Horticultural Technology

E.C. Tigchelaar and V.L. Foley

Additional index words. tomato, breeding, pest resistance, institutions

Webster defines horticulture as “*the science and art of growing fruits, vegetables, flowers or ornamental plants.*” He in turn defines science as “*a systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses.*” These definitions imply that the science component of horticulture may represent a pursuit of knowledge or understanding, whereas

the art and technology components seek to apply knowledge generated through science, observation, and/or experience to a practical end.

Horticulture was an art or practice long before it was worthy of being called a science. The oldest written records speak of fruits and vegetables that are still consumed

today; the analysis of the food remains of our prehistoric ancestors reveal dietary patterns that suggest that horticulture was practiced by very early humans. The beauty of horticulture also was appreciated by early humans, as flowers were sometimes buried with the dead during the age of the Neanderthal. This historical evidence strongly suggests that, long before humans had constructed a

Purdue University, West Lafayette, IN 47907-1165

“HortTechnology represents an effort.. . to communicate potential new applications of science to the practice of horticulture, and thereby foster a better understanding of the role that science plays in the development and use of horticultural technologies.”

formalized body of knowledge of horticulture, its practice was widespread.

As both a science and an art, modern horticulture serves to bridge the gap between the basic sciences (biology, chemistry, physics, and mathematics) and their application by using information from these sciences to improve the production and handling of horticultural crops. Horticulturists thus apply the methods of science and information from the basic sciences to seek solutions to applied horticultural problems. Technology, according to Webster, is defined as “*a scientific method of achieving a practical purpose.*” Many of the procedures used by horticulturists are, however, very old and have been practiced in similar fashion for many years. The routine task of producing seeds and/or grafting to perpetuate a desired cultivar proceeds today in ways little different from the routines practiced thousands of years ago. Many of our important domesticated crops had already undergone great modification by early farmers centuries before the invention of writing or the rise of cities. Despite their lack of scientific training, our early ancestors left us a horticultural heritage that has formed the basis for modern-day horticulture.

Horticultural science and technology have had a long and proud tradition of service to the world’s horticultural industries, to the consuming public, and to the cause of science, yet this success story remains largely untold and unappreciated. The launching of *HortTechnology* represents an effort by the American Society for Horticultural Science (ASHS) to communicate potential new applications of science to the practice of horticulture, and thereby foster a better understanding of the role that science plays in the development and use of horticultural technologies. It represents an effort to give clearer meaning to the generic and widely used term “biotechnology” by attempting to identify those technologies so classified that have application and relevance to horticulture.

Horticulture is a unique and extremely diverse enterprise that deals with many different plant species and uses for those species. Many horticultural crops do not qualify as food staples, but, rather, are commodities that provide variety to the diet and/or add to the overall quality of life. Because of their relatively minor use in terms of quantity of production, many horticultural crops have received far less attention than the major food and feed commodities.

Horticultural crops are also unique by virtue of the intensive nature of production systems and their high dollar returns per acre. For example, commercial fruit and vegetable production in the United States occupies <2% of the cropland area, but generates ≈ 15%

of annual crop revenues. Another feature of many horticultural commodities is their high perishability and the specialized marketing and handling practices that have evolved to accommodate them. It is clear that horticulture has many unique attributes and that it contributes importantly to the quality of life we take for granted in this country.

History of horticultural technology

The onset of agriculture occurred roughly 10,000 years ago in the fertile crescent of what is now the turbulent country of Iraq. Fruits and vegetables appear to have played an important role as these early agricultural systems changed to feed growing populations. We frequently read of figs and dates in the Bible, and the sacred scriptures of other religions refer to mangoes, pears, and plums. Early New World cultures also provided several important crops (e.g., corn, potato, squash, tomato,) that today help to feed the world. The Greeks will be forever associated with the cultivation of the olive.

In Western civilization, agriculture has undergone at least three periods of significant change during the course of its relatively short history. The first obviously involved the transition from hunters and gatherers to tillers of the soil. The second occurred during the Middle Ages, when ancient patterns of fallowing and crop rotation gave way to more intensive and diversified systems. Legumes such as peas and beans were rotated with other crops to take advantage of the nitrogen and improved soil structure that resulted from their use. This practice may have raised yields as much as 4-fold in comparison with ancient practices, in large measure because of the ability of these plants to fix nitrogen for use by the succeeding crop. Part of this nutritional revolution rested on using plants that had played a relatively minor role in earlier agriculture. This practice evolved long before its scientific basis was understood; it was not until the 1850s that the role of nitrogen as a fertilizer was studied successfully by scientists of that period.

