Flowering Advancement in Herbaceous Peony

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Keywords: Paeonia, flower initiation and development, GA3 drench

Abstract
Cut peony flowers are highly valued in the market, but they are available only for a short period in the late spring and early summer. Peonies have been reported to flower successfully in areas with 2-3 months of freezing temperatures. Our earlier studies revealed, however, that they can bloom successfully in warmer areas with prevailing temperatures above freezing. This was the basis for developing peonies as a cut flower crop in the higher elevation, cooler regions of Israel. The aim of the project was to evaluate the growth cycle of peonies in Israel and to study the effect of environmental conditions on flower formation and dormancy. Periodical morphological studies revealed that flower bud initiation in the underground renewal buds began in late summer and continued until the plants shed their leaves and became dormant in November. Both flower formation and dormancy are autonomous and do not depend on photoperiod. The release from dormancy requires the accumulation of a certain number of chill units, which varies between cultivars. Moderate temperatures are required both during the summer when new flower buds are initiated and following dormancy breaking when the flowers grow and develop. Higher growing temperatures promote flower bud abortion.

Based on this information, two methods were developed for flowering advancement:
1. Growing plants in containers, exposing them to 1-3°C for 6 to 10 weeks in late autumn, drenching the soil with GA3, and moving the containerized plants to unheated greenhouses for growing and blooming. With this method a very early crop can be obtained from mid-January on.
2. Field-grown plants in uncovered greenhouses are exposed to natural winter cold temperatures until they receive a certain number of predetermined chill units. They are then drenched with GA3 and the greenhouses are covered with plastic sheets. Such plants flower about one month earlier than untreated plants grown in open fields.

INTRODUCTION
Herbaceous peony cultivars are primarily derived from Paeonia lactiflora Pall., native to northeast Asia (Bailey, 1916; Everett, 1981; Rogers, 1995). Peonies are widely used as garden plants in temperate climate regions, but are less common as cut flowers, in spite of their beauty, because of their short flowering season.

Peonies have been reported to flower successfully in areas with at least 2 to 3 months of freezing temperatures (Post, 1952). However, Byrne and Halevy (1986) found that dormancy of two cut-flower cvs. of containerized herbaceous peony was broken satisfactorily after 8 weeks storage at 1 or 5°C, and upon transfer to a greenhouse heated to 17°C, they bloomed in 6 to 10 weeks. However, most of the flowering shoots did not reach anthesis and most flower buds aborted. Evans et al. (1990) advanced shoot emergence of noncooled crowns by drenching them with 2,000 mg L⁻¹ GA3, but all flower buds aborted.

Cut peony flowers are highly valued in the market, but they are available for only a short period in late spring and early summer. The overall aim of this study, therefore, was to prolong the marketing period by advancing the flowering time.
To achieve this goal we studied the annual life cycle and determined floral initiation and development of peonies under field conditions in the higher elevation regions of Israel. We evaluated the chilling requirement for dormancy breaking, the use of gibberellin (GA₃) drench to enhance sprouting and flowering, and the effect of various growing temperatures on flowering.

MATERIALS AND METHODS
Crowns of ‘Sarah Bernhardt’ and ‘Duchesse de Nemours’ were imported from a Dutch commercial source and were grown in an open plot in the Golan Height or Western Galilee regions located in the northwest part of Israel at elevations of 500-700 m above sea level. The climate is characterized by relatively cool winters (temperatures in December-January average 11-13°C, with an average precipitation of 650 mm), warm dry summers and short, moderate temperature springs when air temperatures increase rapidly. Soils in the region are mostly Terra Rossa, a typical red Mediterranean type, with very good structure.

Experiments were conducted either with plants in ground beds or in containers, under natural ambient conditions or under controlled conditions in the phytotron. Full details of the experimental designs were presented elsewhere (Halevy et al., 2002; Kamenetsky et al., 2003)

EXPERIMENTAL RESULTS

Annual Life Cycle and Floral Development
Detailed morphological studies were carried out with ‘Sarah Bernhardt’ plants, field-grown in higher elevation regions in Israel (Upper Galilee and Golan Heights) (Barzilay et al., 2002).

The renewal buds for the following year originated on the underground “crown” (tuberous compressed rhizome), at the base of annual stems. Bud emergence began in early spring. Stems elongated rapidly and reached heights of 50 to 70 cm in 60-70 days. Flowering began in April and continued until the end of May. After flowering, the leafy stems remained green until September-October, when the leaves senesced and the peony plant entered the dormancy stage for 3-4 months. The new monocarpic shoots were initiated in the renewal bud at the end of June with the formation of the first leaf primordia and continued to increase in size and to initiate new leaf primordia until February. During summer, the renewal buds remained vegetative. The apical meristem of the renewal bud ceased leaf formation during senescence of the aboveground shoots in the fall. During September, the apical meristem of the renewal buds reached the generative stage and achieved the form of a dome, but remained undifferentiated. In October, floral parts became visible. Floral differentiation was terminated at the beginning of December. Flower initiation in peonies was apparently autonomous i.e. without a need for an external signal of temperature or photoperiod (Wilkins and Halevy, 1985).

