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. 1993, 1997). Additionally, recent risk perception research studies are particularly informative because they have been conducted in many different countries, allowing comparisons among geographic and cultural factors (Lamb 1993, Reas and Shephard 1996, Torgerseen and Seifert 1997, Gaskell et al. 1999).

In this article, we discuss 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 assessment 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 (Cavallo et al. 1988, National Research Council 1997, Slovic 1987). In general, public perceptions of risk are the product of intuitive biases and economic concerns that often reflect cultural values (Kasprow 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 pattern risk perception. The psychometric framework attempts to identify the multi-
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 23 potential hazards and 2.5 risk characteristics. As with many other psychometric approaches, the data were subject to principal-component analysis to determine principal facets. Three major groupings of risk characteristics accounted for 87% of the variance. They included severity, probability, and number of people exposed. The "severity" category (45.3% of the variance) included factors such as "concern," "seriousness for future generations," "threatening widespread disaster 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 assessment." 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, generic 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 structures.
tare used by the public to assess food haz-
ards was broadly similar to those used by
Sparks and Shepherd (1994) even though
many of the hazards were different. Princi-
pal 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 Shep-
derd (1994). The “awareness” component was
similar to the “unknown” component from
the results of Sparks and Shepherd (1994).
Residues on foods were perceived as a
severely and moderately unknown
Genetic engineering of foods was per-
cieved as a relatively moderate but highly
unknown risk.

A key concern of the psychometric ap-
proach is that the characteristics of risk per-
tection 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) char-
acterized lay perceptions of chemicals in
foods in a two-part study conducted in the
United Kingdom. They first interviewed sub-
jects about their knowledge of different
chemicals that may occur in food. The
conclusions drawn by the subjects were
validated using a survey instrument and a
labor 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 per-
tections were similar to other studies (Five-
Shaw and Rowe 1996, Sparks and Shep-
derd 1994). Respondents had the most nega-
tive attitudes about pesticides when they
evaluated the terms “weedkillers,” “insecti-
cides,” “pest control products,” and “pesti-
cides used during food storage.” Pesticides were
perceived as among the most poison-
ous 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, aluminium,
and nitrates. Additionally, pesticides were
considered the least natural chemicals in
foods.

Other studies that did not focus on char-
acterizing perceptions of food risks also sup-
port recent findings. Several surveys con-
ducted in New Zealand indicated that a sig-
nificant proportion of the public is concerned
about pesticide residues in food (MacKall and
Hare 1994, New Zealand National Re-
search 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) ob-
 served that 20% of 1,000 respondents in
a 1991 survey of New Zealanders believed
that pesticides were the most serious food
problems.

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 approx-
imately 1,000 adults, 72 to 82% of respon-
dents indicated that pesticides represent a
serious hazard when asked directly about
their perceptions of pesticides in food (Van
Ravensway 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 residue 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 sys-
tem disorder, and impaired immune func-
tion also were mentioned by respondents (Van

Understanding how perceptions of risk
from pesticide residues in food translate into
changes in consumer food-purchasing be-
havior has been difficult. Several researchers
have examined the link between perceptions
and purchasing behavior but, to date, stud-
es have not focused on characterizing the
integration of perceptions, behavior, and
valuation (Fran 1994). Although some stud-
ies have shown an association between risk
perceptions and food purchases in real mar-
ket situations (e.g., Brown and Schrader
1990, Smith et al. 1984, Van Ravensway
and Hoehn 1991), others have demon-
strated that food consumption patterns do
not seem to be related to risk perceptions
and health concerns (Chaffant and Alston
1988, Ott et al. 1991). In a self-reported
questionnaire of 51 people in New Zealand,
only 33% of the respondents indicated that
they would eat an apple knowing it had been
sprayed with pesticides to reduce pest dam-
age (Richardson-Harman et al. 1998). How-
ever, nearly 100% of apples in New Zealand
are sprayed with pesticides, and over 95% of
consumers in the study were regular con-
sumers of apples.

In an economic valuation study attempt-
ing to integrate public perceptions, behav-
ior, and valuation, 65% of 567 citizens sur-
veyed in North Carolina indicated they
would avoid produce containing pesticide
residues to reduce health risks (Rott 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 sim-
ply by the technical risk information pro-
vided” (Rott 1994). The association between
perceptions and valuation was weak. Con-
sumers expressed willingness to pay a sub-
stantial premium for safer produce in return
for only small reductions in risk. Addition-
ally, the price premium was insensitive to the
amount of risk reduction.

