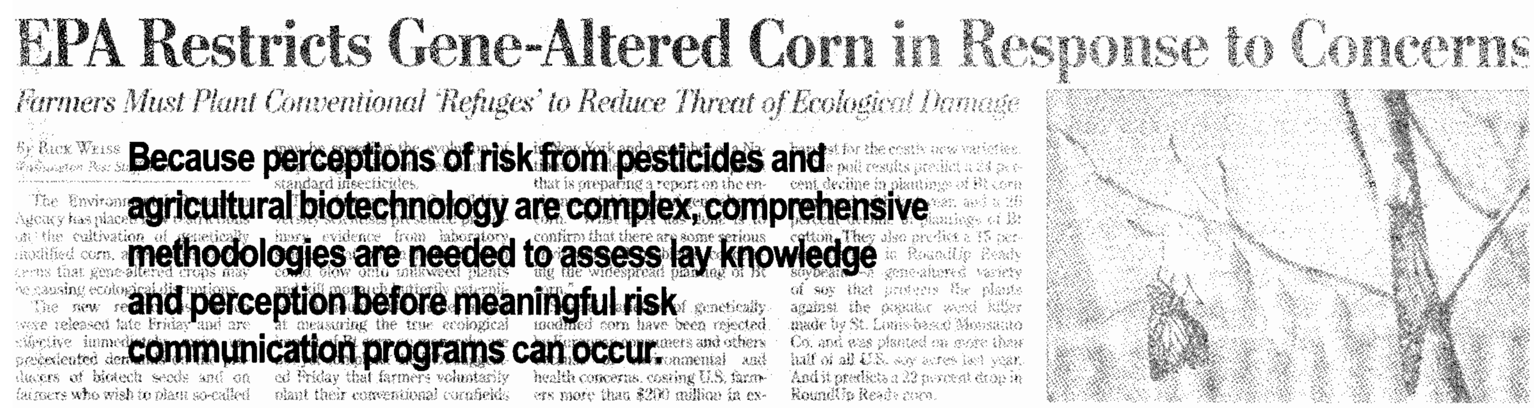
Made in United States of America
Reprinted from AMERICAN ENTOMOLOGIST
Vol. 46, No. 1, Spring 2000

Public Perceptions of Agricultural Biotechnology and Pesticides: Recent Understandings and Implications for Risk Communication

Robert K. D. Peterson



In the last few years, a substantial amount of research has been published on public perceptions of risk from pesticides and biotechnology. This information is particularly valuable given that before 1993, few studies specifically addressed perceptions of risk from these technologies (Peterson and Higley 1993). Most studies have assessed public perceptions of risk from a considerable range of technological activities (Fischhoff et al. 1978, Slovic 1987). Often, pesticides and biotechnology have been included in these assessments but have not been the focus of the studies.

Research on public perceptions of risk before 1993 tended to focus on human health concerns. Several recent research studies have focused specifically on perceptions of ecological risk, which can be especially valuable when considering communication strategies about pesticide use or agricultural biotechnology (McDaniels et al. 1995, 1997). Additionally, recent risk perception research studies are particularly informative because they have been conducted in many different countries, allowing comparisons among geographies and cultures (Lamb 1993, Raats and Shepherd 1996, Torgersen and Seifert 1997, Gaskell et al. 1999).

In this article, are discussed public perceptions of risk from pesticides and agricultural biotechnology. The scientific literature published since 1994 is reviewed. (The literature on public perceptions of pesticide risk published before 1994 is discussed by Peterson and Higley 1993.) Implications of the research are presented, especially with regard to future research directions and opportunities for improving risk communication for pesticides and agricultural biotechnology products.

Comparing and contrasting public perceptions of pesticides and agricultural biotechnology are important because, although both technologies impact public perceptions of food safety and ecological health, they differ in many respects. Pesticide technology has been an ongoing public concern for several decades. To lesser or greater degrees, the public has been exposed to issues surrounding pesticides such as benefits, human health effects, and ecological effects. In contrast, agricultural biotechnology is a recent development and the public is only beginning to be exposed to its myriad issues. Potential benefits and risks are not well understood, even by experts. In light of this, an understanding of perception similarities and differences between the two technologies will inform future research and communication efforts.

Perceptions of Risk—A Brief Overview

Research conducted during the past 20 years consistently has established that public assessments of risk from modern technologies and activities are different than expert assessments. Whereas experts primarily evaluate risk in terms of narrowly defined deleterious events, the public considers broader factors such as control, catastrophic potential, dread (possible delayed and/or disturbing effects), level of knowledge, equity, clarity of benefits, trust, effects on future generations, and effects on children (Covello et al. 1988, National Research Council 1989, Slovic 1987). In general, public perceptions of risk are the product of intuitive biases and economic interests that often reflect cultural values (Kasperson 1986).

Cognitive psychologists and decision researchers have determined many of the underlying patterns of how an individual perceives risk. The psychometric paradigm has been the predominant approach to assess the patterns risk perception. The psychometric framework attempts to identify the mul-

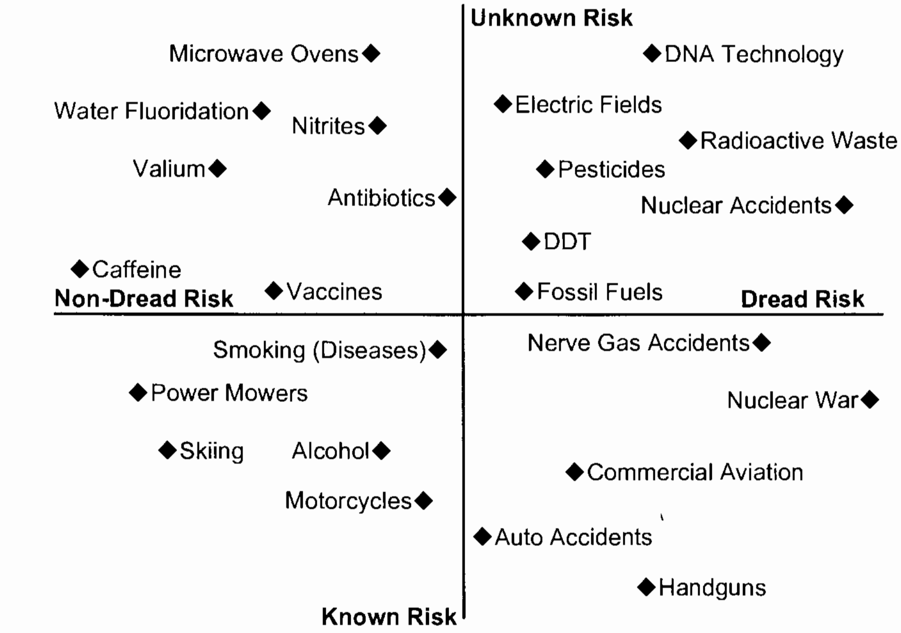


Fig. 1. Public perceptions of hazards within a two-component space, representing dread risk and unknown risk as the components. Based on data from Slovic (1987).

tidimensional characteristics influencing lay perceptions of risk through scaling and statistical methodologies (McDaniels et al. 1995, Slovic 1987). First, psychometric scales are developed to reflect characteristics of risk to different hazards. Second, people evaluate the list of hazards or activities in terms of each scale. Finally, multivariate statistical techniques are used to identify and interpret the underlying factors that explain the variation in the data (McDaniels et al. 1995). Although the psychometric paradigm has not been without criticism, it is a particularly robust technique to characterize public perceptions of risk.

