SOCIETY & NATURAL RESOURCES
2021, VOL. 34, NO. 9, 1194–1212
https://doi.org/10.1080/08941920.2021.1946628

Effects of Message Framing on Public Responses to Using Genetic Engineering to Restore American Chestnut Trees

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ABSTRACT
Data from two studies examined the: (a) attitudes and behavioral intentions of the public regarding the use of genetic engineering (GE) for addressing chestnut blight and helping to restore American chestnut trees (AC); and (b) extent that these attitudes and intentions are susceptible to message framing. Data from a representative sample of the United States public ($n = 278$) showed this sample felt, on average, neutral to slightly positive about using GE to restore AC trees. The majority (57%) would vote for this use of GE and were certain of these intentions. Data from an experiment (multiple treatments) conducted with other members of the public ($n = 528$), however, showed that these attitudes and intentions are susceptible to persuasion, as both between- and within-subjects comparisons showed that support dropped dramatically once messages provided negative or opposing arguments. Negatively worded information coupled with messages about scientific consensus in opposition yielded the most negative responses.

ARTICLE HISTORY
Received 23 April 2020
Accepted 16 June 2021

KEYWORDS
Attitudes; chestnut trees; framing; genetic engineering; intentions; persuasion

Introduction

The American chestnut (AC) (*Castanea dentata*) is a tree species that was common in the eastern United States (U.S.). The AC provided food and habitat for several wildlife species and supplied lumber and food for people (e.g., chestnuts). Chestnut blight (CB) is a tree disease that was accidentally brought into the U.S. from Asia around the year 1900 and this fungal pathogen has devastated this tree species ever since this time, as the native range of the AC has reduced by approximately 99%. Relatively common silvicultural methods (e.g., breed the AC with Asian chestnuts, hybridization) have shown some effectiveness against CB, but genetic engineering (GE) has been the most promising. Inserting the oxalate oxidase (OxO) gene from bread wheat has generated the most resistance to CB, and researchers are now pursuing regulatory and agency approval to release these transgenic (i.e., insert genes from one organism into a different organism) AC trees at a wider scale (NASEM 2019; Powell 2016; Zhang et al. 2013).

GE in trees can provide benefits such as reducing the need for herbicides and pesticides, improving forest health, and increasing tree growth, harvest rates, and profitability (Kempken and Jung 2010; NASEM 2019). However, concerns include possible

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changes or reductions in the genetic diversity of native trees (through gene flow), long-term impacts on biodiversity that are currently unknown, and the role of humans in manipulating nature (NASEM 2019). The ability to utilize biotechnologies such as GE is partly dependent on public attitudes and support. Attitudes are defined as psychological tendencies to evaluate an issue or object, such as GE, as favorable or unfavorable (bad/good, negative/positive; Eagly and Chaiken 1993). Attitudes can predict intended behaviors and actual behaviors (Fishbein and Ajzen 2010). These attitudes and behavioral intentions can be influenced by message framing that uses positive or negative terminology, or provides scientifically accurate information or biased viewpoints lacking scientific consensus (e.g., "climate change is a hoax and not influenced by humans;" Boykoff and Boykoff 2004). Framing messages from trustworthy or credible sources (e.g., scientists) and providing quantitative substantiation of scientific consensus (e.g., "98% of scientists agree") can also impact attitudes and intentions (Nan 2009). Message framing is defined as a process "to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described" (Entman 1993, 52).

Many studies have examined attitudes and intentions associated with GE, especially in the disciplines of agriculture and food. Even though chestnuts are occasionally eaten by some people, more popular examples of GE in food and agriculture include potato, soy, and corn. Research has shown that although the public can have extremely negative and positive views of GE in agriculture and food, public attitudes are, on average, generally negative (especially in Europe), many people are concerned about potential health hazards, and public knowledge is low (NASEM 2016; Scott et al. 2018). Research has also examined the influence of information and framing on attitudes toward GE in agriculture and food, with studies showing that attitudes either do not change or they become more negative or positive depending on the information and framing provided (Lusk et al. 2004; NASEM 2016; Rousu et al. 2007; Scott et al. 2018).

By comparison, only a few studies have examined public perceptions of using GE in trees to address threats to forest health such as CB (NASEM 2019), with studies showing that the public often views GE in trees differently (more positively, mostly driven by perceived environmental benefits) than they view GE in more common food and agricultural uses (more negatively, mostly driven by perceived human risks; Jepson and Arakelyan 2017a, 2017b; Petit, Needham, and Howe 2021a, 2021b). Little research has also examined how message framing influences responses to using GE in trees. This article examined public attitudes and intentions associated with using GE to restore AC trees, and the effects of message framing (positive, negative terminology; scientific information, consensus) on these attitudes and intentions. Two research questions were examined. First, what are public attitudes and intentions regarding the use of GE for addressing CB and helping to restore AC trees? Second, to what extent are these attitudes and intentions susceptible to message framing? Given the valuable services that forests provide for animals (e.g., habitat) and people (e.g., air, lumber, recreation), it is important to examine what people think about biotechnologies (e.g., GE) that can mitigate threats (e.g., CB) to the health of forest species (e.g., AC), and whether message framing may influence these responses.

