Application of calcium, boron and sucrose on cut peony stems (*Paeonia lactiflora* Pall.) cv. Karl Rosenfield

Aplicación de calcio, boro y sacarosa en varas de corte de peonias (*Paeonia lactiflora* Pall.) cv. Karl Rosenfield

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ABSTRACT

In cut flowers, there must be clear guidelines for export, therefore, it is essential to proper postharvest management, to store the flowers for as long as possible in top condition, both for transit and vase life; in Chile there is very little knowledge about this operation. In order to address these questions, a study was conducted to evaluate the performance of postharvest life of the peony cultivar 'Karl Rosenfield', using four treatments: water, preharvest Borocal® with water, Borocal® with 100 g sucrose/L of water, and 100 g sucrose/L of water, some of which had Borocal® added preharvest and sucrose applied postharvest; evaluating four quality parameters in cut flowers: floral diameter, stem curvature, stem weight and vase life. The present study lasted 25 days, which was the total time of refrigerated storage. The results showed that peony stems with preharvest applications of Borocal® and postharvest applications of only water presented the highest values in terms of floral diameter, stem weight and particularly increased vase life, with no significant differences in stem curvature.

Key words: pre-harvest, post-harvest, cut flowers, boron, calcium.

RESUMEN

En flores de corte, deben existir objetivos claros en cuanto a la exportación, por lo tanto, es fundamental tener un manejo adecuado de poscosecha, que permita mantener las flores por el mayor tiempo posible en condiciones óptimas, tanto durante el transporte como su condición de vida en el florero, existiendo en Chile muy poco conocimiento sobre este manejo. Con la finalidad de solucionar estas dudas, se realizó un ensayo para evaluar el comportamiento de la vida en postcosecha de peonías cultivar 'Karl Rosenfield', utilizando cuatro tratamientos: agua; Borocal® en precosecha más agua; Borocal® más 100 g sacarosa/L de agua y 100 g sacarosa/L de agua entre los cuales a algunos se les adicionó el producto comercial en precosecha denominado Borocal® y sacarosa aplicado en poscosecha; evaluando cuatro parámetros de calidad en flores de corte; diámetro floral, curvatura de varas, peso de varas y vida en florero. Este ensayo se evaluó durante 25 días, que fue el tiempo total de almacenamiento refrigerado. Los resultados arrojaron que las varas de peonías con la aplicación de Borocal® en precosecha y sólo agua en poscosecha, alcanzaron los valores más altos en cuanto a diámetro floral, peso de varas y en particular una mayor vida en el florero; no existiendo diferencias significativas en la curvatura de las varas.

Palabras clave: precosecha, poscosecha, flores de corte, boro, calcio.

Introduction

During the last few years, the production of flowers, such as lilies, peonies and callas has increased, both for small and medium producers. Peony (*Paeonia lactiflora* Pall.) is a very interesting alternative for production in central, south and southern Chile, with harvests from October in the central region and until January in the southern region of Magallanes (Chahín and Saez, 2003). Peony acreage in Chile is estimated to be between 35 to 40 ha, with the concentration of most production in Región de Los Lagos in the south of the country. The main focus is the international market, mainly the United States and Europe. In 2005, peony was the third main species of Chilean floral exports, amounting to U.S. $ 405,074, 108% higher than the previous season (Reyes, 2007).

Appropriate postharvest management is vital to export objectives, maintaining flowers for as long as possible in top condition, both for transit and vase life. In Chile, there is very little knowledge about this area, so if quality products are going to be used to reach foreign markets, research is needed to improve this technique.

This research aimed to study quality aspects associated with peony flower stems through pre and post harvest use of calcium, boron and sucrose during refrigerated storage.

