Molecular biology and the sugarbeet industry in the United States.

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The results of molecular biotechnology are beginning to affect the sugarbeet industry in the United States. Soon herbicide tolerant varieties will be available in some domestic growing areas. Resistance to Beet Necrotic Yellow Vein Virus (rhizomania) using viral coat protein genes may also soon be used by farmers to reduce loss to that difficult disease. Other new transgenic traits will begin to appear, and likely the number will increase more rapidly with time. These developments seem to be of great potential usefulness to sugarbeet growers, and should improve the efficiency of sugarbeet production while helping to reduce environmental costs. Some in the public are concerned about the nature of the new technology and unforeseen risks that might be associated with it. My concerns are different. Currently, the majority of work on sugarbeet transformation and molecular biology is carried out by private seed companies or consortia between seed companies and universities, almost exclusively in Europe. Is this reliance on European work in the best interests of the American industry? Correspondingly, does the relative lack of research on sugarbeets in the U.S. deprive the industry worldwide of the talents of scientists who could significantly advance both basic science and the interests of the industry? Much fundamental work on sugarbeet physiology and plant breeding has been carried out in the U.S.,. The work of Albert Ulrich and others (Ulrich and Hills, 1990) on sugarbeet nutrition and the discovery of the *Rz* gene for rhizomania resistance are just two examples of many possible examples of contributions from U.S. scientists and plant breeders to the worldwide industry.

Reliance on European seed companies for the production of new varieties may particularly disadvantage the industry in California. Sugarbeets have been grown commercially in California since 1870, longer than anywhere else in the U.S.,. In recent decades, acreage has declined from approximately 360,000 (145,000 ha) to less than 100,000 (40,000 ha) (figure 1). The stabilization and then decline of sugarbeet acres has corresponded to the establishment of a yield plateau in California of approximately 25 to 28 t ac^{-1} (56 to 63 t ha^{-1}). This is lower than realistically achievable yields in most years and locations. During that same period, costs have risen while prices received by farmers have remained steady. In this setting, alternative crops such as cotton and processing tomatoes have displaced beets on many farms.

The loss of the beet crop in California would make it more difficult for farmers to meet the increasingly difficult management challenges they face in complying with new environmental regulations. Sugarbeets are among the most tolerant of all crops to soil and irrigation water salinity and to boron. They are highly tolerant to ozone, an air quality problem in the San Joaquin Valley. When planted in autumn and harvested in early summer, they make use of winter rainfall, and become one of the most water efficient crops available. They are very deep rooted and can make use of water lost by shallower rooted crops in the rotation and recover residual soil N, preventing leaching. They also help maintain more diverse crops rotations, with largely positive benefits for agriculture. These characteristics are not all shared by other crops, so there is a public interest in maintaining the sugarbeet crop in California. To do so, however, yields must rise and costs must fall. Molecular biology offers the promise of helping achieve both those goals, and in at least one instance, may offer the only opportunity.

Beet Yellows Virus (BYV) has been a problem in California since at least 1950. Direct yield losses to this disease can be quite high (> 50 %) if seedlings are uniformly infected, but even with lower losses, yields can rapidly become uneconomic (Kaffka and Lemaux, 1996). Besides direct yield losses, a noteworthy quarantine system has been developed, limiting planting and harvesting in certain areas. Typically, new plantings must be delayed until after peak flights of the green peach aphid (*Myzus persicae*) in late April, and fields must be isolated from each other. It is generally thought that delayed planting leads to lowered yields in and of itself, whether or not the disease occurs. Also, the requirement to breed resistant lines to this disease, constrains classical plant breeding programs, making steady progress in developing yield and quality characteristics, and the achievement of resistance to other plant diseases like powdery mildew, less obtainable. Unfortunately, resistance to BYV may not be available in the *Beta* genome. Resistance breeding has been difficult (figure 2). For average yields to rise again in California, high levels of resistance to BYV, approaching immunity, may be necessary.