Conceptual Foundation

Attitudes and Intentions Regarding GE in Forestry

A small number of studies, especially in Canada and Europe, have investigated attitudes and intentions toward using GE to address forest health threats such as pests, diseases, and climate change (NASEM 2019). For example, Jepson and Arakelyan (2017a, 2017b) measured public attitudes regarding GE in the United Kingdom and found these applications for addressing global threats (e.g., poverty, forest diseases) were generally favorable. These researchers also found that 30–38% of their public sample approved of GE ash trees that are resistant to ash dieback and planting them in woodlands across the countryside, whereas larger percentages approved of planting these trees in plantations. Kazana et al. (2016) found that students in most European nations had positive attitudes toward planting GE trees in plantations. Nonić et al. (2015) used similar methods and reported similar findings. Hajjar and Kozak (2015) and Hajjar et al. (2014) reported that approximately 50% of residents within Western Canada supported the planting of trees with traits from GE to enhance forest resistance to climate change. In a more recent study in this same region, however, only 25% of residents supported using reforestation with trees based on GE to respond to climate change (Peterson St-Laurent, Hagerman, and Kozak 2018). Studies have shown greater public support for using GE to help mitigate specific threats to the health of forests (e.g., diseases, pests) compared to when GE is considered for addressing more general issues, such as climate change, that transcend forests (NASEM 2019).

Biased Processing and Strength of Attitudes and Intentions

Attitudes and intentions can be susceptible to change from messaging and other persuasion approaches (Eagly and Chaiken 1993; Petty and Cacioppo 1986). For example, weaker or less stable attitudes are less resistant to change, so they can be susceptible to messaging campaigns aimed at changing attitudes. Conversely, more salient, accessible (retrievable), or strongly held attitudes (strength, certainty) can be resistant to contradictory information and more predictive of higher-order intentions and behaviors (Howe and Krosnick 2017). Frewer, Howard, and Shepherd (1998) and Lusk et al. (2004), for example, found that existing attitudes were determinants of how respondents viewed information about GE foods.

Psychological phenomena such as biased processing (selective processing of information skewed by existing beliefs) can reduce the impact of persuasive messages on attitudes and intentions, especially when attitudes and intentions are strongly held and highly accessible (Fazio 1986; Wood, Rhodes, and Biek 1995). McFadden and Lusk (2015), for example, showed that prior attitudes biased interpretation of messages about GE foods, as information incongruent with these attitudes was selectively ignored or refuted. Teel et al. (2006) presented respondents with exaggerated information about drilling for oil in the Arctic National Wildlife Refuge framed as expert testimony to Congress, but found that attitudes were not influenced much by this messaging. These findings are examples of biased processing and this phenomenon is similar to cognitive dissonance, which contends that people can ignore messages (a behavior) that oppose their attitudes (Festinger 1957). In other words, people can compare their existing attitudes and intentions with new messaging and refute any observed inconsistencies.

Positive Versus Negative Framing

Despite these potential biases, framing messages using positive terminology can generate more favorable attitudes and intentions, whereas negative terminology can have the opposite effect (Lu et al. 2018). Research has examined whether positive (e.g., benefits) or negative (e.g., risks) information is more influential on attitudes and intentions (Frewer et al. 2016). Theories such as prospect theory (Kahneman and Tversky 1979) and gain/loss or risk aversion theories (Tversky and Kahneman 1991) propose that losses and other forms of negative framing can be more influential over decision making compared to gains or positive messaging. Other research, however, has shown that positive framing can be more influential when detailed processing is not required, whereas negative information can be more influential when complex processing is activated (Maheswaran and Meyers-Levy 1990). Gain/loss framing and goal pursuit theories such as regulatory focus theory (Higgins 2000) suggest that describing issues positively (promotion, gains, benefits) or negatively (prevention, losses, risks) can have corresponding positive or negative effects on attitudes and intentions that result in risk seeking or risk averse decisions, respectively (Cesario, Grant, and Higgins 2004).

Scientific Information

Providing factual or scientific information in messages can also influence attitudes and intentions. Petty and Cacioppo (1984) examined the influence of messaging on agreement and found that providing more factual information enhanced persuasion. Davidson et al. (1985) found the amount of scientific information presented also influenced relationships between attitudes and behaviors. In the context of GE in food, McPhetres et al. (2019) found that greater knowledge about the science behind this biotechnology led to more positive attitudes and willingness to consume these foods. Similar findings have been found by others (Hallman et al. 2003; Klerck and Sweeney 2007). Most research in this and other contexts, however, has found relatively weak effects of providing scientific information (e.g., Frewer, Howard, and Shepherd 1998; Scott et al. 2018; Wuepper, Wree, and Ardali 2019). This is consistent with most social science research that has largely discredited the "deficit model," which claims that people would be more supportive of an issue if they simply understood or knew more about the issue (Allum et al. 2008).

Research based on information processing and persuasion models (e.g., elaboration likelihood model [ELM], heuristic-systematic) has shown that credibility or trustworthiness of information sources (e.g., scientists, managers) can also influence attitudes and intentions (Eagly and Chaiken 1993; Frewer, Howard, and Shepherd 1998; Nan 2009; Petty and Cacioppo 1984, 1986). For example, Zuwerink-Jacks and Cameron (2003) stated that "source derogation" and reduced cognitive change can occur when people think a messaging source lacks credibility.

Balance as Bias

Scientific consensus can also influence attitudes and intentions because consensus among people perceived as experts is an important heuristic when processing messages, as demonstrated by persuasion models such as the ELM (Eagly and Chaiken 1993; Petty and Cacioppo 1984, 1986). When there is scientific agreement about an issue, messaging and public sentiment should reflect this consensus. Lewandowsky, Gignac, and Vaughan (2013), for example, assessed public acceptance of the validity of issues such as climate change and HIV/AIDS, and found increasing acceptance when scientific consensus was highlighted. However, public opinions do not always mirror this consensus due to various biases and misrepresenting issues as contentious (scientific disagreement) in some media coverage. In addition, theories such as the cultural cognition of risk (Kahan 2012; Kahan et al. 2009) and cultural cognition of scientific consensus (Kahan, Jenkins-Smith, and Braman 2011) suggest that societal values can shape public perceptions of scientific consensus regardless of the actual amount of objective consensus, especially for controversial issues receiving substantial media attention (e.g., guns, climate change).