The next great period of agricultural advance came in the 1700s and 1800s, and it, too, rested in part on using products and practices of earlier ages and other cultures. During this period New World crops such as corn, squash, pumpkins, potatoes, and tomatoes (the vegetable that we will focus on to illustrate the history of change) were introduced to European farmers for the first time. Native Americans had devoted millennia to develop literally thousands of varieties of these and other crops, which helped propel Europe into an unprecedented new stage in

the human condition-the Industrial Revolution. The age of mass manufacture would probably have been much less successful if it had not been for the introduction of these commodities into Europe and their contribution to improving the efficiency of European agriculture so as to free labor to contribute its skills and muscle power to this revolution.

Not all of the outcomes of this revolution were pleasant ones, however, as evidenced by the role of the potato in changing the history of Europe. Scholars have estimated that the lowly spud enabled higher caloric yields per acre than any other native European crop. After initially resisting the potato for fear it was harmful, the peasantry in some places, notably Ireland, began to rely on it almost to the exclusion of other crops. The Irish population began to grow after centuries of poverty and stagnation and then, in the 1840s fell by perhaps one-third when the potato crop, on which they had become so dependent, was attacked by the late blight epidemic for several years in a row. Part of the population emigrated, but hundreds of thousands starved. This pattern has been repeated on a smaller and less disastrous scale for other crops and areas of the world to reveal the vulnerability of agricultural systems to forces of nature over which we may have little control. In this sense, all of agriculture is a most unique and distinctive enterprise that policymakers and the consuming public seldom appreciate or understand. We take for granted the cornucopia of foods that grace our tables each day and seldom give thought to the science and technology that has made this possible.

A number of modern critics of today's agriculture have suggested that we return to something like the highly varied agriculture of the past to buffer against possible shocks arising in the future from our present system of monoculture and specialized agriculture. Given the pressures on our agricultural resources to feed a rapidly expanding population, such an adjustment may be difficult to accomplish in the short-term, despite the effects such changes might have on perceptions of food safety and the impacts of agriculture on our environment. It is clear that concerns regarding the stability and sustainability of present arrangements for using our natural resources (including our agricultural ones) are growing at an unprecedented rate. The best minds in our profession must address these issues so that the consuming public continues its faith that our production technologies are environmentally sustainable and provide products that are wholesome and worthy of their trust and confidence.

If we trace the historical record, we find that, in times of uncertainty and stress, we often look back along our path of travel to try

to see if there were points where we may have diverged from a better way. Since horticulture is something of a bridge between the sophistication of modern science and technology and the simpler but time-tested older ways, it plays an important role in such a reassessment. For example, much of the modern-day furor over dieting today could be resolved by the simple conclusion that a balanced diet containing a variety of foods in reasonable quantities is probably the best way to avoid the follies and excesses of some of the more extreme dietary proposals marketed to those who have "battled the bulge." This pattern of consumption would deemphasize the relatively few crops that have become modern agricultural staples and encourage a more varied diet richer in the diverse products of our horticultural industries. The recent rapid rise in the consumption of fresh fruits and vegetables may suggest that this is, in fact, occurring today.

The tomato: A case study

No horticultural crop has received more attention and detailed study than that most popular and pampered vegetable-the tomato. It is a model crop for many experimental studies and the knowledge and information gathered from these studies have contributed to the dramatic improvements in production that have occurred during this century. In view of its brief history as a food crop, it provides an ideal example to illustrate how science and technology have converted an ornamental curiosity into an important food commodity in the United States.

History. The tomato originated in South America, where numerous wild and cultivated relatives are found still in the uplands of Peru, Chile, Ecuador, and Bolivia. Relatives of the tomato also have been reported in the Galapagos Islands off the coast of Peru. Domestication and cultivation of the tomato occurred first outside of its center of origin by early civilizations of Mexico. The name "tomato" probably was derived from the Nahuatl language of Mexico, and variants of the name have followed the tomato in its worldwide distribution. Seven distinct primitive relatives of the tomato can be intercrossed with cultivated forms (although in certain cases, only with difficulty) to provide an almost inexhaustible gene pool for improvement of the crop. These wild relatives have provided most of the pest resistance found in modern-day tomato cultivars. The great diversity that existed among primitive crops came from their wild ancestors, which, during their long history of domestication and evolution, became adapted to many different environments in their centers of origin

"We take for granted the cornucopia of foods that grace our tables each day and seldom give thought to the science and technology that has made this possible."

