

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

Heiner Lieth, Plant Sciences, University of California, Davis CA 95616 USA

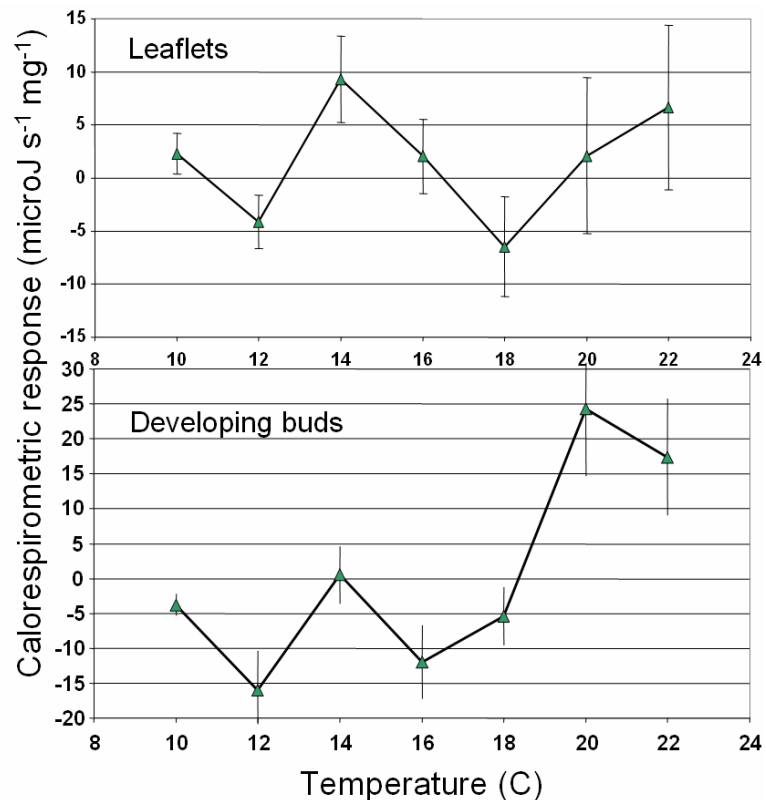
Michael Raviv, Agricultural Research Organization, Israel

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Calorespirometry is a scientific technique where plant tissue is evaluated with regard to its energy utilization. With this technique it is possible to determine various metabolic rates of various parts of the plant and, thus, assess the plant's ability to grow various tissues. This approach also allows us to determine a potential growth rate for the tissue and to evaluate how various conditions (e.g. temperature) affect the tissue and this potential rate. In past research we found that this concept is valid for various purposes related to horticulture (Raviv et al. 2001 a & b). That research found that: (1) tissues of different cultivars of rose have significantly different functional responses to temperature; (2) tissues from different organs of rose (e.g. leaves vs roots vs flower buds) have significantly different functional responses to temperature (Raviv et al. 2001b). Prior to the development of microcalorimetry, it was not feasible to measure these sorts of organ-level processes to the accuracy level needed to assess potential growth rates.

One of the interesting discoveries of our calorimetry work on roses was that the temperatures that result in the greatest potential growth were much lower than anticipated for some processes on some plants. For example, Figure 1 shows the calorimetric evaluation of the rose variety 'Milva'. Note in particular that the response for leaflets at 14°C suggests metabolic activity of these tissues at temperatures that are generally accepted as being low for rose production.

The project as proposed and funded by the Joseph Hill Foundation consists of two parts: (1) development of the response curves for metabolic activities in relation to temperature using calorimetry and (2) testing of resulting hypotheses with regard



**Figure 1** Calorespirometric response of Milva leaflets and emerging buds.

to temperature management in greenhouse cut flower rose production. The first part was completed in Israel by Dr. Raviv and his team and a previous progress report describes the results of that part. The second part was slated originally for UC Davis upon completion of the first phase. However, due to circumstances beyond our control, we were unable to get the second part started until this summer. The second part is currently underway and is the subject of this report.