Media exposure of largely discredited viewpoints toward some natural resource issues (e.g., "climate change is a hoax and not influenced by humans") can influence public attitudes, despite these viewpoints being largely refuted by scientific consensus. The balance as bias (false balance, balance fallacy) phenomenon occurs when messaging communicates a false lack of expert consensus (e.g., contentious televised debate between one climate change believer and one denier), leaving public opinion susceptible to misinformation. Boykoff and Boykoff (2004), for example, examined press coverage of climate change in the U.S. and found that despite extensive scientific consensus on this issue, providing equal balance to both sides of the issue created polarization that contributed to public uncertainty. Likewise, risk theories such as the social amplification of risk (Kasperson et al. 1988) suggest that negative attention toward an issue (e.g., GE, nuclear power, air travel) can increase public concern, regardless of science demonstrating low risks. Frewer, Miles, and Marsh (2002), for example, found evidence supporting a change in perceived risks and negative views with increased media about GE foods, whereas positive views of benefits did not change.

Methods

Study 1 (Representative Sample)

To address the first research question, data were obtained from a mixed-mode survey of U.S. residents. Sampling of these residents occurred from January to June 2015 and the sample was stratified based on whether people lived in the historic native range of the AC (i.e., chestnut counties) or in the remainder of the contiguous U.S. (i.e., non-chestnut counties). These residents were sampled randomly from postal records and this sampling was conducted proportionate to population sizes at the county level. Residents were contacted six times to increase response rates and sample sizes. The first contact was a postcard mailing informing residents about the study and giving them an option to answer the questionnaire online. The second contact was a full mailing containing the questionnaire, a cover letter, and a postage-paid reply envelope. The third

Imagine ***both*** of the following are happening:

- ***Chestnut blight*** has killed more than 99% of adult American chestnut trees within their native range. This disease is caused by a fungus that was accidentally introduced to North America around the year 1900.
- ***Genetic modification*** is being used to help trees resist chestnut blight and restore American chestnut forests. This involves using modern laboratory approaches to change genes that are already present or add new genes from another organism. These new genes may come from closely related trees, other plants, or distantly related organisms such as bacteria. The genetically modified trees (also known as genetically engineered trees) contain thousands of genes from the original tree, plus one or a few genes that have been changed or added. Although this can add desirable traits to trees, there are concerns that the modified genes could unintentionally spread into nearby forests by seed, pollen, or other means.

Figure 1. Scenario presented to respondents in Study 1.

contact involved mailing a postcard reminder that included an option to answer the questionnaire online. The fourth contact involved telephone calls encouraging participation. The fifth contact was a second full mailing, and the sixth contact involved a final full mailing. Six contacts is considered to be high for most survey research, as two, three, or four contacts are more commonplace (Vaske 2019). Funding limitations and constraints imposed on this human subjects research by the university institutional review board (IRB) prohibited any further contacts.

A total of 278 questionnaires were completed and received ($n = 142$, 12% response rate from chestnut counties; $n = 136$, 11% response rate from non-chestnut counties). A telephone nonresponse bias check of 107 nonrespondents was administered to examine whether respondents and nonrespondents differed, but there were no substantive differences. To also address the representativeness of the sample, demographic characteristics of respondents were examined in comparison to census information to determine if there were any differences between the sample and the larger population. Education (slightly more educated sample) and age (slightly older sample) slightly differed, so the sample data were weighted based on these characteristics from the census information to improve representativeness of the sample and ensure that demographics of the sample were almost identical to those of the population. There were few substantive differences in responses between residents of counties within the historic native range of the AC and residents of the other counties, so the data from these two groups were combined.

A scenario was embedded within the questionnaire describing the forest health threat (impacts of CB on AC) and intervention (GE), worded as neutrally as possible to avoid framing effects (Figure 1). Following this scenario, questions assessed: (a) attitudes, which were measured on a 5-point semantic differential scale ("bad" to "good"); and (b) behavioral intentions, which were measured with questions assessing directionality ("vote for" or "vote against") and certainty (4-point scale of 1 "not certain" to 4 "extremely certain").

Study 2 (Experiment)

To address the second research question, data were obtained from a Qualtrics online research panel of residents (self-selected sample) from the eastern U.S. where AC trees and CB were most common (Pennsylvania, Massachusetts, Connecticut, New York, New Jersey, West Virginia, Kentucky, Tennessee, Virginia). Panel members completed an online questionnaire in October 2016 and 528 questionnaires were completed. Response rates were not recorded because this is difficult with a panel where people

Imagine ***both*** of the following are happening:

- Chestnut blight is a disease that has killed more than 99% of adult American chestnut trees within their native range. This disease:
    - Is caused by a fungus that generally enters trees through wounds or cracks in the bark.
    - Was accidentally introduced to the United States from Asia around the year 1900.
    - Is most commonly found in the eastern region of the United States.
- Genetic modification (also known as genetic engineering) is being used to help trees resist chestnut blight and restore American chestnut forests.
    - This involves using modern laboratory approaches to change genes that are already present or add new genes from another organism.
    - These new genes may come from closely related trees, other plants, or distantly related organisms such as bacteria.
    - The genetically modified trees contain thousands of genes from the original tree, plus one or a few genes that have been changed or added.

