Acoustic Emission Profiles of Cut Roses as a Prognosis Component for Vase Life

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Abstract

Plants subjected to water stress are emitting ultrasound signals due to cavitations in their water conductive systems. As reported in the literature, these cavitation signals are used for quantifying water stress status of plants, analyses of water stress phenomena and also for practical applications in irrigation control. This paper deals with long time observations on cut roses during postharvest phase and analyses of cavitation profiles as a prognosis component for vase life.

Roses with good vase life potential often show four different phases in their cavitation profile. During the first phase, i.e. immediately after harvest and/or an adequate storage for up to 2-3 days, only few acoustic emissions are detectable. The second phase typically shows a high amount of signals and expressed light/dark rhythms. Decrease of intensity and frequency of emissions during day and increase of emissions during night is characteristic for phase 3 during which often wilting of petals, first leaf wilting and with susceptible cultivars also bent neck can be observed. Phase 4 marks the end of vase life, then often a strong increase of acoustic emissions is detectable, possibly caused by mechanical degradation of fibres and vessels and not by cavitations. Such profiles are probably of high interest for studying water relations of cut flowers and the influencing factors, but for the use as a prognosis component information results too late and due to a high variance is not reliable enough for practical applications.

In contrast to that, characterization of the endogenous water stress management (testing of stomata function at fluctuating light/dark phases and the refilling potential of vessels at short time de- and rehydration experiments) seems to have a better perspective for the application of cavitation profiles in prognosis of vase life.

INTRODUCTION

Quality tests in the market channel of cut flowers are standard today. A lot of criteria exist to judge the outer quality of products, whereas no tests are available to check the inner quality i.e. for example the vase life potential of cut flowers or the establishing potential of pot plants. Different attempts have been made until now, as for example the use of biophotonic or chlorophyll fluorescence technique, obviously not very successful exempt from *Rhododendron simsii* (Lootens and Heursel, 1999).

Possible reasons for this are: vase life of cut flowers is a rather complex process and measured parameters e.g. the quantum efficiency of photosystem II have no causal relationship to factors dominating the vase life of cut flowers.

It is well documented in literature, that vase life is limited by an occlusion in stems, leading to premature symptoms of water stress (van Doorn, 1997). This occlusion is due to bacterial growth or cavitations in the xylem vessels. Therefore early detection of cavitation in flower stems seems to be one of the important components for characterization of potential water stress of cut flowers and for vase life prognosis. Application of ultrasonic techniques for measuring cavitation events in the water conductive system is well documented in literature (Milburn and Johnson, 1966; Tyree and Dixon, 1983; Dixon et al., 1988; Milburn, 1993). When plant water potential is falling below a critical threshold xylem vessels start to cavitate. This process is combined with an emission of ultrasonic signals, but the origin of these signals is still not fully understood. For characterizing water stress it was important that cavitations are combined with a reduction of hydraulic conductivity (LoGullo and Salleo, 1991; Hacke and Sauter, 1995) and that these signals can be obtained earlier than wilting symptoms (Milburn, 1993).

In contrast to intact plants at present only few papers are available about cavitations of cut flowers. Early experiments with cut roses have shown that cavitations can be initiated already at a relatively high water potential of about –0.2 to -0.4 MPa, and a mild water stress of only -0.5 MPa could result in up to 40 % loss of hydraulic conductance (Dixon et al., 1988). The relationship between water potential and emission frequency seems to be cultivar dependent. In dehydration experiments with different rose cultivars 'Cara Mia' showed cavitations at a much higher water potential than e.g. 'Madelon' or 'Sonia' (van Doorn and Suiro, 1996). In addition could be shown in this paper that intact rose stems with a high number of cavitations lead to a reduction of water uptake after cutting. *Acacia* flower stems behaved similar to roses and showed good correlation between water potential and ultrasonic acoustic emissions (Williamson and Milburn, 1995) whereas with cut stems of *Tryptomene calycina* even at –5.3 MPa no cavitations were detectable (van Doorn and Jones, 1994).