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Materials and methods

The research took place in the town of Lontué Hijuelas, No. 3 Tríeles property, Curicó Commune (35°02' S and 71°17' E), in the Maule region, south-central Chile. This area is classified as mesothermal temperate, with annual average temperatures of 13.6°C and rainfall of 753 mm (Santibanez and Uribe, 1990). The scientific research was conducted on established peony crops. The soil of the established crops had a clay texture, and was part of the Treiles series. Holes were dug at 50 x 50 cm with a depth of 75 cm. Planting distance was 1 m between rows. A layer of stones 10 cm in height and width was placed at the base, which was covered with 5 cm of sand. Each hole was filled with a mixture of materials disinfected with methyl bromide (700 kg ha^{-1}) at the time of preparing the soil. The mixture consisted of guano, sand, location soil and dried grapes at a ratio of 1:1:1 (Suarez, 1998). The planting depth was 5 to 10 cm of soil over the crown. The 20 cultivars were introduced from France, China and Holland. The cultivars were arranged North-South to take in higher levels of light, with one row for each cultivar used as a control. Once the plants emerged and 15 d past after the application of the herbicide Roundup® and during the epic phenological state, the lateral buds were removed in order to deliver all the nutrients to the apical flower of each stem, in the same manner, leaf samples were taken to determine nutrient levels via foliar analysis.

The selected cultivar was 'Karl Rosenfield' because it has the best conditions and is one of the cultivars with the highest number of flower stems per plant. The plants were 50 in number, of the said cultivar, and were arranged in rows. Borocal® was used preharvest, and has an active ingredient based on calcium oxide (10% w/w) and boron (0.3% p/p) and was applied using a 6 L Gamma 5® pump (Italian). Borocal® applications were made every 10 d, with the first application made at the start of spring in the morning, choosing the plants completely randomly, selecting half for a total of 25 plants, with the choice being as homogeneous as possible and with similar conditions to apply a dose of 4 mL L^{-1} of Borocal®, using a total of 5 L of solution for 25 plants, abundantly over the vegetative structure, including the forming bud. Later, the second and the third applications were made at 30 d after the first application, in the same conditions. The applications were made in the morning, to prevent possible evaporation.

The harvest consisted of cutting 6 stems that had been treated with Borocal® and 36 that had not. To homogenize the material for use, the harvest index used was: a closed calyx, but soft to the touch, with loose outer petals and showing true color; this work was done very meticulously, as the cultivar 'Karl Rosenfield' has petals looser than the other cultivars. The stems were harvested by cutting 41 cm above the base.

Fresh cut floral stems were deposited in a cardboard box and wrapped in newspaper to prevent dehydration and maintain turgor, keeping Borocal® treated stems apart from those that were not, for later transport to Laboratorio de la Universidad Católica del Maule, in the city of Curico, south-central Chile.

The materials used for assessing weight, diameter and curvature were a digital scale, Precisa 2200C® and a micrometer caliper ruler.

The stems were placed on a counter and the excess foliage was removed, leaving only three leaves to homogenize the stem, and cut to a length of 41 cm to fit inside the refrigerator.

The doses of sucrose used for treatments Borocal® plus 100 g sucrose/L of water and 100 g sucrose/L of water, were prepared using 4 L of water in which the said ingredients were dissolved, for the other water treatments; preharvest Borocal® with water was prepared in the same volume of water, but without sucrose. Then the stems were placed in their respective containers with different applications, for a time of 4 h to absorb the solutions. The containers were 20 L and made of nontransparent plastic. Then the floral stems were removed from the containers and placed horizontally in the refrigerator, separated into compartments depending on the applications, and wrapped with waxed paper to prevent dehydration. The temperature in the refrigerator was 1°C with a relative humidity of approximately 95% with a total storage time of 25 d.

We used a completely randomized design with a factorial arrangement of 6 x 4, establishing 24 treatments, which resulted from the combination of four applications: water as control, preharvest Borocal® with water, Borocal® with 100 g sucrose/L of water and 100 g sucrose/L of water, and six periods of refrigerated storage, 0, 5, 10, 15, 20 and 25 d. Each treatment had three repetitions, with each repetition having an experimental unit of one stem. The measurement dates began in late October and ended in the third week of November.

The obtained data produced a 2-way interaction for each of the variables. When analyzed, the Tukey test was used for multiple comparisons for treatment type and identifying