In recent years, however, the sugarbeet industry in the southern most region of the state (the Imperial Valley), has experienced steadily increasing yields. Good crop management practices are followed there, but the most important factor was accidental. In 1991, a new white fly species invaded the Imperial Valley, completely displacing the previous one. The new species increased rapidly to devastating numbers and eliminated a number of crops, including cotton and melons. More importantly, the new white fly proved to be an ineffective vector of the Lettuce Infectious Yellows Virus, which had been liming the yield of sugarbeets for many years (figure 3). Release from this chronic viral disease has allowed the crop to improve steadily in yield and the Imperial Valley may now be the highest yielding sugarbeet region in the world. It seems reasonable to think that similar results would occur if the industry in California's central valley were freed of BYV as well. In other parts of the U.S., equivalent benefits may be achievable if other chronic pest and disease problems could be overcome.

Because of the limited acres of sugarbeets now grown in California, and because germ plasm needs to have special characteristics, including bolting, curly top, erwinia, root rot and other types of resistance, it is unlikely that new transgenic traits will be available to California growers as soon as they are needed, and that the traits available will not be the most important ones. Limited markets may delay the development of commercial transgenic lines by European-based companies.

Recently, Persidis and Persidis (1996) have written about the development in Europe of biotechnology consortia. These consortia involve private companies and universities. They enable the participants to organize a "critical mass" of scientific ability otherwise lacking in one institution, and similarly assemble resources such as laboratories and equipment to support a biotechnology effort. Often the groups are linked through electronic communication (a "virtual" research group) and are limited risk, i.e., they focus on a finite, well defined problem. Benefits are shared through the consortia. This collective effort allows the consortium to overcome the often considerable inertia and start up problems associated with a new research initiative.

Sugarbeet growers in California have many challenges which are unique to the state or which have a more severe effect than elsewhere. BYV is one such problem, but the severity of losses to a worldwide problems like rhizomania was another. The varieties and management methods developed in California are now finding application elsewhere in the western U.S. as that disease increases in occurrance. Losses ultimately should be much lower as a result in those newer areas. For the benefits of molecular biotechnology to become available to smaller acreage states like California, particularly those with special germ plasm requirements, the creation of research consortia may provide the needed resources and focus to make a difference. Solving some of the hard problems faced in California, should benefit the industry elsewhere in the future, as it has in the past.

References

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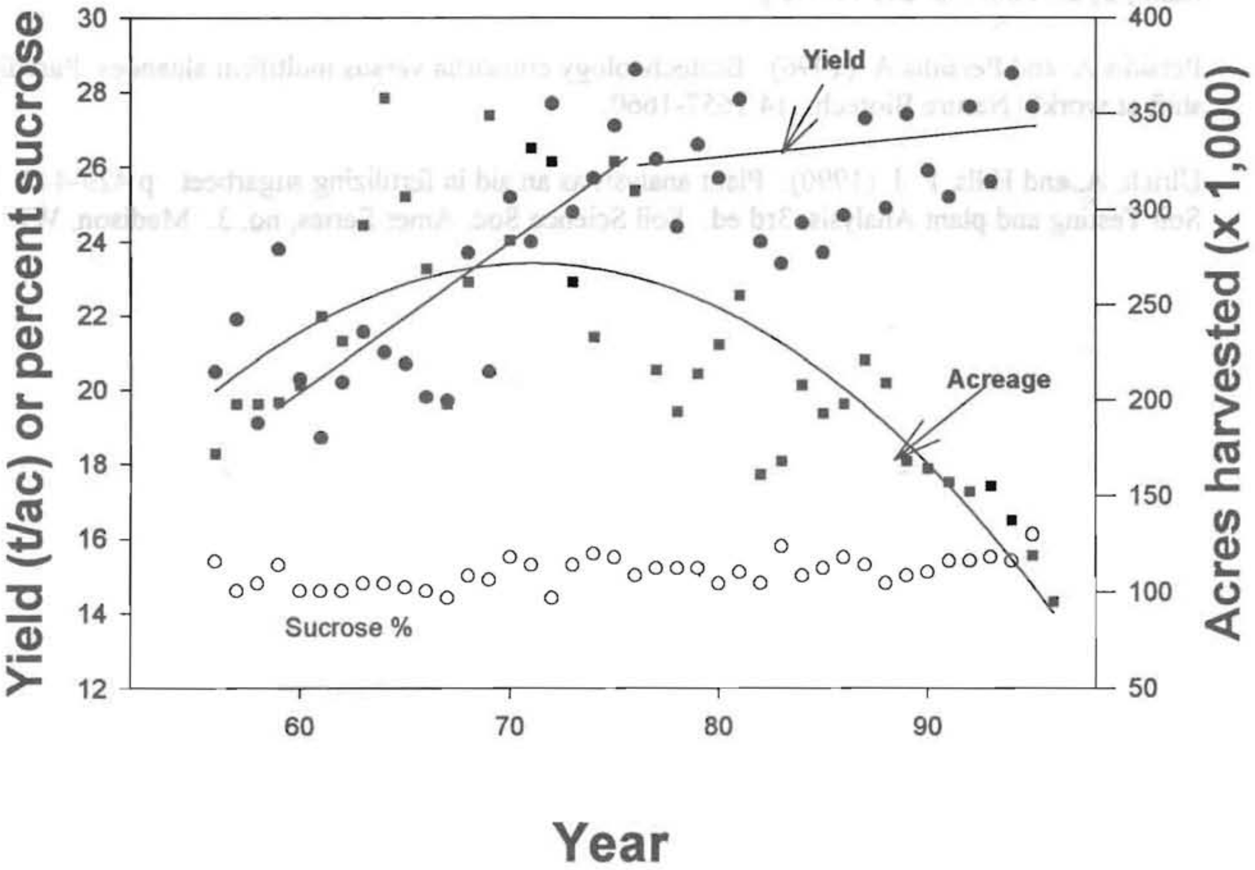