From these experiments can be concluded that also with cut roses xylem cavitations are a significant factor, influencing water conductance of stems, and thus vase life. For practical applications in water stress detection the acoustic emission technique has the advantage of non destructive measurements, and a high technical safety due to a lot of applications in material testing in the industry. Objective of the presented research is to quantify water stress status of cut roses and to test the hypothesis of cavitation profiles to be a help in detecting potential water stress problems in the market channel or with the customer. For this aim two approaches have been chosen. First one is to observe cavitation events under conventional climate conditions and to compare cavitation profiles of roses with different vase life. In the second approach the parameters of water stress management as stomata function and the refilling potential have been tested as prognosis component for vase life.

MATERIALS AND METHODS

Observation of Cavitation Events

For studying acoustic emissions of cut roses (*Rosa* × *hybrida*) with different vase life potential, cultivars with known differences in bent neck risk, roses from own production as well as imported products and also roses with different storage durations or other pre-treatments have been used. Before the start of each experiment rose stems were recut in air and than kept individually in 100 ml tubes with tap water. Climatic conditions were very similar to those for vase life tests (light at a level of about 15 µmol/m^{-2} sec^{-1} photon flux [about 1000 lx], 12 hours by means of fluorescent lamps, 20 °C, and a relative humidity of about 40-60%). In addition to recording of cavitation events, flower development (after Goszczynska, 1989) as well as water stress symptoms (wilting of leaves and petals, bent neck) were recorded daily, and at the critical stage twice per day. Vase life was determined as time until rose lost its decorative value (occurrence of bent neck or wilting of petals). At the end of the experiment also leaf area and stem diameter were measured.

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 attached to roses by thin rubber bands and as a coupling media silicone paste was used. Ultrasonic emissions were recorded continuously at flower peduncle 3 cm below the sepals. This part of the stem has been proven to be the most sensitive one for detecting cavitations. For each treatment 4-7 single stems were tested. To avoid background noise only UAE data above 36 dB_{AE} were considered.

Measuring of Water Stress Management

For studying the endogenous water stress management of roses two test conditions were developed. For testing the stomata function (experiment 1) the effect of fluctuating light/dark rhythms of 3 hours on cavitation events was studied. To test the refilling potential (experiment 2) roses were kept without water for 6 hours twice. These dehydration phases were linked by an 18 h rehydration phase. To avoid photoperiodic effects the experiments were done under 24 h lighting.

RESULTS AND DISCUSSION

Cavitation Profiles during Vase Life Process

As shown by many experiments, in case of roses with good vase life potential often 4 phases with different signal patterns are detectable (Fig. 1). In the first phase immediately after harvest or adequate storage conditions only very few signals occur. From measurements of water potential in published reports (Dixon et al., 1988; van Doorn and Suiro, 1996) it can be concluded that during this phase water potential is still high enough to prevent occurrence of cavitations.

It follows phase 2 with pronounced light/dark rhythm. Roses with good vase life potential often stay in this phase for a long time. The dependence of cavitation rate to light/dark rhythm could be observed with short time rhythms of 3 hours as well as with long time rhythms of 12 hours. In contrast to that under permanent light or during dark periods cavitation rhythms were only slightly expressed. Due to a strong correlation between transpiration rate and cavitation events (data not shown) it can be concluded that the cavitation rhythms are strongly dependent on stomata control and the influence on water potential. These observations with cut roses are supported by earlier studies with intact plants. In experiments with Scots Pine trees (Jackson and Grace, 1994) or with broccoli plants (Bormann et al., 2001) a strong dependence of cavitation rate to day/night rhythms is described. And the experiments of Doi et al. (1999) show that water uptake of cut roses follows the photoperiodic rhythm, too.

Phase 3 is characterized by a decreasing intensity of cavitations during day and an increasing intensity during night. In this phase often first wilting symptoms are detectable and water potential can reach values of about –2 MPa. The decrease of cavitation rate by day is therefore not dependent on the actual water potential but possibly due to a high number of finally embolized vessels which can not be refilled anymore. Maybe the increase of night cavitations is due to a loss of stomata function in the later stage of vase life.

In the end of vase life (phase 4), roses often show typical dehydration symptoms, a strong increase of UAE, especially in the basal parts of stems can be observed. In accordance with interpretations of Milburn (1993) these signals can be assumed to be fracture signals and not cavitation events.

The expression and duration of phases depend very much on cultivars and many endogenous and exogenous factors influencing the stem water potential (for further information see second paper about cavitation profiles in this proceeding). Roses with poor vase life potential often show typical differences to the cavitation profiles described above (Fig. 2). Even at the beginning of measurements a high number of signals can be observed. In addition to that, differences of UAE rate between light and dark phases are only small and the number of UAE decreases rapidly. With such roses often a low water potential at the beginning of vase life already exists and missing rhythms are obviously an indicator for limited stomata control.