Risk perception research has shown that the public views pesticide use as much riskier than many other activities. Further, there is a clear divergence between public and expert assessments of pesticide risk (Krauss et al. 1992, Slovic 1987). Public rankings of pesticide risk consistently are higher than expert rankings (Slovic 1987, 1990). Moreover, the public perceives pesticides as both a dread and unknown risk (Fig. 1). The differences between expert and lay assessments are problematic because the public needs to contribute to pesticide legislation and regulation (Fig. 2), but perceptions by the public and legislators, or public pressure on legislators, may cause policies and resources to be misdirected (Kramer 1990, Peterson and Higley 1993).

Advances in risk perception research have led to the recent emergence of risk communication as a discipline. Recent risk communication strategies have incorporated lay-perception factors and have focused on interactive exchanges of information among parties (National Research Council 1989). Additionally, strategies have been promulgated to improve pesticide risk communication (Peterson and Higley 1993).

Perceptions of Pesticides in Food

Although several studies have characterized public perceptions of risk from technological activities (e.g., Slovic 1987), few have specifically characterized perceptions of food safety. Fortunately, the perception of risk from pesticide residues in food has been evaluated in the food safety studies conducted to date.

Sparks and Shepherd (1994) first used the psychometric paradigm approach to assess public perceptions of risks associated with food production and food consumption. They surveyed 216 people in the United Kingdom about 25 potential hazards and 23 risk characteristics. As with many other psychometric approaches, the data were subjected to principal-components analysis to determine principal factors. Three major groupings of risk characteristics accounted for 87% of the variance. They included: severity, unknown, and number of people exposed. The "severity" category (45.3% of the variance) included factors such as "concern," "seriousness for future generations," "threatening widespread disastrous consequences," "dread," and "becoming more serious." The "unknown" category (32.5% of the variance) included factors such as "known by the people exposed," "known to science," and "accuracy of assessments." The "number of people exposed" category (9% of the variance) included only one factor, the same factor name as the category name. When displayed in a risk perception factor map, pesticide residues were perceived as the second most severe risk after environmental contamination and a moderately unknown risk to food safety (Fig. 3). In contrast, genetic manipulation of plants was perceived as a moderate risk, but the most unknown risk.

Fife-Shaw and Rowe (1996) also evaluated public perceptions of food hazards using the psychometric approach. Their study characterized perceptions from a nationally representative population in the United Kingdom. Respondents rated 22 potential food hazards on 19 risk characteristics. Experimental results indicated that the factor struc-

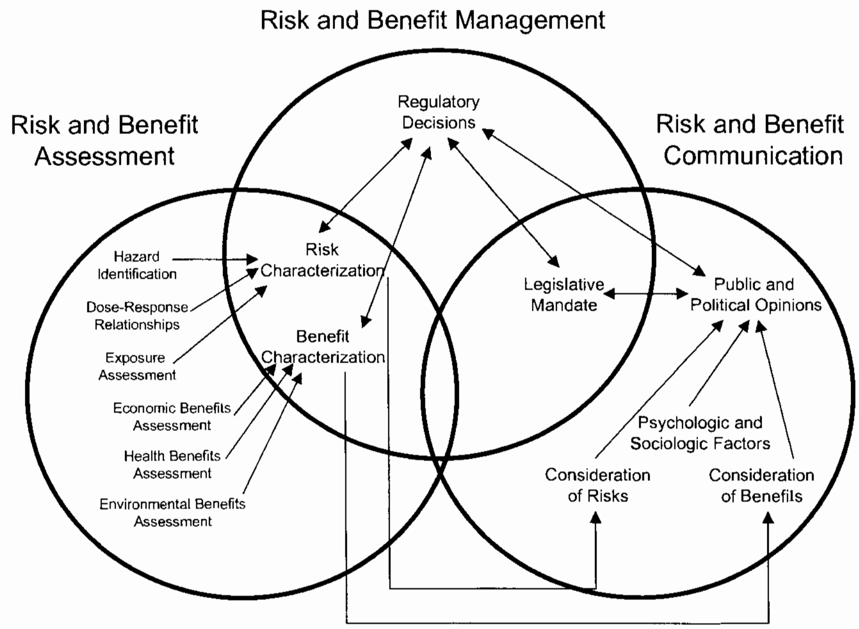


Fig. 2. Framework for societal decision processes regarding risk and benefit management of technology.

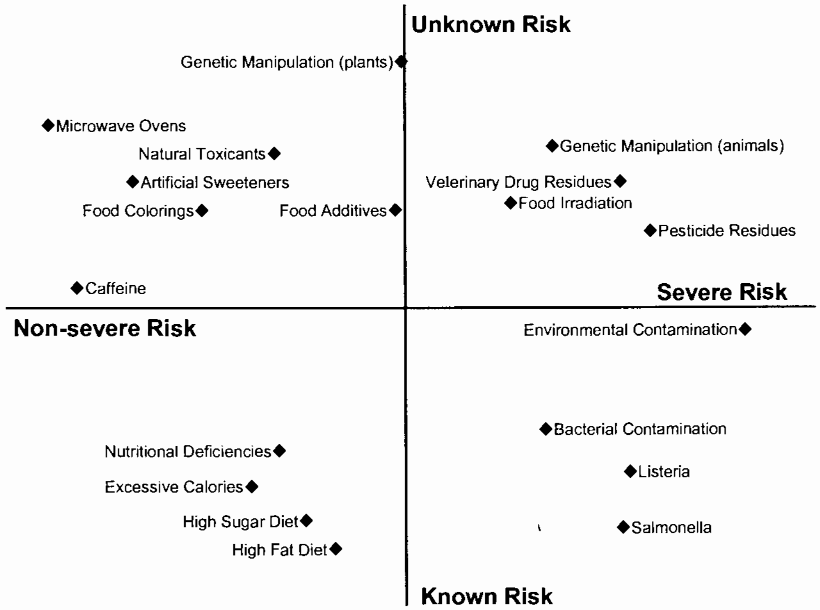


Fig. 3. Public perceptions of food-safety hazards within a two-component space, representing severe risk and unknown risk as the components. Based on data from Sparks and Shepherd (1994).

ture used by the public to assess food hazards was broadly similar to those used by Sparks and Shepherd (1994) even though many of the hazards were different. Principal perception factors were "severity" (62% of the variation) and "awareness" (20.1% of the variation). The "severity" component was similar to the component of the same name from the results of Sparks and Shepherd (1994). The "awareness" component was similar to the "unknown" component from the results of Sparks and Shepherd (1994). Pesticide residues on food were perceived as a severe and moderately unknown risk. Genetic engineering of foods was perceived as a relatively moderate but highly unknown risk.