Figure 1. Yield and acreage trends in California, (1956-1996). When yields stopped increasing, acreage stabilized and then declined

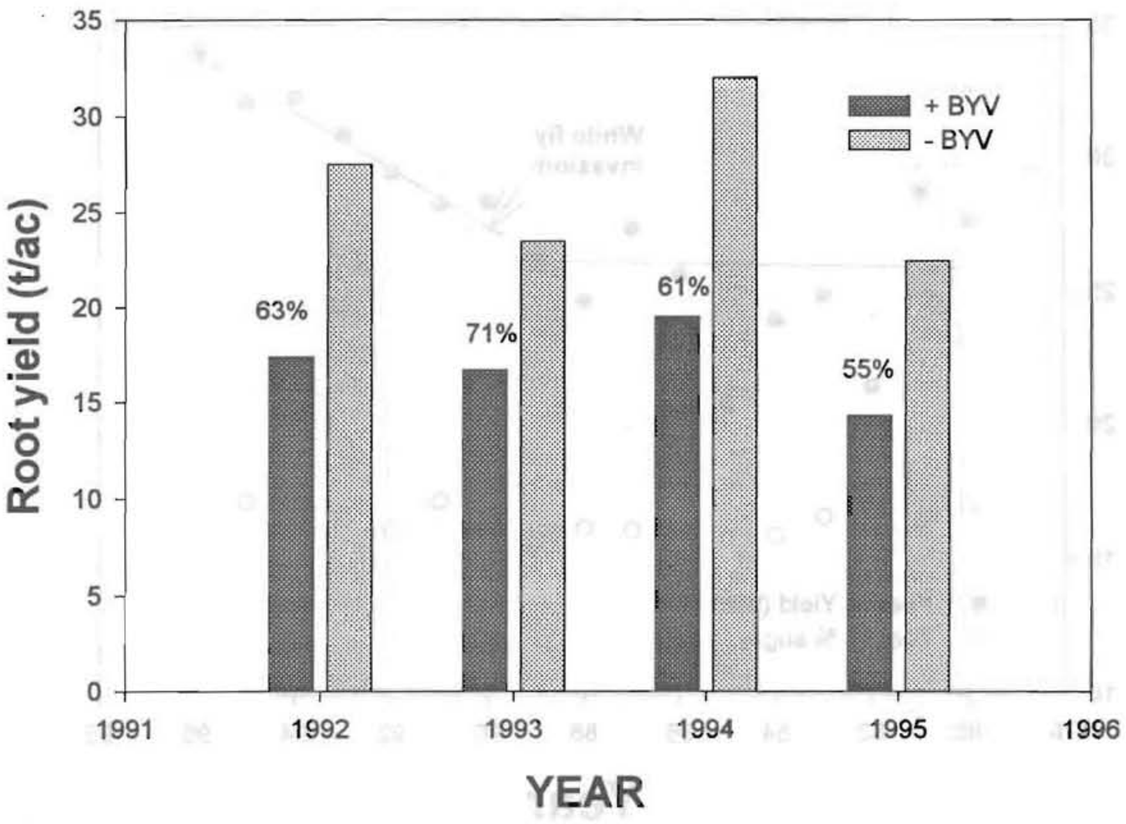

Figure 2. Evaluation of hybrids and experimental lines for reaction to beet