Editorial overview


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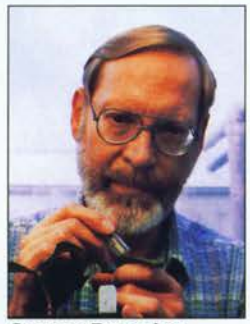
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New technologies are changing the face of agriculture

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The first issue in the special *California Agriculture* series, "Future in Focus: 2000-2025," (January-February 2000) projected that the world's population will reach 8 billion in the next 25 or 30 years, and California's will reach 50 million. This portends a dramatic rise in the demand for food globally, and the need to feed 50% more people in California. Simultaneously, loss of the state's agricultural land continues at an alarming rate, 1.3 million acres between 1992 and 1997 (see p. 23). Meanwhile, 9 million acres of California's 27.7 million acres of remaining farmland are irrigated; with the trend toward high-value crops, we expect the proportion of irrigated acreage to increase.

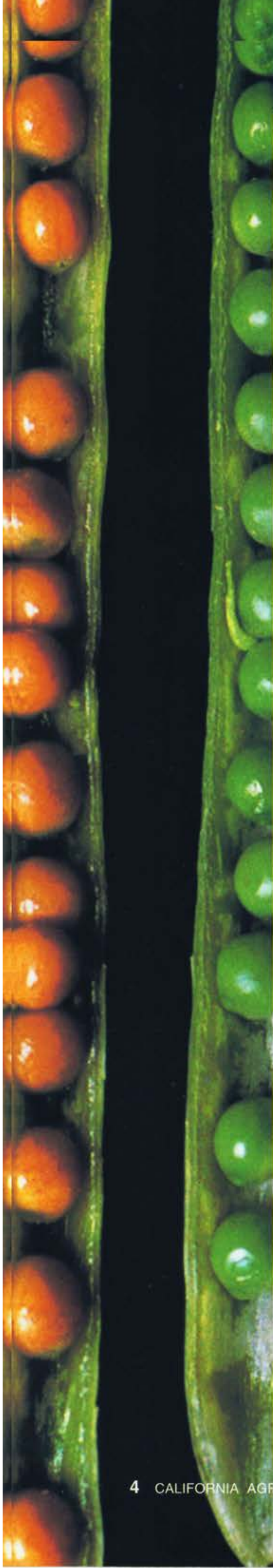
The second issue of the special series (March-April 2000), on critical issues concerning our natural-resource base, emphasized the conflicts surrounding competition for water use and how they have become the focal point for debate among farmers, conservationists, developers, city-dwellers and legislators.

The historic success of California in employing its natural resources to build agriculture can be attributed to the development and dissemination of new information and technology, which skillful farm managers have been able to utilize effectively. As we look forward to the year 2025, the increased and competing needs for food and housing, as well as demands for environmental quality, will place even more pressure on farmers to be innovative and efficient in their crop production.

In this third issue of the special series, we examine ways in which agriculture may protect the environment and natural resources while maintaining a strong and competitive position. The new information, practices and technologies described in this issue will aid innovative growers in this challenge.

Trends. For California's producers, the continuous shift away from field crops to more intensively cultivated and high-value fruits, nuts and vegetables will result in greater market fluctuations and risk (see p. 16). To remain competitive, growers must aggressively adopt new practices and technologies to improve productivity within a sustainable agricultural system. Consumer and market demands have created an expanding niche market for organically grown produce, which under current regulations may not be derived from transgenic crops. This demand for products of nonconventional farming is likely to continue in the near future (see p. 26).

However, we believe that the distinctions between "conventional" and "nonconventional" ag-


Crops engineered to provide nutritional enhancements are a reality. Canola plants have been genetically modified by Calgene to express provitamin A, or beta-carotene. Typical seeds are green. The orange of transgenic seeds is due to accumulated beta-carotene. Photo by *Sacramento Bee*/Chris Crewell.

riculture are likely to blur in the future, and production will become more sustainable, as growers integrate the greatly expanding knowledge base of biological processes such as pest dynamics and soil microbe-plant interactions with modern crop biotechnology. Managing crops at a spatial scale smaller than the individual field, called "precision agriculture" or "site-specific management," was pioneered with field crops in the Midwest and is receiving increased attention in California (see p. 66). These techniques apply new information-gathering technologies to monitor mineral-nutrient levels, soil texture and chemistry, and moisture; input levels are adjusted according to what is appropriate for different portions of the field. These techniques save money, improve yields and reduce unwanted environmental effects.

