# Factors Influencing Acoustic Emission Profiles of Cut Roses

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**Abstract**

**The influences of several endogenous and exogenous factors influencing water stress of cut roses during vase life have been studied using ultrasonic technique. Measurements of cavitations, detected as ultrasonic acoustic emissions (UAE), have been done at the peduncle due to a high sensitivity of this stem segment. To improve the information value of cavitation events long time UAE profiles instead of cumulative UAE are used in this paper.**

**As documented in literature for intact woody plants also for cut roses a close relationship between UAE rate and transpiration rate could be detected. Factors influencing transpiration such as photoperiod, leaf area and temperature influenced UAE in a strong way. Stems which did not follow this pattern often showed a reduction in vase life, obviously due to their loss of stomata control. Factors influencing water uptake or transport also determine occurrence and intensity of acoustic emissions. Shortening the stem length or the addition of preservatives delays the occurrence of acoustic events. Rose cultivars exhibit varying patterns of acoustic emission profiles. For water stress tolerant genotypes a delayed onset of cavitations under water stress and well expressed day/night rhythm of cavitation rates were characteristic.**

**From these experiments it can be concluded that cavitation profiles have a good perspective for studying water stress phenomena of cut roses. The use of such profiles opens up possibilities for optimizing the post-harvest process, for detecting water stress tolerant genotypes, and possibly also for a vase life prognosis of cut roses.**

## INTRODUCTION

It is well documented in literature that plants under water stress emit acoustic signals due to cavitations in their water conducting system. The audio detection of cavitations was first reported by Milburn and Johnson (1966) and could be optimized very much through application of the ultrasonic technique by Tyree and Dixon (1983). Observation of ultrasonic acoustic emissions (UAE) is accepted now as a non-destructive, dynamic and highly sensitive measurement of water stress signals of plant stems. As it could be shown in many papers (e.g. Dixon et al., 1988; Tyree and Sperry, 1989; van Doorn and Suiro, 1996) a good correlation exists between plant water relations (water potential, hydraulic conductivity, transpiration or water uptake rate) and acoustic emission rate. And recently, the onset of cavitation events in leaves is assumed to have a signal character for controlling stomata (Salleo et al., 2000).

So far research about cavitation phenomena has been focused mainly on intact woody plants (e.g. *Thuja*, *Tsuga*, *Pinus*, *Acer*, *Castanea*, *Malus*, *Laurus*, *Ceratonia*, *Rhododendron)*. In comparison to that only few articles are dealing with cavitations of cut flowers (*Acacia*, *Chrysanthemum*, *Rosa*, *Thryptomene*). From early experiments of Dixon et al. (1988) it can be seen that cavitations of cut roses can become initiated even at a high water potential of about -0.4 to -0.6 MPa. 90 % of cavitation events occur at a stem water potential below –2.5 MPa. The critical water potential for the occurrence of cavitations with cut roses seems to be cultivar dependent (van Doorn and Suiro, 1996). Furthermore, it is documented in literature that the sensitivity of cut flowers to cavitations is quite different between plant species. After cutting and placing into water roses and chrysanthemums remained with only low UAE for many days (van Doorn and Cruz, 2000), whereas stems of *Thryptomene saxicola* showed a lot of cavitations within a few hours after harvest (van Doorn and Jones, 1994).

Critical with this technique is that recorded ultrasonic events can be generated not only by cavitations, but also by different phenomena as dehydration of fibres or parenchymatic cells (Milburn, 1993). Therefore, the number of recorded signals can not be used as a direct evidence for the number of cavitated elements (Raschi et al., 1990). In addition to that, refilling processes of vessels can often lead to a high cavitation rate, whereas water stress is only low. And similar to any other physiological parameter also the cavitation rate has a very high variance between observed objects. The possible extent of variability can be seen from experiments with *Tryptomene* species where frequency of UAE varied between 0-400 hits per hour up to 1200 hits per hour (van Doorn and Jones, 1994).

