

Progress report to the International Cut Flower Growers Association

Calorespirometry: a novel approach to predicting energy requirements of greenhouse flower crops

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Introduction

A plant's actual growth rate can generally be characterized as the mediation of its potential growth rate (PGR) by the multitude of environmental factors to which it is exposed. While it is a relatively simple matter (albeit tedious) to quantify actual growth, predicting *potential* growth has been impossible in the past. Calorespirometry has been suggested as a method to characterize PGR along with plant adaptation to various environmental conditions (Criddle *et al.*, 1991a).

The partners for this project demonstrated the validity of this concept also for horticultural purposes (Raviv *et al.* 2001 a & b). In relation to the current project, two new and relevant findings were found: (1) different cultivars of rose have significantly different functional responses to temperature (Raviv *et al.*, 2003), (2) different organs of rose have significantly different functional responses to temperature (Raviv *et al.* 2001b).

Based on the difference in the response of the sprouting buds and that of the unfolding leaflets, we hypothesized that for certain cultivars it may be possible to save fuel (energy costs) as well as to improve flower quality, without compromising the total yield, by lowering the temperature for a certain period during the flush.

Consequently, the objectives of the current project are: (1) to characterize the calorespirometric response of sprouting buds and of unfolding leaflets of several commercially important cultivars, growing under standard greenhouse conditions and tested under a wide temperature range. The resulting responses should suggest differential temperature requirements of the tested cultivars. (2) To test the assumed temperature requirements of the tested cultivars under temperature-controlled greenhouse conditions.

Materials and Methods

a. Treatment of plant material.

Work on this project has begun in Israel in the fall of 2004 when relevant plant material was acquired. The following cultivars were selected based on international availability: Golden Gate® (Kordes), Prophyta® (De Reuter), First Red® (NIRP), Lovely Red® (Meilland) and Milva® (Tantau). At a later stage we realized that the Lovely Red plants were not true-to-type so that the following tests were conducted only with 4 cultivars. Ten rose plantlets of each selected cultivar, grafted onto *Rosa indica* Major are grown in 2-liter containers, filled with coconut coir. The reason for using a relatively small container is experimental: in order to shorten the time between organ excision and start of the measurement, we bring the whole plants into the lab so it is preferable to keep it as light as possible. The plants are grown in a greenhouse at the Newe Ya'ar Research Center, ARO under temperature range of 17°C (at winter nights) to

28°C (at summer days). This range is maintained using heating system in the winter and fan and pad in the summer. The minimal relative humidity allowed is 50%. The plants are treated as a commercial rose crop. Weak stems are pinched and bent down to maximize photosynthesizing area.

Initially we started the measurements by testing calorimetric response of leaflets, rather than buds, due to the relative abundance of the former organ. This was partially reported in the progress report submitted at May 2005. In the current report we describe the conclusion of the leaflet tests and the beginning of the tests, conducted using excised buds.

b. Calorespirometric measurements

Calorespirometric measurements are conducted using differential scanning calorimeter Model CSC 4100 (Calorimetry Sciences Corporation, Provo, UT). Two units of this instrument exist in Newe Ya'ar, allowing for 6 replicates in each run.

Figure 1: The calorimetric setup at Newe Ya'ar.



The calorimeter is operated in isothermal mode in the range 10-22°C for both rose buds and leaflets. Young developing buds (upper buds taken from stems, 4-5 days after cutting them back, 2.0-4.0 mg DM) and leaflets of uniform size and developmental age (ca. 10 mm, 8-13 mg FM, 2.0-3.5 mg DM) are sampled and analyzed seconds after excision. The measurement itself lasts about 30 minutes while total processing time per run is about 3-4 hours. Each calorimeter has four removable ampoules, three of which are used for simultaneous measurements of rate of heat production with the remaining