*“... maintainin
connections with
our past must be
an important
part of the
equation as we
plot our future
and decide upon
the
appropriateness
and relevance of
new
technologies. ”*

or use. The tomato, for example, evolved into several distinct species long before human cultivation. Each species adapted to different environments (altitude, length of growing season, soil types, disease and insect pressures, etc.) to provide modern plant breeders with an almost limitless source of “building blocks” to improve modern cultivars. Diversity and connections with the past are the hallmark of our horticultural heritage; maintaining connections with our past must be an important part of the equation as we plot our future and decide upon the appropriateness and relevance of new technologies.

The tomato was slow to gain acceptance as a food commodity, presumably because of suspicions that its fruits were unhealthy, perhaps even poisonous. Apparently the tomato's similarity to familiar poisonous members of the nightshade family, such as mandrake and belladonna, caused concern over its safety as a food. Such suspicions persisted widely even into the 20th century, and undoubtedly had a major impact in slowing its adoption as a useful and nutritious food crop.

The first documentation of the tomato in Europe appeared in the 1554 writings of the Italian herbalist Mattioli. These first fruits were presumably yellow, rather than red in color, since the plant was first known in Italy as *pomi d'oro*, or golden apple. Its name *pomme d'amour* (or love apple) in France did little to hasten its acceptance there as a food crop. The first recorded mention of the tomato in North America was made in 1710. Thomas Jefferson wrote of tomato plantings in Virginia in 1782, and makes reference to its planting and culinary uses in later writings. Its history as a commercially processed commodity began at Lafayette College in Pennsylvania in 1847, where the commercial canning possibilities of the love apple were first demonstrated. From these humble beginnings the tomato has become the leading processed vegetable crop in the United States. Almost 10 million t was produced in the United States in 1990 for processing use alone, and annual world production for all uses exceeds 60 million t.

Changes in US production. Improvements in tomato production during the past half century have been remarkable. Average U.S. yields for commercial fresh-market tomatoes increased almost 4-fold, from 66 hundredweight (cwt)/acre in the early 1940s, to 257 cwt/acre in 1990. Similar dramatic improvements in processing tomato production occurred during this same period. In the early 1940s, U.S. average yields were reported as 5.4 tons/acre; they were >29 tons/acre in 1990 (a 5-fold increase!). Without these improvements, the tomato might well have

remained an ornamental curiosity or a food commodity that few could afford. Its current popularity is due in large measure to its affordability and versatility and the variety it adds to our diet. As an ingredient in a tossed garden salad or a piping hot pizza, the tomato has indeed become a widely appreciated food commodity.

Revolution or evolution? The remarkable improvements in tomato production efficiency over the past halfcentury fortunately have been repeated for many of our important food crops. Historians undoubtedly may be tempted to label this brief period in history as the greatest of the agricultural revolutions. But has it, in fact been a revolution or simply an accelerated evolution? A closer look at the statistics for tomato production during these 5 decades reveals that gains in per-acre yields have occurred in small, but sustained, steps throughout the period. Per-acre yields of processing tomatoes for 1940 have essentially doubled during each decade from 1940 to to 1990. This would suggest steady evolutionary, rather than abrupt revolutionary, change over the 50 years. Further, it implies that no single technology has played an overriding role in past improvements; rather, implementation of many different technologies and creation of the human resources to implement those technologies have been the key elements. This 20th century agricultural revolution is thus fully as important as any of the earlier ones we have considered.

Impacts of technology. The well-documented statistics of U.S. tomato production and surveys of the extensive research literature provide an historical picture of the roles science and technology have played in these dramatic improvements in tomato production. In most instances, knowledge from the basic sciences (botany, genetics, chemistry, physics, etc.) was necessary to develop an understanding of the biology of the crop and provide essential tools for its improvement. The conversion of processing tomatoes from a hand-harvested crop to a machine-harvestable commodity illustrates the cooperative team approach that was essential in this transition. The development of the first successful machine-harvestable processing tomato cultivar by G.C. Hanna, at the Univ. of California, Davis, required a major redesign of standard cultivar characteristics. This took more than 20 years of research, and included cooperation of tomato breeders throughout the United States. Associated changes in crop culture and management, and the design of an efficient harvester, required many additional skills. Finally, education of the grower and innovations to the production system made at the grower level were necessary to ensure successful implementation.

This successful adoption of mechanical harvest of processing tomatoes has been criticized in a lawsuit against the University of California challenging the use of "tax dollars" to support the research and development that made this change possible. It was argued that development of this technology favored the large producer and displaced large numbers of farm workers. Most modern technologies could probably be criticized or challenged on the same grounds, yet the tomato was singled out to illustrate that problems, as well as benefits, accrue from the implementation of labor-saving technologies. During the course of these debates, the benefits that accrue to the consumer from these developments was seldom considered or publicized to present the other side of the coin.