Therefore, the use of only cumulative signals seems to be little informative for quantifying water stress. It is a major hypothesis of this paper, that long time observations of cavitations and analysis of cavitation profiles are more reliable for characterizing water stress. Furthermore, a better understanding of factors influencing the cavitation rate and the specific response of cultivars to water stress can help in the interpretation of UAE. Against this background several endogenous and exogenous factors influencing the occurrence of acoustic emission during the vase life of cut roses have been studied systematically.

## MATERIALS AND METHODS

### Plant Material

For studying acoustic emissions of cut roses (*Rosa* × *hybrida*), cultivars with a high importance on the German market as `Prophyta Candid´, ´First Red´, ´Pasha´, ´Red Berlin´, ´Circus´, ´Caroussel´ and ´Birdy´ were used. Due to the high import rate on this market, most roses were obtained via importer, e.g. from Kenya and the Netherlands, and only few from own production. Where relevant for the experiments the origin of the roses is mentioned in the text. Most of the used roses were harvested at commercial cutting stage with a stem length of 60 cm. Before start of experiments rose stems were recut in air and then treated for 3 hours with a preservative solution. For this period as well as for the cavitation experiments, roses were kept under conventional climatic conditions for vase life studies (1000 lx, 12 h lighting, 20 °C, and relative humidity at about 40-60 %). For experiments dealing with climate factors the conditions are described separately. In addition to recording of cavitation events, flower development (after Goszczynska et al., 1989) as well as water stress symptoms (wilting of leaves and petals, bent neck) were recorded daily. At the end of the experiment also leaf area and stem diameter were measured.

### Acoustic Emission Measurement

Ultrasonic acoustic emission (UAE) was measured with a digital acoustic emission device (AMSY4, Vallen-System GmbH, Iking, Germany). The piezoceramic sensors of the instrument (VS150-M) had a frequency range of 100 kHz to 450 kHz. The sensors were mounted to roses by thin rubber bands; silicone paste was used as a coupling medium. Ultrasonic emissions were recorded continuously at flower peduncle 3 cm below the sepals. Only in the sensor position experiment sensors were placed along the whole rose stem in 3 cm intervals. During the experiment roses were placed individually in 100 ml tubes in tap water. Floral preservatives were used in separate experiments only. Investigations were performed both in winter and spring at the keeping quality room, conditions mentioned above. Experiments were at least repeated 4-7 times. To avoid a background noise level, which was around 30 $dB_{AE}$, only UAE data above 36 $dB_{AE}$ were considered.

## RESULTS AND DISCUSSION

### Cavitation Profiles

Experiments with different rose cultivars and different water stress conditions have shown that the number of UAE per time often provides only little information about water status and vase life potential. As it can be seen from figure 1 and many other examples, roses with good vase life often have similar or even more UAE during test period than poor roses. In contrast to that, long time cavitation profiles of good and bad roses show typical differences in the pattern of the signals (profiles). Good roses often start later with emissions and a typical rhythm, following the light/dark rhythms can be detected. With bad roses, however, rhythms are only poor or not visible and the UAE rate decreases very quickly. Possible explanations for these differences are a better stomata control and/or a high refilling potential of good roses. Detailed information about profiles and their typical phases will be described in a second paper about cavitation profiles in this proceeding.

### Position Effects

As it could be shown in many experiments, the peduncle of roses is the most sensitive position for detecting acoustic emissions (Fig. 2). At this part of the stem, UAE rate was several folds higher than in the middle or basal parts, which are often used to observe cavitation events (e.g. van Doorn and Suiro, 1996). In dehydration experiments cavitations start at the peduncle only a few minutes later than in the basal part, showing that water stress signals are not delayed in this segment.

The different stem structure of the middle part of the stem and the peduncle could possibly be the reason for the higher cavitation rate at the rose neck. In comparison to the mid-sections, the peduncle is characterised by shorter vessels with relatively large diameter (Put and Clerkx, 2003). And, the more xylem conduits at the vicinity of the sensor, the higher might the cavitation potential be. In addition to that, vessels with larger diameter are supposed to be more sensitive for cavitation occurrence (Milburn, 1993).