Figure 2. Scenario 2 (descriptions and scientific information) presented to respondents in Study 2.

self-select and are compensated for participating (Brandon et al. 2014; Vaske 2019). Similar to most experiments in social psychology where the purpose is not to generalize results to a larger population, but rather to test for any effects of the experiment on groups (e.g., treatment groups), sample representativeness was less important for this Study 2 (Vaske 2019). Regardless, these Study 2 respondents were almost identical in age (mean $[M] = 45$, standard deviation $[SD] = 15$ years) and political orientation ($M = 3.09$, $SD = 1.13$ on a scale of 1 "very conservative" to 5 "very liberal") to the weighted data from Study 1 (age: $M = 48$, $SD = 16$ years; political orientation: $M = 2.94$, $SD = 1.02$), but there were more females in Study 2 (72%) than Study 1 (53%). No other demographics were measured.

Six questionnaire versions (treatments) were developed to experimentally measure the influence of message framing approaches. Each version contained one scenario providing framing effects: (a) simple descriptions of both GE and CB (version/scenario 1); (b) these descriptions plus factual and neutrally worded scientific information about using GE to mitigate CB (version/scenario 2); (c) these descriptions and scientific information plus positively worded expert testimony to Congress (from a fictitious distinguished university professor) about benefits of this use of GE (version/scenario 3); (d) these descriptions, scientific information, and positively worded testimony plus a statement that 98% of scientists support this use of GE (version/scenario 4); (e) the descriptions and scientific information plus negatively worded testimony to Congress about drawbacks of this use of GE (version/scenario 5); and (f) these descriptions, scientific information, and negatively worded testimony plus a statement that 98% of scientists oppose this use of GE (version/scenario 6). To illustrate, Figure 2 shows version/scenario 2 and Figure 3 shows version/scenario 6.

There was only one scenario per questionnaire version (treatments) and the Qualtrics software randomly assigned one version to each respondent ($n = 84$–91 [16–17% of sample] per version/scenario). Power analysis using G*Power software showed that a total sample size of at least 354 was needed for between-subjects analyses and 56 per version/scenario was needed for within-subjects analyses. These were exceeded ($n = 528$, 84–91 per version), increasing the power of Study 2 results. A manipulation check was conducted by asking after the positive and negative scenarios "How factually correct do you think the information presented in the testimony was" with responses of 1 "not correct" to 4 "entirely correct." Between 83% and 92% of respondents said moderately or entirely correct, only 1% said not correct, and there were no differences among

Mr. Speaker and Members of Congress:

It is a privilege to be here. I oppose the use of genetic modification (also known as genetic engineering) to help trees resist chestnut blight and restore American chestnut forests. Chestnut blight is a disease that has killed more than 99% of adult American chestnut trees within their native range. This disease:

- Is caused by a fungus that generally enters trees through wounds or cracks in the bark.
- Was accidentally introduced to the United States from Asia around the year 1900.
- Is most commonly found in the eastern region of the United States.

Genetic modification is being used to help trees resist chestnut blight and restore American chestnut forests.

- This involves using modern laboratory approaches to change genes that are already present or add new genes from another organism.
- These new genes may come from closely related trees, other plants, or distantly related organisms such as bacteria.
- The genetically modified trees contain thousands of genes from the original tree, plus one or a few genes that have been changed or added.

I will make my testimony brief by listing the following facts in opposition to using genetic modification to help trees resist chestnut blight. Importantly:

- 98% of scientists and other experts agree that genetic modification is not safe and not effective for helping trees resist chestnut blight.

This genetic modification also:

- Adds dangerous traits to trees that can contaminate forests.
- Has been shown to be unsuccessful in helping American chestnut trees resist chestnut blight.
- Poses risks to humans and the environment.
- Is just as harmful as approaches used for modifying many fruit, vegetables, and nuts we eat.
- Is not safe.
- Does not improve the quality of wood products from forests.
- Does not improve forests for outdoor recreation.
- Does not protect forests from negative impacts such as diseases, insects, and environmental change.
- Harms the overall health of forests by introducing alien genes that can spread across forests.
- Is unethical.
- Is morally unacceptable.

For these reasons, I strongly oppose using genetic modification to help trees resist chestnut blight, and I feel that genetic modification should not be allowed. This is an important issue, especially given the benefits of forests for wood products, wildlife habitat, outdoor recreation opportunities, and other services. After all, this resource belongs to all Americans, and it is time that we protect forests for the enjoyment and health of future generations.

Thank you for your time today.

Dr. John Chapman
Distinguished University Professor of Natural Resources

Testimony to Congress on January 11, 2016

Figure 3. Scenario 6 (descriptions, scientific information, negative wording, 98% consensus in opposition) presented to respondents in Study 2.

scenarios ($p = .487$). Unlike Study 1 that was a *probability* sample using *random selection* of people from a larger population to improve sample representativeness, this Study 2 was a *non-probability* sample using *random assignment* of people to place them into these treatment groups to improve the experiment (Vaske 2019).

These scenarios are examples of narrative or storytelling messages, which have been used in attitude change research (Teel et al. 2006). Narrative messages can yield less resistance to persuasive information (Dahlstrom 2014) and serve to dissuade counterarguments and increase interest (salience, importance), comprehension, and reading and recall speeds (Green 2006). Contemporary information processing and persuasion models, such as the Extended-ELM (E-ELM), have incorporated narratives and found them useful for facilitating change in attitudes and intentions (Slater and Rouner 2002). Framing narratives from an arguably credible and neutral source (a distinguished university professor) is also consistent with persuasion models (e.g., ELM, E-ELM, heuristic-systematic) showing that sources perceived as credible or trustworthy can be effective at changing attitudes and intentions (Eagly and Chaiken 1993; Nan 2009).

To allow both within- and between-subjects analyses, attitudes were assessed before (pretreatment) and after (post-treatment) each scenario with the statement "I am in favor of using genetic modification of trees to help them resist chestnut blight" and responses on a 5-point scale of 1 "strongly disagree" to 5 "strongly agree." Intentions were measured only after each scenario (between-subjects post-treatment) with questions assessing directionality ("vote for" or "vote against") and certainty (4-point scale of 1 "not certain" to 4 "extremely certain"). This human subjects research was approved by the authors' university IRB (protocol numbers: 5834/8528).