ampoule used as a reference. Fifty μl of water is dispensed into the ampoules and the leaflets' and buds' bases are inserted in the water. It is assumed that the RH within the ampoule reached close to saturation shortly after sealing the cap. The R_{CO_2} is determined via the methods of Criddle *et al.* (1991b) and Fontana *et al.* (1990). R_{CO_2} measurements are facilitated using the bottom 3 mm of a thin-walled micro Eppendorf tube. Called a "base trap", these small containers are filled with 40 μl of 0.4 N NaOH and inserted into the ampoules to absorb CO_2 produced by respiring tissue samples. The heat of the exothermic reaction between CO_2 and NaOH forming carbonate is used to calorimetrically estimate respiration rates. The CO_2 reaction heat rate divided by the change in enthalpy between the reaction of CO_2 with NaOH in the base trap (108.5 J/mol) is used to determine R_{CO_2} (Hansen *et al.*, 1994). Maintenance heat (q) released by the different organs is very uniform, thus 6-8 replicates are needed to estimate this parameter, with standard error of 2-8% of the average. R_{CO_2} , on the other hand, is much less uniform, so that about 12 replicates are required, in order to obtain a standard error of 10-25% of the average.

Results

Up to now we concluded the leaflet RSG measurements for the 4 cultivars. For this we conducted an average of 8 replicates for each temperature/cultivar combination for the value of q and 12 replicates for the value of R_{CO_2} . The presented results describe the calculated RSG and they are summarized in the following figures. Standard errors (SE) values of RSG were calculated according to the following equation:

$$SE_{\text{RSG}} = (SE_q^2 + SE_{R_{\text{CO}_2}}^2)^{0.5}$$

Figure 1: Calorespirometric response of Golden Gate leaflets.

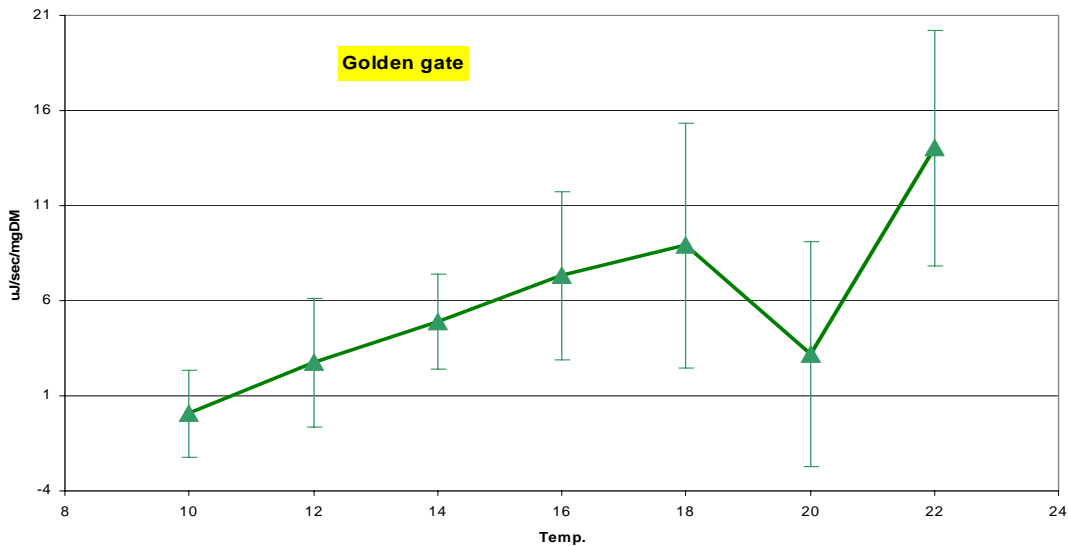


Figure 2: Calorespirometric response of Prophyta leaflets.