A key concern of the psychometric approach is that the characteristics of risk perception are investigator-selected instead of being provided by the surveyed subjects. In other words, the respondents are asked to evaluate risks based on characteristics that were provided for them. In response to that concern, Raats and Shepherd (1996) characterized lay perceptions of chemicals in foods in a two-part study conducted in the United Kingdom. They first interviewed subjects about their knowledge of different chemicals that may occur in food. The conclusions drawn by the subjects then were validated using a survey instrument and a large group. The data from the survey were subjected to principal components analysis so that key factors could be elucidated. They determined that both study groups perceived the chemicals similarly. Moreover, risk perceptions were similar to other studies (Fife-Shaw and Rowe 1996, Sparks and Shepherd 1994). Respondents had the most negative attitudes about pesticides when they evaluated the terms "weedkillers," "insecticides," "pest control products," and "pesticides used during food storage." Pesticides were perceived as among the most poisonous and harmful chemicals in food. Pesticides also were perceived as the fourth group of chemicals most likely to build up in the human body, ranked behind lead, aluminum, and nitrates. Additionally, pesticides were considered the least natural chemicals in foods.

Other studies that did not focus on characterizing perceptions of food risks also support recent findings. Several surveys conducted in New Zealand indicated that a significant proportion of the public is concerned about pesticide residues in food (Maskill and Harre 1994, New Zealand National Research Bureau 1990). According to a 1990 telephone survey of 800 people, 80% of those sampled were "somewhat" to "very" concerned about chemicals added to food and contact with pesticide sprays. Specific categories of concern were that pesticides represented health risks, were dangerous, and had effects on the body. Lamb (1993) observed that 20% of 1,000 respondents in a 1991 survey of New Zealanders believed that pesticides were the most serious food problem.

The survey and study results discussed above must be evaluated cautiously because not enough studies have been conducted to assess perceptions objectively. Consequently, discrepancies in results are numerous. For example, in a U.S. national survey of approximately 1,000 adults, 72 to 82% of respondents indicated that pesticides represent a serious hazard when asked directly about their perceptions of pesticides in food (Van Ravenswaay 1995). However, a much smaller number (14–19%) identified pesticides when asked what they believed were the major threats to food safety.

Perceptions of deleterious health effects from exposure to pesticide residues in food are variable. Indeed, recent studies suggest that there is substantial variation in perceived health effects. Although cancer is cited most frequently by the public, other health effects such as allergies, heart disease, nervous system disorder, and impaired immune function also were mentioned by respondents (Van Revenswaay et al. 1992).

Understanding how perceptions of risk from pesticide residues in food translate into changes in consumer food-purchasing behavior has been difficult. Several researchers have examined the link between perceptions and purchasing behavior, but, to date, studies have not focused on characterizing the integration of perceptions, behavior, and valuation (Eom 1994). Although some studies have shown an association between risk perceptions and food purchases in real market situations (e.g., Brown and Schrader 1990, Smith et al. 1988, Van Ravenswaay and Hoehn 1991), others have demonstrated that food consumption patterns do not seem to be related to risk perceptions and health concerns (Chalfant and Alston 1988, Ott et al. 1991). In a self-completed questionnaire of 511 people in New Zealand, only 33% of the respondents indicated they would eat an apple knowing it had been sprayed with pesticides to reduce pest damage (Richardson-Harman et al. 1998). However, nearly 100% of apples in New Zealand are sprayed with pesticides, and over 95% of consumers in the study were regular consumers of apples.

In an economic valuation study attempting to integrate public perceptions, behavior, and valuation, 65% of 567 citizens surveyed in North Carolina indicated they would avoid produce containing pesticide residues to reduce health risks (Eom 1994). Their perceptions resulted in behavioral changes. Respondent preferences for safer produce were explained "primarily by price differences and the risks they believed were associated with pesticide exposure, not simply by the technical risk information provided" (Eom 1994). The association between perceptions and valuation was weak. Consumers expressed willingness to pay a substantial premium for safer produce in return for only small reductions in risk. Additionally, the price premium was insensitive to the amount of risk reduction.

Huang (1993) found that the linkage between risk perceptions from residues in foods and willingness-to-pay for residue-free produce was not significant in a study involving 389 citizens from Georgia. Respondents who preferred more restrictive regulations were more likely to perceive a greater risk from pesticide use. African-Americans and people between the ages of 35 and 50 were more likely than their cohort groups to have a positive attitude toward banning of pesticides in fresh produce production. Additionally, females who were married with children were more concerned about pesticide residues than their counterparts. This trend was also observed by Penner et al. (1985) Interestingly, previous personal experiences influenced respondent risk perceptions. People who previously used pesticides were less likely to perceive risk from pesticide residues in produce (Huang 1993).

Perceptions of Agricultural Biotechnology

Although biotechnology issues have been covered by the media for many years, the general public is still in the early stages of forming opinions about this relatively new technology. This is because the medical and agricultural products produced from biotechnology are just beginning to reach the market (Hallman 1996). Public perceptions are likely to change as more products are available, but recent perception studies and polls, primarily from Europe and the United States, provide valuable and often detailed information that can be used to develop more effective risk communications.

Public perceptions of biotechnology are extremely complex and cannot be generalized easily. There are differences in perception by age, gender, income, education, cultures, and among types of biotechnology products. Additionally, separate studies and surveys cannot be compared empirically because different questions were asked. As a broad generalization, lay knowledge of biotechnology continues to be poor throughout Europe, the United States, New Zealand, and Latin America (Hagedorn and Allender-Hagedorn 1997, Hallman 1996, Lujan and Moreno 1994, Richardson-Harman et al. 1998, Sant'Ana and Valle 1995, Torgersen and Seifert 1997, Zechendorf 1994). Although the public in most countries perceives substantial potential risk from biotechnology products, most people have a relatively high acceptance of biotechnology, including Europeans (Hallman 1996, Zechendorf 1994). Indeed, the public seems more concerned with the risks associated with specific products produced from biotechnology than with the process of genetic engineering itself (Hallman 1996). This lay position seems to diverge from the current position of several environmental groups (Tal 1997).

Public concerns about biotechnology products typically are not centered around technical issues, but rather focus on issues of ethics, morality, safety, and value (Hagedorn and Allender-Hagedorn 1997, Hoban et al. 1992). Scientific and regulatory communities tend to focus on research and technical issues such as the escape of transgenes by cross-pollination with wild species, escaped and mutated viruses and bacteria, inadvertent production of toxins, and selection for resistance (Boulter 1997).

In most countries where studies have been conducted, sociological and economic variables generally explain attitudes about biotechnology. Support for biotechnology generally is lower for women and less educated and older age groups, whereas support is higher among males, higher income, and well educated, urban, and younger-age groups (Torgersen and Seifert 1997). The use of biotechnology for new drugs typically receives more support than agricultural biotechnology. The benefits associated with medical biotechnology products are most likely more apparent and immediate than other uses, and therefore, acceptance is greater.

The United States

In general, acceptance of biotechnology is relatively high, but the majority of survey respondents in several polls fear potential health hazards (Zechendorf 1994). Although there were differences in questions and measurement among surveys, "acceptance" generally means that those surveyed support or tolerate risk from biotechnology (Gaskell et al. 1999, Zechendorf 1994). In other words, they do not oppose biotechnology. Acceptance of genetically-modified organisms varies between transgenic plants and animals. In a 1992 survey of 552 North Carolina residents, 70% accepted plant biotechnology whereas only 42% accepted animal biotechnology (Hoban et al. 1992).

A relatively thorough survey of 604 New Jersey residents in 1993 revealed several aspects of risk perception from biotechnology products. Nearly 20% of respondents had negative initial thoughts about genetic engineering (Hallman 1996). Most residents (61%) approved of using genetic engineering techniques to produce hybrid plants, but only 28% approved of genetic engineering to produce hybrid animals. Interestingly, approximately 50% of the residents who believed genetic engineering is morally wrong also indicated they approved of its use to create new drugs and more nutritious grain to feed people in poor countries (Hallman 1996).