At the basal part of stem, the lower sensitivity to cavitations might be due to a lower total number of vessels (Salleo et al., 2001) near to the sensor then in the peduncle and/or due to a high number of vessels which have been already embolized due to cutting. To answer these questions further anatomical analyses of rose stems are required.

### Transpiration and Cavitation

It is known in practice, that reduction of leaf number can reduce bent neck risk or leaf wilting of roses very efficiently. In accordance to that, cut roses with bigger leaf area and higher transpiration showed UAE much earlier and at a much higher extend than those ones with smaller leaf area. Similar effects can be obtained from climatic conditions influencing transpiration rate. Higher temperatures and/or high radiation increases cavitation rate of cut roses, often not only by day but also by night. In this regard cut roses seem to behave as it has been described for intact plants (Jackson and Grace, 1994; Bormann et al., 2001). Corresponding measurements of water potential support the assumption, that with increasing transpiration rate and/or decreasing water uptake rate the water potential in xylem vessels is decreasing and consequently the risk of cavitations is increasing.

The strong dependence of cavitations to transpiration and stomata function could be demonstrated in experiments with short-time fluctuating dark-light rhythms of 3 hours and simultaneous measurement of gas-exchange. Transpiration rate of cut roses ‘Prophyta Candid’ followed consequently the light/dark rhythm as cavitation rate did. The only difference between these two profiles was that under the chosen climate conditions, cavitations started with a delay of about 24 hours after transpiration rhythms.

### Floral Preservatives

In addition to transpiration, water uptake or transport rate can influence the occurrence of cavitations via water potential very much. So, the application of floral preservatives and biocides (e.g. HQS) prevented bacterial occlusions in the vessels and considerably delayed the onset of UAE occurrence in cut roses (Fig. 3). Similar effects have been observed by Williamson and Milburn (1995) with cut *Acacia* stems. Adding citric acid to vase water prevented a quick decline of water potential, and thus UAE occurrence was delayed. Contrary to that, adding sucrose to the vase solution increased the UAE rate, possibly due to a limitation of water uptake by influencing the osmotic potential of the vase solution (data not shown).

### Cultivar Effects

Acoustic emissions of different rose cultivars showed not only differences in signal intensity but also in profile type. For cultivars as ‘Birdy’, ‘Grand Prix’ or ‘Red Berlin’ a late beginning of cavitation occurrences and a long period of expressed dark/light rhythms were characteristic (Fig. 4). In contrast to that ‘Circus’ or ‘Caroussel’ often started earlier with cavitations and showed a higher UAE rate by night. Differences in xylem anatomy and/or stomata function of cultivars could not yet be identified as factors that cause differences in cavitation profiles (van Doorn and Otma, 1995; Durso, 1979).

## CONCLUSIONS

Long time cavitation profiles seem to be a significant method studying water stress phenomena of cut roses during the postharvest period. In addition to characterization of the actual water status, information can be gained also about influencing factors and involved mechanisms. These possibilities in connection with the advantage of a non-destructive method opens up practical applications in the optimization of postharvest processes and detection of water stress tolerant genotypes, and possibly also the use as an important component for vase life prognosis.

## Literature Cited


Bormann, M.W., Ernst, M.K. and Liebig, H.P. 2001. Concurrent non-destructive measurement of ultrasonic acoustic emission and transpiration on broccoli (*Brassica oleracea* L. convar. *botrytis* var. *italica* Plenck). J. Applied Botany 75:173-177.

Dixon, M.A., Butt, J.A., Murr, D.P. and Tsujita, M.J. 1988. Water relations of cut greenhouse roses: The relationship between stem water potential, hydraulic conductance and cavitation. Scientia Hortic. 36:109-118.

Durso, M. and Bloodley, J.W. 1979. The relation of water stress to bent neck in roses. HortScience 14:68.