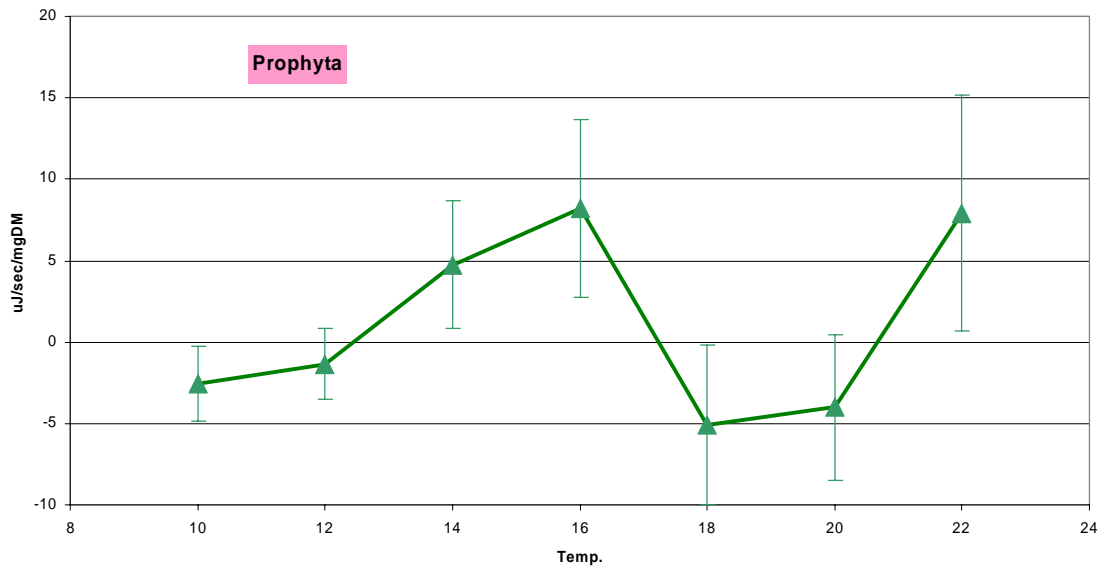


Figure 3: Calorespirometric response of First Red leaflets.

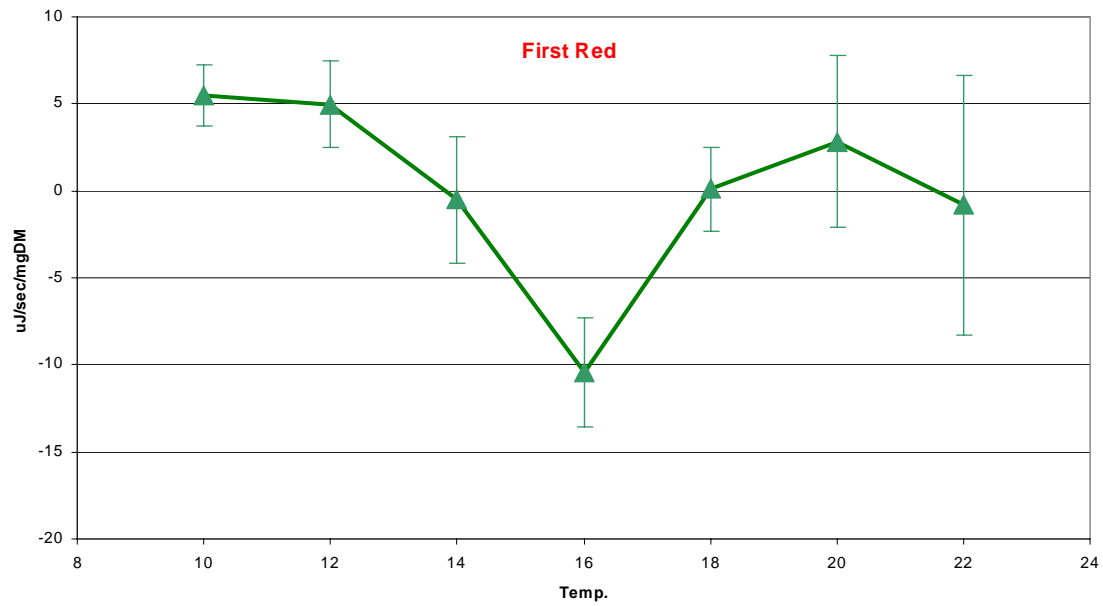
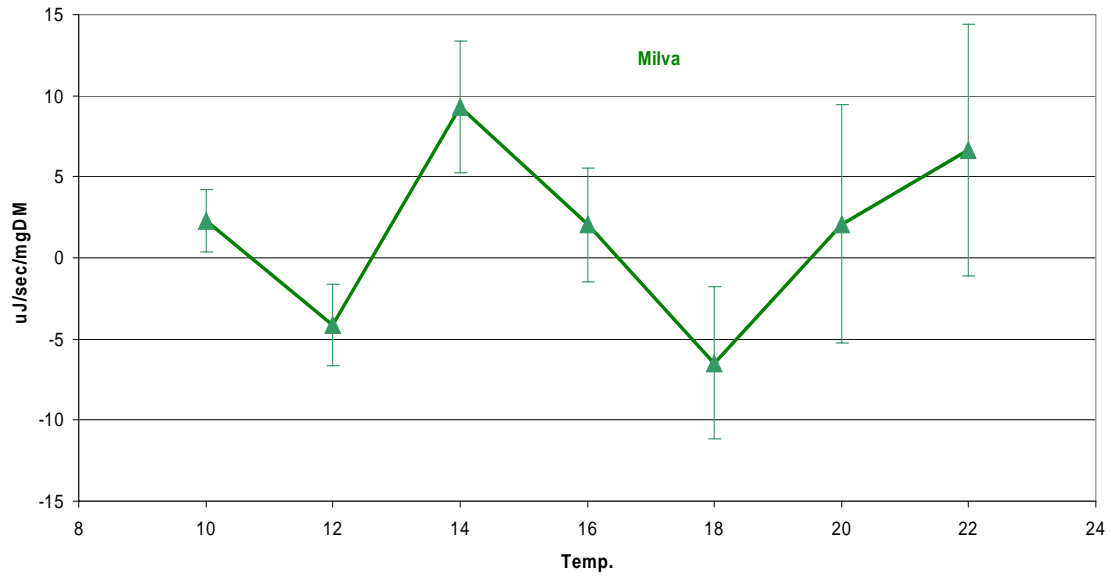


