

Paeonia spp. Production and Future Developments

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Executive Summary

Paeonia spp. is a popular herbaceous flowering plant native to temperate regions of the world. Though demand for the cut flowers is high year-round current production methods and physiological barriers of the plant itself limits availability. This paper is an overview of the history, current methods of production, and proposes a new, more efficient, indoor system for *Paeonia spp.* centered upon temperature and hormone regulation.

1. Introduction

A. Study Species

Herbaceous peonies have long enjoyed significance in Western and Asian cultures for their outstanding floral displays as well as their medicinal properties. The genus *Paeonia* houses several horticulturally important species of flowers including *Paeonia officinalis* (common garden peony), *P. lactiflora* (Chinese peony), among others. Herbaceous peonies are primarily grown for use in the horticultural industry as a home garden plant and are also cultivated as a commercially cut flower. They are also harvested for their medicinal properties (He & Dai 2011) and even for their use as a herb (Nehrling & Nehrling 1978) though these industries are relatively small compared to the ornamental market value. Due to the extensive hybridization ability within the genus *Paeonia* this crop review paper will focus on the economic importance and future opportunities within the herbaceous type *Paeonia spp.*

B. Taxonomic Classification and Geographic Distribution in the Wild

Paeonia spp. is a perennial herbaceous plant that grows approximately 80-110 cm tall from thick tuberous roots. The foliage is oppositely arranged biternately, composed of a terminal primary leaflet and two lateral primary leaflets (Page 2005). Flowers are produced in the spring and are usually large, 15-30 cm, round shaped with petals and stamens in multiples of five. This description may not cover all cultivars produced as there are now close to three thousand to choose from (Fearnley-Whittingstall 1999). Alice Harding noted in her book The Peony “The compelling charm of the improved types of peony lies not only in the grace and comeliness, but in the infinite variety of both flowers and foliage” (Harding 1993).

Due to variation in classification, the *Paeonia* genus has been debated among botanists. Originally botanists classified the genus in the Ranunculaceae family. The Paeoniaceae was created in the mid-20th

century to encompass both the herbaceous types of *Paeonia* as well as the tree form, *P. suffruticosa* (McGeorge 2006). Genetic analysis has shown that peonies are most closely related to Crassulaceae which includes *Sedum* and *Crassula* (McGeorge 2006).

Paeonia is the lone genus in Paeoniaceae which is subdivided into 33 species that usually separate along five geographical regions, Mediterranean, central Asia, Western Himalaya, Eastern Asia, and Pacific North America (McGeorge 2006). All peonies need a long period of cold in order to flower and so they are limited in their range to northern temperate climates. It is thought that during the Pleistocene era peonies diverged into diploid and tetraploid species and, because the tetraploid species are so much more adaptable, they spread further than their diploid counterparts (Rodrigo-Lopez 2010). The Paeoniaceae family has retained the majority of its compatibility as most *Paeonia* species can inter-hybridize.

The most recognizable of these species *P. officinalis*, or common garden peony, native to Europe which has been hybridized with others in the genus to produce bigger and better flowers. The Chinese peony, *P. lactiflora*, is a popular garden plant but is also grown for the tuberous roots used in traditional medicine. This has led to overharvesting of wild types in their native habitats (Page 2005).

Paeonia spp. are incredibly winter hardy, slow growing, and long-lived plants that often live over a century. In their native habitats peonies are often found at high altitudes on cliffs in rocky or otherwise inhospitable terrain (Page 2005). They can be grown successfully down to USDA Zone 3 and can survive up to Zone 9, provided there is an adequate period of cool temperatures. Although they are well adapted to difficult growing conditions the best flower production comes from well drained and fertilized soils rich in organic matter (Coit 1908).