Huang (1993) found that the linkage be-
tween risk perceptions from residues in foods and willingness-to-pay for residue-free produc-
duce 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 15 and 50 were more
likely than their cohort groups to have a
positive attitude toward banning of pesti-
cides in fresh produce production. Addition-
ally, females who were married with children
were more concerned about pesticide resi-
dues than their counterparts. This trend was
also observed by Perser et al. (1983) Inter-
estingly, previous personal experiences in-
fluence 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 bio-
technology 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
exremely complex and cannot be general-
ized easily. There are differences in percep-
tion by age, gender, income, education, cul-
tures, and among types of biotechnology
products. Additionally, separate studies and
polls cannot be compared empirically be-
cause different questions were asked. As a
result, generalization, lay knowledge of bio-
technology continues to be poor through-
out Europe, the United States, New Zealand,
and Latin America (Hagedorn and Alles-
ander-Hagedorn 1997; Hallman 1996, Luhan
and Moreno 1994, Richardson-Harman et al.
1998, Sert'Ara and Valle 1995, Torgersen and
the public in most countries perceives
substantial potential risk from biotechnol-
ye products, most people have a relatively
high acceptance of biotechnology, including
Europeans (Hallman 1996, Zeichendorf
1994). Indeed, the public seems more con-
cerned with the risks associated with specific
products produced from biotechnology than
with the process of genetic engineering
(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 Allesander-Hagedorn 1997,
Hoban et al. 1992). Scientific and regulatory
communities tend to focus on research and
technical issues such as the escape of transgen-
ics by cross-pollination with wild species,
escaped and mutated viruses and bacteria,
and inadvertent production of toxins, and
selection for resistance (Boilier 1997).

In most countries where studies have been
conducted, sociological and economic vari-
bles generally explain attitudes about bio-
technology. Support for biotechnology gen-
erally 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 bio-
technology for new crops typically receives
more support than agricultural biotechnol-
y. The benefits associated with medium of bio-
technology products are more likely to
seem 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 surveyed
respondents in several polls fear potential
health hazards (Zeichendorf 1994). All
though there were differences in question
and measurement among surveys, "accep-
tance" generally means that those surveyed
support or tolerate risk from biotechnology
(Gaskel et al. 1999, Zeichendorf 1994). In
other words, they do not oppose biotech-
nology. Acceptance of genetically-modified
organisms varies between transgenic plants
and animals. In a 1992 survey of 532 North
Carolina residents, 70% accepted plant bio-
technology whereas only 42% accepted ani-
mal biotechnology (Hoban et al. 1992).

A relatively thorough survey of 604 New
York residents in 1993 revealed several
aspects of risk perception from biotechnology
products. Nearly 20% of respondents had
negative initial thoughts about genetic engi-
neering (Hallman 1996). Most residents
(61%) approved of using genetic engineering
techniques to produce hybrid plants, but only
28% approved of genetic engineering to pro-
duce hybrid animals. Interestingly, approxi-
mately 50% of the residents who believed
genetic engineering is morally wrong also in-
dicated they approved of 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 bi-
technology. Approximately 55% of those
surveyed indicated they would buy gene-
"engineered" apples, and 40% would buy
fresh vegetables as long as they were labeled
as being produced by genetic engineering.
Approximately 85% believed that "grow-
genetically engineered plants that con-
tain higher levels of naturally occurring
chemicals that protect against pests and dis-
eease 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 per-
cussions in the New Jersey survey, 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 biotech-
nology products for reasons of choice and
consumer empowerment (Hallman 1996).

Europe

A substantial amount of information has
already been collected about European per-
cussions of biotechnology. Unfortunately, the
information is often contradictory, making
generalizations difficult. For example, in one
survey the public viewed pharmaceutical pro-
duction in animals as acceptable, but viewed
biological engineering of animals as unaccept-
able (Boilier 1997).

Northern Europe (England, Germany,
Belgium, The Netherlands, Luxembourg,
Denmark, Australia). In general, northern-
ern 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 (Zeichendorf
1994). The British had an average acceptance
and risk perception rate, but the acceptance
rate for food applications of genetic engi-
nery was lower. Denmark had the highest
perceptions of risk but also had above aver-
age acceptance of biotechnology when com-
pared to other European countries.

The German public was strikingly differ-
ent from most of the other countries. Al-
though the citizens are the most knowledgeable
about biotechnology in Europe, they had the
second highest perception of risk and lowest
support. Generally, the Germans had the level
of knowledge and education, the general sup-
port for biotechnology (Torgersen and Seifert
1997, Zeichendorf 1994). Germany, Denmark,
and Austria are exceptions to this pattern.
Torgersen and Seifert (1997) suggested that past
experiences with Nazi totalitarianism and eugenics
could contribute to the low support for biotech-
nology 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 manipulation (Zechendorf 1994). Interestingly, the differences in European opinions between northern and southern countries were observed in Switzerland, which straddles the cultural borderlines. The northern Alemannic 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 shown that the public is greatly concerned about the effects of pesticides (Van Ravenway 1995) and agricultural biotechnology (Shutz and Wiederholt 1998) on the environment. This concern may even exceed concerns about food safety. McDaniel 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 pests 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 to more information 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, cleaftcutting, 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, clearing. landfills, air conditioning, nuclear power, and acid rain.