The New Jersey survey also provided a glimpse into perceptions of agricultural biotechnology. Approximately 55% of those surveyed indicated they would buy genetically-engineered apples, and 60% would buy fresh vegetables as long as they were labeled as being produced by genetic engineering. Approximately 85% believed that "growing genetically engineered plants that contain higher levels of naturally occurring chemicals that protect against pests and disease is better than using pesticides" (Hallman 1996). However, 40% were concerned that genetically engineered organisms could pose a "likely threat" to the environment if they could reproduce.

Despite the complex nature of public perceptions in the New Jersey study, more than 66% indicated that "the potential danger from genetic engineering is so great that strict regulations are necessary." Additionally, 60% favored the labeling of agricultural biotechnology products for reasons of choice and consumer empowerment (Hallman 1996).

Europe

A substantial amount of information has already been collected about European perceptions of biotechnology. Unfortunately, the information is often contradictory, making generalizations difficult. For example, in one survey the public viewed pharmaceutical production in animals as acceptable, but viewed genetic engineering of animals as unacceptable (Boulter 1997).

Northern Europe (England, Germany, Belgium, The Netherlands, Luxembourg, Denmark, Austria). In general, northwestern European countries have a relatively well-educated public who perceive high risks from biotechnology and raise ethical objections to its use. However, most citizens in these countries accept biotechnology (Zechendorf 1994). The British had an average acceptance and risk perception rate, but the acceptance rate for food applications of genetic engineering was lower. Denmark had the highest perceptions of risk but also had above average acceptance of biotechnology when compared to other European countries.

The German public was strikingly different from most of the other countries. Although the citizens are the most knowledgeable about biotechnology in Europe, they had the second highest perception of risk and lowest support. Generally, the greater the level of knowledge and education, the greater the support for biotechnology (Torgersen and Seifert 1997, Zechendorf 1994). Germany, Denmark, and Austria are exceptions to this pattern. Torgersen and Seifert (1997) suggested that past experiences with Nazi totalitarianism and eugenics may contribute to the low support for biotechnology in Germany and Austria because of the public association of biotechnology with eugenics.

Southern Europe (France, Spain, Portugal, Greece, Italy, Switzerland). Countries in southern Europe differ from northern Europe with respect to perceptions of risk from biotechnology. The public typically has poorer knowledge of biotechnology, but a lower perception of risk from and a higher acceptance of biotechnology (Zechendorf 1994). The French had high perceptions of risk and about average acceptance when compared to other European countries.

In a 1990 and 1991 survey of 1,127 Spanish adults, most questioned the ethics of biotechnology and believed it could be useful for humanity, but 72% were not supportive of its use for food production (Lujan and Moreno 1994). Italians surveyed were not supportive of plant and human manipulations (Zechendorf 1994). Interestingly, the differences in European opinions between northern and southern countries were observed in Switzerland, which straddles the cultural borderlines. The northern Alemanic population's acceptance of biotechnology was 49% while the southern Romanic population's acceptance was 69% (Zechendorf 1994).

Perceptions of Ecological Risks from Pesticides and Agricultural Biotechnology

To date, few studies have characterized public perceptions of ecological risk to any appreciable degree. Those that have show that the public is greatly concerned about the effects of pesticides (Van Ravenswaay 1995) and agricultural biotechnology (Shutz and Wiedemann 1998) on the environment. This concern may even exceed concerns about food safety. McDaniels et al. (1995) characterized perceived ecological risk using the psychometric paradigm. They first elicited a set of scale characteristics and risk categories from focus-group participants. Then, 68 university students completed a survey instrument in which they rated 65 items on 30 characteristics scales. Statistical analysis of the completed surveys indicated that five factors primarily were responsible for perceptions of ecological risk: impact on wildlife species, human benefits, impact on humans, avoidability, and knowledge of impacts. Pesticides and biotechnology (genetically altering plants and animals) ranked 44th and 42nd, respectively, out of the 65 items in terms of overall risk to natural environments. Biotechnology was rated among the highest risks in terms of unknown impact to ecosystems.

The public view of ecological risks posed by each potential risk item is more informative than the overall rank of risks. When considering impact on wildlife species and human benefits, pesticides were viewed as offering neutral to slightly positive human benefits and less negative impact on species than energy production, clearcutting, soil erosion, and several other categories of risk. Biotechnology was rated as offering slightly positive human benefits and moderately negative impacts on nonhuman species. Both pesticides and biotechnology were rated as having less negative impacts on humans than many other environmental threats including acid rain, clearcutting, landfills, air conditioning, nuclear power, and air pollution.

Results from McDaniels et al. (1995) are interesting but potentially limited because the sampled population was not representative of the general public. Participants in the study consisted of 40 female and 28 male students, 18 to 39 years of age, from the University of British Columbia. Consequently, the sampled population was younger and better educated than the general public.

Results from McDaniels et al. (1995) are intriguing because there were similarities between factors the public uses to assess human health risks and ecological risk. In particular, factors such as "impact on humans," "avoidability," and "knowledge of impacts" often are important in evaluations of both types of risk (National Research Council 1989, Slovic 1987). Additionally, respondents in the McDaniels et al. (1995) study rated natural risks relatively lower than human-produced risks even though natural risks such as droughts, floods, and earthquakes can result in catastrophic damage to ecosystems. This response also has been seen in other studies on human health risks (National Research Council 1989, Slovic 1987).

McDaniels et al. (1997) continued previous research on public perceptions of ecological risk by examining perceptions of risk to water environments. In this study, participants included 183 citizens from three residential communities in the Fraser River Basin of British Columbia, Canada, and 47 students of the University of British Columbia, Canada. As with the McDaniels et al. (1995) study, the researchers first elicited a set of scale characteristics and risk categories from a focus group consisting of experts who were individuals working in the aquatic sciences at the University of British Columbia. Participants then were surveyed about various risk items by being asked how they thought about and judged "various kinds of hazard (items), in terms of the risk that each may pose to the health and productivity of water environments within the Lower Fraser Basin of British Columbia." Respondents evaluated 33 risk items in terms of characteristics such as knowledge, controllability, scope, benefit, people affected, species loss, equity, immediacy, reversibility, alternatives, predictability, and need to regulate. In contrast to results from McDaniels et al. (1995), pesticides ranked 6th out of 33 risks in terms of general risk to water environments. Experts ranked pesticide use 13th. (Biotechnology was not included as a risk category in this study.)

Perhaps more importantly, the principal factor structure observed in McDaniels et al. (1995) also was observed in McDaniels et al. (1997). The principal perception factors in the 1995 article were impact on species, impact on humans, human benefits, avoidability, and knowledge. The principal perception factors in the 1997 paper were human benefits, knowledge, controllability, and ecological impact (including impacts to nonhuman species and humans). Ecological impact was most significant. A risk- perception map was constructed by examining the factors "ecological impact" and "human benefits." This map reveals that pesticide use was perceived to have moderate ecological impact and neutral to slightly negative human benefits, somewhat similar to results from McDaniels et al. (1995).