The plants flower once a year in the spring and blooms are relatively short lived lasting only 1-2 weeks. Peonies need an extended period of cold, at least 900 hours around or below freezing (Jacob et al. 2006),

in order to go dormant and rebloom the next year. If the temperature does not drop low enough they will fail to produce flowers. *P. spp.* spread by expanding root systems as well as by seed. Seeds have a thick hard seed coat that needs cold stratification and scarification to germinate (Peony:herbaceous 2015). Despite being so well adapted to many climates peonies are not considered invasive because they are such slow growers. Due to their commercial popularity both for ornamental as well as medicinal value, wild species are in danger of being overharvested and some are considered endangered (Page 2005).

2. Crop History

A. Breeding and Domestication




Humans have been cultivating peonies for millennia. The earliest written description of *Paeonia* was recorded by Pliny the Elder in his book “Natural History” written around 79AD and describes it as “the most ancient plant of all” (Harding 1993). Peonies were so named for the Greek mythical figure Paeon who was doctor to the gods (Nehrling & Nehrling 1978). They continued to be culturally important in the west with references to them in the Homer’s “Iliad” as well as Shakespeare’s play “Taming of the Shrew”. As time progressed peony seeds became popular in Europe as a spice and accompaniment to meat dishes as well as for their floral beauty.



Chinese have been cultivating and breeding peonies for over 1500 years in order to harvest roots for medicinal purposes (Fearnley-Whittingstall 1999) but they were not bred for ornamental purpose until the 11th century (Harding 1993). *Paeonia lactiflora* roots have been shown to have anti-inflammatory properties (He & Dai 2011) and are used in traditional medicine to treat arthritis. Peonies are symbolic of financial prosperity and are given as tokens of good luck (McGeorge 2006).

Scientifically recorded hybridization coincided with the emergence of plant collectors in the 17th century who brought back specimens from China, though regular trade between the East and West before that time probably resulted in undocumented hybridization. In 1621 the first botanical garden in England was established and included at least two types of peony (Harding 1993). By 1731 a different botanical garden recorded seven different types of peonies and by the mid-19th century there were over 250 recorded types of *Paeonia spp.*(Harding 1993), many of which are still offered today.

The increase in cultivars can be directly correlated to the introduction of the Chinese species *P. lactiflora* to cross with the English species *P. officinalis*. Hybrids had much better blooms and many new shades of color including yellow, a previously unheard of color in peonies(Nehrling & Nehrling 1978). They were also bred for their distinct scent, the more fragrant the better(Harding 1993). At this time different flower forms were developed as seen in Table 1.

Table 1. *Paeonia* spp. flower types with floral descriptions and pictorial illustrations (Types of Peony Flowers 2015)

Flower Type	Floral Description	Pictorial Illustration
Single	Flowers have a single row of either 5 or 10 petals that surrounds fully functional stamens and carpels in the center of the bloom. This is the wild form of <i>Paeonia</i> flowers.	
Japanese/Anemone	A single row of either 5 or 10 petals that surrounds stamens that have broad and flattened filaments with incomplete anthers on the tips. The flattened filaments are often differently colored than the surrounding guard petals.	
Semi-double	Some stamens have fully transformed into petals forming an outer ruff around a typically bright yellow center that holds functional carpels and stamens.	

Double	<p>All stamens have been transformed into petals creating one large ball of color.</p> <p>Carpels are not usually functional but are located in the center of the petal mass.</p>	
Bomb	<p>A double form that has an outer ring of guard petals which are longer than the mass of petals in the middle giving the impression of a ball on a plate. Stamens and carpels are not usually functional.</p>	

Modern breeding efforts continue to bring variations into these flower forms with different colors and shapes. Beyond flower variation, a type of *Paeonia spp.* that blooms outside the very limited period of flowering is desired. One cultural practice solution that is now in use to overcome the limited blooming season is moving growing operations farther north to extend availability of flowers to customers. For example, peonies are Alaska’s first and currently only agricultural export (Fitzgerald 2004). Another tactic is to use artificial cold conditions as well as hormone treatments to induce flowering at different times of the year (Halevy et al. 2002). There are breeding initiatives being investigated to produce reblooming in herbaceous peonies. Tree peonies possess this quality so it would be possible for the intersectional hybrids to inherit the reblooming trait (Zhou et al. 2013). Breeders also are demanding traits specific for the cut flower market such as improved stem strength and adaptability to containers to make industrial production more controlled and cost effective (Jacob et al. 2006).

