

NITROBEECH



Photos du marquage foliaire à l'urée ^{15}N de branches de hêtres (à gauche et au centre) et des prélèvements d'échantillons à différents temps après le marquage pour le suivi du transfert d'azote dans les branches (à droite)

How do severe drought and defoliation alter nitrogen cycle in beech trees?

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Context — A better understanding of forest vulnerability to extreme events like repeated severe drought events are essential in order to develop mitigating forest management strategies. Drought not only affects C and H₂O balances of trees, but also the N balance notably through a decreased soil nutrient availability (Rennenberg *et al.* 2009, Kreuzwieser and Gessler 2010), and reductions in root N uptake (Rennenberg *et al.* 2006). As a consequence, internal tree N cycling, including N assimilation, translocation, storage and remobilization capacities can be significantly affected by drought.

Objectives — Drought and defoliation are environmental factors expected to affect drastically the N balance of trees by decreasing access to water and nutrient of the soil (drought) or through a major loss of leaf N (defoliation). We hypothesised that such events limit nitrogen supply for trees. Using several short-term stable isotope labelling with ^{15}N , the objectives were to track the pool of N from leaves to the other tree compartments according to the season and the experimental treatments (control, drought, defoliation). Precisely, the following questions were posed:

1. Will the treatment influence the absorption rate by leaves of applied ^{15}N -urea and its assimilation form?
2. Where beech will allocate ^{15}N resources during drought stress: proximal perennial organs like branches or other compartments (terminal shoot, trunk, roots)?

Approach — 10-year-old beech trees were submitted to repeated drought or defoliation events for two consecutive years. The second year, two short-term ^{15}N labelling were carried out:

1. At the branch scale

We labelled the leaves of one branch per tree on 12 trees per treatment with ^{15}N urea in spring (before defoliation) and in summer (after defoliation). We followed at short term (0.5, 1, 2, 4, 7 and 14 days after labelling) the ^{15}N content in labelled leaves. After 14 days, we harvested labelled leaves and wood of the branches to follow the fate of ^{15}N between leaves and wood. We also estimated the long distance transport of N from leaves to the apex of the trees by measuring ^{15}N in the terminal shoot.

2. At the tree scale

We labelled the leaves of whole trees with ^{15}N urea in September, just before the remobilization of N from senescing leaves and their storage in perennial compartments of the tree. We followed the leaf ^{15}N fate and changes in all tree compartments (leaves, branches, trunk and roots) at three times after labelling: (1) in

autumn, one month after labelling at the beginning of the N remobilisation from senescing leaves. At the end of the winter, at the maximal N storage time in the tree; (2) in spring, at the end of leaf expansion in order to evaluate its redistribution between the compartments source of N and the sink compartments (new shoots).

Key results —

1. At the branch scale

In Spring, ^{15}N stayed mainly in labelled leaves for local metabolic needs (including for example RuBisCO synthesis). ^{15}N results in defoliated branches suggest an increased need for ^{15}N inside the youngest branch part compared to control. In spring, ^{15}N mainly remained in the newly formed leaves that are metabolically active and have high N requirements for the synthesis of carboxylic enzymes (such as Rubisco synthesis) involved in the Calvin cycle. The need for carbon skeletons (photoassimilates) is indeed important during growth.

In summer, ^{15}N in the leaves is in lower concentration than in spring in the defoliated treatments. This decrease in ^{15}N concentration may be due to an increase in the export of ^{15}N (and thus total leaf N) from the marked leaves to the wood portions of the bearing branch and beyond. In water-stressed trees, the export of ^{15}N in summer would be more limited due to internal hydraulic limitations generated by lack of water. At this time of year storage begins most of the growing needs being met.

2. At the tree scale

In October 2015, in autumn before leaf fall, more ^{15}N was retained in leaves in control than in stressed trees ($p < 0,05$). More ^{15}N was found in proximal woody compartments (e.g twigs) in both drought treatments.

In February 2016, in winter, at the theoretical maximum storage of nitrogen, we found no difference between treatments. In all treatments, the trunk is the main compartment for N storage, due to its large biomass. ^{15}N was found mainly in aboveground part of the tree in all treatments.

In May 2016, in spring, after leaf expansion, ^{15}N was mainly concentrated in leaves and proximal woody compartments in control treatment whereas in other treatments, ^{15}N was still high in other perennial compartments.

Main conclusions including key points of discussion — The results at the branch scale revealed that beech trees have a conservative strategy concerning N face to water and nutrient constraints. As beech trees are also highly survival to constraints, this conservative strategy could be the secret of beech tree resistance. The seasonal dynamic revealed interesting differences between treatments in autumn. ^{15}N exportation from leaves to perennial compartments occur early in drought treatment with more ^{15}N found in twigs than in leaves. This earlier nitrogen remobilization is linked to an early leaf senescence in response to water constraint. At the end of the winter, the partitioning of the ^{15}N stored was the same according to the treatment whereas in spring, more ^{15}N was observed in leaves and young wood in the control trees where the nutritional needs for growth are the highest.

Future perspectives — It will be interesting to quantify also the impact of the stress on N reserve dynamics in surviving and dead trees. For that, whole trees harvested in this experiment will be used to quantify non-structural N compounds (amino acids and soluble proteins) in the different tree compartments. This will be also done in dead trees harvested in the same time.

Valorisation —

Posters

Chuste, PA, Massonnet, C, Zeller, B, Maillard, P (2016) Drought and defoliation impacts on nitrogen dynamics in branches of 10 year old beech trees investigated through several short ^{15}N urea pulses. JESIUM, 4-9 September 2016, Ghent, Belgique.

Chuste, PA, Massonnet, C, Zeller, B, Breda, N, Tillard, P, Wortemann, R, Thirion, E, Maillard, P, (2017) Whole-tree nitrogen dynamics across seasons in response to defoliation and drought in 10 year-old beech trees. IPNC, 21-24 August 2017, Copenague, Danemark.

Publications in preparation

CHUSTE P.A., MASSONNET C., ZELLER B., GERANT D. , LEVILLAIN J. , HOSSANN C., ANGELI N., WORTEMANN R., BREDA N. and MAILLARD P. Short-term nitrogen dynamics in branches of 10-years-old beech trees submitted to repeated drought and defoliation. In preparation for Annals of Botany

CHUSTE P.A, MASSONNET C., ZELLER B., LEVILLAIN J., TILLARD P., THIRION E. WORTEMANN R.¹, BREDA N. and MAILLARD P. Whole-tree nitrogen dynamics across seasons in response to drought and defoliation in 10 years-old beech trees. In preparation for Tree physiology.

Reports

Rachel RANAIVOMIARANA Impact d'une sécheresse ou d'une défoliation sur la dynamique de l'azote foliaire. Projet Tuteuré de M1 FAGE, 17pp.