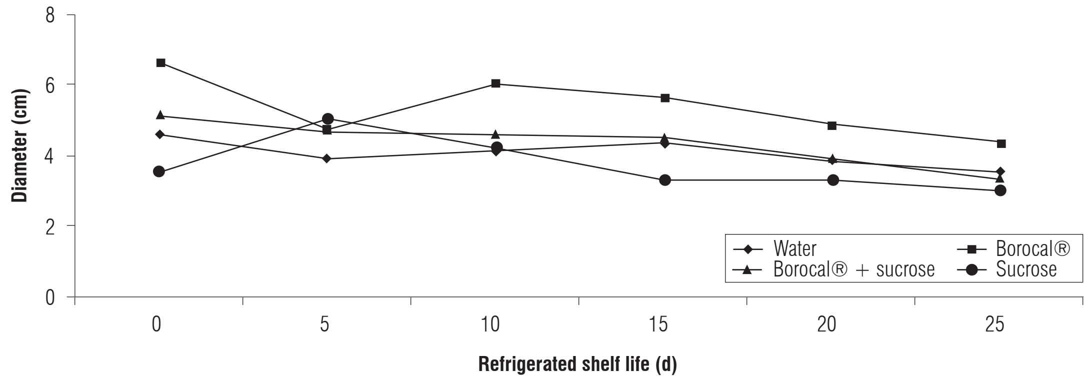

FIGURE 1. Evaluation of the floral diameter parameter in water, preharvest Borocal® with water; Borocal® with 100 g sucrose/L of water and 100 g sucrose/L of water, and the doses during the 25 d of storage at 1°C.

homogeneous groups, using a significance level of 95%, and analysis with the statistical software XLSTAT 2007®.

Results and discussion

Floral diameter

The variations in the diameter of the flower bud in relation to elapsed time of storage days are shown in Fig 1. In the experiment, it was found that the floral diameter of the peony 'Karl Rosenfield' stems was affected by the different treatments over time and whose value declined with the passage of storage time for all treatments except preharvest Borocal® with water at 10 d and 100 g sucrose/L of water at 5 d.

Of the four treatments, preharvast Borocal® with water had the best results for floral diameter, with high values observed from day 0 to day 25 (Fig. 1).

The same effect can be seen in all treatments, possibly for two reasons: on the one hand because the time of harvesting was done in the morning. In woody plants like roses and peonies, several antecedents lead to optimal harvest being in the afternoon, as the sugars would be stored during daylight and gradually disappear (Verdugo, 1998b; Paulin, 1997).

The second reason is that the flowers were not immediately refrigerated after harvest, approximately 5 h without cooling, which is essential to decrease the respiration rate, ethylene production and minimize the use of carbohydrates, which prevent floral damage to quality and floral diameter (Sáez *et al*., 2003).

The average values observed during the 25 d of storage are seen in Fig. 2, and according to which, the T1 treatment

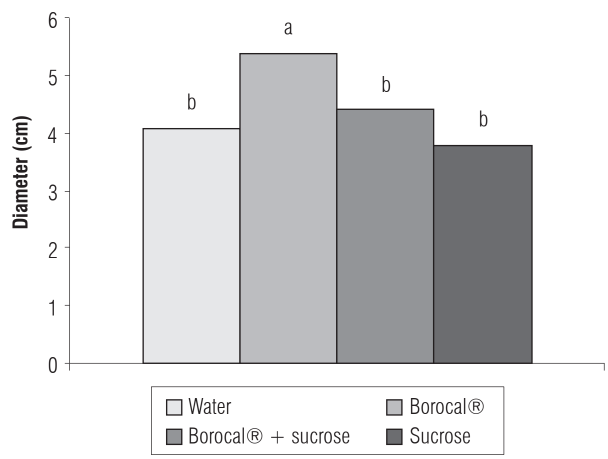

FIGURE 2. Averages for the floral diameter parameter (cm) observed during the 25 d of storage. Means followed by the same letters are not statistically different according to Tukey's test ($P \leq 0.05$).

showed the highest values for floral diameter (preharvest Borocal® with water), with no significant differences for water, Borocal® with 100 g sucrose/L of water and 100 g sucrose/L water. Probably the Boron, Calcium and water added preharvest allowed the cut flowers to have better cell structure in the tissues of the stems and flowers influencing their diameter.

The results show values exceeding those shown by Saez *et al*. (2003), who, in investigations of 29 cultivars of peony flowers, observed diameters between 2.10 and 5.37 cm for the cultivar Show Mountain and Henry Bocktoce with white and red tones, respectively.

On the other hand, studies on several peony cultivars (Stevens *et al*., 1993) yielded average values for the floral diameter parameter ranging from 2.8 cm for white cultivars to 4.1 cm for cultivars red. In this test, higher values were observed only with the Borocal® with 100 g sucrose/L of water, with a diameter of 5.4 cm, suggesting a positive effect from the application of preharvest Borocal® on the red cultivar (Karl Rosenfield) for the floral diameter parameter.