Tomato breeding and the use of pest resistance. The use of pest resistance in tomato breeding serves to illustrate further the evolutionary and cooperative nature of science and technology. The earliest record of attempts to select and develop improved tomato cultivars in North America is credited to Livingston in the 1870s. Much of the very early improvement of the crop, however, must be credited to those who first domesticated and cultivated tomatoes.

The tomato has become a model for genetic and biotechnological research, and this prominence has aided greatly in its improvement during the past half century.

The breeding of pest-resistant cultivars has been a major achievement in tomato production. For certain pests, production would be considerably more restricted, difficult, or costly without host resistance. Pest resistance remains a major goal in tomato improvement as new diseases achieve significance or new races of existing pests become established. Progress in the use of host resistance was fostered during the early 1950s by a national cooperative effort to evaluate cultivated and wild tomatoes for their reactions to important tomato diseases. Scientists from several disciplines, representing both the public and private sectors, participated in this national program to develop appropriate screening procedures and to identify and use valuable sources of pest resistance. In

many cases, new techniques were required to accomplish the arduous task of transferring resistance genes from wild species to cultivated forms before this resistance could be exploited effectively. This cooperative effort identified important new sources of pest resistance that provided the blueprint for modern-day cultivars and F₁ hybrids, many of which now possess multiple resistance to several problem diseases.

Highlights in the history of tomato breeding in the United States are well-documented in the horticultural literature and in the descriptive listings of new vegetable cultivars that have been published by ASHS and the American Seed Trade Assn. since 1936. These listings provide a useful source of information to trace the important developments that helped form the blueprint for most modern-day tomato cultivars. Since 1936, more than 550 new tomato cultivars have been described in these listings; they provide a picture of the historical use of host resistance for the improvement of this crop.

Exploiting this host resistance has been limited to a relatively small number of tomato pests (Table 1). Host resistance has been used widely for three common soil-borne pests

Table 1. Use of host resistance in North American tomato cultivars (1936–1986).

Pest	Causal organism	Resistant cultivars	
		No.	Percent
Fungal pathogens			
Fusarium wilt	<i>Fusarium oxysporum</i>		
	race 1	232	41
	race 2	50	9
	race 3	0	0
Verticillium wilt	<i>Verticillium albo-atrum</i>		
	race 1	171	30
	race 2	0	0
Gray spot	<i>Leaf Stemphylium solani</i>	21	4
Early blight	<i>Alternaria solani</i>	3	0.5
Late blight	<i>Phytophthora infestans</i>	2	0.3
Septoria leaf blight	<i>Septoria lycopersici</i>	1	0.2
Bacterial pathogens			
Bacterial canker	<i>Corynebacterium michiganensis</i>	0	0
Bacterial speck	<i>Pseudomonas tomato</i>	0	0
Bacterial wilt	<i>Pseudomonas solanacearum</i>	0	0
Bacterial spot	<i>Xanthomonas campestris</i>	0	0
Viral pathogens			
Tobacco mosaic	Tobacco mosaic virus (TMV)	16	3
Spotted wilt	Tomato spotted wilt virus (TSWV)	5	1
Curly top	Beet curly top virus (BCTV)	5	1
Cucumber mosaic	Cucumber mosaic virus (CMV)	0	0
Insects and nematodes			
Root-knot nematode	<i>Meloidogyne</i> spp.	62	11
Insect damage	Many	None reported

Fig. 1. *History of the use of host resistance to fusarium wilt in tomato (1936–1986).* Source: *New Vegetable Variety Listings* published by ASHS (1936–1986). Public = percent of tomato cultivars released by public institutions. F₁ hybrid = percent of cultivars identified as F₁ hybrids. Fus 1 = percent of cultivars reported to be resistant to race 1 of fusarium wilt. Fus 2 = percent of cultivars reported to be resistant to race 2 of fusarium wilt.

(fusarium and verticillium wilts and, in recent years, the root-knot nematode). The development of new strains of these pests presents a continuing challenge to stay ahead of the evolving organism. Chemical control has been the option of choice for most other tomato pests. Less than one-half of 1% of cultivars released during this period were reported to be resistant to late blight, the same organism responsible for the Irish potato famine and a disease that may wreak havoc during winter production in subtropical production regions. Early blight, a common problem in most humid production regions, continues to be controlled by chemical means, despite reported resistance in the relatives of the tomato. With the exception of tobacco mosaic virus, the use of host resistance to facilitate control of bacterial, viral, or insect pests has been virtually unexploited in cultivar development despite documented reports of resistance to virtually all of these disorders in the wild relatives of the tomato.