The objective of the project at this stage is to see whether we can exploit the low-temperature metabolic response of specific organ during specific periods of time so as to, perhaps, allow us to reduce the night temperature in cut-flower rose production. It is well known that lowering either day or night temperature lengthens development time of the crop, but if flower development continues despite this, then it may be possible for growers to reduce energy costs. The fundamental objective of this work is to see if the findings from microcalorimetry can be used to identify cultivars which can be used in a production program that involves low night temperatures, at least for part of the production cycle.

To carry out this work we are now trying to validate the predictions based on the thermodynamic model, as found using calorespirometric work and test whether it can be used to save energy in greenhouse production.

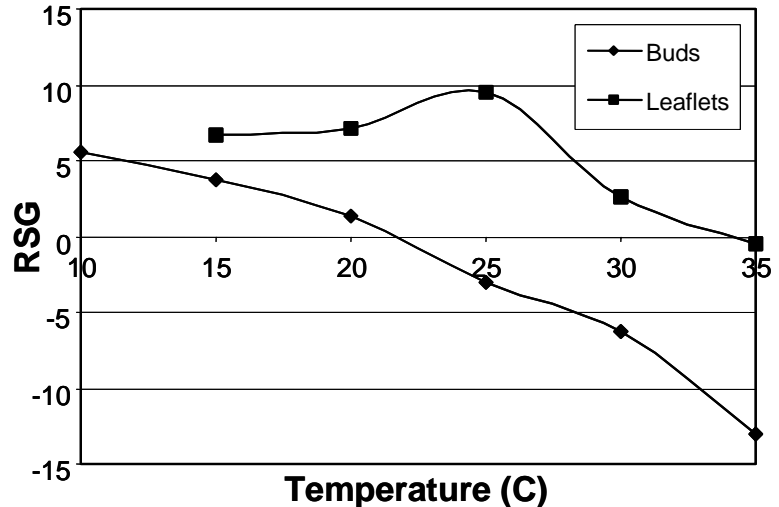
## Materials and Methods

Two varieties that showed contrasting patterns with regard to low temperatures were 'Milva' (see Fig 1) and 'Kardinal' (Fig 2).

The current phase of the trial is being carried out at the University of California, using the greenhouse for day-time conditions and cold-chambers for night conditions.

The plants being used in this trial are mounted on movable carts so that they can be transferred to growth chambers at various temperatures during the night. The Milva plants were obtained from California

Pajarosa and were repotted into coir from their hydroponic buckets. Kardinal plants were available to us as small plants. Both sets of plants were repotted into 3-gallon containers filled with coir. The first few weeks were used as an acclimation period.



**Figure 2** Calorespirometric response of Kardinal leaflets and emerging buds.

## Experimental plan

Eighteen plants of each cultivar are used for the experiment. The plants stayed in the greenhouse, under standard conditions, for an adaptation period of 6 weeks. On August 14, 2006 the plants of each cultivar were divided into 9 pairs of apparently uniform plants. The experiment started after pruning/pinching all plants so as to synchronize their developmental stage as much as possible. The plants were pruned again on October 26, 2006 (second flush) and on January 13, 2007 (third flush).

### *Kardinal*

The interesting element of the calorimetric results for Kardinal is the high metabolic activity of small buds at temperatures between 10 and 15°C (see Fig 2). This is extremely surprising because all models for rose physiology developed in the past indicate that development rate declines with temperatures below 15°C. Thus our objective for Kardinal is to determine if this aberration can be used to our advantage by using low night temperatures during the period of bud break. It should be noted that this is completely opposite of what growers practice since the general trend in the industry is to raise temperatures during this period.

Three to five uniform shoots per plant were tagged after every pruning and served for detailed measurements. All other flowering buds/stems were also harvested and recorded. Half the plants stayed in the greenhouse both day and night at around 20-25°C day and 16-19 °C night; the other half of the Kardinal plants were in the same daytime temperature conditions in the greenhouse, but were transferred nightly (around 4:45 pm) to the cold conditions (14±1°C) from August 15 until bud break had occurred for most of the tagged shoots (August 23). The carts were rolled back from the cold storage to the greenhouse every morning, as early as possible (between 7:00 and 7:30 am). Full bud break was determined as a 5 mm long bud.

The same procedure was repeated after the second and third pruning events for periods of 10 days in both cases.