The differences in terms of the flower bud diameter may be due to the important role the time of cutting plays, because red cultivars should be harvested when the first outer petals are loose or are more open, such as in the case of the studied cultivar Karl Rosenfield, because an earlier cut means the flower will not properly develop, on the other hand, for pink and white cultivars, harvest is done when the flower bud is soft to the touch, but showing true color like in 'Sarah Bernhardt' and 'Kansas' (Stevens *et al*., 1993; Reyes, 2002). The applications of treatments with water, Borocal® with 100 g sucrose/L of water and 100 g sucrose/L of water produced no significant differences, similar to other studies by other authors (Stevens *et al*., 1993; Sáez *et al*., 2003), this may be due to the fact that the use of sugar solutions do not impart improvements to the cultivar Karl Rosenfield with increased floral diameter, further, applications of products such as Borocal® and sucrose do not have a positive impact.

Stem curvature

The foliar fertilizer, with the trade name Borocal®, applied preharvest, and postharvest sucrose applications did not indicate a possible change in the degree of stem curvature of peony cv. Karl Rosenfield. Variations of this parameter, with the different treatments over time, as storage time passed are seen in Fig. 3.

The ranges of variation in stem curvature are seen in (Fig. 3), with cuttings between 40 and 41 cm. The values show that although there was curvature at the floral bud level, it was not significant, remaining almost constant over time during the 25 d of refrigerated storage. Originally, this parameter was considered because is in some species of flowers the presence of some degree of curvature in the stems is seen, such as gerberas and carnations (Paulin, 1997), and since the peony flower has a heavy floral bud, the same condition could occur, causing a variation in stem length due to curvature; this phenomenon was not seen in the present study.

Furthermore, studies by Halevy and Mayak, (1981) indicated excessive stem elongation in various cultivars of tulips associated with curvature, one of the main problems in this species. In this study, there was no significant curvature of the stem nor internode elongation as observed with and without addition of the Borocal® product (Borocal® with 100 g sucrose/L water) and water, respectively. This could be due to the structural characteristics of the stem of the cultivar studied, as well as the nutrition available in the soil for the plants.

Stem weight

Of all the parameters studied, only stem weight showed a level of interaction between treatment and storage period (Tab. 1). Furthermore, the same effect occurred independently in the factors of treatment and time. The treatment factor showed a p value of zero, highly significant, with a high incidence for product applications, either preharvest or postharvest, likewise for the storage time factor. At the level of interaction between treatment versus time, the values were significant, thus, there was an influence from these two factors. Applications that were made both preharvest and postharvest showed clear influence during storage time.

For all treatments, there was a clear decrease in stem weight as storage time passed, except for the cut floral stems in the control treatment (water) which showed an increase in stem weight at day 10 of storage and then decreased.

Among the treatments Borocal® with 100 g sucrose/L of water presented the highest values from day 0 to day 25 of

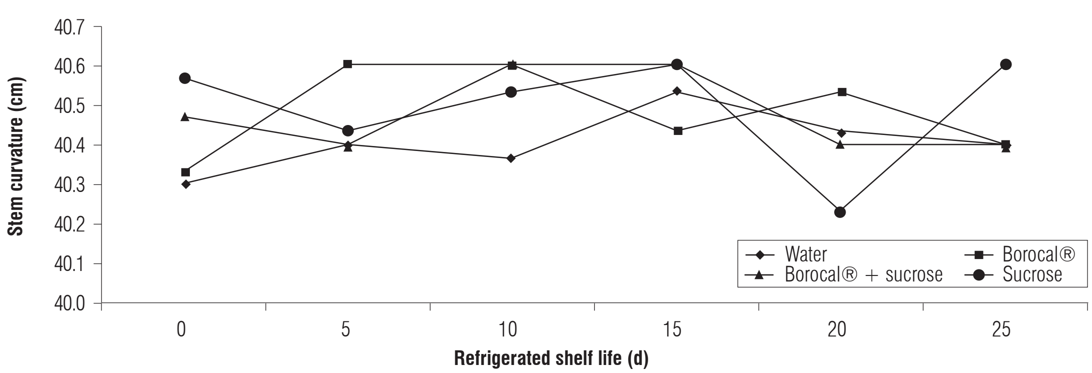

FIGURE 3. Evaluation of the stem curvature parameter for the four treatments and doses during the 25 d of storage at 1°C.