The expanding use of host resistance during the 52-year period of publication of these listings also can be extracted from this record of tomato improvement in North America (Fig. 1). Prior to 1951 few cultivars with genetic resistance to fusarium wilt were reported; however, during the past 3 decades, host resistance to this disease has become a major achievement of tomato improvement efforts. Modern cultivars may possess resistance to several problem pests. There seems to be little doubt that this recent emphasis on pest resistance was prompted by earlier efforts to identify valuable sources of host resistance to major problem diseases and to transfer these building blocks into horti-

culturally adapted breeding lines. With few exceptions, these early efforts to identify and use new sources of pest resistance were carried out by public plant breeders and freely shared with their counterparts in the private sector. History of the use of genetic resistance for control of the fusarium wilt organism illustrates an additional feature of most agricultural systems. Agricultural systems are not permanently stable, such that once resistance is found, it remains effective as long as the crop is grown. On the contrary, disease organisms change to overcome the host resistance and the process of identifying sources of resistance to new strains of the pest, and incorporating these new building blocks into adapted cultivars must be repeated. In the past 30 years, two new strains of fusarium wilt have appeared and new sources of resistance have been used successfully to combat these new problems (Fig. 1). In the 1960s, a new strain (identified as *Fusarium* race 2) was reported in Florida, and soon spread to other tomato-producing regions in the United States. By the early 1970s, host resistance was combating this new strain effectively. In the late 1970s, a third strain of this organism appeared in Australia and, again, host resistance is being exploited to control its impact where it is now present. This biological instability provides job security for the plant breeder and requires continual vigilance to identify and monitor the appearance of such new strains. As new problem pests evolve, new sources of resistance must be located and incorporated into competitive cultivars just to sustain crop productivity.

The situation with respect to this use of host resistance for tomato cultivar improvement illustrates two further important points with respect to horticultural research. The tomato, despite its preeminence among horticultural crops and as a model crop for experimental studies, remains somewhat of an orphan with respect to the attention it receives for crop improvement. While impressive progress has been made in controlling common pests, genetic resistance has not been exploited for pests of lesser importance or in minor production regions. These pests continue to be controlled by more costly chemical means while host resistance remains a viable alternative. Most other horticultural crops fall into the same category, but to a much greater degree.

The second point that this history of the tomato illustrates is the commitment and cooperation required to transfer such important building blocks from wild or unadapted forms to usable forms. This task has been accomplished historically via cooperative efforts among the public and private sector and the appropriate scientific disciplines. The

early cooperative efforts to identify new sources of pest resistance and to transfer these valuable new genes into adapted cultivars undoubtedly served as the foundation for use of the host resistance that is exploited today. The present erosion in funding of tomato improvement and the resulting decline in publicly released cultivars or germplasm (Fig. 1) would not appear to be consistent with the historical contributions that have been derived from strong public support of crop improvement activities. It would appear that a much greater public effort than is currently being expended to maintain this progress would be in the best interests of the producer and consumer alike. The recent trend to market proprietary F_1 hybrid cultivars (Fig. 1) has facilitated the task of combining resistance to several diseases into a single cultivar; however, this trend will be short-lived if longer-term research needed to expand the use of host resistance to those important crop pests that have long been neglected is not encouraged. Recent expansion of support for "trendy biotechnology" at the expense of the tried and proven, but more traditional, plant breeding methodologies would seem premature, given the uncertainties of these yet unproven technologies.

Technology development and implementation: Whose responsibility?

The tomato represents only one of many food crops for which remarkable gains in production efficiency during the past 5 decades have been made. Yields and production efficiencies for most of our food staples (corn, wheat, rice, etc.) also have increased several-fold during this same time span, to provide a general standard of living only dreamed of 50 years ago. The current surpluses of some of these commodities represents one of the greatest achievements of science, given the problems society would be facing without these remarkable improvements! Continued improvement is needed but two fundamental questions arise as we project for the future and analyze the source of these remarkable gains, i.e., 1) what forces have contributed to these rapid and sustained improvements, and 2) are such improvements sustainable for the future? These questions appear to be so fundamental to the long-term future of society and health of agriculture that a major inquiry into these topics should be a top priority for agricultural planners.

The forces of changes. Several obvious factors have contributed to our rapidly changing and highly productive agriculture.

