# Responses of water-stressed grapevines in Ecotron device :

# Discovery of cavitation phenomenon in the grapevine under shaking.

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## Abstract

This article focuses on the nature of the sounds emitted by stressed plants. It restores the history of discoveries on the acoustic detection of cavitation phenomena. This research is part of a global program of ecophysiological study of the water regime of the vine, carried out in the original device named for the first time 'Ecotron'.

## Preamble

Scientific study for sounds produced by plants as responses to stress or communication strategies is of permanent interest. Our team at Viticulture station – INRA Bordeaux was the first to discover cavitation phenomenon in the grapevine (Loth C. de, 1986 ; Loth C. de, Carbonneau A., 1987). This study was initiated when we experimented the multiple effects of physical shaking, stimulating different mechanical harvesting prosesses. Such interest for cavitation phenomenon was also published by the Swiss Changins team (Zufferey et al., 2009 ; Zufferey, 2013). Recently the following publication put emphasis on sounds produced by plants, which were supposed to be some expressive

signals and communication means. Due to our disagreement on this interpretation, it seemed useful to us to recall both a history of our research and an update on the interpretation of such phenomena.

The scientific review 'Cell' published in 2023 the following article : « Sounds emitted by plants under stress are airborne and informative. Authors : Itzhak Khait, Ohad Lewin-Epstein, Raz Sharon, ..., Nir Sade, Yossi Yovel, Lilach Hadany ». The summary was : «Stressed plants show altered phenotypes, including changes in color, smell, and shape. Yet, *airborne sounds emitted by stressed plants have not been investigated before*. Here we show that stressed plants emit airborne sounds that can be recorded from a distance and classified. We recorded ultrasonic sounds emitted by tomato and tobacco plants inside an acoustic chamber, and in a greenhouse, while monitoring the plant's physiological parameters. We developed machine learning models that succeeded in identifying the condition of the plants, including dehydration level and injury, based solely on the emitted sounds. *These informative sounds may also be detectable by other organisms.* This work opens avenues for understanding plants and their interactions with the environment and may have significant impact on agriculture ».

This study is interesting but some information is open to criticism : our study of sound emitted by stressed grapevine is much more older, and our interpretation can't fit such conclusions. Therefore, it is useful to remind our older researchs on water-stressed vines which revealed for the first time production of acoustic signals by stressed plants, and to discuss about the interpretation of such signals.

## Introduction

As responsible of a research team specialized in Grapevine Ecophysiology at INRA Bordeaux in the period 1973-1993, Alain Carbonneau concentrated research on consequences of water stress on the Grapevine particularly focused on characteristics of the sap flow (1980-1987). That choice was justified on a general point of view by the importance of water limitation within an optimal zone to guarantee optimal berry maturity and wine quality, and on a specific point of view by the hypothesis

that mechanical harvesting using the lateral shaking process was supposed to induce some stress on the vine.

The experimental design was called ‘Ecotron’ and based on culture of vines in huge containers in which we controlled water and mineral alimentation through drip fertigation, and light interception by the foliage by different controlled canopy architectures. This device which combines light interception and transpiration demand, and water supply, was original as well as its name ‘Ecotron’ which was invented on that occasion. It was presented in 1985 (Carbonneau A., Loth C. de, 1985).

‘Ecotron’ was used to study different effects of water stress, in relation to rootstock selection (Carbonneau A., 1985) or the definition of a moderate water stress in relation to photosynthetic regulation(Carbonneau A., 1987). Besides, a precise study of xylem vessels and the characteristics of the sap flow was performed by Da-Peng Zhang (Zhang D.-P., Carbonneau A., 1987 ; Zhang D.-P., 1987), in relation to trunk morphology or different pruning types including new ones designed for mechanization.