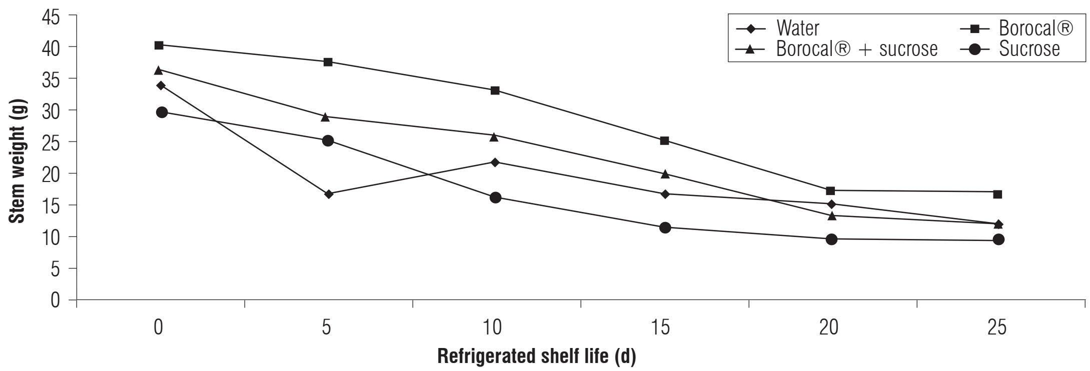

FIGURE 4. Evaluation of the stem weight parameter in the four treatments and doses during the 25 d of storage at 1°C.

refrigerated storage. The lowest values were obtained with 100 g sucrose/L of water, although the first 5 d of storage had weight values higher than the control stems. Notwithstanding, the observed values of stem weight, due to the action of all treatment applications, became constant from day 20 to 25 of storage (Fig. 4).

Research by Huber (1994), with gladioli, said that flowers, once harvested and placed in water, initially increased but then decreased stem weight; this was not observed in any of the treatments of this study. The same author said that after this increase, a decline began, both of which were due to cutting the stem from the plant, in the absence of irrigation, which would cause a water deficit in plant cells in the stem, and hence slow the tissue water potential, creating a capillary effect, which would favor absorption once the plants are placed in water. However, with increasing water content in the tissue, due to placing the stems in the containers, vase life begins, water potential decreases, and thus the pressure gradient is smaller, so water consumption decreases. The latter is consistent with that reported by Paulin (1997) who stated that after harvest, cut flowers placed in water showed an initial increase in fresh weight, followed by a decrease. The surface of the plant tissue would see a vapor pressure deficit between the tissues and the environment, increasing water loss by the flower with respect to its absorption rate through the conducting vessels in the basal cutting, thereby causing the flower to wilt (Fuentes, 1998).

In general, during days 20 and 25 of refrigerated storage, visual inspection showed that the stems and flower buds began to dry; almost constant water loss was observed at the foliar level. Different methods are used to prevent this problem in peonies, one of which involves wrapping stem groups in clear plastic and sealing the ends for the storage stage. The use of plastic is to prevent freezer burn in the stems and flowers and loss of stem fresh weight, preventing them from drying out (Stevens *et al.*, 1993).

Borocal® with 100 g sucrose/L of water produced significantly higher values, and 100 g sucrose/L of water presented the second highest values, obtaining higher values of stem weight. Furthermore, the lowest stem weight was observed in water and 100 g sucrose/L of water, which had no Borocal® applications (Fig. 5).

According to Retamales (2001), high levels of N cause physical changes in membrane integrity, causing a high respiratory rate, this being lessened by adding Ca. Calcium and boron play a major role in increasing floral stem weight and are closely related.

Stem weight is highly affected mainly by treatments with preharvest applications of Borocal®, probably because the product features compounds such as Ca and B. Regarding tissue senescence, applied Ca decreased cellular structure ruptures and reduced respiration, preventing transfer of

TABLE 1. ANOVA for the stem weight parameter for the treatment and time factors in an independent manner and the degree of interaction (treatment-time).

Effect	DF	CM	DFE	MSE	F	P
Treatment	3	434.33	48	13.99	31.04	0.00
Time	5	857.45	48	13.99	61.27	0.00
Treatment-Time	15	29.17	48	13.99	2.08	0.03

P values for treatment and time and their interaction are statistically different according to Tukey's test ($P \leq 0.05$).