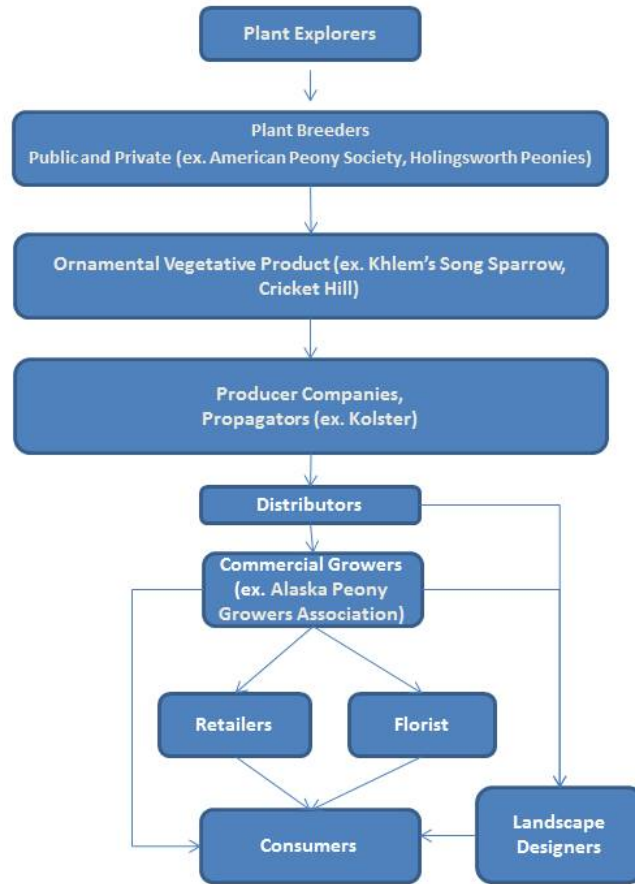


Figure 1: Flow chart illustrating *Paeonia spp.* production and distribution

The challenge with breeding and producing successful cultivars is the long length of time it takes for a seedling to become full grown. Typical seeds of *P. officinalis* are black with a thick hard protective covering around the seed. The seeds need cold stratification as well as scarification to germinate and then another three years with traditional production methods until the seedling produces its first blooms. The vast majority of peonies are propagated and sold vegetatively through root divisions because of the prohibitive length of time it takes from sowing to flowering. Current growing techniques can shorten this time to two years but this is still a relatively long process for a herbaceous crop (Jacob et al. 2006). Figure 1 illustrates the typical *Paeonia spp.* distribution chain from initial discovery of wild germplasm to final consumer.

3. Production Information

A. Current Production Practices

All of *Paeonia spp.* produced for the cut flower market are grown in field production (Finnegan 2014). This is because of the long period of cold temperatures needed for flower production as well as the long period of establishment plants take until commercial production is possible. As shown in table two, typical time to full production of a peony plant produced by root divisions is five years.

Table 2: Traditional herbaceous peony production schedule for cut flowers (Stevens et al. 1993)

Stage	Time period	Treatment
Vegetative divisions of roots arrive from the breeder/wholesaler and are planted in the field	Year 0: Autumn before ground freeze	Soil is amended with organic matter prior to planting and mulch is placed on top of the plant to prevent frost heave damage
Shoots emerge	Early spring every year	Fertilize with half the yearly amount needed
Plant dies back for winter dormancy	Autumn every year	Fertilize with remaining fertilizer from spring
Flower buds emerge	Years 1-3: Spring	Soft pinch flower buds to encourage vegetative growth
Flower buds have formed	Year 4 and on: Spring	Lateral flower buds are removed in order to promote larger flowers and stems in auxiliary buds
Flowers are at "soft bud" stage	Year 4 and on: Spring	Harvest ¼ of blooms in year 4 and half of blooms year 5 and on.