Predictions. In the quest for more profitable, environmentally friendly and productive agriculture, and for improved nutrition for the planet, we expect to see in the coming decades:

- A transition from a commodity-based agricultural industry to one with differentiated, value-added products.
- A competitive advantage for farmers who become more proficient in the use of emerging information technologies.
- An increase in the use of the components of biologically integrated and organic farming systems that protect the environment and respond to consumer interests.
- The widespread adoption of precision agriculture, a confluence of technologies that reduces inputs by matching them more closely to actual crop requirements.
- The synthesis and application of novel chemicals with enhanced specificity toward target pests, that can be applied at very low rates and degrade quickly in the environment.
- The application of the new agricultural biotechnologies, including tools of advanced molecular biology and the construction of transgenic plants and animals possessing valued production and quality traits.

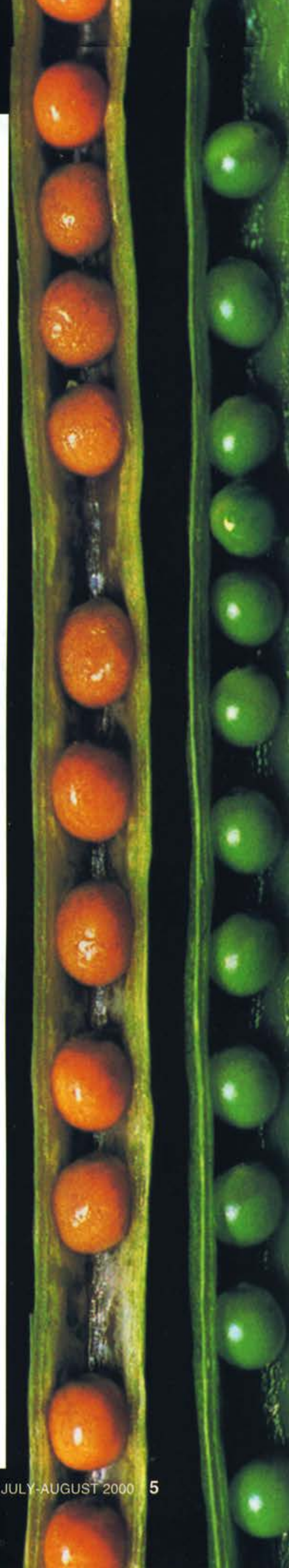
The role of genetic engineering

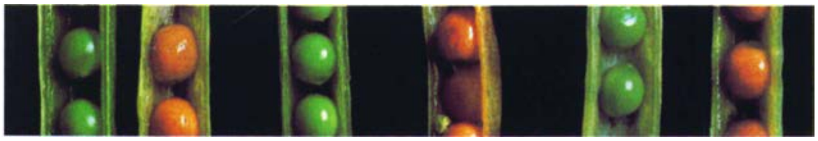
The most controversial, and possibly the most influential, changes in agriculture at the end of the 20th century are associated with genetic engineering of agricultural species. This 15-year-old approach to genetic improvement has introduced valuable agronomic traits into some crop lines and promises many other improvements in our ability to more efficiently raise animals and crops and to generate new and improved agricultural products (see pp. 36, 49 and 57). Nonetheless, the road to commercializing genetically engineered ("transgenic") products has been, and likely will continue to be, an uneven one (see p. 6).

The potential of transgenic crops to revolutionize pest management has been demonstrated by their widespread adoption since introduction in 1996. During the 2000 growing season, growers planted more than half of the cotton and soybean acreage in the United States with engineered varieties. Greater benefits can be expected with experience in integrating engineered crops into more traditional practices.

