} = \sum_{ti=1}^{maturity} [a_{ti} * \Delta I_{ti} / I_{maturity}]$$

Where $a_{ti}$ is the average root age of the root produced from plant age $d_{ti-1}$ to $d_{ti}$, $i$ is the $i$th °Cday of root sampling and $\Delta l_{ti}$ represents the change in root length from $d_{ti-1}$ to $d_{ti}$ (Fig. 3A).

***Estimate of the Relative $NO_3^-$ uptake capacity of Fine-root ($RF_{ti}$)***
According to Fig. 1B, the $RF_{ti}$ parameter is calculated assuming that the lowest value of the IRSA parameter (young root segments) for each soil layer corresponds to full nitrate uptake capacity (100 %), while the highest IRSA value (old root segments) was reached for absorption equal to zero (Fig. 2B):

$$RF_{ti} = 1 - (IRSA_{ti} / IRSA_{maturity})$$

***Estimate of the Active Root Absorbing Biomass ($ARB_{ti}$)***
Then, the active root biomass (ARB) involved in nitrate absorption within the different soil layers during the whole growth cycle (Fig. 3) is calculated according to:.

$$ARB_{ti} = 1 - (IRSA_{ti} / IRSA_{maturity}) . Dw_{root, ti}$$

## Results

**Plants absorb nitrate with few active root biomass**
Use of ARB parameter induces a drastic reduction of the root biomass involved in nitrate uptake in the top soil layers (0-30; 30-60 cm; Fig. 3A and B). Predicted values of N exported by the crop match well with field-measured values (Fig. 4B).

**Estimate of relative capacity of $NO_3^-$ absorption by root**
Although the ARB parameter allows to estimate a weighted active root biomass across the whole root system, it can not identify which fraction of the fine-root system is active in nitrate uptake. However, it points out that root ageing is a critical component to model the N uptake rate at field level (Figs. 1 and 4). Due to a close interaction between the building of root structure and root properties, the N uptake efficiency can not be improved without reconsidering the thermodynamic aspects involved in root absorption and shaping [5,6,7].

## Conclusion

The ARB is a powerful parameter to assign a root absorption capacity at a specific age of the root in 1-dimensional N uptake models. Hence, the effect of N applications on root senescence delay needs to be unravelled at molecular and physiological levels. It will allow to develop quick screening methods to improve the N uptake efficiency of crop species in breeding programs.

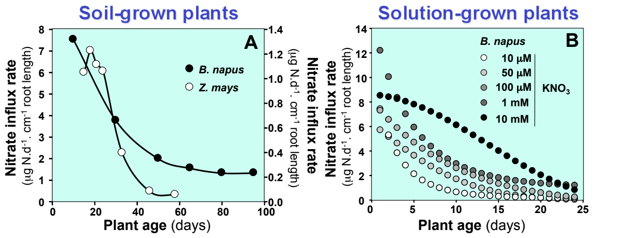


Fig. 1: Down-regulation of $NO_3^-$ uptake rate with the root aging. **(A)** Effect of root age on nitrate uptake rate of field-grown *B. napus* and *Z. mays* plants (from Edwards and Barber, 1976 and Barraclough, 1989). **(B)** Effect of root age on nitrate uptake rate of solution-grown *B. napus* plants (from Bath et al., 1979). The plants were grown in a continuous flow culture system and supplied with different external nitrate concentrations.

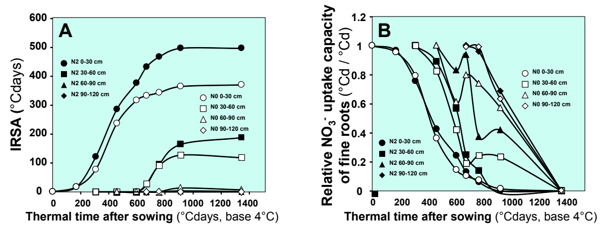


Fig. 2: Variations of the Integrate Root System Age parameter (IRSA) **(A)** and the relative $NO_3^-$ uptake capacity of fine roots (RF) **(B)** during the whole growth cycle in each soil layers for N0 (0 Kg N/ha), N1 (135 kg N/ha) and N2 (272 kg N/ha) fertilization levels.

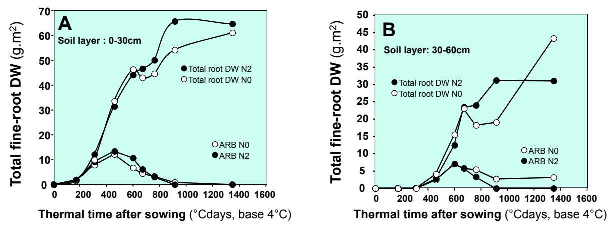


Fig. 3: Estimation of Active Root Biomass (ARB) in the different soil layers for two levels of fertilization (N0= 0 Kg N /ha and N2 = 272 kg N/ha). **(A)** Estimates of ARB in first soil layers (0-30 cm) and **(B)** estimates of ARB in the second soil layer (30-60 cm).

## Model outputs

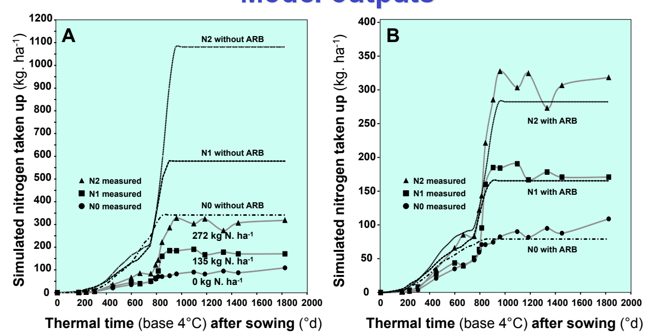


Fig. 4. Simulated (dotted lines) versus measured outputs (symbols) of the total nitrogen taken up by a winter oil seed rape crop at field level (*Brassica napus* 'Capitol'). **(A)** The simulated values are obtained without using ARB parameter. **(B)** The simulated values are obtained after using of ARB parameter to estimate the active root biomass. The simulated values are indicated by a dotted line and the values measured in the field by simple symbols and a full line .

## References

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