However, our study of more than 100 cavitation profiles shows that differences between good and poor roses are not always expressed as described above. There were also examples where roses with only a short phase 2 and a long phase 3 have had good vase life and in some cases roses showed bent neck even in phase 2 despite expressed light/dark rhythms. These observations and the delayed onset of cavitation occurrence have led to the conclusion, that information from cavitation profiles comes too late for prognosis, and their reliability is not yet high enough for quality tests in practice.

Water Stress Management

The test of mechanisms controlling water relations of plants was the second approach to gain early information for prognosis of water stress during vase life. The hypothesis of this work was that stems with a good stress control have also a good vase life perspective. For testing stomata control roses were kept under indoor conditions with fluctuating light/dark rhythms of 3 hours. In many of these experiments cavitation profiles of roses with good vase life perspective followed these rhythms for a long time, and they often showed a high hit rate also at the beginning of phase 2 (Fig. 3). Additional measurements of transpiration rate showed the same pattern and documented that cavitation profiles under these conditions are mainly controlled by stomata status.

To measure the refilling potential of the water conductive system, cavitation events have been observed under short time de- and rehydration experiments. Figure 4 shows such profiles for roses with good and such ones with limited vase life potential. Typical for roses with good vase life potential was a very strong increase of cavitation events at the beginning of the dehydration phase, followed by a period with nearly no cavitations in the rehydration phase. During the second dehydration phase good roses showed again a very strong increase in cavitation events. The pattern of this cavitation profile has led to the assumption that roses with good water stress management

1. have a high cavitation potential (vessels are filled with water before start of dehydration experiment and are not embolized) and
2. they have a good refilling potential (otherwise the high cavitation rate at the second dehydration phase could not be explained).

In contrast to that, roses with limited vase life potential showed only a little increase in cavitation events during dehydration phase 1 (probably due to a limited cavitation potential) and nearly no reaction during dehydration phase 2 (vessels are probably already embolized). In further experiments it shall be tested whether the difference between the cavitation rates of the two dehydration phases is a suitable indicator for the refilling potential.

CONCLUSIONS

Observations of cavitation events under conventional vase life conditions are a good description of the water stress status of cut roses. But, for prognosis purposes the information is gained late and not yet reliable enough. In contrast to that, cavitation profiles of cut roses under water stress can provide important information about refilling potential and stomata function (endogenous water stress management). By acceleration of this test procedure, cavitation profiles of stressed roses have a certain perspective to be used as one component for vase life prognosis.