### *Milva*

The calorimetric results for Milva showed an unusual pattern for leaflet metabolic activity with a peak at 14°C. Again, this is completely unexpected since no grower would consider this temperature to be conducive to enhanced flower development. Our objective for Milva is to test whether we can use this low temperature during the part of the production period where the leaves are forming and unfolding.

Three to five uniform shoots per plant were tagged and served for detailed measurements. All other flowering buds/stems were harvested and recorded as well. All Milva plants were initially left in the greenhouse, under 18-20°C night conditions, until unfolding of the first leaflet of the majority of the newly developed shoots (August 28, 2006). At this point one plant of each pair was transferred each night into a cold chamber (14°C, 57°F), while its counterpart remained in the greenhouse during the night. The carts were rolled back from the cold storage to the greenhouse every morning, as early as possible (between 7:00 and 7:30 am). This procedure was

repeated until the stage of visible flower bud was reached in most of the tagged shoots. This occurred after 17, 13 and 14 days in the first, second and third flushes, respectively. From this stage on, and until harvest, the plants stayed in the greenhouse.

### *Measured variables*

The length of each tagged shoot was measured three times per week. At harvest, flower length, fresh and dry weight was measured, as well as the number of petals. Since number of petals did not show any connection to the treatment or to any other parameter during the first two flushes, it was not done in the third flush

Data loggers were installed on representative carts so that exact temperature trajectory for each treatment was recorded even as the plants were moved to the various temperature regimes. Thermal units will be calculated from these data and used during data analysis.

Nightly greenhouse temperatures were kept at 62-68°F (16.7-20°C) from the beginning of the experiment and until August 25. At this day the range was narrowed to 65-68°F (18.3-20°C).

## **Results and Discussion**

Blindness of tagged stems was a major problem in the second and third flushes. During the second flush, light conditions were very poor, and this led to a very high level of blindness among the tagged stems and presumably among non-tagged flowers (Table 1).

Table 1: Flush, treatment and cultivar effects on blindness percentage among tagged pruned stems.				
Cultivar	Treatment	Flush 1, 8-9/06	Flush 2, 11-12/06	Flush 3, 1-2/07
Kardinal	Test	13	57	28
	Control	15	56	45
Milva	Test	21	68	41
	Control	44	61	50

For this reason we will present the results of the second flush only partially. Before starting the third flush, supplementary lighting was installed above the plants. It was operating daily, only when all carts were in place, (07:30 am – 4:30 pm).

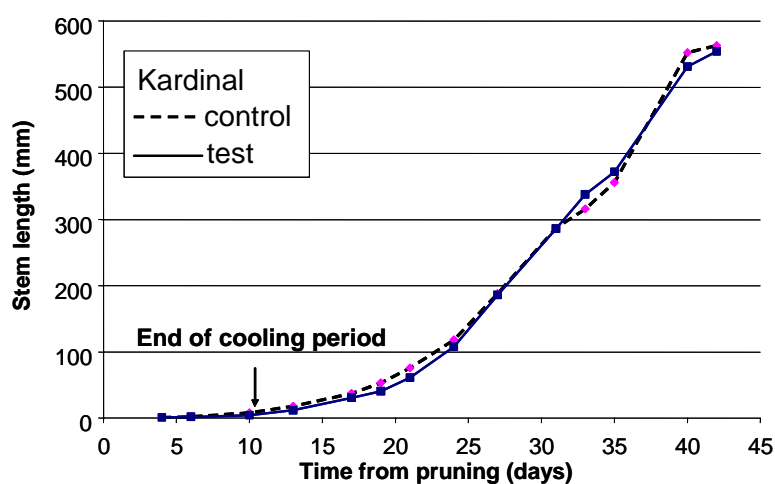
Harvest of the third flush has just started at the time of submitting this report. We will therefore report yield data only of the first two flushes (Table 2).