The life cycle of field-grown ‘Sarah Bernhardt’ plants in Israel is presented schematically in Fig. 1.

Chilling Requirements for Release from Dormancy
Late in the autumn peony leaves senesced and died and the underground buds entered dormancy. Unlike in most deciduous trees, short photoperiods were not the signal for dormancy, since peony buds became dormant even when plants received supplementary lighting in the field throughout the night, from the beginning of June (Wilkins and Halevy, 1985).

In order to emerge and begin to grow in the spring, the dormancy of the underground buds must be broken by exposure to low temperature. The chilling required for release from dormancy was determined by exposing field grown plants to ambient winter-cold weather then covering the greenhouses with plastic sheets on different dates. The accumulated chilling units were calculated according to Fishman et al. (1987) and Erez.
et al. (1988). The chill units for the various areas of Israel is computed and reported by the Meteorological Service of Israel. The computerized model accounts for the hourly temperatures before and after each recorded temperature. A chill unit corresponds to exposure for 24 hours to 6°C. Results of Fig. 2 show that chilling saturation was reached at 42 chill units for cv. ‘Sarah Bernhard’ and at 36 chill units for cv. ‘Duchesse de Nemours’. When container grown plants were cooled artificially in the autumn at 1 to 3°C for various periods before moving them to the greenhouse, it was found that various cultivars required different length of cooling periods between 6 to 10 weeks.

**Evaluation of Optimal GA₃-Application**

Earlier studies have shown that GA₃ application to the buds on the crown can promote bud sprouting and shoot growth (Halevy et al., 1995; Wilkins and Halevy, 1985). The optimal GA₃ concentration was found to be 100 mg L⁻¹ (Halevy et al., 2002).

The combined effect of GA₃ drench and a foliar spray application was tested. Results in Table I show that double GA₃ treatment of drench and spray was, in most cases, not better than a single drench and in some cases even reduced flowering percentage by promoting flowering abortion.

**Effect of Growing Temperature on Flower Development**

The temperature requirements of ‘Sarah Bernhardt’ peonies during the various stages of growing were studied with container grown plants under controlled conditions in the phytotron. Results in Table 2 demonstrate that growing temperatures had a major effect on plant development: moderate temperatures of 22/10°C (day/night) were best for enhancing both flowering and stem elongation; higher temperatures enhanced stem emergence, but reduced stem length and increased percentage of aborted flowers. High temperatures of 28/22°C (day/night) drastically reduced the percentage of flowers reaching anthesis. Increased growing temperatures during the first period after chilling advanced blooming with relatively minor negative effects on flower development and quality, while high temperature at later stages of flower development promoted flower abortion (Kamenetsky et al., 2003).

We further studied the effect of temperature during the summer period after flowering and before the plants became dormant. Results clearly showed that high temperatures (28/22°C) greatly reduced flower formation in the underground buds. Moderate temperatures are thus clearly required both before and after the chilling requirement of the dormant buds.

**DISCUSSION AND CONCLUSIONS**

The developmental behavior of herbaceous peonies is similar in some ways to that of certain geophytes (Barzilay et al., 2002) and deciduous fruit trees. They bloom in the spring, initiate their flowers during the summer, and shed their leaves and enter dormancy in late autumn. However, unlike deciduous trees, foliage senescence and dormancy are not induced by short days in peonies and flower formation and development are also unaffected by photoperiod (Byrne and Halevy, 1986; Wilkins and Halevy, 1985).

The factors inducing flower initiation, leaf abscission, and bud dormancy of peonies are unknown. Breaking of bud dormancy requires exposure to a certain chilling period, as known for most deciduous trees and geophytes (Erez et al., 1998; De Hertogh and Le Nard, 1993). In peonies, this requirement can be achieved not only by freezing temperatures, as assumed previously (Post, 1952), but also by low temperatures above freezing (Byrne and Halevy, 1986; Fulton et al., 2001; Halevy et al., 2002). The length of the required chilling varies in the different varieties (Halevy et al., 2002; Fulton et al., 2001). Application of GA₃, directly to the dormant buds on the crown can partially complement the cold requirement for breaking dormancy and promote bud sprouting and shoot growth. In herbaceous peonies, all growing shoots will initiate terminal flowers at moderate temperatures after forming a certain number of leaves depending on the cv. “Blind shoots” that have reached a certain length are, therefore, not vegetative but shoots that aborted their
flower initials. Therefore, the chilling requirement is required to release buds from dormancy, and does not have a specific effect on flower initiation (vernalization). GA₃ treatment does not promote flower initiation and differentiation in peonies per se. It is applied to reproductive dormant buds, and is not effective if applied before flower formation (Halevy et al., 1995). A crown drench with 250 ml of 100 mg L⁻¹ GA₃ per plant was found to be optimal. Too low concentrations caused a low number of shoots to sprout and too high concentrations, or excessive applications, induced sprouting of many shoots but many of them aborted and did not produce flowers (Table 1, Halevy et al., 2002).