Figure 4: Calorespirometric response of Milva leaflets.



Bud RSG values were calculated in a similar manner. We plan to complete this set of measurement in a few more weeks, to allow the planned validation experiment, to be conducted in UC Davis during the coming spring. Non-final sets of values, accumulated so far, appear below.

Figure 5: Calorespirometric response of Golden Gate developing buds.

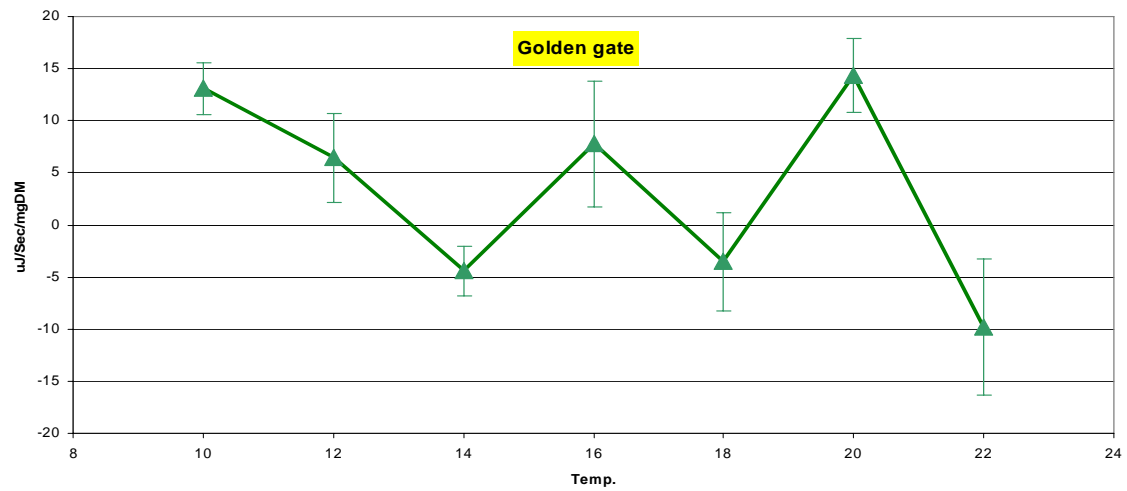


Figure 6: Calorespirometric response of Prophyta developing buds.