Cultivar	Treatment	Flush 1, Aug-Sep 2006			Flush 2, Nov-Dec 2006		
		Flowers/ plant	Biomass/ plant (g)	Flower stem length (cm)	Flowers/ plant	Biomass/ plant (g)	Flower stem length (cm)
Kardinal	Test	6.6 a*	66.8 a	59.4 a	2.3 a	18.2 a	58.6 a
	Control	6.2 a	57.4 a	54.4 a	2.1 a	17.4 a	56.6 a
Milva	Test	9.1 a	111.7 a	53.8 b	2.1 a	25.7 a	64.5 a
	Control	8.7 a	120.6 a	61.6 a	2.4 a	31.8 a	68.9 a

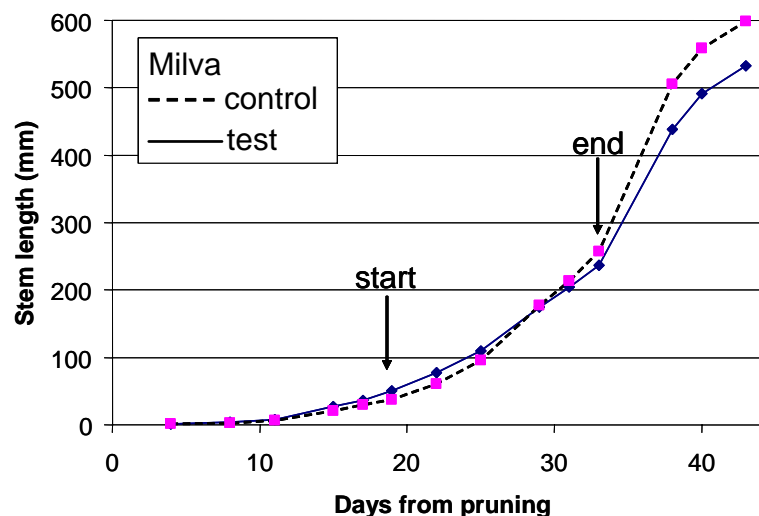
\* Means with identical letters in the same subcolumn (by cultivar) are not significantly different

It is noteworthy that periods of 10 days (Kardinal) or 13-17 days (Milva) under night temperature of 14°C did not affect flower or biomass production of both cultivars. Average flower length, however, was negatively affected by the low temperature, in the case of Milva, first flush. We assume that since it was conducted under summer conditions, the first flush can be referred to only as training replicate. Since the second flush was hit by high blindness percentage, we regard the third flush as the most representative one for our purposes. It is yet to be seen whether these results will be repeated in the third flush. For the time being we can report for this flush about the elongation process of the tagged stems (Figures 3 and 4).

At this point we are still collecting data for flush 3 so that it is too early to report results from this flush. However, preliminary indications of the third flush (Figures 3 and 4) suggest that the



**Figure 3** Average stem length of Kardinal stems during third flush



**Figure 4** Stem length of tagged Milva flower stems during the third flush

results obtained in the first flush are also showing in the third flush (no differences for Kardinal stem length; but significant differences for Milva). In other words: no yield loss or quality difference for Kardinal, and a slight negative effect of the cooling treatment on stem length of the Milva flowers

When energy costs were lower than they are now, it was economically feasible to grow plants at high temperatures; currently growers are interested in anything that will let them reduce energy costs. Doing so may well require a change of cultivars. In fact, the reason South American growers typically use a different set of cultivars is for this very reason: they prefer cultivars that can be produced at colder temperatures, even if it means much longer production cycles. As growers with heated greenhouses seek ways to reduce energy costs by shifting cultivars, they will need to know which of their cultivars stay productive under cooler temperatures and which will not.

We recognize that this is a fairly high gamble and that there are many more plant processes that combine to form a harvestable flower shoot than just the metabolic activity of buds or leaflets. Yet if we can use this tool to learn how to use low temperatures to our advantage in cut-flower rose production then this will be a major advance. Also, if we find that we can use calorimetry as a tool to test cultivars' responses to various temperature levels, then this will be a very important tool for breeders since this gives them a tool they can use even before cultivars are scaled up into commercial testing or released to the public.

#### Literature cited

Raviv, M., J.H. Lieth, D.W. Burger and R. Wallach (2001a). Optimization of Transpiration and Potential Growth Rates of 'Kardinal' Rose with Respect to Root-zone Physical Properties. *J. Amer. Soc. Hort. Sci.* 126: 638-645.

Raviv, M., D.W. Burger and J.H. Lieth (2001b). Microcalorimetry: A novel approach to decision making in cut rose production. *Acta Hort.* 547: 105-110.