Goszczynska, D.M., Michalczuk, B. and Rudnicki, R.M. 1989. The effect of floral preservative enriched with calcium nitrate on keeping quality of cut ‘Sonia’ roses. Acta Hort. 261:281-286.

Jackson, G. and Grace, J. 1994. Cavitation and water transport in trees. Endeavour, New Series 18:50-54.

Milburn, J.A. 1993. Cavitation: a review: past, present and future. In: Borghetti, M., Grace, J. and Raschi, A. (eds.). Water transport in plants under climatic stress, p. 14-26. Cambridge University Press, Cambridge.

Milburn, J.A. and Johnson, R.P.C. 1966. The conduction of sap. II. Detection of vibrations produced by sap cavitation in *Ricinus* xylem. Planta 66:43-52.

Put, H.M.C. and Clerkx, A.C.M. 2003. Xylem structure and function in cut roses. In: Encyclopedia of rose science, edited by Roberts, A.V., Debener, T., Gudin, S., Vol. 2, p.530 – 549.

Raschi, A., Torri, F., Zienna, P., Galli, L. and Vazzana, C. 1990. Cavitation events in *Solanum melongena* L. measured after water stress cycles in field conditions. Acta Hort. 278:119-128.

Salleo, S., Nardini, A., Pitt, F. and LoGullo, M.A. 2000. Xylem cavitation and hydraulic control of stomatal conductance in laurel (*Laurus nobilis* L.). Plant, Cell and

Environment 23:71-79.
Salleo, S., LoGullo, M.A., Raimondo, F. and Nardini, A. 2001. Vulnerability to cavitation of leaf minor veins: any impact on leaf gas exchange? Plant, Cell and Environment 24:851-859.
Tyree, M.T. and Dixon, M. 1983. Cavitation events in *Thuja occidentalis* L. Ultrasonic acoustic emissions from the sapwood can be measured. Plant Physiol. 72:1094-1099.
Tyree, M.T. and Sperry, J.S. 1989. Vulnerability of xylem to cavitation and embolism. Ann. Rev. Plant Physiol. Biol. 40:19-38.
van Doorn, W.G. 1997. Vascular occlusion in cut flowers. I. General principles and recent advances. Acta Hort. 482:59-63.
van Doorn, W.G. and Cruz, P. 2000. Evidence for a wounding-induced xylem occlusion in stems of cut chrysanthemum flowers. Postharvest Biology and Technology 1:47-57.
van Doorn, W.G. and Jones, R.B. 1994. Ultrasonic acoustic emissions from excised stems of two *Tryptomene* species. Physiol. Plant. 92:431-436.
van Doorn, W.G. and Otma, E. 1994. Vascular occlusion in cut flowering rose stems exposed to air: role of water entry into the lumina of the xylem conduits opened by cutting. J. Plant. Physiol. 145:78-82.
van Doorn, W.G. and Suiro, V. 1996. Relationship between cavitation and water uptake in rose stems. Physiol. Plant 96:305-311.
Williamson, V.G. and Milburn, J.A. 1995. Cavitation events in cut stems kept in water: implications for cut flower senescence. Scientia Hort. 64:219-232.

**Figures**

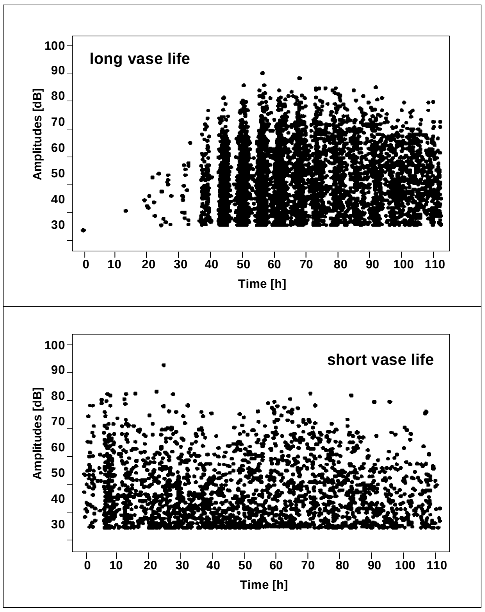


Fig. 1. Ultrasonic acoustic emissions of ’Pasha‘ roses with long and short vase life.