As illustrated in Table 2, commercial growers do not start plants from seed, but from vegetative root divisions. These divisions come from plant breeders who start from seed. Peony seeds need a warm-cool-warm cycle and stratification in order to overcome the thick protective seed coat and germinate. Germination actually occurs during the first warm period of the warm-cool-warm period however the sprouts need a period of cool dormancy before they can continue growing (Nehrling & Nehrling 1978). These requirements are so significant it is very rare for consumers to be sold *Paeonia spp.* from seed.

Root cuttings are sold to commercial growers and consumers from breeders or propagators (often the same company). They can come in the fall for growers to plant and mulch but typically propagators ship the cuttings in the spring precooled and ready to grow that year (Finnegan 2014). From seed to a plant that is able to be propagated through root cuttings it takes three years (Fitzgerald 2004). Each cutting will have three to five nodes or “eyes” on it from which shoots will emerge.

Once plants are at commercial production they will continue to produce at that level for up to 25 years. Therefore, choosing and amending a site is critical to production. Peonies need well drained soil rich in organic matter and supplemented with regular fertilization in early spring and immediately after dormancy (Finnegan 2014). They should be placed 60cm apart for commercial cultivation (Stevens et al. 1993). Irrigation is recommended as a drip to reduce possible flower damage by overhead water damage and to reduce the possibility of diseases such as mildew or anthracnose (Auer & Greenberg 2009).

Harvest occurs when buds are somewhere between 3.1cm-4.4cm in diameter, depending on cultivar. The buds will be still closed yet are soft in a “marshmallow” stage (Stevens et al. 1993). If the temperature is above 26°C it may be necessary to harvest more than once a day since heat speeds along the blooming process. Flowers are harvested with at least 30cm of stem (Fitzgerald 2004). Half of all

flowers on a plant are able to be harvested for commercial production, the other half should be left on to allow the plant to recover.

Postharvest, the buds cannot immediately be put in water or else they will open prematurely, also known as “blast”. Handlers must wait at least twenty minutes after harvest before putting stems in water. Flowers are kept in clean water at approximately 4°C for 1-2 hours after harvest and drying period before they are ready to be graded (Stevens et al. 1993).

The USDA has strict grading standards specifically for *Paeonia spp.* in effect since 1938. These standards cover proper stem length and overall general health of the bloom (USDA-AMS 1997). Peonies are bundled in groups of five or ten and then stored horizontally wrapped in florist wrap at 1-2°C. With proper care buds can last up to four weeks. To open buds stems need only be placed in water (Finnegan 2014).

While most species of cut flowers on the market have moved their growing facilities closer to the equator to take advantage of year-round production *Paeonia spp.* has not. Due to the need for a long period of cold dormancy the industry has instead shifted production to colder or more mountainous regions such as Alaska or Chile during off peak production (Fitzgerald 2004). United States grown peonies bloom starting in mid-April with California growers forcing plants with the use of high tunnels or transportable flower pots (Stevens et al. 1993). From there as the season progresses *Paeonia spp.* commercial operations bloom steadily north following the warming temperature.

Attempts to force *Paeonia spp.* using only growth regulators without a chilling period so far have proved unsuccessful for commercial application as all the flower buds aborted (Evans et al. 1990). However, using growth regulators to force plants that have fewer cooling hours than the 1,000 below 5°C needed for an untreated plant to break dormancy has been successful (Yeo et al. 2012). A combination of shortened cooling time along with growth regulator regimen has also been found to be successful in

Israel (Halevy et al. 2002). If the dormancy period can be shortened or even eliminated *Paeonia spp.* will be able to grow in any climate and perhaps even rebloom during a growing season. Absence of a required cold period would also make it possible for production to move indoors to more controlled environments such as greenhouse production.

There is slight flexibility of approximately 1-2 weeks in bloom time between cultivars (McGeorge 2006). However, the majority of the market does not utilize these varieties (Finnegan 2014). This could be due to the long establishment period needed for production or an aversion to risk. Developing attractive cultivars that bloom during different times of the year would allow wider availability of *Paeonia spp.*

B. Current Production Statistics

Worldwide floriculture is currently a \$20 billion industry with cut flowers occupying about half of that market. Overall the industry has enjoyed a significant increase over the last decade however the last few years have been stagnate (Figure 2). Floriculture is heavily dependent on disposable income and it is possible that the recent market unrest is due to declining demand from traditional consumers during an economic downturn.

