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A Perspective on the Need for Intensive Breeding Programs for Ornamental Plants and the Role of Biotechnology©

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INTRODUCTION

One aspect about ornamental horticulture that is so enticing is the vast diversity of plants we have available with which to work. Most of these plants are unique selections or cultivars. If one asks the question "where do most of our cultivars come from?", the answer is not the same as one would get if the question addressed most agronomic, forestry, or vegetable crops. Our selections of ornamentals, especially woody genera, most likely are derived from chance finds or selections gleaned from the landscape or production fields by observant horticulturists. This source contrasts with the agronomic/forestry/vegetable producers, which most likely develop their selections utilizing intensive, structured breeding programs. Another question then arises: Should we use intensive, structured breeding programs more commonly to improve our perennial and woody ornamentals?

One obstacle to using intensive breeding for woody plants is the biology of perennial plants. The longer life cycles of perennial plants makes multiple generations of breeding not only highly time-consuming, but expensive. For example, a typical hypothetical woody plant may require about 5 years to commence flowering as a seedling. Three generations of breeding are often required to achieve the early goals in a program with each generation including at least three seasons for selection of traits. The final selections will need more extensive testing in out-plantings in multiple regions. Putting this altogether, it can easily require 25+ years to properly complete the early phases of a woody ornamental intensive-breeding program. Not only does such a time period encompass much of the professional life of the breeder, but also who is willing to predict the market demand for a product two to three decades down the road? This is especially difficult in a market where a wide diversity of plants is the norm, thus limiting the potential economic return from any single group of new releases. On the surface, undertaking an intensive-breeding program for perennial and woody ornamentals seems too risky and expensive.

The main goal of this presentation, however, is to argue the opposite position. I feel our industry needs to invest more into well-structured and intensive breeding programs for improving woody ornamentals. I feel that such approaches can generate far more "product" than might initially be perceived, thus making the "cost" much more reasonable. In addition, the incorporation of modern biotechnological methods can shorten the overall breeding cycle, thus making intensive breeding

programs even more feasible. Let me demonstrate these ideas by referring to a research program that we have undertaken — the genetic improvement of several of the members of the highly useful ornamental genus *Viburnum*.

THE VIBURNUM BREEDING PROGRAM AT UNIVERSITY OF WISCONSIN-MADISON

Our program is working with two ornamental species of viburnums, *V. lantana* and *V. carlesii*, both of which are popular ornamental shrubs for temperate climates and have multi-season interest. *Viburnum lantana* sports white, nonfragrant flower clusters in the spring, clean foliage all season, very ornamental red/black fruit clusters in the fall, and good fall foliage color. In addition, *V. lantana* has excellent winter hardiness, but tends to be a large shrub and often is characterized by rank seasonal growth. *Viburnum carlesii* has superb highly fragrant pink/white flower clusters in the late spring, clean foliage, excellent fall color, but no significant fruit display. *Viburnum carlesii* is a medium-sized shrub of more compact growth habit, but will show winter injury in severe locations or seasons. Our objective in initiating the breeding program was to combine the best of the characteristics of each species, thus creating a medium-sized, compact shrub with fragrant flowers, colorful fruiting, bright fall color, and high winter-stress hardiness.

The first obstacle encountered was an incompatibility of crosses between these two species. The biotechnological tool of embryo rescue overcame this. Crosses between these viburnum species do produce viable sexual embryos, but endosperm (stored food to support the embryo) is lacking, thus the seed aborts after early development. Harvesting the fruits early in their development, aseptically removing the embryo, and continuing its growth in microculture obtained seedlings from the crosses (Hoch et al., 1995). Since these hybrid seedlings were already in microculture, another biotechnological tool was readily used — micropropagation. Each hybrid was micropropagated to generate clonal copies of the genotype that could then be planted in replicated field plots, thus minimizing the time from hybridization to field evaluation. In addition, the microcultures served as a mode for storage of the germplasm for later use.

Utilizing this protocol, 172 different hybrid clones were generated that successfully transferred to the field. Currently, replicated field evaluations at two sites (differing markedly in winter stress) have been planted for 3 years. Flower bud set is high this season (2003) and promises the first overall evaluation of flowering and fruiting in 2004. Meantime, vast differences in plant form, growth characteristics, fall color, and winter hardiness (tested by a –30 °C winter) have been recorded. This diversity within the seedling hybrids is itself becoming a reason to undertake such a structured and intensive program. The vast diversity observed in these plantings promises that selections can be made to meet a variety of purposes, including landscaping using small to large shrub habit, suitability for the cut flower industry (where "rank" growth is desirable), or even usefulness for flowering pot plant culture. Without such extensive out-plantings of numerous hybrid seedlings under replicated and controlled conditions, many of these potential products would not have been apparent.

In addition to a broad array of products from such an intensive breeding program, two new objectives emerged unexpectedly after the program was initiated.