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Figures

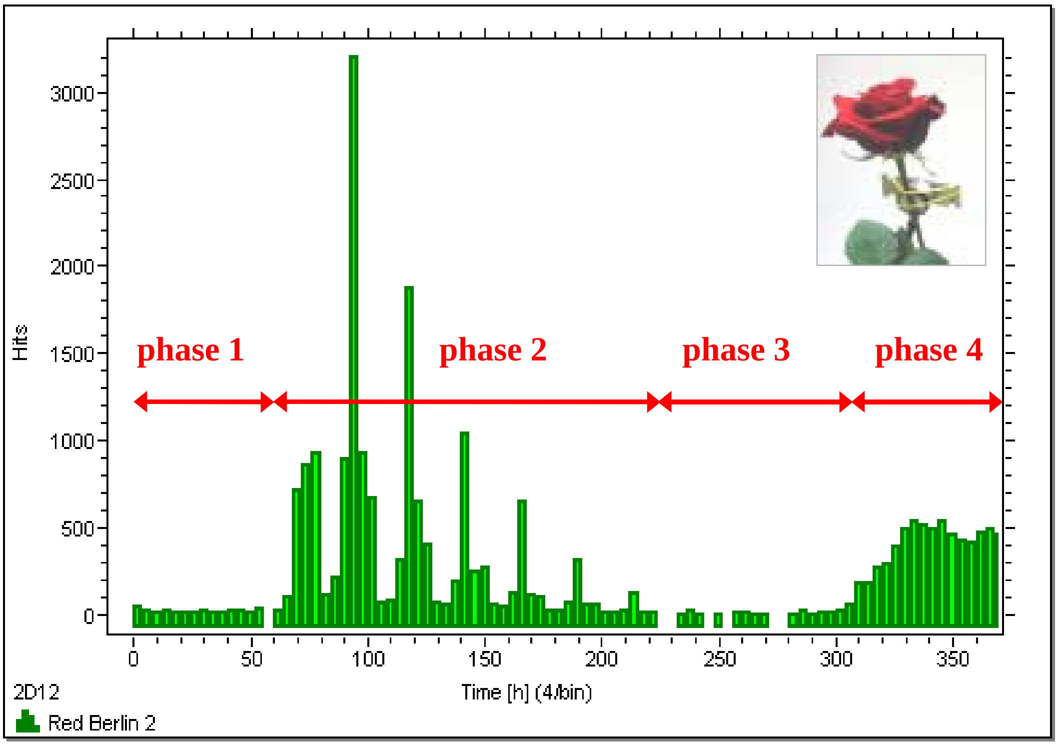

Fig. 1. Typical cavitation profile of ‘Red Berlin‘ roses with long vase life. Flower stems were imported. Acoustic emission measurements under conventional indoor conditions.

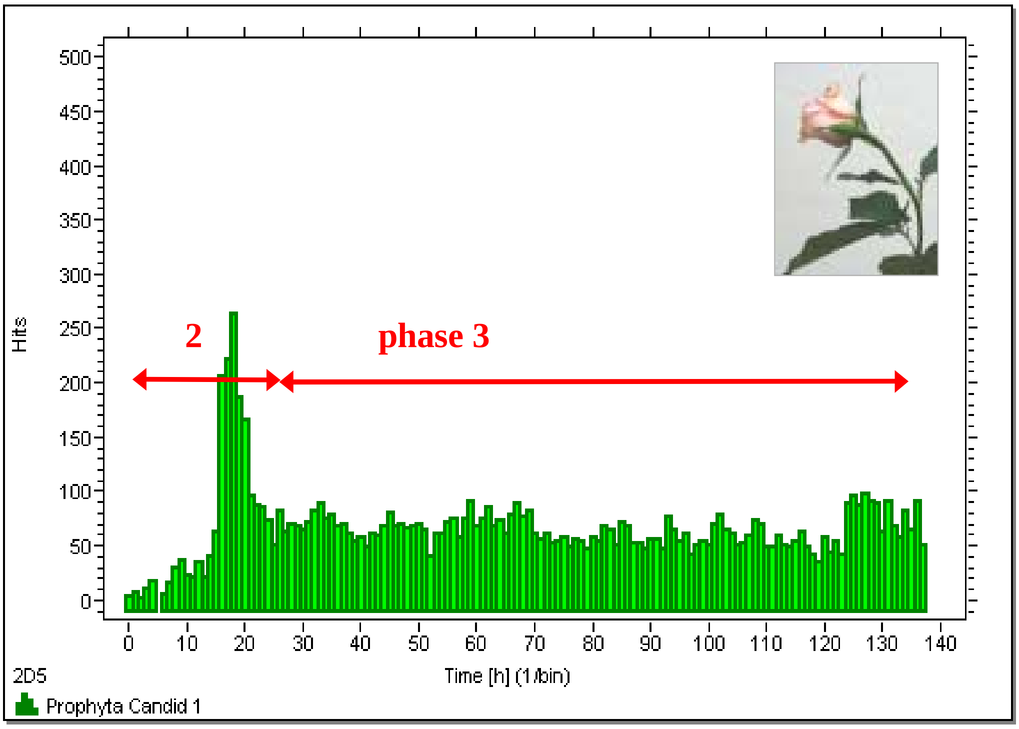

Fig. 2. Cavitation profile of ’Prophyta Candid‘ roses with early bending and short vase life.