McDaniels et al. (1995, 1997) observed that the public seemed to use a common set of criteria for perceiving ecological risks. These criteria also are commonly used by the public to assess human-health risks from technological activities (Slovic 1987). As with McDaniels et al. (1995), the 1997 study cannot be extrapolated to a large population because the authors assessed risk perceptions from a small population only in British Columbia. However, the results from both studies were similar to each other and support opinions about public risk perception in general. Consequently, the results most likely are valuable when considering ecological risk perception in a broader context.

Perceptions of Pesticides and Agricultural Biotechnology: Similarities and Differences

Results from recent risk perception studies of pesticides and biotechnology support current understandings about risk perception of technological activities, namely that the factors the public uses to assess risk from all technological activities are different from expert assessment of risk, and that these differences have been established empirically (Slovic 1987). Although the public assesses risks from pesticides and agricultural biotechnology using many similar factors to describe the risks, there are some key differences.

Pesticides

The public consistently has viewed pesticide use as both a dread and unknown risk. The studies on food safety and ecological risk reviewed here support the idea that similar factors are used to assess risk from pesticides. Specific risk characteristics that are continually associated with pesticides include dread, uncontrollable, catastrophic, not equitable, serious for future generations, involuntary, increasing risk, not observable, unknown to those exposed, effects delayed, and unknown to science (see Peterson and Higley [1993] for a thorough discussion).

The public clearly does not perceive as much benefit from pesticide use as experts (Slovic 1987, Van Ravenswaay 1995, Van Ravenswaay et al. 1992). This is understandable given that the benefits of pesticide use are indirect and not apparent immediately to the average consumer, as are, for example, the benefits from driving an automobile or taking medicine. Moreover, the benefits are not equitable across all of society. However, perceiving benefit is an important determinant to perceiving risk (Alhakami and Slovic 1994). Therefore, discussions of benefits likely will be important in risk communication programs.

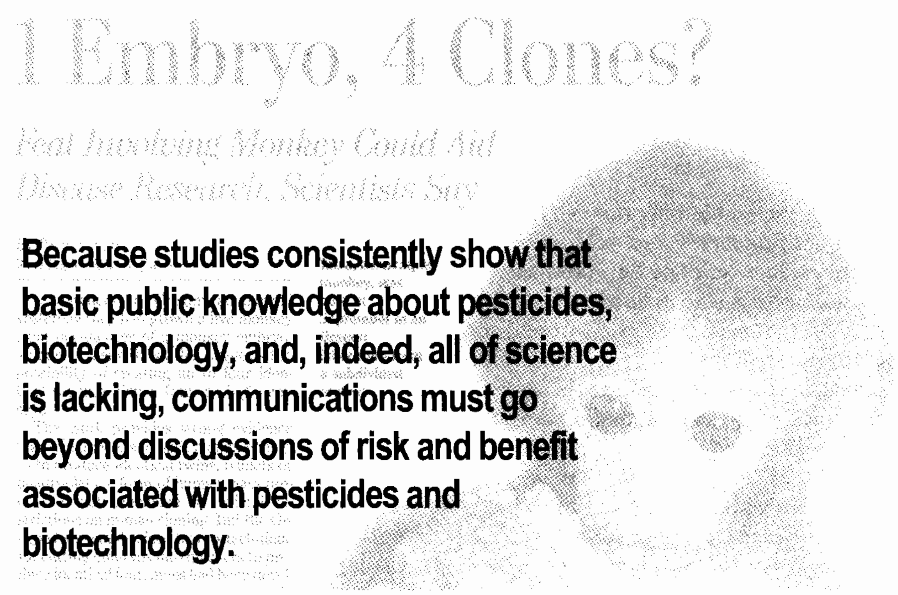
The public continues to view pesticides as chemicals that biomagnify both in ecosystems and in humans. This is evident by the "effects delayed," "increasing risk," "serious for future generations," and "impact on species" perception factors (Fife-Shaw and Rowe 1996, McDaniels et al. 1995, Slovic 1987, Sparks and Shepherd 1994). Moreover, survey respondents specifically mentioned that pesticides build up in the human body as a result of consuming residues in food (Raats and Shepherd 1996) and that all pesticides cause cancer (Potter and Bessin 1998). These views are not supported by empirical evidence.

Agricultural Biotechnology

More empirical research on public perceptions of agricultural biotechnology is needed before substantive generalizations can be made. To date, studies seem to indicate that although acceptance of biotechnology is moderate to high, there is less support for agricultural biotechnology than for medical biotechnology. Knowledge of biotechnology is limited, especially with regard to potential benefits. Consequently, this poor understanding is likely to affect initial acceptance of the technology.

Perhaps most important is the perception that agricultural biotechnology, indeed biotechnology in general, represents a large unknown risk. This is reflected in both perceptions of human health and ecological risk and seems to be the dominant perception factor (Hallman 1996, McDaniels et al. 1995, Slovic 1987, Zechendorf 1994). As an unknown risk, biotechnology most likely is seen as a risk that is unknown to science, unknown to those exposed, delayed, and not observable easily. Additionally, biotechnology is perceived as a dread risk. As a dread risk, biotechnology most likely is viewed as a risk that is uncontrollable, globally catastrophic, not equitable, not easily reduced, and increasing.

Agricultural biotechnology and pesticides are perceived as unknown and dread risks. However, perceptions of biotechnology seem to differ greatly from pesticides with regard to ethics, morals, and values. The ethics and morality of the use of pesticides are not nearly as disconcerting among the public as they are with the use of biotechnology. Public concerns about the ethics and morality of biotechnology most likely reflect factors such as recent introduction of the technology, ability of the technology to dramatically change the genetics of an organism, lack of societal and scientific knowledge about the consequences of deploying the technology, seemingly unnatural methods used, and fear of humans "playing God" (Boulter 1997).



Because studies consistently show that basic public knowledge about pesticides, biotechnology, and, indeed, all of science is lacking, communications must go beyond discussions of risk and benefit associated with pesticides and biotechnology.

Risk Communication

Attempts to improve risk communication for pesticides and agricultural biotechnology must acknowledge public perceptions. Moreover, experts must focus on modern risk communication as an interactive process of risk information and opinion among individuals, groups, and institutions (National Research Council 1989). The interactive exchange of information undoubtedly is a key component for improving pesticide and agricultural biotechnology risk communication given the complexities of the technologies, potential risks, and benefits (Peterson and Higley 1993).

Peterson and Higley (1993) presented a general framework for the communication of pesticide risks and suggested specific proactive approaches to improve risk communication. The recent risk perception research findings discussed here suggest that the risk communication approaches discussed by Peterson and Higley (1993) will continue to provide a relevant paradigm. Briefly, five general recommendations have been proposed: (1) empathize with and genuinely consider public concerns, (2) interact with and inform the public, (3) respond promptly and with complete openness, (4) respond with simplicity and clarity, and (5) relate to the public that experts are determined to control, limit, and understand medical and environmental risks associated with pesticide use. Of course, these recommendations also would apply to agricultural biotechnology.

