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Editors' Note: This is the second in a six-part series of articles highlighting the research being performed at the University of Florida in Gainesville.

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A New "Look" at Flower Fragrance

Research shows that fragrant blooms boost human well-being, but breeding for other factors has weeded out those scents. Research at the University of Florida suggests there's progress to be made in bringing fragrance back to those now genetically superior plants.

By David G. Clark

Since ancient times, floral fragrance has had a prominent influence on societal customs, and much value has been placed on fragrant flowers and fragrances derived from them. As technology has advanced, we have been able to analyze the chemical compositions of different flowers' scents and copy them for use in consumer products, from perfumes to detergents and cleaning products to aromatherapy items. We now know that many of the compounds found in floral fragrances have positive effects on human behavior, and medical research groups around the world are actively trying to understand this phenomenon as a means to develop tools for enhancing human well-being.

As professionals in the floriculture industry, we all know where to get great-smelling roses, lilacs, gardenias, snapdragons, geraniums, petunias and others if we want them. But at the consumer level, fragrance is harder to find in plants that have received a lot of attention from breeders. Fragrance has historically not been the focus of ornamental plant breeding programs, and flowers have lost their characteristic fragrance as breeders now concentrate primarily on factors such as flower color and longevity, plant growth habit and disease resistance. In fruit and vegetable industries, a similar phenomenon has been observed with selection for taste characters. Selection for yield-enhancing traits along with visual and postharvest characteristics have displaced selection for the qualitative traits needed for production of taste compounds, thus resulting in tomatoes that look good and store well but don't taste very good.

In defense of these breeders, this is probably not something we can fault them for: Production of plants often drives their selection criteria, and fragrance has always been considered a niche characteristic in most plants. To add to that situation, many breeders do not have fancy analytical techniques and costly equipment available to them to help analyze complex fragrance mixtures like we do in the ivory tower of academia; they just have their noses. If we consider the wide differences in human sensitivity to fragrance, all it would take is a few breeders lacking a sense of smell to completely lose fragrance genes for any species they might have bred over just a few generations of selection. Just a few days with a common cold or nasal infection while making selections could easily lead to a breeder losing fragrance traits. So here's the big question: How do we get the fragrance back in our flowers?

Above: *Panelists testing petunia flowers for fragrance preferences.* ***Top:*** *Consumer panelists at the University of Florida taking part in a survey focused on defining consumer preferences for flower fragrance.*

Problems With Fragrance?

When talking to industry professionals about fragrance, it is often brought up that fragrance is negatively associated with flowers' vase life; that is, good-smelling flowers don't last very long. There is a long history of thought on this subject — and much discussion about fragrant roses with poor vase life can be found across the Internet — but there is not much scientific proof that this phenomenon actually exists. After investigating vase life of fragrant and non-fragrant cut roses in our lab more closely, it appears that this concept may be a little more complicated. We have observed poor and excellent vase life in both fragrant and non-fragrant roses. More importantly, we have observed closer associations of poor vase life with a rose flower's ability to make and/or sense ethylene. We also have data to suggest that flowers with high respiration rates are more likely to develop faster and have poor vase life than flowers with lower respiration rates, regardless of their fragrance production.

Because ethylene synthesis and perception, as well as respiration rates, are known to be controlled by genes responsible for processes other than fragrance biosynthesis, it is likely that fragrant roses with good shelf life can become industry standards if breeders know what they are looking for and have a means to select for it. Fortunately, breeders at David Austin Roses and Meilland are currently focusing on selecting new fragrant rose varieties with superior vase life, and they are making excellent progress. The fact that they are making pointed hybridizations and selections for fragrance and postharvest traits

with continued success is proof that the negative relationship between fragrance and vase life was probably a myth all along.

