The Role of Calcium and Boron in Rose Development and Petal Blackening:
Observations in Commercial Rose Greenhouses and Shoot Tissue Nutrient Status

Raúl I. Cabrera, Alma R. Solís-Pérez and Jennifer McCormick
Texas A&M University
Research and Extension Center
17360 Coit Road, Dallas, Texas 75252

Dr. Cabrera is now at Rutgers University
Cabrera@aesop.rutgers.edu

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ICFG-HILL, P.O. Box 99, Haslett, MI 48840
ICFG.HILL@yahoo.com

In this report we summarize observations on petal blackening (PB) shared by California rose growers during our visit this winter. We are also reporting on PB observations me made on roses growing in our experimental greenhouses and hydroponic system, along with some preliminary results on tissue nutrient analyses. As the black and white printing of this report in the ICFG bulletin makes it difficult to appreciate the details of the provided photographs (originally in color), we will gladly provide electronic copies (by e-mail) of this, and any previous, report with color photographs to anybody requesting it.

Petal blackening observations in California

We had the opportunity to visit rose greenhouses in California (Watsonville and Carpinteria areas) and obtain first hand information on petal blackening from these growers. Climatic conditions in coastal California differ from those commonly observed in Colombia (Sabana de Bogotá), namely lower (sea level) elevations, a good deal of overcast and cooler days during the winter months and less UV solar radiation. If you read our previous reports about petal blackening (PB) under Colombian conditions, you'll realize that those growers' comments and opinions pointed to a significant involvement of UV-radiation (fairly high at the 8,000 ft. plus elevations in that region), albeit they indicated also the need for overcast days with relative cool temperatures and high RH for the development of the PB symptoms. Our visit to California growers revealed that while certainly the overcast, humid and short-photoperiod days of the winter months exacerbate PB problems in red cultivars, these can be present for most of the year (except during hot summer days), and that there is a strong genetic component. Table 1 lists those cultivars that have been reported to show significant levels of PB symptoms, some of which are illustrated in Figure 1.

Table 1. Greenhouse rose cultivars (red color) that have been reported, by US rose growers (mostly from California), to show significant petal blackening (PB) symptoms.

Cultivar	Observations
"Freedom"	This cultivar, not grown in the US, is the most cultivated one in Colombia and highly susceptible to PB. Our experimental plants of this cultivar in Dallas, TX also have readily shown PB symptoms.
"Happy Hour"	A most troublesome cultivar showing PB year round in all coastal production areas of California.
"Bulls' Eye"	PB symptoms observed in postharvest, after cooling, but rarely in the greenhouse. PB problems, occurring mostly during Jan-Feb, are more severe in young (1-3 year old) plants. Older plants (over 3 years) show less severe symptoms.
"Magnum"	One California grower reported this as a cultivar most susceptible to PB, even under the most controlled environments.
"Prestige"	This cultivar presents slight blackening on the inside borders of both guard (outside) and inner petals. A grower reported that whitewashing greenhouse roofs have minimized problems.
"Grand Prix"	Similar to 'Magnum'
"Kardinal"	PB symptoms in this cultivar have been observed as late as June.

Figure 1. Petal blackening symptoms in some red rose cultivars. From left to right: 'Bull's Eye', 'Prestige' and 'Happy Hour'. Notice severity of PB symptoms on 'Happy Hour' and how mild they are on 'Bulls' Eye'.

Confirming our suspicions and previous observations, one grower pointed to the development of two distinctive PB phenomena, one readily observed during greenhouse production or preharvest (like with 'Happy Hour' and 'Freedom') and the other observed mostly in postharvest (like 'Bulls' Eye' and the old 'Royalty'), after exposure to cooling treatments followed by placement in vases under standard temperature and lighting (household) conditions. The postharvest development of PB symptoms in 'Bulls' Eye' was also associated with plant age, being more acute in younger plants (less than 3 years old) and less pronounced in older (> 3 year-old) plants.

The dominant comment and observations about the development of PB under California conditions was, however, on its significant association with minimum greenhouse temperatures. Most growers agreed that temperatures below 50-60 ºF (10-15.6 ºC) for a 1-2 week period before flower harvest were the most conducive to PB development. It was also agreed that the most susceptible the cultivar, the higher the minimum temperature needed to be maintained to minimize or completely eliminate the problem. Two growers indicated that maintenance of minimum temperatures above 60 ºF (15.6 ºC) –one had them set as high as 65 ºF (18.3 ºC)– resulted in an almost zero incidence of PB, even in the most troublesome cultivars. These observations are supported by the literature. Anthocyanins are the pigments responsible for the red color in roses and other flowers, and temperature is one of the most significant external factors affecting their biosynthesis and accumulation. Low temperatures increase anthocyanin concentration and the opposite occurs at high temperatures; the higher the concentration of anthocyanins the darker the color, which eventually can turn necrotic (Biran and Halevy, 1974). Dela *et al*., 2003 have observed that while transient (short-term) changes in temperature, like 1-day, did not affect the synthesis and accumulation of anthocyanins in 'Jaguar' roses, longer exposures (3-days and above) to temperature treatments, particularly at the last stages of flower development, did have a significant effect.

Given this new set observations, comments and research results, the extensive PB disorders we observed in Colombia during February-March of 2006 (see report in January 2007 ICFG Bulletin), and which growers there attributed to high UV radiation, may have been in fact strongly influenced by temperature. Most Colombian greenhouses do not have heating, and thus can experience relatively low temperatures during both day and night hours. PB symptoms, just like the devastating downy mildew they are experiencing, were observed in all growing operations without climatic control, except those that were retrofitted with heating. Furthermore, the observation of worst PB symptoms on plants by the edges of the plastic houses (where the side curtains are lifted daily for passive ventilation purposes),

and less severe on the inside plants, also point to a strong temperature gradient component (without ruling a possible radiation issue). Colombian growers noted that they had been experiencing a rather long period of fairly cool, humid and overcast days with intermittent sunny and warm days, conditions that historically have been strongly associated with the development of PB symptoms.