Results

Study 1 (Representative Sample)

On average, respondent attitudes were neutral to slightly positive ($M = 3.30$, $SD = 1.35$ on 1 "bad" to 5 "good" scale), and the largest proportion (44%) viewed this use of GE favorably, 30% viewed it negatively, and 26% were neutral. The majority (57%) would vote for this use of GE (43% would vote against) and 71% were moderately or extremely certain of these intentions ($M = 2.94$, $SD = .90$ on 1 "not certain" to 4 "extremely certain" scale).

Study 2 (Experiment)

Between-subjects post-treatments. On average, attitudes were positive (in favor) after reading scenarios 1 through 4 (descriptions, scientific information, positive framing, scientific consensus in support; Table 1). Although the most positive response ($M = 4.12$ on 1 "strongly disagree" to 5 "strongly agree" scale) was after reading scenario 4 (descriptions, scientific information, positive framing, scientific consensus in support), the Tamhane's T2 post-hoc tests showed that attitudes across these four scenarios were statistically equivalent ($p > .05$, point-biserial correlation effect sizes $r_{pb} = .03–.14$ or

Table 1. Between-subjects analyses comparing post-treatment attitudes and intentions toward using GE to restore AC trees across six experimental framing treatments (Study 2).

	Description only	Scientific information	Positive framing	Positive + scientific consensus	Negative framing	Negative + scientific consensus	F or $\chi 2$	p	Eta (η) or Cramer's V effect sizes
Attitudes[1]	3.87^{a}	4.04^{a}	3.99^{a}	4.12^{a}	2.70^{b}	2.61^{b}	40.92	<.001	.53
Behavioral intentions[2]	80^{a}	90^{a}	84^{a}	93^{a}	40^{b}	29^{b}	158.90	<.001	.55
Behavioral certainty[3]	2.84^{a}	2.96^{ab}	3.21^{b}	3.25^{b}	3.10^{ab}	3.09^{ab}	3.13	.008	.17

[1]Means on 5-point scale: 1 "strongly disagree" to 5 "strongly agree" that "I am in favor of using genetic modification of trees to help them resist chestnut blight." Means with different letter superscripts (^{a,b}) across this row differ ($p < .05$) using Tamhane's post-hoc tests. Means with the same letter superscripts do not differ ($p > .05$). Point-biserial correlation (r_{pb}) effect sizes between the 4 superscript ^{a} and 2 superscript ^{b} = .46–.59, among the 4 superscript ^{a} = .03–.14, and between the 2 superscript ^{b} = .04.

[2]Percentages (%) who voted for using GE to help trees resist chestnut blight. Percentages with different letter superscripts (^{a,b}) across this row differ ($p < .05$) using the decomposed Likelihood ratio χ^2 tests. Percentages with the same letter superscripts do not differ ($p > .05$). Phi (ϕ) effect sizes between the 4 superscript ^{a} and 2 superscript ^{b} = .41–.66, among the 4 superscript ^{a} = .05–.18, and between the 2 superscript ^{b} = .12.

[3]Means on 4-point scale: 1 "not certain" to 4 "extremely certain." Means with different letter superscripts (^{a,b}) across this row differ ($p < .05$) using Tamhane's post-hoc tests. Means with the same letter superscripts do not differ ($p > .05$).

Table 2. Within-subjects analyses comparing pre- and post-treatment attitudes toward using GE to restore AC trees (Study 2).

	Pretreatment[1]	Post-treatment[1]	Difference[2]	Paired *t*	*p*	Cohen's *d* effect sizes
Description only	3.20	3.87	$+0.67^{a}$	7.70	<.001	.67
Scientific information	3.51	4.04	$+0.53^{a}$	6.49	<.001	.56
Positive framing	3.34	3.99	$+0.65^{a}$	5.54	<.001	.66
Positive framing + scientific consensus in support	3.43	4.12	$+0.69^{a}$	6.89	<.001	.75
Negative framing	3.30	2.70	-0.60^{b}	4.70	<.001	.51
Negative framing + scientific consensus in opposition	3.37	2.61	-0.76^{b}	4.87	<.001	.67

[1]Means on 5-point scale: 1 "strongly disagree" to 5 "strongly agree" that "I am in favor of using genetic modification of trees to help them resist chestnut blight."
[2]Numbers with different letter superscripts (^{a,b}) down this column differ ($p < .05$) using Tamhane's post-hoc tests. Numbers with the same letter superscripts do not differ ($p > .05$). $F = 35.59$, $p < .001$, $\eta = .50$. The patterns in these results are consistent with those in Table 1.

"minimal" [Vaske 2019]). However, the two negative treatments (scenarios 5 and 6) yielded significantly less favorable and negative attitudes, with the most negative response ($M = 2.61$) after scenario 6 (descriptions, scientific information, negative framing, scientific consensus in opposition). These between-subject comparisons showed that attitudes differed significantly among the six scenarios (ANOVA $F = 40.92$, $p < .001$) and the eta (η) effect size of .53 suggested that the strength of these differences was "substantial" based on guidelines from Vaske (2019).

Almost all respondents (80–93%) would vote for this use of GE after reading scenarios 1 through 4 (descriptions, scientific information, positive framing, scientific consensus in support), but this dropped dramatically to just 40% after scenario 5 (descriptions, scientific information, negative framing) and even further down to 29% after scenario 6 (descriptions, scientific information, negative framing, scientific consensus in opposition). These differences among scenarios were significant (chi-square $\chi^2 = 158.90$, $p < .001$) and "substantial" (Cramer's V effect size = .55; Vaske 2019). Certainty of these intentions was lowest ($M = 2.84$ on scale of 1 "not certain" to 4 "extremely certain") for scenario 1 (descriptions only) and highest ($M = 3.21$–3.25) for scenarios 3 and 4 (descriptions, scientific information, positive framing, scientific consensus in support), and these differences were significant ($F = 3.13$, $p = .008$), but not strong ($\eta = .17$).