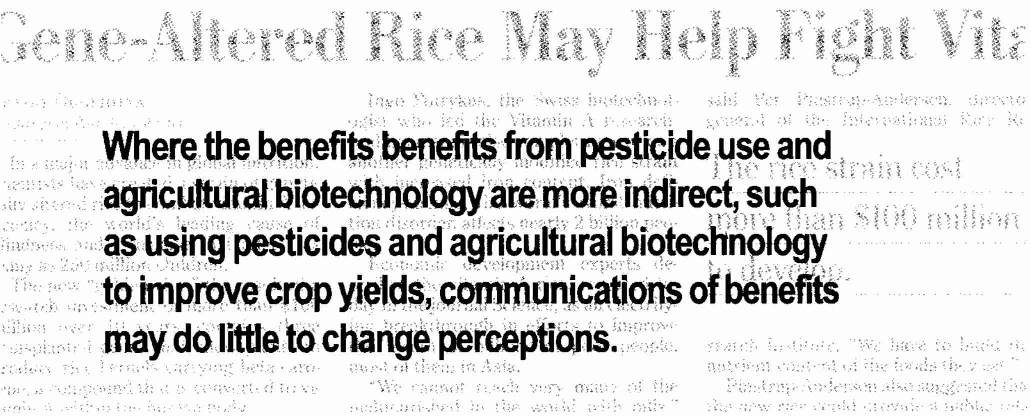
The importance of the media's role in risk and benefit communication cannot be overstated. Several articles have suggested improvements in media coverage of risk, especially with regard to enhancing interactions between scientists and journalists. Examples include clearly defining technical terms, providing complete information, accommodating the deadlines of reporters, and organizing forums that bring scientists and reporters together (Curtis 1995, National Research Council 1989, Peterson and Higley 1993).

In addition to the general recommendations of Peterson and Higley (1993), recent empirical findings suggest that risk communications and risk perceptions for pesticides and agricultural biotechnology may benefit from cultivating the public trust and perceptions of credibility, discussing basic educational information whenever possible, targeting specific educational programs to demographic groups that perceive the most risk, and discussing benefits within risk communication efforts.

Cultivating Trust and Credibility

Recent studies about biotechnology in the United States and Europe indicate that the public has lower trust and faith in industry and government organizations than grower groups, consumer protection groups, and environmental groups (Gaskell et al. 1999, Zechendorf 1994). In a New Jersey survey, 604 respondents indicated that the most credible sources for information on biotechnology were university scientists, local farmers, and environmental groups (Hallman 1996). Least credible were state and federal government agencies and biotechnology companies. In a series of European surveys conducted across several countries, respondents had the most trust in environmental groups, consumer organizations, and universities; and the least trust in public authorities, political organizations, trade unions, and industry (Torgersen and Seifert 1997). Frewer et al.(1997) found that medical sources were viewed by the public as being most knowledgeable about food risks.

Public trust in institutions will impact the perception of risk and the effectiveness of risk communications (Frewer et al. 1997, Kasperson 1986, Laird 1989, Slovic 1997). Indeed, risk assessment, management, and communication only can succeed in a climate of public trust. The public increasingly is unwilling to defer many important decisions to institutions, officials, or experts (Laird 1989). Consequently, with the decline of deference, we have seen the rise of citizen groups that challenge institutionalized decision making. Peters et al. (1997) showed that trust and credibility in risk communications are determined by knowledge and expertise, openness and honesty, and concern and care. However, the factors that determine trust are not invariant across organizations. For industry, increases in lay perceptions of concern and care most strongly influence public trust. For government, increases in perceptions of commitment most influence public trust. For citizen groups, increases in perceptions of knowledge and expertise most influence public trust (Peters et al. 1997).



Where the benefits benefits from pesticide use and agricultural biotechnology are more indirect, such as using pesticides and agricultural biotechnology to improve crop yields, communications of benefits may do little to change perceptions.

Clearly, perceptions of risk will change appreciably only with a concomitant increase in public trust of information sources. An example of demonstrating concern and care to the public has been the promulgation of the Chemical Manufacturers Association's Responsible Care® initiative. The initiative requires member companies to continuously improve their performance in health, safety, and environmental quality, and to speak openly with the public about any concerns (Hakkinen and Jeep 1996). Regardless of their affiliation, experts must recognize and exercise the factors that govern public trust. Additionally, experts must realize that trust is cultivated slowly but can be eliminated instantly. Once lost, the public trust may never be regained (Slovic 1997).

Communicating Basic Knowledge

Because studies consistently show that basic public knowledge about pesticides, biotechnology, and, indeed, all of science is lacking, communications must go beyond discussions of risk and benefit associated with pesticides and biotechnology. Misunderstandings in basic concepts can contribute to differences between lay and scientific views (Fisher 1991, Krauss et al. 1992). To participate meaningfully in any interactive communication process, the public and legislators need to become more scientifically literate. This issue of scientific literacy impacts all of society and extends well beyond risk and benefit communication.

Where pesticides and agricultural biotechnology are concerned, basic educational programs must focus on fundamental concepts of chemistry, biology, genetics, ecology, critical thinking, and the scientific method. Relevant topics associated with pesticides and agricultural biotechnology should include the concepts that toxicity is a function of dose, risk is a function of toxicity and exposure, the source of the chemical product (natural or synthetic) has no bearing on its toxicity, and pesticides and/or products of biotechnology do not necessarily persist in the environment.

Targeting Specific Demographic Groups

Perceptions of risk from pesticides and agricultural biotechnology are somewhat similar among demographic groups. Perceptions of risk for pesticides are greater for middle- to older-age groups (ages 35 and over), African-Americans, and women (especially females with children). Indeed, a woman's perception of risk increased by about 20 percentage points if she had children in the household (Penner et al. 1985). Additionally, there is some research evidence that perception of pesticide risk is inversely proportional to education and income level (Van Ravenswaay 1995). For biotechnology, perceptions of risk are greater for middle- to older-age groups, less educated groups, and women. Clearly, risk communication and education efforts need to be directed at appropriate demographic groups to be most effective.

Discussing Benefits

Because lay views of risk and benefit determine overall risk perception, discussions of benefits are critical to risk communications. This especially is salient for pesticides and agricultural biotechnology products because the benefits may not be readily apparent to the general public. Moreover, the average citizen does not perceive a direct benefit from the technologies of pesticide use and agricultural biotechnology. The importance of communicating benefits cannot be overstated, but the communications must be appropriate. Presentations of benefits must be refined and as neutral as possible. (The scientific literature includes such presentations, but this type of communication is not appropriate for the general public.) In my opinion, many presentations of benefits from pesticide use are coarse, biased, and overly simple (but see Pike et al. 1997). Many statements about benefits from pesticide-use simply state that pesticides are needed to feed a growing world population and without pesticides, more land would have to be brought under tbe plow. Although these statements are accurate, they oversimplify the benefits from pesticide-use and have not proven to be successful communications. The public is confronted with conflicting messages regarding the need for pesticides. Therefore, discussions of the benefits of pesticides should focus on their role within integrated pest management programs. More specifically, discussions should emphasize the inherently destabilizing nature of pests in systems that humans have manipulated for their benefit and the role of pesticides in stabilizing those systems.

Successful communication about benefits from pesticide use and agricultural biotechnology may continue to prove difficult. Where the benefits are more direct, such as using pesticides to manage insects that vector human diseases, communication about benefits may impact risk perception. However, where the benefits are more indirect, such as using pesticides and agricultural biotechnology to improve crop yields, communications of benefits may do little to change perceptions. Because perceptions of risk are confounded by perceptions of benefit, it may be possible to reduce risk perceptions by increasing benefit perceptions (Alhakami and Slovic 1994). However, benefit-induced changes in risk perception may be small. Consequently, despite the importance of benefit information, it should not be used as the sole method to attempt to allay public concerns.