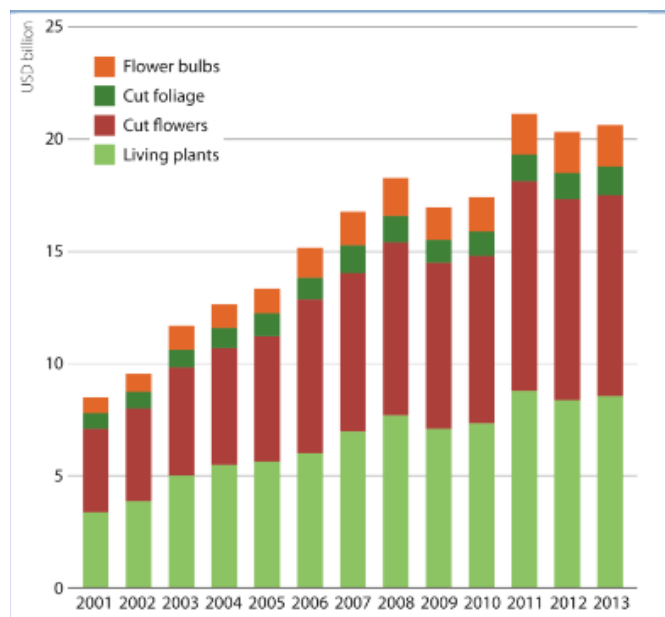


Figure 2: World floriculture market of four ornamental plant categories from 2001-2013 in USD billions (Van Rijswick 2015)

More specifically, the United States cut flower market has been on an upward trend with demand outpacing local supply. Historically, the US has not imported a significant amount of cut flowers, instead meeting demand with domestic production (Van Rijswick 2015). However, over the last five years the import amount of cut flowers in USD has been steadily increasing indicating that domestic demand is outpacing supply (TradeStats Express. International Trade Administration 2015). Of the few cut flowers that are exported from the US 95% of them go to Canada because there are no tariffs restricting trade in that market (Auer & Greenberg 2009).

Paeonia spp. is associated with and grown traditionally for the Mother’s Day holiday market (Stevens et al. 1993). Globalization has led to consumers demanding availability of cut flowers year-round. Peonies are a specialty cut flower meaning they have distinct seasons in which flowers are available and not available as opposed to year round production. The industry has responded by producing *Paeonia spp.* all over the world and shipping them to wherever the demand is highest. The Dutch market is the

world's largest supplier of cut peony flowers (Finnegan 2014). Other major players include the United States, New Zealand, Israel, and Chile (Auer & Greenberg 2009). There are two seasons in which peonies are available to consumers, spring and early winter (Figure 3).