Within-subjects pre- and post-treatments

On average, attitudes were neutral to slightly positive ($M = 3.35$, $SD = 1.04$ on 5-point scale) and 48% viewed this use of GE favorably before reading any scenario (pretreatment). Although the samples were different, these results were almost identical to those from Study 1 reported earlier ($M = 3.30$, $SD = 1.35$, 44% favored). Attitudes, however, became even more positive after reading (post-treatment) scenarios 1 through 4 (descriptions, scientific information, positive framing, scientific consensus in support) with mean responses increasing from $M = 3.20$–3.51 pretreatment to $M = 3.87$–4.12 post-treatment (Table 2). Conversely, attitudes declined dramatically after the two negative treatments (scenarios 5 and 6; descriptions, scientific information, negative framing, scientific consensus in opposition) with mean responses decreasing from $M = 3.30$–3.37

Table 3. Within-subjects changes in attitudes toward using GE to restore AC trees between pre- and post-treatments (Study 2).[1]

Pretreatment vs. post-treatment changes	Description only	Scientific information	Positive framing	Positive + scientific consensus	Negative framing	Negative + scientific consensus
Became negative (disagree)						
Neutral to disagree	0	0	1	0	22	23
Agree to disagree	0	0	2	0	11	17
Became positive (agree)						
Neutral to agree	25	23	29	25	6	5
Disagree to agree	9	6	7	8	1	5
Became neutral						
Disagree to neutral	4	6	5	0	2	2
Agree to neutral	0	2	1	1	11	9
No change						
Stayed disagree	8	6	3	5	15	12
Stayed neutral	13	3	8	7	8	10
Stayed agree	41	55	44	54	24	17

[1]Percentages (%). $\chi^2 = 248.60$, $p < .001$, Cramer's $V = .29$. Initially measured on 5-point scale: 1 "strongly disagree" to 5 "strongly agree" that "I am in favor of using genetic modification of trees to help them resist chestnut blight."

pretreatment to $M = 2.61$–2.70 post-treatment. These changes in attitudes were statistically significant (paired-samples $t = 4.70$–7.70, $p < .001$) and the Cohen's d effect sizes (.51–.75) indicated that the strength of these changes can be interpreted as "typical" to "substantial" (Vaske 2019). The largest changes in attitudes (pre- vs. post-treatment) resulted from the two scientific consensus scenarios (scenarios 4 and 6; Cohen's d = .67–.75, change in M = .69 and −.76).

For scenarios 1–4 (descriptions, scientific information, positive framing, scientific consensus in support), attitudes for the largest proportions of respondents stayed positive (in favor; 41–55%) or increased from negative or neutral to positive (29–36%) between the pre- and post-treatments (Table 3). Among these four scenarios, the largest proportion changed attitudes (45%) after reading scenario 3 (descriptions, scientific information, positive framing) with most becoming more positive. Conversely, attitudes for 33% of respondents declined from positive or neutral to negative (i.e., did not favor) after scenario 5 (descriptions, scientific information, negative framing) and 40% changed their attitudes to negative after scenario 6 (descriptions, scientific information, negative framing, scientific consensus in opposition).

Interestingly, attitudes for 27–31% of respondents remained positive or became positive after the two negatively framed scenarios (5 and 6), and 5–6% remained negative or became negative after the two positive scenarios (3 and 4; Table 3). In fact, 13–15% responded inconsistently to these positive scenarios and 39–41% responded inconsistently to the negative scenarios. Respondents were consistent (59–87%) if their attitudes changed in the expected direction from pre- to post-treatments (e.g., from neutral to agree, disagree to agree, disagree to neutral after positively framed scenarios) and inconsistent if they did not change as expected (e.g., neutral to disagree, agree to disagree, agree to neutral after positive scenarios). Those who responded consistently were more easily persuaded, whereas some inconsistent respondents likely exhibited biased information processing. Compared to those who responded inconsistently, those who were consistent had more: (a) favorable pre- and post-treatment attitudes and post-treatment intentions for positively framed scenarios, (b) unfavorable pre- and post-treatment

Table 4. Within-subjects comparisons between those whose attitudes changed between pre- and post-treatments consistent with the positive or negative message framing versus those whose attitudes changed inconsistently (Study 2).

Positive/negative scenarios	Inconsistent[5]	Consistent[6]	t or χ^2	p	Point-biserial correlation (r_{pb}) or phi (ϕ) effect sizes
Positive framing					
Pretreatment attitudes[1]	3.00	3.40	1.37	.175	.15
Post-treatment attitudes[1]	2.29	4.31	7.99	<.001	.76
Post-treatment behavioral intentions[2]	29	95	29.48	<.001	.66
Post-treatment behavioral certainty[4]	2.93	3.27	1.60	.112	.17
Positive + scientific consensus					
Pretreatment attitudes[1]	2.55	3.56	3.54	.001	.36
Post-treatment attitudes[1]	2.36	4.38	7.10	<.001	.78
Post-treatment behavioral intentions[2]	45	100	28.07	<.001	.71
Post-treatment behavioral certainty[4]	2.91	3.30	1.22	.249	.20
Negative framing					
Pretreatment attitudes[1]	3.69	3.02	3.03	.003	.31
Post-treatment attitudes[1]	3.97	1.83	13.77	<.001	.83
Post-treatment behavioral intentions[3]	22	87	39.06	<.001	.65
Post-treatment behavioral certainty[4]	2.89	3.25	1.94	.056	.21
Negative + scientific consensus					
Pretreatment attitudes[1]	3.38	3.35	0.10	.920	.01
Post-treatment attitudes[1]	3.82	1.83	13.49	<.001	.83
Post-treatment behavioral intentions[3]	32	96	44.52	<.001	.69
Post-treatment behavioral certainty4	2.82	3.26	2.53	.013	.27