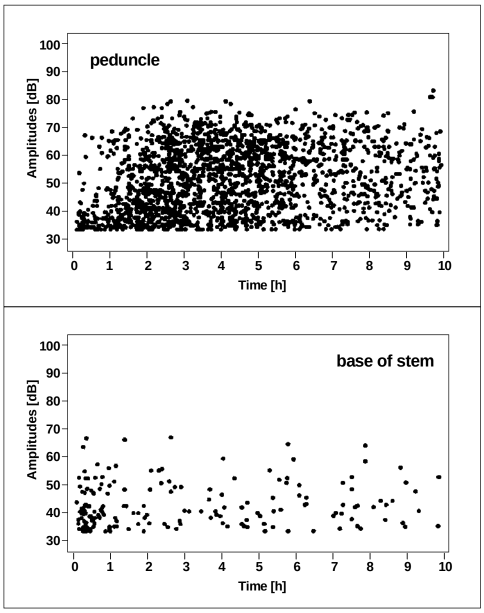


Fig. 2. High acoustic emision rate at rose peduncle, but only low at stem base.

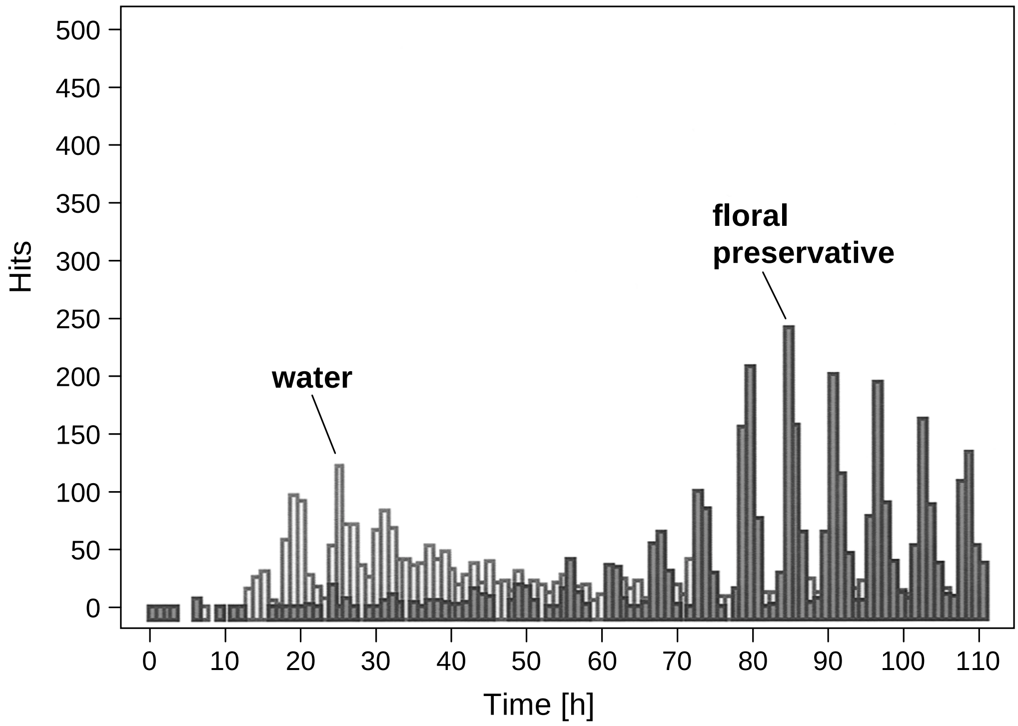


Fig. 3. Application of floral preservative delayed the occurrence of cavitations (experiment with ’Pasha‘ rose)