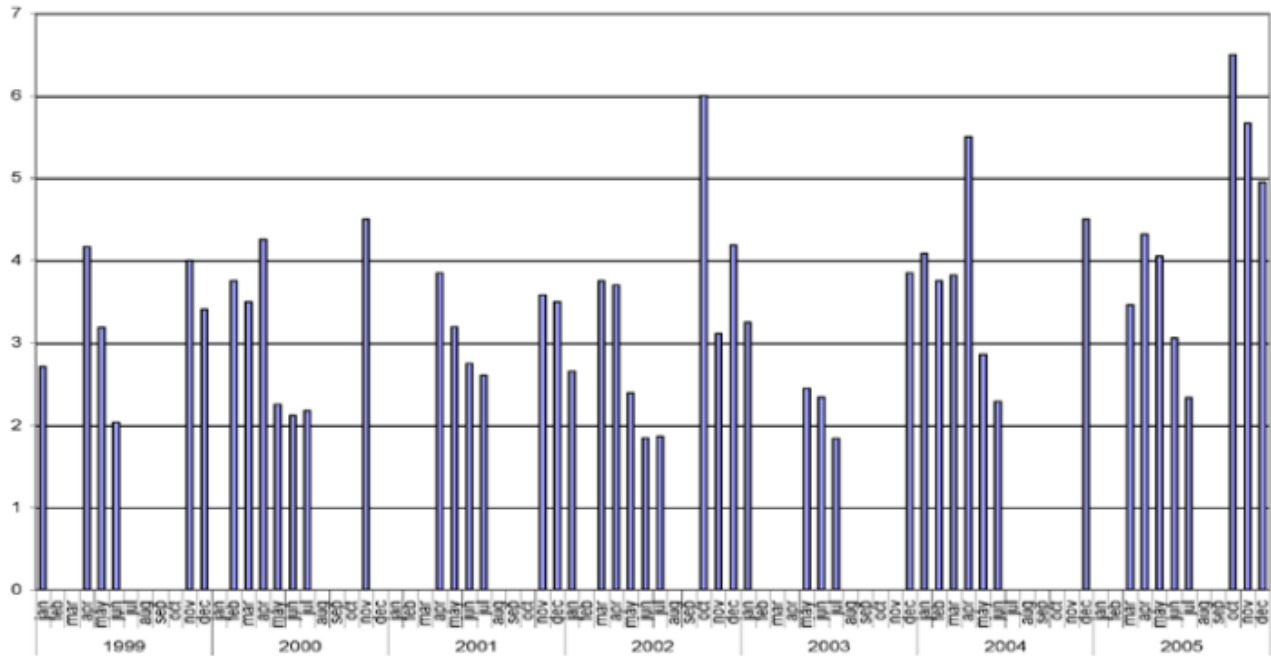


Figure 3: Average monthly price (in USD) of herbaceous peonies sold as single stems at U.S. wholesale markets 1999-2005

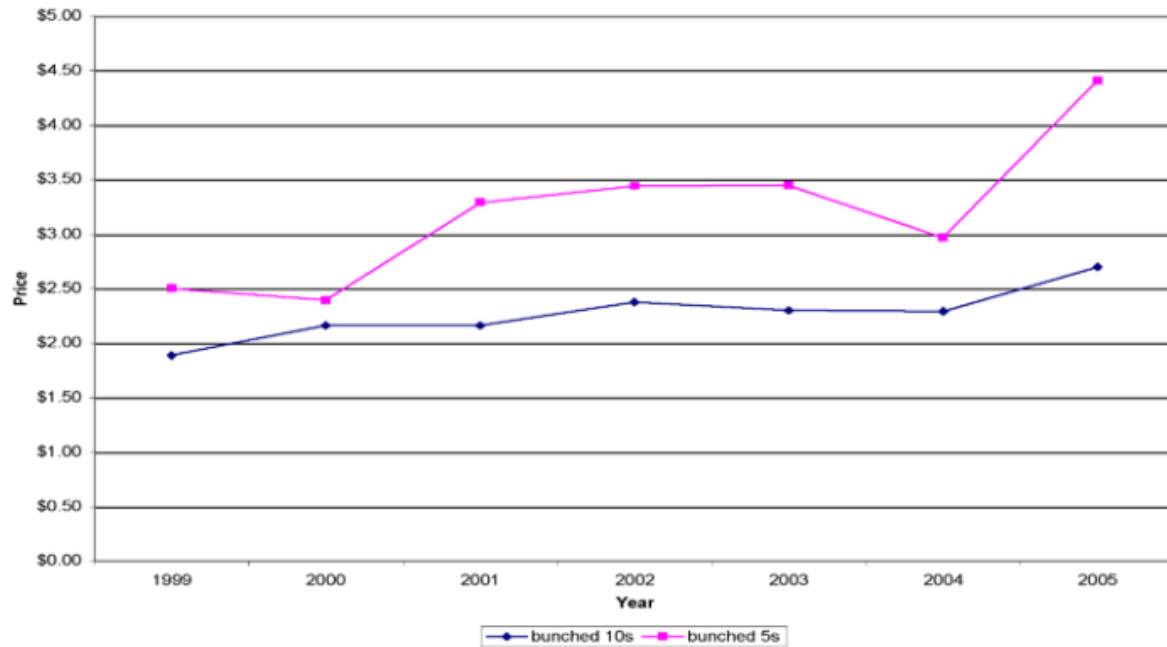


Figure 4: Average per-stem price of peonies sold in U.S. wholesale markets as bunches of five and ten from 1999 through 2005 in December 2005 dollars (Auer & Greenberg 2009).