A specific study was developped by Chantal De Loth (Loth C. de, 1986 ; Loth C. de, Carbonneau A., 1987 ) on stressed induced by physical impacts on vine shoots due to lateral shaking, as they occurred during mechanical harvesting, which were simulated in ‘Ecotron’. This research was initiated in 1980 by some professionals in the South of France who observed a weakening of their vines after 10 years of mechanical harvesting. The hypothesis was that the vines suffered from a decrease in transpiration, after having checked there were not injured in terms of shoot or bud morphology. We relied this possible stress to the impact of slappers on the shoots when the vine suddenly changed direction for the opposite side during the shaking.

On that occasion we adapt to the grapevine the acoustic detection of the cavitation phenomena. **This was the first time we ‘eared’ a plant reacting to a brake of sap flow.** Even if cavitation phenomena were known particularly when a strong increase in transpiration is induced by a quick air demand (ie : quick microclimate change from a cloudy situation to a sunny and windy one), we demonstrated that it was possible to detect the noise it produced : the sap flow which is under tension may be broken

allowing air to be mixed with the sap and creating bubbles ; these air bubbles explode when trying to pass through ponctuations betwen adjacent xylem vessels. This explosion makes in fact a noise which could be detected. The originality of our work was to record such noises proving the existence of cavitations.

## Materials and methods

Alain Carbonneau adapted to the Vine the method used in Entomology for detecting the presence of undesirable insects in grain containers (Fleurat-Lessard, personal communication) : installation and fixation of small transductors on vine shoots close to leaf petioles, and related to an automatic acoustic recorder. Then all experiences were managed by Chantal de Loth as part of her PhD.

Small portable shaker reproducing the movement of horizontal (not attached) slappers of a commercial harvesting machine was installed under several individual vines at the level of bunches in the 'Ecotron' design. The lateral shaking process was performed in few seconds, checking that shoots were impacted similarly than during a classical mechanical harvesting while berries dropped down.

Basic measurements of stomatal conductance were regularly made before and after the shaking process.

## Results

Full results were published by Chantal De Loth (Loth C. de, 1986 ;Loth C. de, Carbonneau A., 1987).

Acoustic recordings. Before shaking no acoustic detection was observed. About less than 1 mn after shaking, the transductors installed on the shoots close to petioles of leaves situated above the shaken zone began to occurr. The sound was clearly noticed and resembled a succession of elastic cord pinches which lasted several minutes. These sounds were directly eared through head sets and also recorded. Thus, the link was made between the physical impact of shaking, the occurrence of cavitation phenomena due to the mixing air and sap, the sound induced by air bubbles explosions through ponctuations between xylem vessels.

Physiological monitoring. Stomatal conductance of leaves close to transductors was measured regularly and showed a significant decrease after shaking, confirming the perturbation of the sap flow and transpiration. A normal recovering was observed on shaken vines versus controlled vines, the day after shaking on fully irrigated vines in the 'Ecotron', and no recovering 2 weeks after on water stressed vines.

NB : a smaller experiment of vertical shaking under the fruiting zone or pruning wire was also performed using a modified portable shaker. Practically no sound was recorded, showing that the break of the sap flow was immediate when the impacts are lateral to the shoot, and negligeable when they are vertical which is physically explainable. On a practical point of view, one can assume that classical mechanical harvesting using the lateral shaking process may stress vines which are already water stressed to some extent, and that it would be possible to avoid that by using another process such as the vertical shaking under the fruiting zone, or the general trunk shaking, because those both systems do not create direct lateral impact on the shoots. Notice that after our study, the following generation of harvesting machines used attached slappers in order to reduce lateral impacts.

## Discussion

In conclusion, under those conditions the grapevine can react by producing cavitation phenomena, which are precise and real-time indicators of water regime perturbation. This was the first time one can ear such noise produced by a grapevine.

On a general point of view, stressed plants can also react in a similar way, but in any case plants are proven to produce sounds, meaning intelligible sounds or communicating signals, a it was suggested by Khait et al. (2023). *Stressed plants such as the grapevine are proven to produce acoustic signals : noise but not sound !*

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