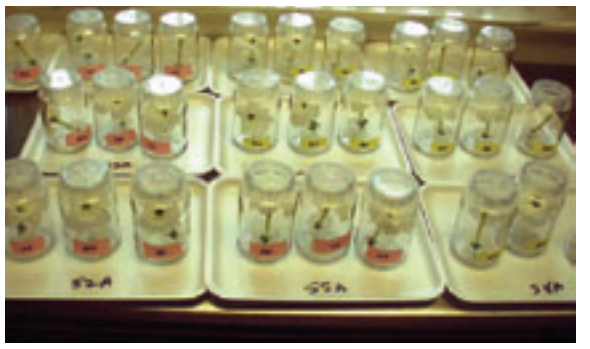
Unfortunately, there is minimal publicly available marketing research data that investigates the value added by making new flower varieties with enhanced fragrance. So a significant new question for our industry is, "How valuable is fragrance?" Because it is harder to place a value on human emotions than it is on a box of cut roses or rooted cuttings, perhaps now is the time to step back and take a different perspective on how we capture the value of fragrance.

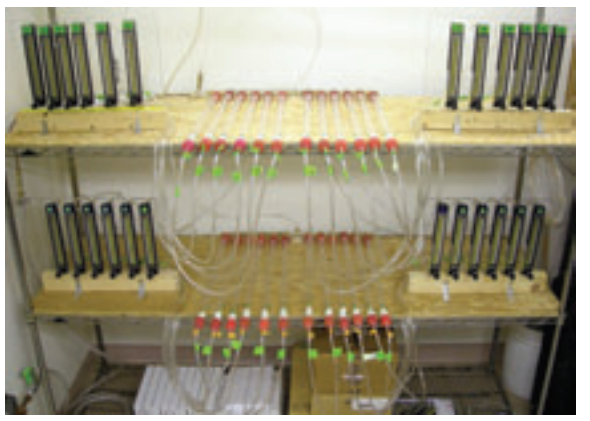
Bring in the Psychologists!

In the past few years, several excellent psychologists have become interested in the influences of flowers on human well-being. Common sense has driven the basic hypothesis that humans like flowers, but some intriguing research done by psychologists Drs. Nancy Etcoff (Harvard University) and Jeanette Haviland-Jones (Rutgers University), and behavioral scientist Dr. Roger Ulrich (Texas A&M University) has led to new discoveries that get closer to measuring the impact that flowers have on human emotions, well-being and productivity.

Work in Dr. Etcoff's group at Harvard has shown that flowers feed compassion, chase away anxieties and create positive feelings at home, and provide a boost of energy and enthusiasm at work. Dr. Etcoff believes that putting flowers where groups of people converge, especially in the mornings, is more likely to transfer positive feelings and create what she calls a "mood contagion" that spreads positive emotion through the group for the rest of the day. To support this idea, research in Dr. Ulrich's group at Texas A&M showed that workers had better ideas and were more creative problem solvers when they worked in environments with flowers and plants. Measured employee performance increased up to 15 percent, so this study suggests that a company's small investment in flowers could lead to a greatly enhanced bottom line. I'm surprised I haven't seen this idea marketed and advertised at the consumer level in our industry. Corporate America could probably use a few flowers to cheer them up and make a little more money these days!

More extensive work investigating the effects of flowers on human behavior in recent years in Dr. Haviland-Jones' group at Rutgers has shown that scented flowers have an immediate impact on happiness and are a "positive emotion inducer." Her group has shown that even a single flower given to a test subject can create long-term positive effects on mood. In senior citizens, flowers decrease depression, refresh recent memory and encourage companionship. Researchers have gone further to show that people who give flowers to others are perceived as being happier, smarter, more capable and more courageous. In a world where first impressions are very important, it makes me wonder why we don't all have flowers in our hands when we meet with important people! Unfortunately, there is little existing theory in any scientific discipline that can explain why flowers make people feel good, but with scientific interest on the rise, I expect the gains in this area to be rapid over the next few years.