Paeonia spp. continues to be a popular cut flower all over the world. The price (adjusted for inflation) of single stems has risen despite floriculture market instability indicating a rise in popularity (Figure 4). In 2014, the most popular cultivar of *Paeonia spp.* is 'Sarah Bernhardt' which accounted for at least 50% of the cut flower production (Finnegan 2014). A chart comparing some characteristics of major cultivars is illustrated in table three.

Variety	Colour	Flowering Time	Bloom Type
Dr Alexander Fleming	Deep pink	Mid season	Double
Duchess de Nemours	White	Mid season	Double
Festiva Maxima	White with red	Early	Double
Kansas	Red	Early	Double
Red Charm	Deep red	Early	Bom
Red Sarah Bernhardt	Red	Late	Double
Sarah Bernhardt	Pink	Late	Double

Table 3: *Paeonia* spp. cut flower cultivars and characteristics (Finnegan 2014)

This rise in popularity could be due to new cultivars on the market that have unique colors and shapes. The fact that ‘Sarah Bernhardt’ is such a popular cultivar may have more to do with the extended length of time it takes to get a cultivar to market as well as grower’s reluctance to change varieties in a perennial crop than it does with consumer preference. If peonies are to continue to grow in popularity there needs to be a faster turn-around time from development to commercial production. Hybridization has created all the colors and flowers needed for universal consumer appeal now breeders need to focus on a quicker maturity and dormancy period in order to increase sales.

4. Proposed *Paeonia* spp. Transformation

A. *Paeonia* spp. Production Changes for the Future

Since *Paeonia* spp. has consistent demand and even appears to be gaining in popularity it is time for the commercial growers to rethink their production methods. Field planting may be convenient however the long establishment period of new plants makes it prohibitively costly to change cultivars to offer

consumers new choices. Breeding efforts focusing on cultivars that are quicker to full production would further peonies significantly.

Current developments in cultivation techniques aimed to bring *Paeonia spp.* indoors to containerized production (Evans et al. 1990; Halevy et al. 2002) are already progressing. Projects like Halevy's also aim to shorten the cooling period needed for flower development. Reduction of the cooling period needed will allow growers to offer continuous availability of flowers to consumers. At this time the challenge is not "Is it possible to shorten the cooling period needed?" but rather "How do we get growers to adopt new production methods?" The techniques for faster production are close to being perfected yet growers are reluctant to adopt them.

It is hard to argue with traditional field production methods. *Paeonia spp.* is a particularly tough and long lived plant. They are drought tolerant, cold hardy, unappetizing to vertebrates, and generally resistant to pathogens. However, having a relatively easy production does not mean plants are being used to their full potential. Peony production is poised to move into containerized controlled environments. Shortening the dormancy period is just one of the advances that leads to indoor cultivation. The drip style irrigation needed for field production already lends itself well to water saving methods employed by greenhouse production. It is also advantageous of peonies to have flower initiation independent of photoperiod (Fearnley-Whittingstall 1999), also known as being day neutral. Since flower initiation is controlled by temperature supplemental lighting or shading is often not needed for production.

B. A New Production Schedule for *Paeonia spp.*

Changes needed in the current production methods of *Paeonia spp.* center around the management of temperature as a means to control both speed and quality of cut flower production. Specifically,

growers would utilize coolers set at 2°C to produce the best quality and quality of blooms in the shortest amount of dormancy time needed. They then would drench the plants with 250mL of 100mg/L GA₃ and move them to a temperature controlled greenhouse set at 22°C day/10°C night (Table 4). This shortens the time period needed for flower bloom from 12 weeks to 8 weeks and gets flowers to market in off seasons.

