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Ultrasonic acoustic emissions: freezing pattern and relation with cavitation and freeze-thaw induced embolism in woody species.

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Abstract:

Freezing is a limiting factor for plant life, as it can cause damage on living tissues and embolism formation in xylem conduits. Ice formation in plant tissues is usually detected by exotherm analysis or infra-red thermography, whereas freeze-thaw induced embolism is measured through loss of hydraulic conductivity (PLC). We used a nondestructive method based on ultrasonic acoustic emissions (UE) generated by the freezing xylem. However, the exact source(s) of UE has not been identified up to now, especially in angiosperm species, in which xylem tissues are composed of several diverse cell types. We report recent advances on how UE detection could enable insights into:

- (i) Ice nucleation and propagation (Charrier *et al.*, in press),
- (ii) Presence of ice within xylem (Charrier *et al.*, 2014a),
- (iii) Loss of hydraulic conductivity after a freeze-thaw cycle (Charrier *et al.*, 2014b),
- (iv) Damages generated on living cells (Kasuga *et al.*, 2015).

Results indicate that cavitation events are generated at the ice front leading to UE. Species-specific cavitation thresholds are thus reached during freezing due to the temperature-dependent decrease of ice water potential, while bubble expansion and the resulting PLC occur during thawing. Contrarily to drought-induced embolism, UE analysis during freeze-thaw cycles may allow to distinguish between cavitation and embolism stages, according to the freezing and thawing processes, respectively. Ultrasonic emission analysis enabled new insights into the complex process of xylem freezing and might be used to monitor ice propagation in a whole plant *in natura* in relation with stress intensities and physiology.

Keywords: Freeze-thaw induced embolism, ultrasonic acoustic emission, cavitation, ice nucleation, ice propagation, infrared thermography, nondestructive monitoring.

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