Technological improvements have undoubtedly played a key role; however, giving exclusive credit to technology may be an oversimplification. Specialization, movement of production to areas climatically best-suited to specific crops, and the accompanying mechanization have played important roles as well. Larger farming units, which permit specialization, mechanization, and other economies of scale may have contributed to increased productivity in the United States, although similar gains in efficiency have also been achieved in countries where farming units remain small and largely unmechanized. A major force in this phenomenal achievement, which often is unappreciated by the agricultural community and the consuming public alike, involves the research and educational infrastructure that under-girds U.S. agriculture. It is embodied in the Land Grant Universities and the U.S. Dept. of Agriculture, which have evolved in partnership with the private sector to serve American agriculture well. This infrastructure has created the human capital that provides the agricultural or horticultural leadership. It has fostered cooperation and communication between the public scientific community and the private sector that has served to prioritize and conduct relevant and site-specific research. It is through this partnership that technologies needed to meet the short- and long-term needs of the consumer and our highly diverse agricultural enterprises have been created. This infrastructure has *decentralized* agricultural planning to give the consumer and public and private sector participants a significant voice in agricultural planning.

The Land Grant Universities

The Land Grant Universities were created in the United States more than a century ago in response to the elitism and limited relevance of the private universities of the time. The basic concept of the Land Grant University was that they would provide continuing education for the masses-particularly in agriculture and the mechanical arts. An additional feature of the Land Grant philosophy was that the university would generate new knowledge and extend that knowledge to solving the problems of society. In every sense, this infrastructure was christened as an agent for economic change and development.

Unfortunately, winds of change have begun to sweep through our nation's Land Grant Universities that threaten to weaken their historical role and partnership with industry as a catalyst for economic development. Schuh, in a provocative article published in 1984, argues that "We seem to have lost sight of

"Recent expansion of support for 'trendy biotechnology' at the expense of the tried and proven, but more traditional, plant breeding methodologies would seem premature..."

“... excessive specialization or lack of relevance in agriculture can be the precursor to instability and sustainability problems.”

this important institutional innovation and have become introverted into our respective disciplines at the expense of relating our knowledge to the problems of society.” This problem appears to have been exacerbated during the decade of the 1980s by changes outside the university that have accelerated this loss of institutional responsibility. Two fundamental and interrelated changes appear to be primarily responsible in bringing this about.

Centralized planning. Possibly the most important force contributing to loss of institutional responsibility has been the trend to centralize agricultural policy planning in federal agencies. This change has resulted in a loss of individual innovation and the regional autonomy required to develop site-specific research and outreach efforts. Further, it has given us “bandwagon science,” dictated by politically oriented “hot topics,” which have redirected many research programs away from local commodity groups by funding only “high-profile,” nationally identified priorities. The end result has been a decline in the service philosophy upon which the Land Grant University system was based. The ultimate effect is to place agriculture and society as a whole at risk while philosophies promulgated with religious fervor are rampantly expounded as the “new science.”

The historical record has shown that excessive specialization or lack of relevance in agriculture can be the precursor to instability and sustainability problems. This comparison might also be extended to argue against excessive centralization in the ecological sphere and in the sphere of human institutions and political arrangements. It would appear unwise to attempt to simplify human arrangements too much and at the same time sacrifice the stability-conferring diversity that nature often seems to prefer. Political analogies to ecosystem instability are seen all too clearly in the tendency of overcentralized decision-makers to change the rules in agriculture in ways that may seem rational from the standpoint of international rivalries, but that leave the agricultural sector gasping for its financial breath. Nature has its own rhythms, and changing the rules too rapidly in the legislative hall or the marketplace can cause serious inconsistencies when only short-term maximization is attempted. Most often, nature does not adjust to maximize, but rather to optimize, and the latter is often more sustainable in the longer-term than the narrow pursuit of short-term goals.

Privatization. As public institutions abandon problem-solving research and concentrate on more esoteric basic research, applied research and outreach is increasingly limited to the private sector. This change is

distorting the public/private sector partnership inherent in the Land Grant philosophy and reduces the regional and national cooperation that has been such an important component of past agricultural progress. It also reduces the scope of applied research and emphasizes short-term projects that have a high probability of short-term payback. Research cannot be classified simply as basic or applied, but rather represents a continuum between the two. The important element to consider here is the reliance of each on the other for insight and stimulation. Effective progress is achieved only when there is an appropriate balance between these extremes in both public and private sectors. A strong public sector involvement is needed to evaluate the appropriateness and relevance of evolving technologies and to serve as an unbiased “third party” judge in evaluating these technologies.