Top: *Trays of petunia flowers waiting for panelist testing at the University of Florida.* ***Bottom:*** *A collection system used for concentrating petunia flower fragrance for volatile chemical analysis. Clean air running through the columns allows for concentration of fragrance volatiles for further analysis.*

Bring in the Biochemists and Molecular Biologists!

In the past decade, our understanding of the biochemistry and physiology of floral scent has progressed rapidly. Floral scent is a highly ➧

Concentrated fragrance samples from petunia being prepared for analysis by gas chromatography at the University of Florida.

variable, complex mixture of low-molecular-weight, volatile organic compounds that attracts insect and animal pollinators. Hundreds, perhaps thousands, of different volatile compounds are emitted from flowers in varying levels and mixtures. In many species, including antirrhinum, petunia and rose, petals are the primary site of floral scent emission with fragrance compounds emitted from the petal's epidermal layers. Fragrance is a dynamic characteristic, with quantitative and qualitative changes occurring during flower development, in response to pollination, through day-night cycles, and in response to the environment.

Foundational research in the labs of Eran Pichersky (University of Michigan) and Natalia Dudareva (Purdue University) has led to the discovery of biosynthetic pathways for many important floral scent compounds. Since their early work in snapdragon and clarkia, work in this field has been expanded with other groups like ours at the University of Florida working on petunia to determine which genes are responsible for controlling how plants make chemicals like rose oil (2-phenylethanol), clove oil (eugenol/isoeugenol) and many others. While there are obvious benefits to studying floral scent in multiple plant species, petunia has emerged as a key model system for studying floral scent. In recent years, the fragrance profile has become well characterized, and many of the genes responsible for petunia fragrance have been isolated. To date, the floral fragrance of petunia has been modified both by changing the expression levels of endogenous genes, thereby altering ratios of volatiles naturally produced in petunia, and by introducing novel biosynthetic pathways.

Ultimately, it is unlikely that biotechnologists will be introducing new genetically engineered fragrant flowers to the market. However, we now know the DNA sequence of many of the important genes controlling fragrance, and we know how to use them as molecular markers to assist breeders in quickly identifying plants of all species containing genes important for fragrance. When combined with new analytical tools for measuring floral fragrance, it is now possible for breeders to focus on fragrance like they never have before.

Everyone Come Together Now!

I may not be a clinical psychologist, but it is clear to me that regardless of age or gender, flowers — especially fragrant ones — have a positive influence on human well-being. The big question to me as a biologist now is *why* flowers make people feel good. It's a complicated question. Dr. Haviland-Jones hypothesized that cultivated flowers exploit an evolutionary niche because they have evolved to induce positive emotions in humans.

From what I know about genetics and plant breeding, it is clear to me that we can now go further in bringing desirable fragrance back into plants if we join forces with diverse groups of scientists, and at the University of Florida, we are doing just that. Plant geneticists and biochemists can produce new fragrant plants with a variety of appealing aromas, and we think psychologists and food scientists should be able to use these plants as tools to determine which components of fragrance have the most important influences on human behavior. Using consumer panels, we will determine which fragrances humans like best. Once we have that information, we will then dissect and identify the chemical components of good and bad aromas made by the flowers. Then, molecular genetic markers can be developed for the most important genes controlling synthesis of good fragrance chemicals. These markers

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can ultimately be used by breeders in combination with modern biochemistry techniques for analysis of the fragrance chemicals to make efficient advances in their selections for fragrant new varieties without having to rely on their noses.

Yes, it should be possible to bring the fragrance back into your flowers, and if we do it correctly this time, we should be able to show that we can make people feel better with them as well! Once we produce the new varieties, industry professionals should have no problem finding a way to market the effects of fragrance on human well-being and capture more value from fragrant flowers.

Just a note to all the flower breeders out there: The genes controlling fragrance are available in almost all plant species if you go back to their native origins. Don't wait for the data to come in before you start taking a little time to stop and smell your breeding stocks — you might find something out there that makes you (and your boss) smile! GPN

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