yellows and beet western yellows virus at UC Davis

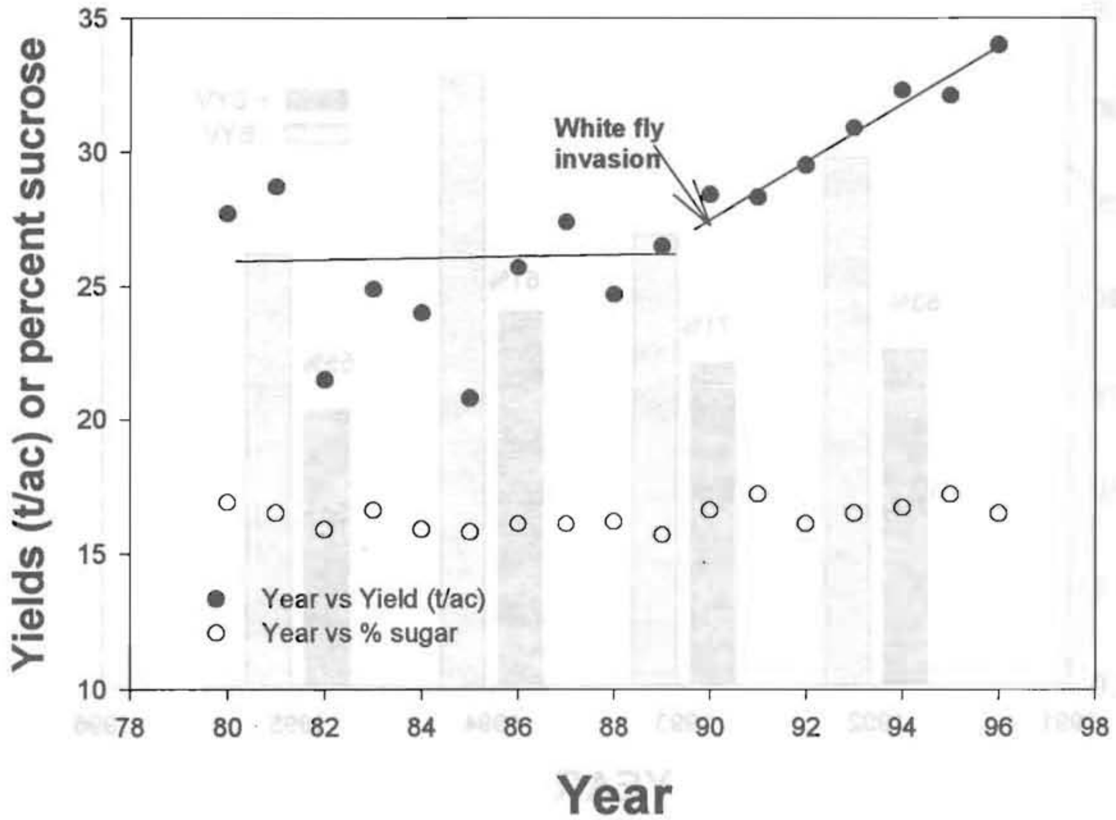

Figure 3. Yield trends in the Imperial Valley (1982-1996). When a new white fly species displaced the older one, LIYV was eliminated as a sugarbeet pathogen