An additional impact of the privatization of agricultural research has been the trend to patent new developments or develop proprietary products to gain a marketplace or pricing advantage. The recent debates concerning the patenting of life forms and, more recently, genes themselves, portends disturbing changes for future crop improvement. The history of the use of tomato pest resistance clearly suggests that free exchange and use of these community resources has been an important factor in encouraging recent progress. Legislation that will effectively provide proprietary control over these resources would not appear to be in the best interests of future progress or the consuming public. Such changes undoubtedly will alter further the public/private sector partnership that has served American agriculture so well, and will foster a spirit of competition and secrecy rather than cooperation and openness. It would appear that a strong public sector role in applied horticultural research will be essential to sustain the improvements that have been the hallmark of the past half century.

Schuh, in describing the changing Land Grant Universities, decries the departure of today's Land Grant Universities from the original concept. To quote: “*Today, applied research is frowned upon, or at best, looked down upon. The criterion for promotion is to do scholarly work, which means to publish in scholarly journals. There is almost a perverse turning away from institutional responsibility. They are concerned with advancing the state of knowledge and hence publishing for their professional peers, not generating and applying knowledge in the solution of society's problems.*” This scathing indictment of today's Land Grant Universities may not be universally justified but it is a concern of the

Land Grant fraternity and many outside of the system. Schuh suggest that “... *an important idea in this original conception was that the institution had a mission. Individual faculty and staff were a means to that end. They were managed and administered with a great deal of missionary zeal and tended to be rewarded only as they contributed to administratively determined missions of the institution. Moreover, they were rewarded as they contributed to the solution of societies’ problems and not solely for publications in scholarly journals,*”

Funding horticultural research and service

Probably the single most important reason for the loss of “missionary zeal” in some of our nation’s Land Grant Universities is the declining financial support for its tripartite mission of education, research, and outreach. Increased centralized planning has encouraged a shift in public support from mission-oriented or applied research and service to costly, competitively funded, short-term basic research. The question is not whether the public sector should be involved in applied or basic research; it is, rather, the issue of what represents an appropriate balance between the two to maintain a strong private/public sector partnership to address the future needs of agriculture. As basic research is funded at the expense of applied research and service, who will provide the critical link between the researcher in the laboratory and the emerging void in field-testing and application of evolving new technologies? Will horticulture departments disappear and be replaced by ever-larger biology departments, whose historical function has been only to understand biological systems? Will horticulturists and agronomists who apply this knowledge to the problems of the user community no longer be needed to provide the link between the laboratory and the application of science? Will the pragmatism and sense of service to our agricultural communities that was inherent in the original Land Grant concept be replaced by futuristic or esoteric activities that may have little relevance to the future needs of society? Will corporate considerations be the primary political forces driving the future of agriculture toward the 21st century? Restoring the Land Grant philosophy and a strong public commitment to agriculture would appear to require a restoration of an appropriate balance between short-term, competitively funded basic research and longer-term, applied “regional” research and service to ensure future program continuity and relevance. An appropriate feedback mechanism between

the two would maintain an emphasis on relevant areas of basic science and encourage implementation of new concepts.

The Land Grant philosophy and infrastructure is unique to U.S. agriculture. In most other countries, agricultural education, research, and outreach are administratively separate entities, resulting in a cumbersome system in which these three essential elements are largely unlinked. Schuh argues that “*One essential element of a modern Land Grant University is that it integrates basic and applied research with education and outreach under the same organizational umbrella, and that we keep ourselves motivated to a problem-solving mode at the same time that we push out the frontiers of knowledge.*” Schuh’s appeal for a return to the problem-solving mode of the original Land Grant concept will require a major change in the way we perceive our mission and responsibilities. He argues that “*It is unrealistic to expect that society will reward us to just do what we want to do. It is our responsibility to once again make ourselves relevant to the society we should be serving, or else see our salaries and support continue to decline and periodic retrenchmentsslash away at us.*”

Relevance to the problems of society and to the commodity groups we serve would seem to be the key to our future growth and survival. Funding support for our efforts undoubtedly will continue (and grow!) if society values our work. If, on the other hand, public universities continue to drift further from public perceptions and concerns, one can expect an eventual backlash. It is not essential that the public understand the fine details of science in order to levy a judgment on it. It is more than sufficient that problems appear to be growing faster than solutions, or that the supporting society is falling behind other countries in terms of economic health or other functional standards to encourage this backlash. We may be seeing the beginning of such a backlash today in such areas as the concern over the use of agricultural chemicals or actions in California to place limits on the ways in which tax money is spent for agricultural research. These issues may be interpreted as a statement from the consuming public for accountability from the scientific community. There is already in the political spectrum a vocal group critical of the large business corporation and its apparent insensitivity to the public good. Large public universities have not been the focus of similar criticism since the 1960s, but there appears to be a growing concern for the declining emphasis on our educational mission in our Land Grant Universities. Insofar as higher education

“...commitment to agriculture would appear to require a restoration of an appropriate balance between short-term, competitively funded basic research and longer-term, applied ‘regional’ research...”