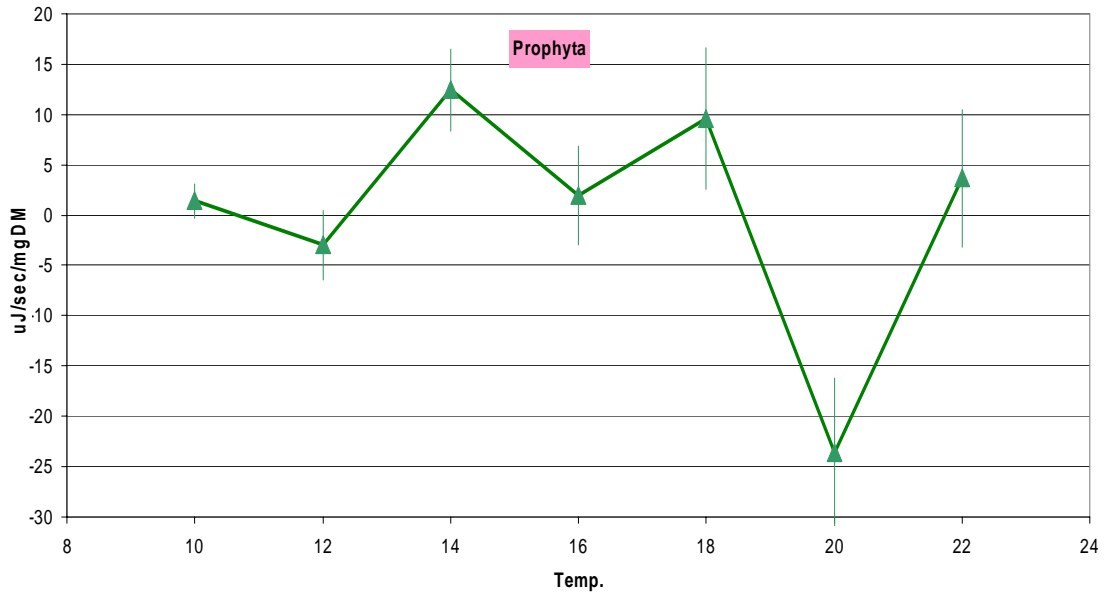


Figure 7: Calorespirometric response of First Red developing buds.