Research in Dallas

For the first time in seven years, we have observed rose petal blackening symptoms in our research greenhouses in Dallas. These observations were made during November and December of 2006, and specifically in the cultivars 'Freedom' (growing in 5-gallon containers with peat-based substrate) and 'Happy Hour' (growing in the recirculating hydroponic units; shown at right). These months have been cool and overcast, with night temperatures steadily dropping below 60 ºF (see Fig. 2). These low temperature ranges have been due in part to repairs and upgrades to our heating units, which required their disconnection during November to mid-December.

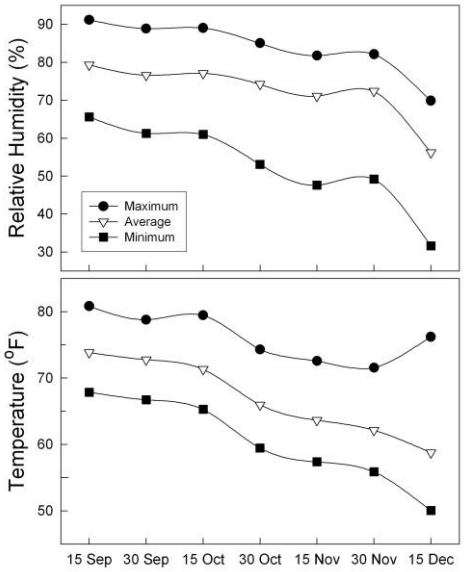

Figure 2. Relative humidity and temperature in experimental rose greenhouses at Texas A&M University at Dallas. Each data point is the 15-day average readings taken (hourly) with an automated (datalogger) monitoring system.

Flowers from the containerized 'Freedom' plants (grafted on 'Natal Briar') were harvested in November and pooled in two groups, with and without PB symptoms. The flower shoots were dissected into outer petals, inner petals, sepals plus ovaries/reproductive structures, peduncle, upper ½ leaves, upper ½ stems, lower ½ leaves and lower ½ stems, then dried and ground, and finally analyzed for mineral nutrient concentrations. While the tissues were analyzed for all essential mineral nutrients, we show only data for nitrogen (N), potassium (K), calcium (Ca) and boron (B). The first two elements, N and K, were the only ones that showed meaningful overall differences in concentration between flower shoots with and without PB; basically those with PB symptoms had higher concentrations. We also show data for Ca and B as these are the two elements that we have hypothesized having an involvement in the development of PB symptoms. In this particular exercise, however, we could not appreciate concentration differences that could have pointed to their involvement in the development of PB. These plants are currently being transplanted into the

recirculating hydroponic units to induce carefully controlled deficiency conditions and observe whether they induce PB-like symptoms (something that many years ago we were able to do with 'Royalty' plants- see our previous reports for details).

Table 2. Concentration of selected mineral nutrients on tissues of 'Freedom' flower shoots with or without petal blackening symptoms. Flowers were harvested in November from container-grown plants irrigated with a modified ½ strength Hoagland solution.

Nutrient ➔	**N - %**		**K - %**		**Ca - %**		**B - ppm**	
Petal Blackening ➔	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*	*No*	*Yes*
Outer petals	2.18	2.21	1.95	1.89	0.14	0.13	14	13
Inner petals	2.22	2.54	1.78	1.80	0.12	0.13	13	14
Sepals/ovary	2.39	2.55	2.67	2.77	0.76	0.81	22	19
Peduncle	1.41	1.50	1.80	1.97	0.37	0.39	20	18
Upper ½ leaves	3.60	3.85	2.39	3.43	1.57	0.96	64	96
Upper ½ stem	1.48	1.63	1.09	1.14	0.32	0.35	21	22
Lower ½ leaves	3.62	3.89	2.99	2.56	0.97	1.45	94	56
Lower ½ stem	1.16	1.30	1.08	1.16	0.23	0.25	14	17

The 'Happy Hour' plants, growing on either *R.* x *manetti* or 'Natal Briar', were grown over one flowering cycle with modified ¼ strength Hoagland solutions supplemented with either 4 meq/L of $CaCl_2$ or 4 meq/L KCl. The rootstock had a differential effect on the accumulation of some nutrients in flower shoot tissues, namely higher P, Ca S, Mn and Na concentrations in *R.* x *manetti* plants (data not shown). The supplemental salt treatments only had a significant effect on tissue Ca concentrations (higher in plants receiving 4 meq/L of $CaCl_2$). The pattern of nutrient accumulation in tissues was similar to that shown in the flower shoots of the container-grown 'Freedom' plants (Table 2). As far as statistical interactions in the hydroponic study, the only one was a salt X organ, and only for the accumulation of Ca, which was the highest in leaves of plants supplemented with $CaCl_2$ and lowest in stems of KCl-supplemented plants. We should report that despite some obvious differences in concentrations of nutrients in leaves and peduncles with respect to the supplemental Ca or K salt treatments, there were basically no nutritional differences in petal tissues (data not shown). As it turns out, we found out that most, if not all, of the harvested flowers shoots, regardless of rootstock and supplemental salt treatment, were afflicted by mild petal blackening symptoms. So far we are concluding that genetic predisposition (i.e. cultivar sensitivity) and definitively minimum (or night) greenhouse temperatures (i.e. below 55-60 ºF), are among the most influential factors on the development of PB. In the next months we will be testing whether induced Ca and B deficiencies can, on their own (maintaining temperatures above 60ºF), reproduce PB-like symptoms.

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