“Our profession must have a voice in determining the future of agriculture in this country and beyond.”

adopts a corporate model of organization, it can expect to incur growing resistance, both from the students within its walls and from the public at large.

For all the bounteousness of recent gains in agriculture, there are reasons for caution and concern. Human population has grown in the past century at an unprecedented rate, and doubled during the period from 1950 to 1985. A doubling is expected again by the year 2010. Hunger, poverty, and homelessness has become a common sight in most American cities, not to mention the rampant poverty and destitution in many third-world countries. Worldwide reserves of foodstocks per capita are falling and have been doing so for several years. At the same time, the gains from some of our key agricultural innovations, such as fertilizer, pesticide, and herbicide use, are dropping off, and public concern is growing regarding the environmental impacts of modern corporate agriculture. Topsoil losses in parts of the United States, to say nothing of less-developed countries, continue at unacceptable and unsustainable rates despite conservation efforts. Many ecologists believe that the food supply may be the weakest link in the sustainability equation, as our present short-term consumptive view is projected into the not-too-distant future. The intensive nature of horticultural production practices can and must provide guidelines for more-efficient and sustainable use of these resources.

Failure of the Land Grant Universities to return to the public, in the form of services, a repayment for the financial support it receives is analogous to the failure of most modern cities to return to the soil in a usable form the nutrients that their inhabitants consume. Nature in an undisturbed form is quite good at conserving energy and materials; most of the flows occur in closed loops that lead, time and again, back to their place of origin. This pattern makes a worthwhile model for human society, including its institutions.

***HortTechnology* functions**

An important objective of *HortTechnology* will be to serve as the primary outreach publication of ASHS to strengthen communications and partnerships within our very diverse profession. We have seen that this diversity—this mix of modern and ancient crops, processes, and outlooks—is one of horticulture’s (and nature’s) most valued attributes. Hence, in an age of increasing agricultural specialization, horticulturists can help to act as an integrating force. *HortTechnology*’s intent will be to communicate relevant new developments and technologies to the scientific and user communities. We hope that

future issues will go beyond the technologies of our science to address also important policy issues and societal concerns that have an impact on horticulture. Our profession must have a voice in determining the future of agriculture in this country and beyond. *HortTechnology* can do this and be an advocate for our industry. It must build bridges of communication between the educational and scientific communities, our diverse horticultural industries, the consumer, and those who set policies affecting our profession. It must provide a science-based analysis of the complex events that shape our horticultural industries and our profession to ensure that the broad public good is served as this industry evolves toward the 21st century and beyond. It must provide sound and credible information to maintain consumer confidence in the products of our industry. And, finally, it must serve to ensure that public research remains relevant to the problems of the society that supports these efforts. We owe it to ourselves and to the society of which we are a part to make this effort.

References and Additional Readings

- Alpert, D.* 1984. Performance and paralysis: The organizational context of the American research university. The Center for Advanced Study, Univ. of Illinois, Urbana-Champaign.
- Bonnen J. T.* 1986. A century of science in agriculture. *Amer. J. Agr. Econ.* 68:1065-1080.
- Martin, G.C.* 1990. The corporate university: A place with few values and no soul. *HortScience* 25:1330-1340.
- Rosenburg, N.* 1972. Technology and American economic growth. Harper and Row, New York.
- Rick, C.M.* 1978. The tomato. *Scientific Amer.* 239(2):76-87.
- Schuh, G.E.* 1984. Revitalizing the Land Grant University. Colloq. of the Strategic Management Research Center, Univ. of Minnesota, Minneapolis-St. Paul.
- Tigheelaar, E.C.* 1986. Tomato breeding, p. 135-171. In: M.J. Bassett (ed.). Breeding vegetable crops. AVI, Westport, Conn.
- Weatherford, J.* 1988. Indian Givers. How the Indians of the Americas transformed the world. Fawcett Columbine, New York.

Acknowledgements

We express our appreciation to H.T. Erickson, D.M. Huber, R. J. Joly, and D.D. Knudsen for their critical and constructive reviews.