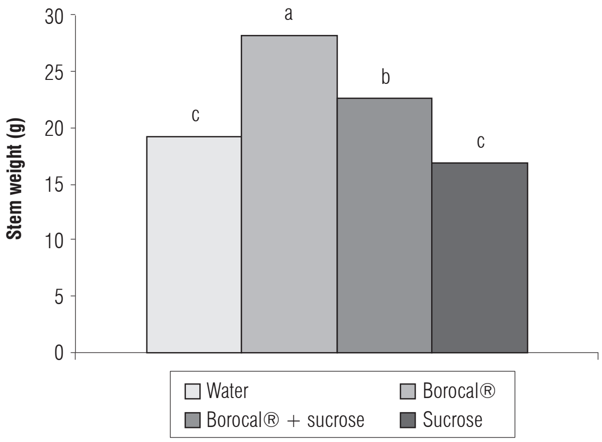

FIGURE 5. Averages for the stem weight (g) parameter observed during the 25 d of storage at 1°C. Means followed by the same letters are not statistically different according to Tukey's test ($P \leq 0.05$).

enzymes accumulated in the vacuoles into the cytoplasm, precisely because the latter serve as cellular respiratory substrate (Smith, 1991; Retamales, 2001). Boron carries out functions of flowering, pollination and fertility, in addition to the translocation of sugars and protein synthesis (Pinochet, 1999). This would explain why Borocal® applications deliver firmer stem structures, preventing excessive water loss through transpiration and respiration, maintaining a greater stem weight compared to other treatments.

Peony stems in treatment of 100 g sucrose/L of water showed lower values in weight, compared to Borocal® with 100 g sucrose/L of water, this may be because sucrose levels in this study may have been relatively unnecessary, which would cause a weight loss at the foliar level, making it possible for the foliage to dry, as has been observed in roses and chrysanthemums, because sugar builds up in the free space at the ends of the leaves creating an osmotic gradient between the cells and the free space (Halevy and Mayak, 1981).

Vase life

A clear decrease in vase life was seen, particularly with the treatments water, Borocal® with 100 g sucrose/L water and 100 g sucrose/L water during the first 15 d of storage, resulting in a slight increase at the end of 20 and 25 d when using Borocal® with water and Borocal® with 100 g sucrose/L water, but not for the control treatment, where postharvest life kept decreasing. Regarding treatment T3 (100 g sucrose / L of water), flowers were negatively affected in their presentation and relation to vase life during the first 5 d of vase life, but in the following days an improvement was seen until day 15 (Fig. 6).

Of all the treatments, in terms of the vase life parameter, Borocal® with water showed the best results, whose active ingredient was based on calcium and boron oxide; these two elements provided positive effects in prolonging vase life in the case of the peony cv. Karl Rosenfield. This is consistent with Halevy and Mayak, (1979), they determined that calcium doses of 10 mg L^{-1} prolonged vase life in species such as carnations, tulips and lilies; the same authors noted that B doses between 100 to 1,000 mg L^{-1} would be useful in carnations and lilies, but toxic in species such as chrysanthemums, *Lillium* and gladioli.

In the studied 'Karl Rosenfield' cultivar, the application of only water and preharvest Borocal® was enough to significantly improve ($P \leq 0.05$) the duration of vase life, particularly in relation to the sucrose with water treatment (Fig. 7).

Preharvest Borocal® applications, in addition to postharvest applications like water and sucrose, showed vase lives statistically equal to the control. The obtained and referenced values for postharvest life of cut flowers subjected to the treatment of 100 g sucrose/L of water proved lower than those obtained by Gast (2000), who investigated 10% sucrose applications in 23 peony cultivars, obtaining a postharvest life of 5 to 7 d with a total of 4 weeks of storage.