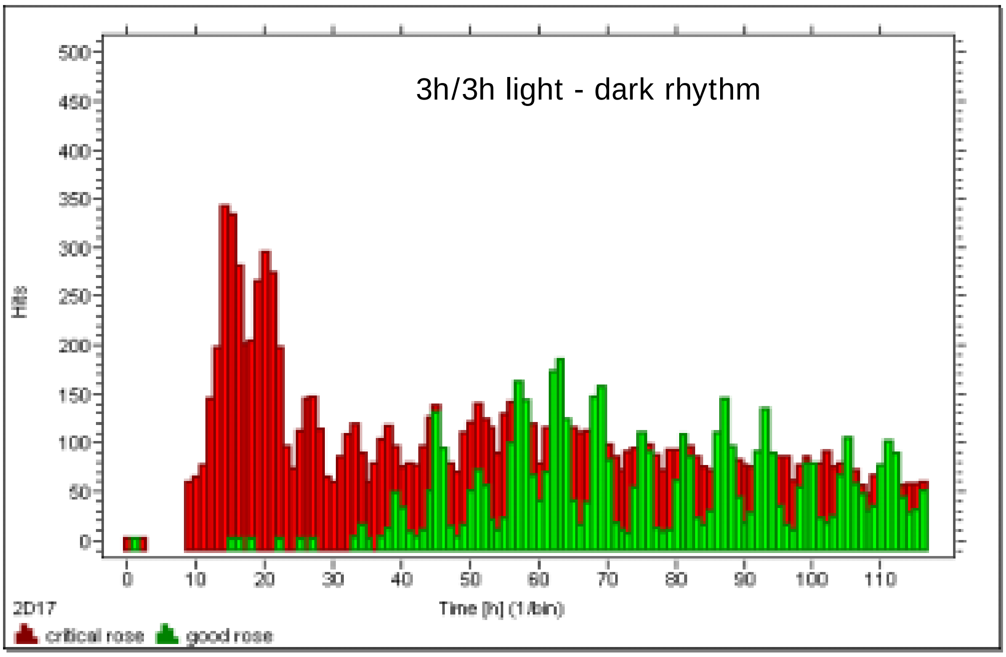

Fig. 3. Roses of ’Prophyta Candid‘ with long vase life show strong cavitation rhythms, following fluctuating dark/night rhythms of 3 hours. Roses with short vase life start earlier with their cavitations and rhyrthms are only poor.

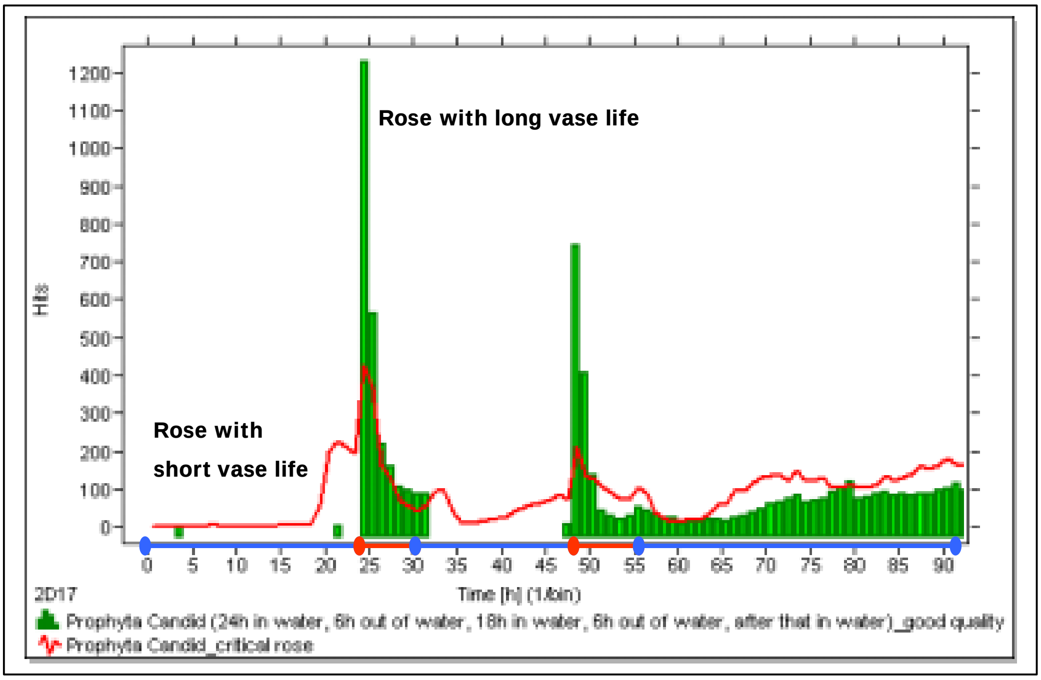

Fig. 4. Typical cavitation profiles of roses with good and poor quality under de- and rehydration conditions.