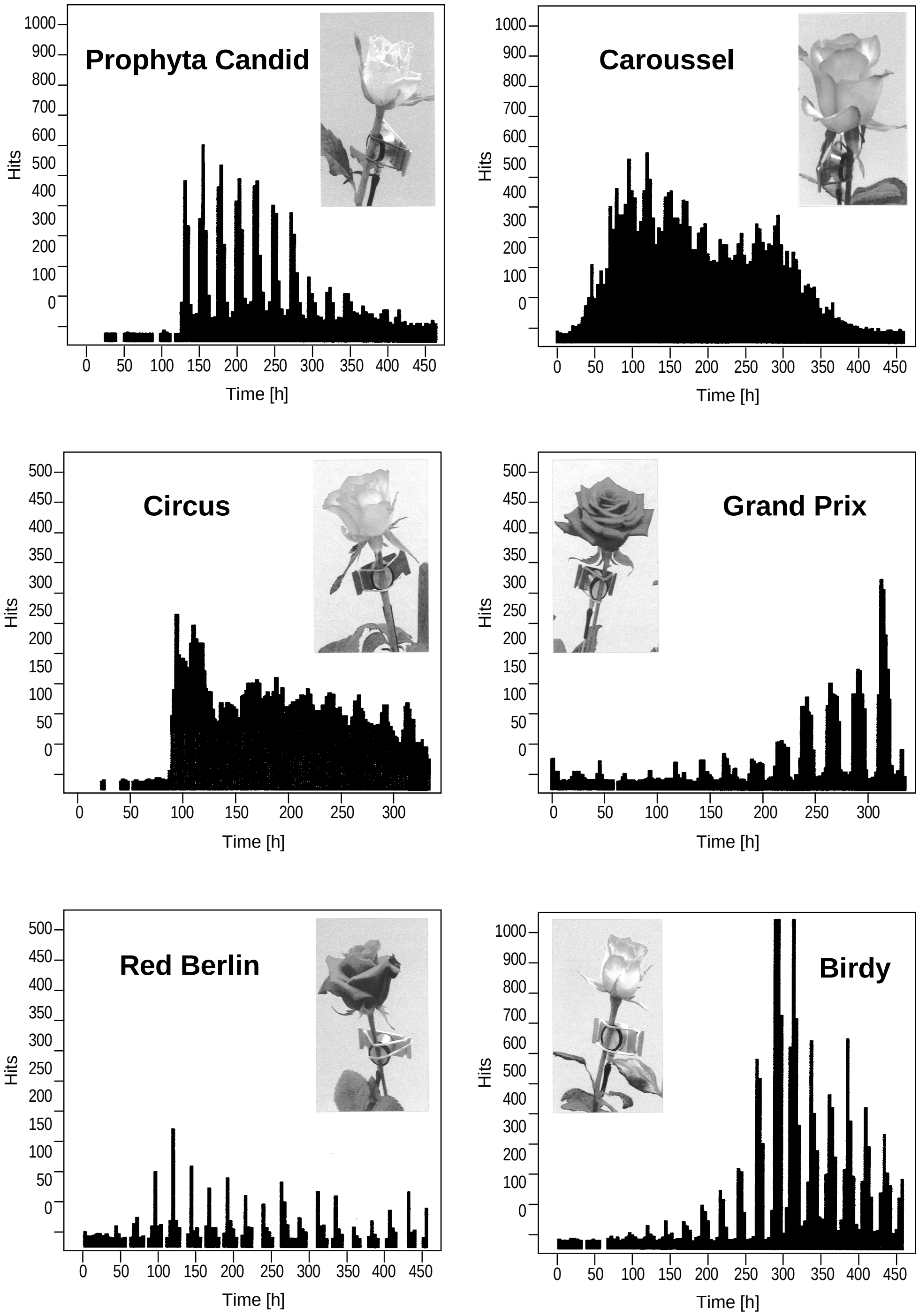


Fig. 4. Cavitation profiles of different rose cultivars