Biotechnology expands pest-management options for horticulture

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Plums resistant to the plum pox virus have been developed by scientists with the U.S. Department of Agriculture but are not yet available to growers.

Fruit and vegetable crops are under constant pressure from pests such as weeds, viruses, fungi, bacteria, insects and nematodes. If not controlled, many of these pests substantially lower yields. Successful agricultural production has depended on the use of pesticides for 100 years, and, yet, losses still occur due to certain pests that are poorly controlled. Some crops incur high costs for hiring laborers to hoe weeds because there are no effective herbicides. In addition, new pests routinely arrive for which effective controls have not yet been developed.

Agricultural researchers continuously seek out new methods to control pests, including biological agents, new chemicals and plant resistance through classical breeding. Biotechnology also offers a solution in some situations where traditional methods are ineffective or costly. Numerous researchers around the world are investigating biotechnological solutions to pest problems of horticultural crops. In 2002, the National Center for Food and Agricultural Policy released a study of current and potential biotechnological approaches to pest management in a wide array of crops (Gianessi et al. 2002).

If plum pox virus reaches California, the transgenic plum could help prevent losses to the state's multibillion dollar stone-fruit industry.

Current plantings. The study identified three varieties of transgenic fruits and vegetables that are currently planted on small acreages in the United States: virus-resistant squash is grown on 5,000 acres in the Southeast, to prevent late-season losses to mosaic viruses; virus-resistant papaya is widely planted in Hawaii (2,000 acres)(see sidebar, page 92); and insect-resistant sweet corn is planted on a small number of acres and has reduced use of insecticide sprays.

Withdrawn varieties. Two transgenic horticultural varieties were available for a short time in the United States but were withdrawn due to marketing concerns. Insect- and virus-resistant New Leaf potatoes were planted on 4% of the nation's acreage in 1999 and were credited with reducing insecticide use. If the transgenic varieties had not been withdrawn due to processor resistance they could have been planted extensively in the Northwest, reducing insecticide use by 1.4 million pounds.

In 1999, the U.S. Environmental Protection Agency (EPA) granted Wisconsin sweet-corn growers emergency permission to spray herbicide-tolerant varieties (see sidebar, page 110). The transgenic varieties were not widely planted due to marketing concerns and growers have not reapplied for the use despite continued production losses.

Crops currently being tested. Numerous fruits and vegetables have been transformed through genetic engineering and are being tested for their potential role in improving pest management. For example, University of Florida researchers are testing virus-resistant tomatoes as a substitute for the extensive insecticide spraying currently utilized to control insects vectoring geminiviruses. In California, herbicide-tolerant processing tomatoes have been tested and have the potential to reduce grower costs by $30 million and replace the use of 4.2 million pounds of fumigants.

UC researchers have tested herbicide-tolerant lettuce that could reduce herbicide use by 140,000 pounds a year. Herbicide-tolerant strawberries could save Eastern growers several hundred dollars per acre in weed-control costs. Nematode-resistant pineapple is being developed at the University of Hawaii to replace 1.4 million pounds of fumigants. Insect-resistant broccoli developed at Cornell University could improve yields in years of heavy insect pressure. Virus-resistant raspberries developed by U.S. Department of Agriculture (USDA) researchers in the Northwest could help combat bushy dwarf virus, which is present in 80% of Northwest plantings. And transgenic apples resistant to fire blight bacteria have been developed and tested at Cornell University; the transgenic varieties would replace the use of antibiotics, which are used to kill the bacteria on 25% of U.S. apple acreage.

Emerging pests. Several research programs are focused on biotechnological approaches to control emerging pest problems. Plum pox virus was detected in the United States for the first time in Pennsylvania, where efforts are under way to eradicate it by destroying infected trees. USDA researchers have developed a virus-resistant plum that is being tested in Europe. If plum pox virus reaches California, the transgenic plum could help prevent losses to the state's multibillion dollar stone-fruit industry.

Pierce's disease threatens California vineyards, and insecticide spraying has occurred to control the disease carrier, the glassy-winged sharpshooter. A researcher at the University of Florida (a state where Pierce's disease has been a problem for 80 years) has transformed grape tissue by inserting an antibacterial protein from another species into the grape genome. As a result, the transformed grape plant can destroy the bacteria without the need for insecticide sprays targeting the carrier.

Tristeza virus has killed 45 million citrus trees in Latin America and threatens the Texas citrus industry. Researchers at Texas A&M University have developed and are field testing virus-resistant trees.

Bacterial canker is present in Florida citrus orchards, and the state is trying to eradicate the disease by destroying infected trees, including millions of orchard and backyard citrus trees. A University of Florida researcher has developed and is testing a canker-resistant citrus tree.

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Reference

Gianessi LP, Silvers CS, Sankula S, Carpenter JE. 2002. Plant Biotechnology: Current and Potential Impact for Improving Pest Management in U.S. Agriculture; An Analysis of 40 Case Studies. National Center for Food and Agricultural Policy, Washington, DC. www.ncfap.org/40CaseStudies.htm.

Cotton has been genetically engineered to express a protein from a naturally occurring bacterium, *Bacillus thuringiensis*, which is toxic to insect pests such as bollworm and budworm. This cotton is widely planted in California and elsewhere in the United States.

when the leaf starts to senesce, leaf life is extended in transgenic plants exposed to drought, nutrition and pathogen stress (Gan and Amasino 1995; Clark et al. 2004).

Ethylene sensitivity. As in fruit ripening, manipulation of ethylene synthesis or sensitivity has applications in the ornamental plant industry. Ethylene accelerates floral and foliar senescence, and chemical methods have been developed to mitigate its effects (Sisler and Serek 2003). Ethylene sensitivity can be reduced in floriculture crops through applications of the ethylene antagonist silver thiosulfate (STS), but unfavorable environmental aspects such as metal contamination of groundwater restrict its commercial use. Another compound, 1-methylcyclopropene, also blocks the ethylene receptor protein and makes plant tissues insensitive to ethylene, delaying ripening or senescence. Although this compound is effective in many crops, its action decreases with time after treatment as the tissues synthesize new ethylene receptor proteins during postharvest transit. By expressing a mutant form of the ethylene receptor protein or by blocking expression of components of the ethylene-signaling pathway, petunia plants with longer lasting floral displays have been produced (Wilkinson et al. 1997). Unfortunately, negative side effects, such as higher susceptibility to fungal pathogens and decreased rooting of vegetative cuttings, have limited the commercial use of these technologies. The key to effective manipulation of ethylene sensitivity will be the use of promoters limiting transgene expression to the target tissue, leading ultimately to plants that have longer lasting flowers with no negative side effects.

Hurdles to commercialization

The lag in commercialization of transgenic horticultural crops clearly is not due to a lack of useful genes or valuable applications. However, several fundamental issues inherent to horticultural crops create significant hurdles (see sidebar, page 84).

Biological diversity. Simply the diversity of crops utilized in horticulture slows the adoption of new technologies. For any given crop, there may be several different species and dozens of cultivars that are currently marketed, and the turnover of new cultivars from year to year is tremendous. For example, as many as 60 distinct cultivars of iceberg lettuce alone may be grown throughout the year as production locations shift seasonally. Add to this the dozens of additional varieties for romaine, leafy, red and other specialty types, and it is evident that introducing a new biotech trait for lettuce requires developing not just one but many new varieties. In perennials such as trees and vines, on the other hand, the choice of a variety is a long-term