Table 4: Revised herbaceous peony production schedule for cut flowers

Stage	Time period	Treatment
Vegetative divisions of roots arrive from the breeder/wholesaler	6 weeks in cooler at 2°C	The divisions are planted in 15L containers and placed in coolers. A high organic well-draining potting mix is used.
Shoots and flower buds emerge	8 weeks at 22°C day/10°C night	Transport plants to greenhouse or high tunnel. Drench with 250mL of 100mg/L GA₃. Fertilize with half the yearly amount needed. Harvest ¼ of blooms.
New flower buds and shoots develop on crown	12 weeks between 28°C and 10°C	Fertilize with remaining fertilizer from spring
Plant dies back for winter dormancy	6 weeks in cooler at 2°C	Transport plants to cooler
Shoots and flower buds emerge	8 weeks at 22°C day/10°C night	Drench with 250mL of 100mg/L GA₃. Fertilize with half the yearly amount needed. When flowers are at “soft bud” stage harvest ½ of blooms.
New flower buds and shoots	12 weeks between	Fertilize with remaining fertilizer from

C. The new *Paeonia spp.* Ideotype

The new ideotype of *Paeonia spp.* is a plant that would offer multiple colors, forms, and scents year-round to consumers of cut flowers while having a standardized production methods across cultivars for the ease of growers. Flowers would have long, strong stems with full blooms that open for consumers after being placed in water. Plants would have the same productivity as field counter parts but would flower in 26 weeks or less instead of 52 and all cultivars would be successful using the same schedule of production.

Paeonia spp. producers would benefit greatly from transitioning to indoor production despite the initial cost. Plants would bloom in half the time it takes in the field and conceivably at any time the grower wanted allowing access to previously untapped consumer markets. Being day neutral, peonies would need little to no supplemental lighting or shading which is efficient and saves the grower money. Greenhouse production also allows plants to be positioned closer together meaning more production and profit in the same space as compared to field production. Drip irrigation from sprout to dormancy streamlines production and saves water by putting it right at the roots where the plant needs it. Fertilization should also be done through irrigation in order to cater to the exact needs of the plant and reduce labor costs that would otherwise go to application.

The initial challenge associated with introduction of the *Paeonia spp.* ideotype is implementation of a new universal production schedule. Not all cultivars have been successfully tested in the proposed system laid out in Table 4 that was designed around 'Sarah Bernhardt'. Some cultivars need more cooling or have been shown to need specific light requirements in order to produce quality flowers.

Another gap in the current knowledge is specific fertilization requirements for containerized production. Field fertilization schedule will be a good reference point but should be adjusted for soilless media.

Furthermore, there has been no research into how long the recovery stage of the plant between bloom and dormancy takes. Peonies form flower buds between the end of bloom and dormancy in the previous year. Forcing using a hormone drench will not be successful if the plant has not fully developed the next set of flower buds. Estimation based on the amount of time field production plants are allowed to regenerate has been given for the purposes of this paper but is probably overstated. More research needs to be done to determine the shortest amount of time it takes to form viable buds.

Beyond production schedule issues lies the problem of cultivar availability. Cut flowers must have very long, strong stems to hold up the large round flowers. There are a limited number of cultivars currently that are able to produce stems of the right length and girth while also having a large marketable flower. The majority available are double type in shades of pink and red. Conventional breeding efforts focused on increasing the diversity of cut flower contenders with new colors, such as yellow, or shapes, such as bomb, will need to fill in this gap.

Paeonia spp. only continues to grow in popularity as a cut flower while producers struggle to find ways to fill the demand year-round. In order to tap into previously unreachable markets and maximize profitability producers must consider nontraditional methods of peony production. Adopting new methods and schedules that rely on temperature to manage developments brings production indoors. Work and research is still needed to clarify details such as time needed for new bud production and a wider range of cultivars suited for cut flower production. Solutions to these problems are within reach and as such peonies are poised to move from field production to the more efficient, faster indoor production.

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