[1]Means on 5-point scale: 1 "strongly disagree" to 5 "strongly agree" that "I am in favor of using genetic modification of trees to help them resist chestnut blight."
[2]Percentages (%) vote *for* using GE to help trees resist chestnut blight.
[3]Percentages (%) vote *against* using GE to help trees resist chestnut blight.
[4]Means on 4-point scale: 1 "not certain" to 4 "extremely certain."
[5]After positive scenarios: changed from neutral to disagree, agree to disagree, agree to neutral, stayed disagree, stayed neutral. Positive framing = 15%, Positive + scientific consensus = 13%.
After negative scenarios: changed from neutral to agree, disagree to agree, disagree to neutral, stayed agree, stayed neutral. Negative framing = 41%, Negative + scientific consensus = 39%.
[6]After positive scenarios: changed from neutral to agree, disagree to agree, disagree to neutral, stayed agree.
Positive framing = 85%, Positive + scientific consensus = 87%.
After negative scenarios: changed from neutral to disagree, agree to disagree, agree to neutral, stayed disagree.
Negative framing = 59%, Negative + scientific consensus = 61%.

attitudes and post-treatment intentions for negative scenarios, and (c) certainty of their intentions in response to positive and negative scenarios (Table 4). These differences were significant ($p < .05$) in 11 of 16 tests, and the effect sizes for these significant tests (.27–.83) were "typical" to "substantial" (Vaske 2019). There were no differences ($p >$ .05) between those who responded consistently versus inconsistently in their demographic characteristics (age, male/female, political orientation) and the amount of consensus (e.g., standard deviations) for their attitudes.

Discussion

Findings from the representative sample of the U.S. public (Study 1) showed that this sample was, on average, neutral to slightly supportive of using GE to mitigate CB and restore AC trees. The majority of these respondents (57%) would vote for this use of GE and 71% were moderately or extremely certain of these intentions. Similarly, Study 2 (experiment) showed that, on average, attitudes were neutral to slightly positive before reading any scenarios (pretreatment). These results are similar to Hajjar et al. (2014) and Hajjar and Kozak (2015) who reported that approximately 50% of residents within Western Canada supported the planting of trees containing traits from GE. Findings are also similar to most other studies showing majority public support for using GE in forestry (e.g., Kazana et al. 2016; NASEM 2019; Nonić et al. 2015). However, these results differ from many studies of GE in food and agriculture (e.g., soy, potato, corn) where attitudes can be relatively negative and partially driven by perceptions of health risks to humans from consuming these foods (NASEM 2016; Scott et al. 2018). Even though chestnuts are occasionally eaten by some people, the public in this study appeared to be more supportive of GE in forestry, with this support partially driven by perceived environmental benefits that include restoration of species such as the AC (Petit, Needham, and Howe 2021a, 2021b).

However, this support for using GE to help AC trees resist CB is sensitive to messaging and susceptible to persuasion, as both the between- and within-subjects comparisons in Study 2 showed that support dropped dramatically as soon as messages provided negative or opposing arguments. The first scenario to include negative framing (scenario 5) caused attitudes and intentions to switch from being supportive to opposed. Although not statistically different from scenario 5, these attitudes and intentions became even more negative when message framing included scientific consensus in opposition (scenario 6). These results are consistent with theories such as prospect theory (Kahneman and Tversky 1979) and gain/loss or risk aversion theories (Tversky and Kahneman 1991), which propose that losses and other forms of negative message framing can be most influential over attitudes and intentions.

The between-subjects comparisons showed that most responses after reading the first four scenarios (descriptions, scientific information, positive framing, scientific consensus in support) were statistically equivalent (post-treatment). In addition, the within-subjects comparisons showed that pretreatment responses became more positive post-treatment even after providing only neutral information (scenarios 1 [descriptions] and 2 [scientific information]). Taken together, these findings may have occurred because the majority of respondents had positive initial attitudes about this use of GE to begin with, so learning more neutral and factual details, receiving positive messages, or learning that there was scientific consensus in support only served to maintain (post-treatment) and in some cases even strengthen (more positive pre- to post-treatment) these attitudes. Responses to these four scenarios, however, differed dramatically from the two scenarios that presented negative information. Maheswaran and Meyers-Levy (1990) examined attitudes toward health issues and found that positive framing was more influential when detailed processing was not required, whereas negative information was more influential when complex processing was activated. Although speculative, the complexity of understanding both CB and GE likely required detailed processing for respondents here, which may explain why the negative messages had a much larger influence on attitudes and intentions.

The within-subjects comparisons showed that the two scenarios depicting scientific consensus (4 and 6) yielded the largest pre- versus post-treatment changes in attitudes. The positively worded message coupled with scientific consensus in support was most favorable, whereas the negative message with consensus in opposition was least favorable. These findings are consistent with research showing that scientific consensus can influence public responses. Lewandowsky, Gignac, and Vaughan (2013), for example, examined acceptance of the validity of climate change and other issues, and found increasing acceptance when scientific consensus was emphasized. Theories and concepts such as the social amplification of risk (Kasperson et al. 1988), cultural cognition of risk (Kahan 2012), cultural cognition of scientific consensus (Kahan, Jenkins-Smith, and Braman 2011), and balance as bias (Boykoff and Boykoff 2004) suggest that public opinion can be skewed away from scientific consensus when messages lacking this consensus are given a communication platform (e.g., a televised debate). The between-subject comparisons, however, showed only a slight increase in attitudes and intentions between scenarios providing positive information (scenario 3) and this information coupled with scientific consensus (scenario 4), and a slight decrease between scenarios with negative information (scenario 5) and this information plus consensus (scenario 6), suggesting that the direction of information (negative vs. positive) was more influential than scientific consensus.