High growing temperatures during the later stage of flower development were found to be detrimental and promoted flower abortion (Table 2). High temperatures during the summer reduced flowers formation in the crown’s buds.

The information gained in these studies formed the basis for developing two practical methods for the advancement of cut flower production of herbaceous peonies in Israel.

1. Growing plants in containers, exposing them to 1-3°C for 6 to 10 weeks in late autumn, drenching the soil with 100 mg L⁻¹ GA₃ and moving the containerized plants to unheated greenhouses for growing and blooming. With this method a very early crop can be obtained from mid-January on.

2. Field-grown plants in uncovered greenhouses are exposed to ambient cold temperatures until they receive a certain number of predetermined chill units. They are then drenched with GA₃ and the greenhouses are covered with plastic sheets, to raise the growing temperatures. Such plants flower about one month earlier than untreated plants grown in open field.

ACKNOWLEDGEMENT
This research was supported by research grants from the Chief Scientist of the Israel Ministry of Agriculture and by Pearlstein Family Fund for research in ornamental horticulture at the Hebrew University of Jerusalem. We thank the donors for their support.

Literature Cited

**Tables**

Table 1. Effect of 100 mg L⁻¹ GA₃ treatment, applied as one (3 Mar.) or two (3 and 20 Mar.) soil drenches of 250 mL per plant or as two drenches and spray (4 Apr.) on flowering of 3-year-old field-grown plants. Means of 20 replicates ± SE (Halevy et al., 2002).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cultivars</th>
<th>Flowers per plant</th>
<th>Flowering period</th>
<th>Flowers per plant</th>
<th>Flowering period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>‘Sarah Bernhardt’</td>
<td></td>
<td></td>
<td>‘D. de Nemours’</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>6.0±0.6</td>
<td>29 Apr-12 May</td>
<td>5.7±0.4</td>
<td>26 Apr-14 May</td>
</tr>
<tr>
<td>One GA₃ drench</td>
<td></td>
<td>9.8±1.1</td>
<td>20 Apr-6 May</td>
<td>13.0±2.1</td>
<td>24 Apr-24 May</td>
</tr>
<tr>
<td>Two GA₃ drenches</td>
<td></td>
<td>5.3±0.9</td>
<td>22 Apr-10 May</td>
<td>12.3±1.9</td>
<td>23 Apr-7 May</td>
</tr>
<tr>
<td>Two GA₃ drenches + spray</td>
<td></td>
<td>3.5±0.5</td>
<td>22 Apr-11 May</td>
<td>13.7±2.2</td>
<td>23 Apr-23 May</td>
</tr>
</tbody>
</table>

Table 2. Effect of forcing temperatures on floral development in peony ‘Sarah Bernhardt’ (Kamenetsky et al., 2003).

<table>
<thead>
<tr>
<th>Growing temperature (°C) (day/night)</th>
<th>Day to flowering</th>
<th>Average number of flowers per plant</th>
<th>% of flowers reaching anthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>22/10</td>
<td>83.2 a*</td>
<td>5.1 a</td>
<td>42.3 a</td>
</tr>
<tr>
<td>22/16</td>
<td>58.3 dc</td>
<td>2.2 ab</td>
<td>18.8 bc</td>
</tr>
<tr>
<td>28/10</td>
<td>62.5 c</td>
<td>2.3 ab</td>
<td>15.2 bc</td>
</tr>
<tr>
<td>28/22</td>
<td>53.2 d</td>
<td>0.5 b</td>
<td>5.2 c</td>
</tr>
<tr>
<td>22/10-28/22**</td>
<td>60.2 dc</td>
<td>2.5 ab</td>
<td>23.5 abc</td>
</tr>
<tr>
<td>28/10-22/10</td>
<td>69.0 b</td>
<td>4.8 a</td>
<td>33.1 ba</td>
</tr>
<tr>
<td>28/22-25/10</td>
<td>54.5 d</td>
<td>2.4 ab</td>
<td>20.7 abc</td>
</tr>
</tbody>
</table>

*Means followed by different letters are significantly different at P ≤ 0.05.
**Moved from one temperature regime to the other after 30 days of growing.
Fig. 1. Life cycle of *Paeonia* ‘Sarah Bernhardt’ field-grown in Israel (Barzilay et al., 2002).
Fig. 2. Effect of covering greenhouses with polyethylene sheets after obtaining various numbers of chill units on number of flowering shoots per plant of ‘Sarah Bernhardt’ and ‘Duchesse de Nemours’ peonies (Halevy et al., 2002).