MEPiB-DEATH

Morphological and Ecophysiological Processes leading to Beech tree DEATH

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Context — Climate change will probably increase frequency of extreme events and abnormal tree mortality. Forest managers and forest health monitoring services indeed historically reported abnormal tree mortality after extreme or recurrent drought events. However, the mechanisms leading to the tree death remain misunderstood and are widely discussed in the international scientific community.

Objectives — The Mepib-death project aims at understanding the physiological mechanisms and morphological properties affected during exceptional constraints imposed experimentally to induce tree mortality (defoliation and drought). This experimental way to alter the water or carbon status of the trees in an attempt to disentangle the assumptions hydraulic failure and carbon starvation in the death of trees. Moreover, the project explores the diversity of responses to these extreme stresses between 14 beech populations originating from Lorraine forests. The project also aimed at improving our understanding of how the carbon allocation scheme is modified from year to year by recurrent stresses.

Approaches — An experimental approach in common garden is used to respectively alter the water or carbon status of 10-year old beech trees planted in the nursery. About 1000 young beech trees are growing under a roof to control the water regime. Three treatments are compared: an irrigated control treatment, a defoliated treatment in June 2014, June 2015and may 2017 and irrigated to impair mainly the carbon status, dry treatment since June 2014 to April 2017 mostly impairing the water status. In each treatment, 14 populations are represented in two blocks of 12 trees.

Key results —
• As trees of the control treatment reached the roof, we remove the roof at spring 2017. The trees of the droughted treatment were re-watered and their resilience is monitored. The phenology of leaves, root, axial and cambial growth were followed during the growing season 2017. But the funding of this project was not accepted at ANR, so this work will be not continued.

• At Spring 2017, the tree mortality was followed and only two trees do not budburst in the dry treatment. So during all the experiment, the tree mortality reached 8.5% in the dry treatment and 0.3% in the defoliated underlying the high resistance of the young beeches to the imposed constrains. Trees from one forest were particularly vulnerable to drought with a mortality rate rising to nearly 25%.
• The year 2017 was dedicated to perform the biochemical analyses (carbon reserves) of samples in alive and dead whole trees and in branches harvested in June and October 2016. Seasonal and annual monitoring (October 2013, October 2014, June 2015, October 2015, June 2016 and October 2016) of starch contents in branches did not show differences between treatments even after three years of stresses. The analyses at the whole-tree scale revealed higher NSC (Non Structural Carbohydrates) concentrations in June than in October in the dry treatment while the opposite was normally observed in the control treatment. Dead trees had significantly less NSC in all the compartments (leaves, branches, trunk and roots) than alive trees (WP1-WP2, PhD PA Chuste, stage BONKOUNGOU E.).

Main conclusions including key points of discussion — During the three years of constrains, growth was the most limited function by the applied stresses, both above- and below-ground compartment being affected. From the water relations perspective, soil water deficit induced stomatal regulation allowing to control the water status of the tree by maintaining its minimum leaf water potential close to potential inducing 50% of conductivity loss. However, during the third season of drastic water shortage, some branches have exceeded 70% of loss of conductivity. From the perspective of carbon status, analyses are underway but suggest that beech widely favours its storage function at the expense of growth. The observation of a dead tree in the defoliated plot in 2016 shows that repeated stress seems to lead to the expected mortality process by carbon starvation. The quantification of total non-structural carbohydrates on samples collected in 2016 showed an interesting inversion of the maximum and minimum NSC dates in the dry treatment compared to the control. This inversion reveals an economy of reserves in the dry treatment due to strong reduction of growth and consequently maintenance metabolism, while increasing the defence function by the additional production of phenolic compounds.

Future Perspectives — A l campaign of height and diameter growth measurements will be done in the winter to analyse the beginning of resilience in the drought treatment in 2017. Furthermore, genetic analyses will begin on the different Lorraine's Provenance since 20 individuals per provenance will be sequenced (BEECHGENOME project funded by the GENOSCOPE in September 2016). The ecological characterisation of the origin sites of provenances should be done to interpret the differences between provenances.

Valorization

- Posters et oraux présentés dans des colloques internationaux:

- 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. Poster, IPNC, 21-24 August 2017, Coppengue, Danemark.

- Massonnet C., Levillain J., Chuste P.A., Bréda N. Water deprivation impacts faster and more severely phenology and growth than carbon starvation in ten years old beech trees. oral presentation, IUFRO, 18-22 September 2017, Freiburg, Allemagne

- Chuste P., Maillard P., Bréda N., Wortemann R., Thirion E., Massonnet C. What role does storage function play in the death of beech trees? oral presentation, IUFRO, 18-22 September 2017, Freiburg, Allemagne

- Trois articles sont actuellement en préparation :

1) MASSONNET C., CHUSTE P.A., LEVILLAIN J, GEREMIA F, MAILLARD P , DREYER E, DUPOUEY JL , BREDA N. Leaf phenological responses to soil water deficit and defoliation in beech saplings: variability between local provenances. In preparation for Agricultural and Forest Meteorology.

2) 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

3) 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.

Submitted projects:

- ROUMMANI Sirine. (2017) Impact d'un déficit hydrique et d'une défoliation sur la phénologie, la croissance et l'architecture de différentes populations lorraines de hêtre. Rapport de projet tutoré Master 1, FAGE, Université de Lorraine, 17 p.
- BONKOUNGOU Elisé (2017) Impact d'une sécheresse intense sur les stocks d'amidon chez de jeunes hêtres (*Fagus sylvatica L*.) âgés de 10 ans Rapport de projet tutoré Master 1, FAGE, Université de Lorraine, 16 p.