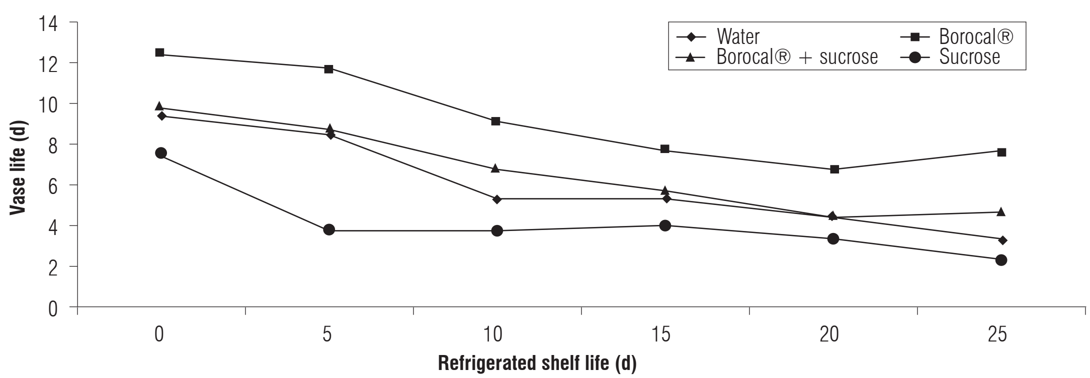

FIGURE 6. Evaluation of the vase life parameter in the four treatments and doses during the 25 d of storage at 1°C.

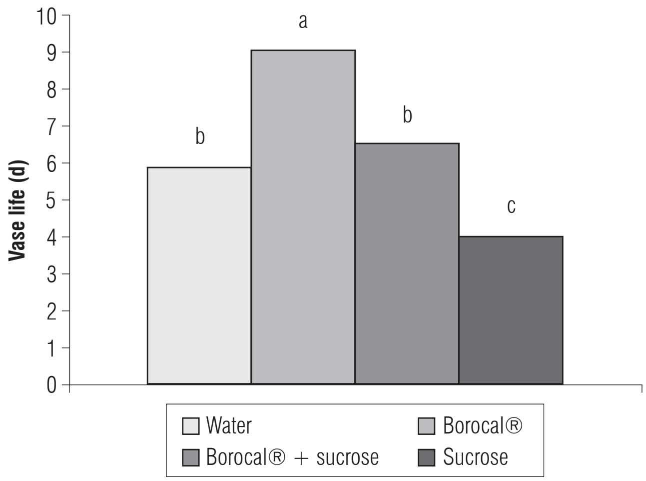

FIGURE 7. Averages for the vase life parameter observed during the 25 d of storage at 1°C. Means followed by the same letters are not statistically different according to Tukey's test ($P \leq 0.05$).

For the other treatments of Borocal® with 100 g sucrose/L of water and Borocal® + 100 g sucrose/L of water, the study showed similar values of vase life to those found by Gast (2000) and Heuser and Evensen (1986).

There were significant differences between treatments Borocal® + 100 g sucrose/L of water and (100 g sucrose/L of water, where the first had Borocal® and the second did not; with sucrose being added post-harvest, showing a positive action in the application of said commercial product before harvest, but improved results were not observed with the addition of sucrose. This disagrees with the findings of Halevy and Mayak (1979), (1981), who stated that the addition of products such as sugars or derivatives thereof would delay the senescence process, confirming that sugar improves water balance and osmotic potential in species such as carnations.

Research by Heuser and Evensen (1986) found that applications of a floral preservative called Floralife® caused an increase in fresh weight and postharvest longevity in three peony cultivars. The same authors reported that the use of a preservative product improves the water balance of the flowers, benefiting water gain and likewise reduces these losses caused by stomatal closure. For Gast (2000), floral preservatives did not improve the vase life or the floral diameter of most of the 23 studied peony cultivars. Thus, in post-harvest handling of peony crops, floral preservatives may be recommended but only as an optional alternative.

Conclusions

Preharvest application of the product Borocal® delivered a positive effect on stem quality in the peony cultivar Karl Rosenfield in the studied parameters: floral diameter, stem weight and vase life; without any change in the degree of stem curvature.

The treatment that showed the best results in terms of the three mentioned parameters was Borocal® with 100 g sucrose/L of water, which added Borocal® preharvest and water postharvest. The lone application of the commercial product and sucrose or only postharvest sucrose did not produce the highest values, but they were within acceptable ranges.

The quality parameter that showed the greatest variation in relation to the different treatments was vase life; on the other hand, stem curvature did not present any significant changes during the 25 d of refrigerated storage.

Incidence was only observed in the stem weight parameter, in terms of the combination of the studied treatments and time of refrigerated storage of the peony stems.

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