Despite these findings, some Study 2 respondents either did not change their attitudes and intentions, or they responded inconsistently to the treatments. For example, 27–31% remained positive or were more in favor of this use of GE after reading negatively framed messages, and 5–6% remained negative or became more opposed after reading positive messages. In total, 13–15% responded inconsistently to the positive messages and 39–41% responded inconsistently to the negative messages. Although these percentages are smaller than for those whose attitudes changed in the expected direction in response to framing (59–87%), they suggest that some respondents likely exhibited biased processing by comparing their preexisting attitudes with the messaging and then refuting any inconsistencies (McFadden and Lusk 2015; Teel et al. 2006). This pattern was most prevalent among those who already had positive attitudes and did not let the negative messages sway these attitudes. Compared to individuals who responded inconsistently, those who responded in the expected direction were slightly more certain of their attitudes in response to the framing scenarios, suggesting that although some who responded inconsistently likely engaged in biased information processing, their attitudes were not necessarily stronger.

Approximately one-quarter of Study 1 respondents had neutral attitudes and were only slightly certain of their intentions. Similar percentages of Study 2 respondents (35%) had neutral attitudes before reading any scenarios (pretreatment). These results suggest that attitudes toward this topic for some people may not be well-formed, salient, accessible, or strongly held (Howe and Krosnick 2017). In fact, the within-subjects comparisons in Study 2 showed that simply adding a short and simple description of this use of GE had a positive influence on attitudes with most respondents being more likely to favor this approach. Adding a small amount of scientific information to this description had a similar effect. In other words, responses became more positive after providing just descriptions and scientific information. These findings are consistent with some previous research (Davidson et al. 1985; Hallman et al. 2003; Klerck and Sweeney 2007; McPhetres et al. 2019; Petty and Cacioppo 1984).

Interestingly, respondents who received the first positive treatment (scenario 3 [descriptions, scientific information, positive framing]) were slightly less supportive of this use of GE than those who received only descriptions and scientific information. In addition, attitudes for a few respondents (7–10%) became positive after being exposed to only negative framing, or became negative after exposure to only positive framing (0–3%). Although these results seem counterintuitive and paradoxical, research has shown that persuasive messages containing only positive or negative information can sometimes be resisted or perceived as disingenuous or lopsided (e.g., a sales pitch), thereby diminishing or changing support and favorability. "The inoculation effect" (Banas and Rains 2010; Eagly and Chaiken 1993) suggests that persuasion attempts are sometimes more effective when messaging contains a weak counter-argument rather than being solely based on unidirectional (one-sided) information in support or opposition.

These findings have implications for practitioners who may use biotechnologies such as GE to manage natural resource issues. Attitudes and intentions regarding the use of GE in this forest conservation context (mitigate CB, restore AC) appear to be supportive, but also malleable to communication messaging and persuasion. The within-subjects comparisons, for example, showed that each of the six message framing treatments had a statistically significant influence on baseline (pretreatment) attitudes. Differences were also observed with between-subjects comparisons where responses to negative treatments (negative framing, scientific consensus in opposition) differed significantly from all other treatments, with attitudes shifting from favorable to unfavorable and intentions dropping from support to opposition. Results also showed that highlighting scientific consensus in support of this use of GE is an effective persuasion tactic for slightly improving support, whereas highlighting consensus in opposition slightly reduces support. Communication campaigns, therefore, might succeed in modifying attitudes and intentions associated with this issue by using targeted message framing. If a goal is to increase favorability or support even more, communication from scientists and other experts is needed that not only focuses on benefits, but also articulates any actual objective risk assessments to ameliorate any misinformation that can accentuate common perceived risks (NASEM 2019).

In conclusion, GE has been used for addressing CB and helping to restore AC trees in controlled field trials and laboratory settings, and researchers are currently requesting regulatory and agency approval for wider release of these transgenic AC trees (Powell 2016; Zhang et al. 2013). Findings suggest that the largest proportions of people would respond positively, but responses are susceptible to communication and persuasion campaigns. These results, however, are limited to two samples of the public and their responses to the use of GE for addressing a single forest health threat (CB) in one tree species (AC). The Study 1 sample was selected randomly from resident addresses and the resulting data were weighted by census information to increase the representativeness of this sample to the larger target population. Even with these efforts to attain a representative sample using survey research methods that are well established in the literature, the sample size and response rate for Study 1 were somewhat low, even after a large number (six) of contacts (Vaske 2019). Response rates have rapidly declined in research involving surveys asking the public about natural resource issues (Stedman et al. 2019). Study 2 was not designed to be representative of a larger population, but instead to experimentally test for effects of the message framing treatments. However, initial attitudes regarding this use of GE were almost identical between Study 1 and Study 2 respondents. Regardless, the applicability and generalizability of findings to larger and more recent samples, as well as to additional forest health threats, such as climate change and other diseases and pests (e.g., emerald ash borer, mountain pine beetle), remain topics for further empirical investigation.

Acknowledgments

The authors thank the US Endowment for Forestry and Communities and the Forest Health Initiative for funding this research. Three anonymous reviewers, the Associate Editor, and the Editors-In-Chief are thanked for their comments on earlier versions of this article.

Funding

Funding was from the US Endowment for Forestry and Communities and the Forest Health Initiative, grant number 2013-015.

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