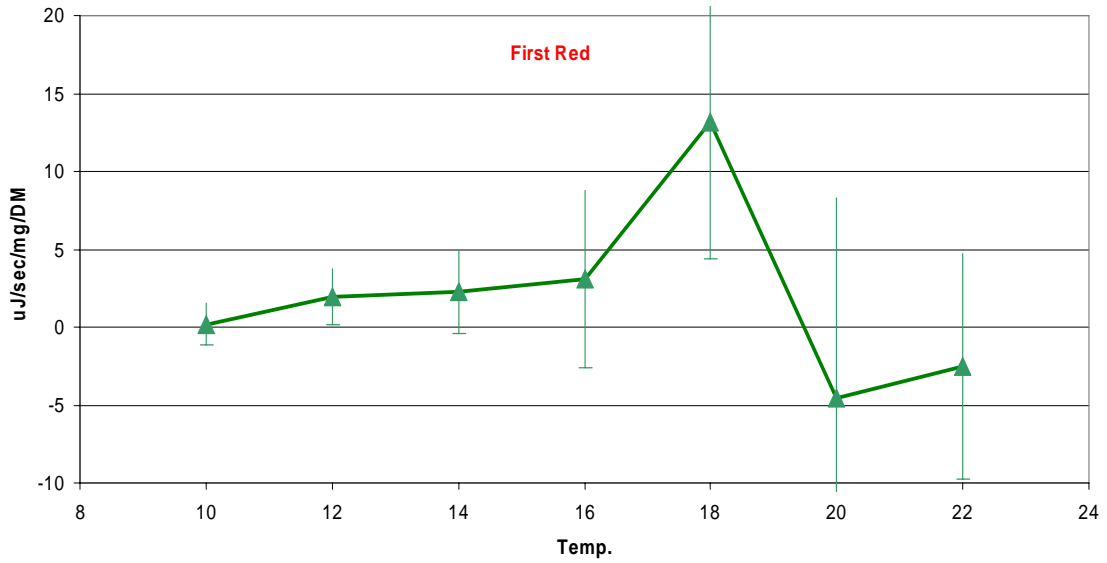
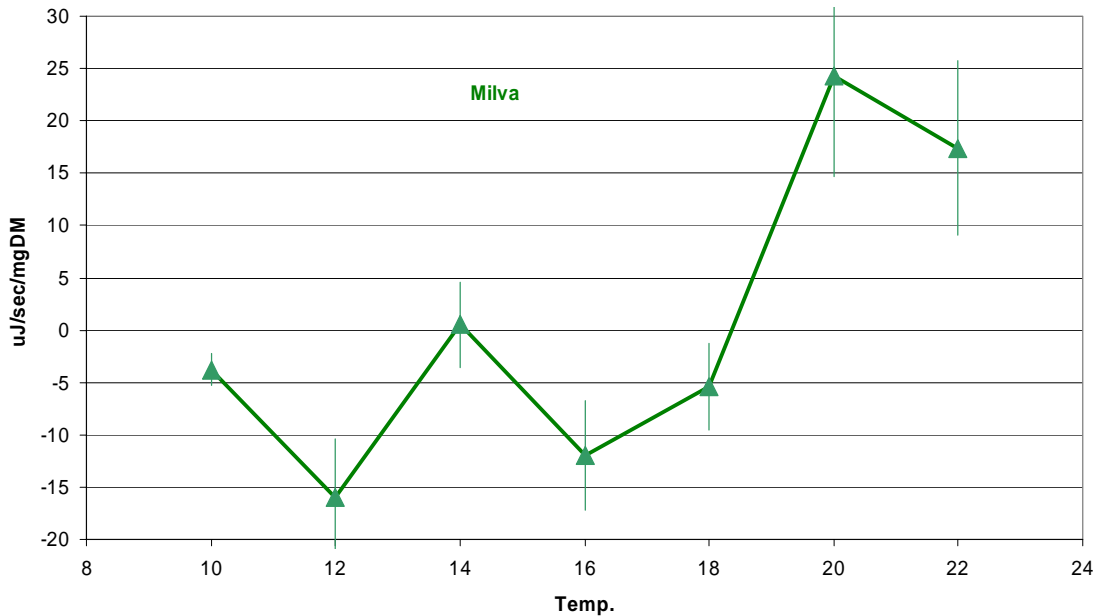


Figure 8: Calorespirometric response of Milva developing buds.



Discussion and Intermediate Conclusions

The results accumulated so far corroborate our initial hypotheses, namely that (1) calorespirometry may serve as a useful screening tool to predict optimal temperatures for growing plant organs; and (2) that various cultivars of roses can have different temperature optima.

A preliminary analysis of the results suggests the existence of at least three main groups.

- First Red and Milva require relatively high temperatures (18-20°C) for optimal bud emergence. Subsequent leaflets development can sustain much lower temperatures (10-12°C for First Red and 14°C for Milva). This can be translated into a two-phase flush course, with an initial 2-week period of high temperatures, gradually falling for the rest of the flower development.
- Golden Gate seems to show an opposite response, namely a very low temperature preference (10°C) during the stage of bud emergence and high temperature requirement of the growing leaflets (16-22°).
- Prophyta represents a cultivar having a relatively indifferent temperature preference for the two developmental stages: the model predicts a 14°C and 16°C as optimal temperatures for bud emergence and for leaflet growth, respectively. This appears as the first potential candidate for a greenhouse low-temperature experiment, due to the relative simplicity of such an experiment.

As we complete the lab work, the stage is set for the greenhouse trials which are essential to corroborate the conclusions using greenhouse experiment. While we had

initially hoped to start this well in advance of the conclusion of the calorimetric analyses, circumstances prevent getting this started. We are now in the process of starting this phase of the project. Our plan is to carry out this work at UC Davis starting spring 2006. Dr Raviv will be spending a sabbatical year at UC Davis from April 2006 to March 2007, in part to assist with this phase of the project.

References

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