Additional Communication Approaches

Communication efforts about risks associated with agricultural biotechnology must consistently address the key public perception factor: unknown risk. Because most scientific information contains uncertainty, it readily can be impaired by perceptions and value judgments (Cothern 1996). Experts must address fully the uncertainty associated with the new technology in nontechnical statements and discuss limitations in both theory and experimental data and disagreements among professionals when they occur.

On the surface, it may seem that aspects of morals and ethics are not readily amenable to risk communication approaches because they are highly variable, defying generalizations. However, concerns about values, ethics, and morals associated with biotechnology are related closely to the perception characteristics determined from the studies discussed above. Therefore, discussions of biotechnology as it relates to perceptions of uncertainty and dread may allay public concerns about the morality and ethical nature of the new technology.

Although the toxicological and environmental properties of most current pesticides are dramatically different than older pesticides, the public still considers these compounds as likely to persist in the environment, biomagnify, and cause cancer. Misunderstandings about persistence relate directly to perceptions of dread, effects on children, damage to ecosystems, and effects on future generations, which are key perception characteristics associated with pesticide use. Contemporary education about the well-known environmental effects of DDT has failed to convey that the environmental and toxicological effects of current pesticides are different (Peterson and Higley 1993) than older chemistries. Clearly, any substantive attempt at risk communication must address the issue of persistence. Further, improvements in public perceptions of pesticides will not occur without a better understanding of persistence.

Future Research and Conclusions

Much remains to be learned about public perceptions, values, and ethics surrounding technological activities. Research conducted to date clearly shows that public perceptions and definitions of risk are more multifaceted than expert assessments. Freundenburg (1996) stated, "while the public reactions are not exactly new, what *is* new—and what I take to be hopeful—is the growing recognition that the problem needs to be addressed with the same kinds of systematic, scientific approaches that have long been sought for the underlying technical questions [of risk assessment]." Continued emphasis on using empirical methods to elucidate public perceptions will provide a solid foundation to test hypotheses concerning risk perception and communication.

Currently, only broad generalizations can be made concerning the extremely complex, interacting components that determine lay perceptions of risk. Results of studies based on investigator-supplied questions will continue to elicit concerns about bias and accuracy. Because perceptions of risk from pesticides and agricultural biotechnology are complex, comprehensive methodologies are needed to assess lay knowledge and perception before meaningful risk communication programs can occur. One promising method is the mental-models approach (Bostrom et al. 1992, Morgan et al. 1992). The mental-models paradigm is an open-ended technique that characterizes people's understanding of hazards and risks through an organizing device, such as a representation of expert knowledge in a diagram (Bostrom et al. 1992). The data then are used to measure, predict, and aid public understandings of risks.

This article has revealed that there are qualitative and quantitative differences in public perceptions between pesticide technology and agricultural biotechnology, but the reasons underlying those differences have not been elucidated empirically. Future research needs to determine whether there are fundamental differences in perceptions between the two types of technologies or whether the differences are strictly due to the novelty of biotechnology. More specifically, perceptions of individual agricultural biotechnology products need to be assessed and compared with each other and conventional pesticide use. For example, are perceptions different between crops that have been genetically engineered to resist pests and crops that have been engineered to produce more nutritious foods? Additionally, are perceptions different between crops engineered to resist pests and pesticides used to manage the same pests? Or, are perceptions different between crops genetically engineered to resist pests and crops that resist pests through conventional breeding?

Because the concept of risk is extremely rich and subject to citizen values and perceptions, no single model is likely to define risk fully (Norton 1996). Therefore, several risk-models with varying considerations of values are needed to improve risk assessment, decision making, and management (Norton 1996). Indeed, to be successful, risk assessment may need to incorporate fully social science, ethics, morals, and values, while at the same time ensure that it is rooted firmly in science and the methods of scientific inquiry.

Attention to public perceptions, values, and ethics of risk associated with agricultural biotechnology and pesticides will improve communication efforts. However, to date, there is little evidence that risk communication has yet made any significant contribution to reducing the gap between technical risk assessments and public perceptions of risk (Slovic 1997). The ineffectiveness of risk communication efforts in the past can be attributed to lack of trust (Slovic 1997). Therefore, emphasis should not be placed on immediate results beneficial to one side or the other but rather should focus on continuous improvement in communication by creating a climate of trust.

Acknowledgments

The thoughts, beliefs, and proposals presented do not necessarily represent the consensus opinion of Dow AgroSciences or the Agricultural Products Industry. I thank G. Oliver, J. Gibson, J. Velovitch, G. Hamlin, J. Wolt, and J. Wright (Dow AgroSciences), and L. Higley and S. Quisenberry (Univ. of Nebraska-Lincoln) for reviewing this manuscript. This is article 12278 of the journal series of the Nebraska Agricultural Research Division, University of Nebraska-Lincoln.

References Cited

Alhakami, A. S., and P. Slovic 1994. A psychological study of the inverse relationship between perceived risk and perceived benefit. Risk Analysis 14: 1085-1096.

Bostrom, A., B. Fischhoff, and M. G. Morgan. 1992. Characterizing mental models of hazardous processes: a methodology and an application to radon. J. Social Issues 48: 85-100.

Boulter, D. 1997. Scientific and public perception of plant genetic manipulation—a critical review. Critical Rev. Plant Sci. 16: 231-251.

Brown, D. J., and L. F. Schrader 1990. Cholesterol information and shell egg consumption. Am. J. Agric. Econ. 72: 548-555.

Chalfant, J. A., and J. M. Alston 1988. Accounting for changes in tastes. J. Political Econ. 96:391-410.

Cothern, C. R. 1996. An overview of environmental risk decision making: values, perceptions, and ethics, pp. 39-67. *In* C. R. Cothern [ed.], Handbook of environmental risk decision making: values, perceptions, and ethics. CRC Press, Boca Raton, FL.

Covello, V. T., P. M. Sandman, and P. Slovic, P. 1988. Risk communication, risk statistics, and risk comparisons: a manual for plant managers. Chem. Manufacturers Assoc., Washington, D.C.

Curtis, C. R. 1995. The public and pesticides: exploring the interface. Natl. Agric. Pestic. Impact Assessment Program, U.S. Dept. Agric.

Eom, Y. S. 1994. Pesticide residue risk and food safety valuation: a random utility approach. Am. J. Agric. Econ. 76: 760-771.

Fife-Shaw, C., and G. Rowe. 1996. Public perceptions of everyday food hazards: a psychometric approach. Risk Anal. 16: 487-500.

Fischhoff, B., P. Slovic, S. Lichenstein, S. S. Read, and B. Combs. 1978. How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. Policy Sci. 9: 127-152.

Fisher, A. 1991. Risk communication challenges. Risk Analysis 11: 173-179.

Freudenburg, W. R. 1996. Strange chemistry: environmental risk conflicts in a world of science, values, and blind spots, pp. 11-36. *In* C. R. Cothern [ed.], Handbook for environmental risk decision making: values, perceptions, and ethics. CRC Press, Boca Raton, FL.

Frewer, L. J., C. Howard, D. Hedderley, and R. Shepherd. 1997. The elaboration likelihood model and communication about food risks. Risk Analysis 17: 759-770.