A new introduced pest, the viburnum leaf beetle [*Pyrrhalta viburni* (Paykull)], has entered the eastern U.S.A. and promises to spread throughout the continent. This pest can severely damage many species of viburnum, even leading to death of established plants. Early work by researchers at Cornell University (New York) indicated that some genetic resistance occurs among viburnum species. Fortunately, the two parental species in our breeding program differ in susceptibility to the leaf beetle. Thus we now have an opportunity to not only select for resistance to this potential pest, but also to observe the segregation of the resistance trait among our population of hybrids and to study the mechanism of resistance. Again, without the intensive and diverse germplasm created in this structured breeding program, we would not have been able to effectively pursue this new work.

When discussing our program with growers, we became aware of yet another character that was an important trait for selection — ease of propagation. Although both of these species root well from semi-softwood cuttings using standard protocols, the survival of rooted plants over the first winter, especially if bare-rooted, is a major limitation for the production of *V. carlesii*. Since *V. lantana* does not suffer from this limitation, our hybrids should show a segregation for the ease-of-propagation trait. Thus we have included this character in our selection program and have launched an additional subproject, funded in part by the Eastern Region I.P.P.S., to record the genetic segregation of the trait within our existing hybrid populations.

OTHER BIOTECHNOLOGICAL TOOLS

In addition to embryo rescue, germplasm storage, and micropropagation, other tools of biotechnology may also be useful in such a structured breeding program for a woody ornamental. Paramount among these is genetic engineering or the transference of genes foreign to our species into our hybrid populations. Genetic engineering of woody plants is now well established and with the emergence of the new tools of genomics, a vast array of genes for new traits is being isolated. So, why not use genetic engineering in our program for viburnum? The answer is complex. In short, genetic engineering offers enormous potential for the rapid genetic improvement of our ornamental crops; however, ornamental crops are not ideal economic or ecological targets for genetic engineering (McCown, 2001). Probably as important, shifting current public attitudes toward the release of genetically engineered organisms further complicate the already significant problem of trying to predict the future market demand for a product such as an ornamental plant.

CONCLUSION

So back to our original question: Should we use intensive and highly structured breeding programs more commonly to improve our perennial and woody ornamentals? After our early experience with our viburnum program, my answer is that we should. Having such programs in place not only expands the number of potential commercial products, but also such programs can underpin studies to gain new biological knowledge as well as allow us to effectively pursue objectives that were not apparent at the initiation of the breeding program. Knowing how interested propagators are in observing and working with new plants, I can see no better group to push for such programs than I.P.P.S.

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pH and Alkalinity are Different©

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Often when I ask growers what the alkalinity of their irrigation water is, I get a response something like: "It's about 6.5." This might be a correct answer to the question: "What is the pH of your irrigation water", but it is not the correct answer to a question about alkalinity. The correct answer to a question about alkalinity will be a number in the range about 20 to 350. Let me explain.

Irrigation water is never absolutely pure H_2O. The water always has ions dissolved in it. These ions include such cations as sodium (Na^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}) and the anions chloride (Cl^-), sulphate (SO_4^{2-}), and bicarbonate (HCO_3^-). The concentrations of these ions and their relative proportions vary enormously amongst water supplies.

Thus rainwater caught in a dam in the higher-rainfall parts of the country will usually have low concentrations of all of these ions (and hence will have a low salinity). Its pH might be something like 6.9 and its bicarbonate concentration might be 20 $mg \cdot L^{-1}$.

In contrast, water pumped from deep underground in the drier parts of Australia could have the same pH (6.9), but could have a bicarbonate concentration of 250 $mg \cdot L^{-1}$ (and a salinity of perhaps 1200 $\mu S \cdot cm^{-1}$).

You will see soon why I pick on bicarbonate to illustrate the difference between these waters.

If the rainwater is used to irrigate a nursery crop whose nutrition is being provided by a fertiliser that releases acidity into the potting mix as it is used (as most fertilisers do), the potting mix will become steadily more acidic. That is, its pH will decrease.

If the underground water is used for the same purpose, despite its identical pH and the same acidity from the fertilisers, it will be found that the pH of the potting mix will steadily rise over time.

The difference in response of the potting mix is clearly not due to the pH of the irrigation water, as it is identical for the two water supplies. Rather, it is due to the difference in their levels of total alkalinity. The total alkalinity of a water supply is expressed as calcium carbonate equivalent ($mg \cdot L^{-1}$) and is calculated by multiplying the bicarbonate concentration in the water by 0.82.

For example, our rainwater with a bicarbonate concentration of 20 $mg \cdot L^{-1}$ has a total alkalinity of $20 \times 0.82 = 16$ $mg \cdot L^{-1}$ calcium carbonate (equivalent); our underground water with a bicarbonate concentration of 250 $mg \cdot L^{-1}$ will have a total alkalinity of $250 \times 0.82 = 205$ $mg \cdot L^{-1}$ calcium carbonate equivalent.

In practical terms, these numbers mean that every time 1 L of water is applied to a plant in a container, the rainwater will deliver 16 mg of lime (calcium carbonate) and the underground water will deliver 205 mg of lime. The underground water has delivered about 13 times more lime to the plant than has the rainwater.