Pest resistance. The first step in any integrated approach to pest management is to select varieties adapted to the soil type, climate and planting timing, and with resistance to anticipated pests. Traditional plant-breeding programs have achieved resistance to pests such as insects, nematodes and plant pathogens. The use of transgenic techniques builds on traditional approaches and accelerates the rate at which new and novel genes can be made available. In addition to incorporating genes for resistance into the plant itself, genetically modified pathogens and other biological agents offer additional tools for incorporation into an integrated pest management strategy for dramatically reducing reliance on chemical pesticides.

New crops. The greatest impact of transgenic crops undoubtedly will be from cultivars with improved products, or even new crops. An estimated 250,000 children in Southeast Asia go blind each year from vitamin A deficiencies, which are also responsible for health problems in 400 million people in developing nations. In many of these areas, rice is the diet staple. Ingo Potrykus' group at the Institute for Plant Sciences in Zurich, Switzerland, genetically engineered rice to synthesize and accumulate beta-carotene (provitamin A) (Ye et al. 2000). This elaborate engineering effort involved the introduction of two genes from daffodil and a bacterial gene into rice. Efforts to release the beta-carotene rice lines to developing countries are still under way, slowed in part because of entangling intellectual-property issues. Genetic engineering of crops usually employs a variety of inventions to prepare and introduce the desired genes, and free dissemination and





We believe that the distinctions between "conventional" and "nonconventional" agriculture are likely to blur in the future, and production will become more sustainable, as growers integrate the greatly expanding knowledge base of biological processes such as pest dynamics and soil microbe-plant interactions with modern crop biotechnology.

commercialization requires the assent of numerous patent holders.

Other nutritional enhancements of grains and crops are possible and perhaps beneficial. More than 30% of the Earth's population is adversely affected by iron deficiencies in their diets. The soybean gene for phytoferritin was introduced as a transgene, creating rice lines with three times the iron content of untransformed rice (Goto et al. 1999; Gura 1999). Beta-carotene- and iron-containing rice are harbingers of the complicated transgenic crop constructions that can be engineered to meet critical nutritional needs.

One of the characteristics of California's dynamic, highly competitive agricultural industry is that it continually renews itself, infusing productive new ideas and innovation from both public-sector and private-sector efforts (see p. 72). As we move into the coming century, it will be ever more important for continued public funding of the land-grant university. UC must continue its missions in teaching, research and extension to further develop the knowledge base that will be necessary to meet the challenges facing our agricultural production system.

The guest editors gratefully acknowledge comments from Belinda Martineau and the anonymous reviewers of the papers included in this issue of California Agriculture.

References

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The case of the FLAVR SAVR tomato

The FLAVR SAVR tomato was the first genetically engineered crop product to be commercialized. The research and marketing efforts that produced the FLAVR SAVR tomato resulted in scientific success, a temporary sales success, and then commercial demise. The FLAVR SAVR story reveals how difficult it can be to bring genetically engineered products to market, how objections with little or no scientific merit can influence the outcome, and how important public opinion is in determining commercial success.

Circumstantial evidence available in the 1980s suggested that the tomato fruit enzyme polygalacturonase (PG), because of its ability to dissolve cell-wall pectin, was key to fruit softening. Researchers at Calgene, Inc., in Davis, proposed to suppress PG accumulation in ripening tomatoes by introducing a reverse-orientation copy of the gene, an "antisense" copy designed to prevent or drastically reduce the formation of PG.

Their expectation was that ripe fruit would remain firm longer, perhaps even allowing it to be transported to market after vine-ripening. Transporting vine-ripened fruit would avoid the practice of picking green fruits and artificially ripening them by ethylene treatment, which gives a ripe tomato color but not the full array of vine-ripened tomato flavors.

By 1987, Calgene researchers identified and cloned a tomato fruit PG gene, developed methods for tomato transformation and regeneration, and produced tomato plants with inserted PG antisense DNA constructions. Some of the resulting tomato lines generated as little as 1% of the PG found in conventional tomatoes. Based on the results from eight contained field trials, in October 1992 the U.S. Department of Agriculture determined that the PG-antisense tomato lines were not a "plant-pest" risk and no longer required permits for field testing or transport.

In May 1994, the U.S. Food and Drug Administration, responding to a Calgene petition, approved the introduction of kanamycin-resistance gene constructions needed to