Results from McDaniel 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 McDaniel 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” are often important in evaluations of both types of risk (National Research Council 1989, Slovic 1987). Additionally, respondents in the McDaniel et al. (1995) study rated natural risks relatively lower than human-produced risks even though natural risks such as droughts, floods, and earthquake 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). McDaniel 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 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, benefits, people affected, species at stake, equity, impact on society, reversibility, alternatives, predictability, and avoidability, and need to regulate. In contrast to results from McDaniel 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 McDaniel et al. (1995) also was observed in McDaniel 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 on 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 McDaniel et al. (1995).

McDaniel 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 McDaniel 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 are 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.

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The public view of ecological risks posed by each potential risk 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 acid rain.

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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 those 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 dreaded 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 pesticid
Specific risk characteristics that are continually associated with pesticides include
dread, uncontrollable, catastrophic, not eq
sitabile, serious for future generations, in
voluntary, increasing risk, not observable, un
known to those exposed, delayed effects, delayed, and unknown to science (see Peterson and
The public clearly does not perceive as much benefit from pesticide use as experts
(Slovic 1987; Van Raanenwazy et al. 1993, Van
Ravenway et al. 1992). This is understand
able 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 equitably across all of society. However,
perceived benefit is an important determin
ant to perceived risk (Albukhary and Slovic
1994). Therefore, discussions of benefit
likely will be important in risk communica
tion programs. The public continues to view pesticides as chemicals that biologically both in ecosys
tems and in humans. This is evident by the
"effects delayed," "increasing risk," "seri
ous for future generations," and "impact on
species" perception factors (Shaw and Rowe
over, survey respondents specifically men
tioned that pesticides build up in the human
body as a result of consuming residues in food (Raisa and Sheperd 1996) and that
all pesticides cause cancer (Porter and Benin
1998). These views are not supported by
empirical evidence.

Agricultural Biotechnology
More empirical research on public per
ceptions 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 med
ical biotechnology. Knowledge of biotechnology is limited, especially with regard to pos
sible benefits. Consequently, this poor under
standing is likely to effect initial acceptance
of the technology.

Perhaps most important is the percep
tion that agricultural biotechnology, indeed biotechnology in general, represents a large
unknown risk. This is reflected in both per
ceptions of human health and ecological risk and seems to be the dominant percep
tion factor (Himmel 1996, McDaniels et al. 1995,
Slovic 1987, Zechendorf 1994). As an un
known risk, biotechnology most likely is seen as a risk that is unknown to science, un
known to those exposed, delayed, and not
observable easily. Additionally, biotechnol
ogy is perceived as a dread risk. As a dread
risk, biotechnology most likely is viewed as
a risk that is uncontrollable, globally cata
strophic, 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 ethical and
morality of the use of pesticides are not nearly
discouraging 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

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.

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Where the 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.

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 least trust in environmental groups, consumer organizations, and universities, and the least trust in public authorities, political organizations, trade unions, and industry (Torgersen and Selmer 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 1996, Laid 1999, 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, officially, or experts (Laid 1999). 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 negative perceptions of concern and care most strongly influence public trust. For citizen groups, increases in perceptions of knowledge and expertise most influence public trust (Peters et al. 1997).

Clearly, perceptions of risk will change appreciably only with a consistent 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 benefits 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 other 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 from 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 appropriately 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 simplistic (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 the 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 perception of risk is 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 ally 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 impinged by perceptions and value judgments (Gorham 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 disagree 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, defining 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 views these compounds as likely to persist in the environment, beorngetic, and cause cancer. Misunderstandings about persistence relate directly to perceptions of death, 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 pests and their control 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 experts assessments. Freidenburg (1996) noted, "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 individual 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 methodology is needed to assess lay knowledge and perception before meaningful risk communication programs can occur. One promising method is the mental-model approach (Boxstom et al. 1992, Morgan et al. 1992). The mental-model 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 (Boxstom 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 these 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 specific, 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? Do we perceive 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 counter-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 (Nisbet 1996). Indeed, to be successful, risk assessment may need to incorporate full 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 efforts beneficial to one side or the other but rather should focus on continuous improvement in communication by creating a climate of trust.

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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-Amercia group at Dow AgroSciences. His research interests include human and ecological risk management, pest management theory, and risk reduction strategy. Corresponding address: Dow AgroSciences, 9330 Zionsville Rd., Indianapolis, IN 46268; kpetersen@dowagro.com