Gaskell, G., M. W. Bauer, J. Durant, and N. C. Allum. 1999. Worlds apart? The reception of genetically modified foods in Europe and the U.S. Science 285: 384-387.

Hagedorn, C., and S. Allender-Hagedorn. 1997. Issues in agricultural and environmental biotechnology: identifying and comparing biotechnology issues from public opinion surveys, the popular press and technical/regulatory sources. Pub. Understanding Sci. 6: 233-245.

Hakkinen, P. J., and C. J. Leep. 1996. Industry's use of risk, values, perceptions, and ethics in decision making, pp.73-81. In C. R. Cothern [ed.], Handbook for environmental risk decision making: values, perceptions, and ethics. CRC Press, Boca Raton, FL.

Hallman, W. K. 1996. Public perceptions of biotechnology: another look. Bio/Tech. 14: 35-38.

Hoban, T., E. Woodrum, R. Czaja. 1992. Public opposition to genetic engineering. Rural. Sociol. 57: 476-493.

Huang, C. L. 1993. Simultaneous-equation model for estimating consumer risk perceptions, attitudes, and willingness-to-pay for residue-free produce. J. Consumer Affairs 27: 377-396.

Kasperson, R. E. 1986. Six propositions on public participation and their relevance for risk communication. Risk Analysis 8: 275-281.

Kramer, C. S. 1990. Food safety: the consumer side of the environmental issue. South. J. Agric. Econ. 22: 33-40.

Krauss, N., T. Malmfors, and P. Slovic. 1992. Intuitive toxicology: expert and lay judgments of chemical risks. Risk Analysis 12: 215-232.

Laird, F. N. 1989. The decline of deference: the political context of risk communication. Risk Analysis 8: 543-549.

Lamb, C. G. 1993. The organic food market: A marketing perspective, paper presented to a New Zealand Marketing Educators' Conference, Lincoln University.

Lujan, J. L., and L. Moreno. 1994. Public perception of biotechnology and genetic engineering in Spain: tendencies and ambivalence. Tech. Soc. 16: 335-355.

Maskill, C., and M. Harre. 1994. Scientific and public perceptions on the health risks of pesticide residues in food. Proc. Nutrition Soc. New Zeal. 19: 64-68.

McDaniels, T. L., L. J. Axelrod, and P. Slovic. 1995. Characterizing perception of ecological risk. Risk Analysis 15: 575-588.

McDaniels, T. L., L. J. Axelrod, N. S. Cavanagh, and P. Slovic. 1997. Perception of ecological risk to water environments. Risk Analysis 17: 341-352.

Morgan, M. G., B. Fischhoff, A. Bostrom, L. Lave, and C. Atman, C. 1992. Communicating risk to the public. Environ. Sci. Tech. 26: 2048-2056.

National Research Council, Committee on Risk Perception and Communication. 1989. Improving risk communication. Natl. Acad.Washington, D.C.

New Zealand National Research Bureau. 1990. Public perception of risk from chemicals. Wellington: Natl. Res. Bur. Dept. Health.

Norton, B. G. 1996. Ecological risk assessment: toward a broader analytic framework, pp. 155-175. *In* C. R. Cothern [ed.], Handbook of environmental risk decision making: values, perceptions, and ethics. CRC Press, Boca Raton, FL.

Ott, S. L., L. Huang, and S. K. Misra. 1991. Consumer perceptions of risks from pesticide residues and demand for certification of residue-free produce. pp. 175-188. *In* J. A. Casewell [ed.], Economics of food safety. Elsevier, New York.

Penner, K. P., C. S. Kramer, and G. L. Frantz. 1985. Consumer food safety perceptions. Kansas State Univ. Coop. Ext. Serv., Manhattan, KS.

Peters, R. G., V. T. Covello, and D. B. McCallum. 1997. The determinants of trust and credibility in environmental risk communication: an empirical study. Risk Analysis 17: 43-54.

Peterson, R.K.D., and L. G. Higley. 1993. Communicating pesticide risks. Am. Entomol. 39: 206-211.

Pike, D. R., F. Whitford, S. Kamble [eds.]. 1997. Pesticides and the bottom line. North Central Region: Pesticide Impact Assessment Program. Crop Science Special Report 1997-10, Univ. Illinois.

Potter, M. F, and R. T. Bessin. 1998. Pest control, pesticides, and the public: attitudes and implications. Am. Entomol. 44: 142-147.

Raats, M. M., and R. Shepherd, R. 1996. Developing a subject-derived terminology to describe perceptions of chemicals in foods. Risk Analysis 16: 133-146.

Richardson-Harman, N., T. Phelps, P. Mooney, and R. Ball. 1998. Consumer perceptions of fruit production technologies. New Zealand J. Crop and Hort. Sci. 26: 181-192.

Sant'Ana, A., and S. Valle. 1995. Public perceptions of biotechnology: problems in the Third World. Tibtech 13: 126-127.

Shutz, H., and P. M. Wiedemann. 1998. Judgements of personal and environmental risks of consumer products—do they differ? Risk Analysis 18: 119-129.

Slovic, P. 1987. Perception of risk. Science 236: 280-285.

Slovic, P. 1990. The legitimacy of public perceptions of risk. J. Pestic. Reform 10: 13-15.

Slovic, P. 1997. Risk perception and trust, pp. 233-244. *In* V. Molak [ed.], Fundamentals of risk analysis and risk management. CRC Press, Boca Raton, FL.

Smith, M., E. van Ravenswaay, and S. Thompson. 1988. Sales loss determination in food contamination incidents: an application to milk bans in Hawaii. Am. J. Agric. Econ. 70: 513-520.

Sparks, P., and R. Shepherd. 1994. Public perceptions of the potential hazards associated with food production and food consumption: an empirical study. Risk Analysis 14: 799-806.

Tal, A. 1997. Assessing the environmental movement's attitudes toward risk assessment. Environ. Sci. Tech. 31: 470-476.

Torgersen, H., and F. Seifert. 1997. Aversion preceding rejection: results of the Eurobarometer Survey 39.1 on biotechnology and genetic engineering in Austria. Public Understanding Sci. 6: 131-142.

Van Ravenswaay, E. O. 1995. Public perceptions of agrichemicals. Counc. Agricul. Sci. Technol., Task Force Rep. 123, Ames, Iowa.

Van Ravenswaay, E. O., and J. P. Hoehn. 1991. Willingness to pay for reducing pesticide residues in food: results of a nationwide survey. Staff paper No. 91-18. Dept. Agric. Econ., Michigan State Univ., East Lansing, MI.

Van Ravenswaay, E. O., J. Wohl, and J. P. Hoehn. 1992. Michigan consumers' perceptions of pesticide residues in food. Staff paper No. 92-56. Dept. Agric. Econ., Michigan State Univ., East Lansing, MI.

Zechendorf, B. 1994. What the public thinks about biotechnology. Bio/Tech. 12: 870-875.

Robert K. D. Peterson is a Senior Research Biologist at Dow AgroSciences and Adjunct Assistant Professor in the Department of Entomology at the University of Nebraska-Lincoln. He currently is a Regulatory Manager in the Regulatory Success-Americas group at Dow AgroSciences. His research interests include human and ecological risk management, pest management theory, and plant-stress physiology. Corresponding address: Dow AgroSciences, 9330 Zionsville Rd., Indianapolis, In 46268, rkpeterson@dowagro.com