Journal of Agricultural Education, 57(4), 160-173.
https://doi.org/10.5032/jae.2016.04160

Saving Citrus: Does the Next Generation see GM Science as a Solution?

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Abstract

Citrus is one of Florida's most prominent commodities, providing 66% of the total United States' value for oranges. Florida's citrus production decreased 21% in 2014 from the previous season, partly due to the disease citrus greening. The science of genetic modification (GM) is one of the most promising solutions to the problem. However, a majority of American adults believe foods produced using GM science are unsafe for consumption. This study investigated the diffusion of GM science among Millennial students in a College of Agriculture at a land-grant university and their intent to consume citrus from a tree developed with GM science. An online survey collected data about Rogers' diffusion of innovation model characteristics and intent to consume GM citrus from 98 respondents. Relative advantage and compatibility of GM science were rated most favorably; observability was rated the lowest. The majority of respondents were likely or extremely likely to consume fruit or juice from GM trees. Compatibility was the only significant predictor of likelihood to consume GM citrus. A better demonstration of GM science's relative advantage, compatability, trialability, complexity and observability through formal education is needed to improve GM science adoption by Millennials.

Keywords: Genetic Modification, Citrus, Citrus Greening, Innovation, Undergraduates

This project was funded by the USDA's National Institute of Food and Agriculture through the Specialty Crops Research Initiative/Citrus Disease Research & Extension. USDA NIFA Award No. 2015-70016-23028. Researchers presented a version of this manuscript at the American Association for Agricultural Education Southern Region Conference in February 2016

Introduction

In Florida, the agricultural industry remains one of the state's top economic contributors, adding more than $104 billion to the state's economy and providing more than two million jobs (FDACS, 2013). The industry produces 300 different agricultural commodities from 9 million acres of farm land and 47,500 farms (FDACS, 2013). Citrus is one of the state's most prominent

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commodities, employing more than 75,000 (Rahmani & Hodges, 2009) and providing 66% of the total United States' value for oranges and 65% of the total United States' value for grapefruit (FDACS, 2013). Florida's 124.0 million boxes of citrus produced in the 2013-2014 season made up 59% of the United States' total citrus production (Hudson, 2015). However, Florida's citrus production was down 21% from 156.2 million boxes produced in the 2012-2013 season (Hudson, 2015).

Citrus greening disease (also known as Huanglongbing or HLB) is a contributing factor to the drop in Florida's citrus production. "Citrus greening is considered to be one of the most serious citrus diseases in the world" (USDA APHIS, 2014, para. 4). Citrus greening was first found in Florida in 2005 and is now prevalent in citrus groves and residential citrus trees throughout the state (Burrow, Spann, Rogers, & Dewdney, 2014). The bacterial disease is spread by the Asian citrus psyllid and causes both the citrus tree and fruit to produce adverse symptoms such as yellowing and decreased fruit size and quality (Burrow et al., 2014; Danyluk, Spann, Rouseff, Goodrich-Schneider, & Sims, 2011). Mature trees infected with citrus greening become less productive and in some cases stop producing fruit. Young trees infected with the disease commonly die within one to two years (Brlansky, Dewdney, & Rogers, 2013). Citrus growers participate in management paractices such as integrated pest mangagement, scouting, and tree removal in an effort to control the spread of the disease, but there is no cure for citrus greening (Brlansky et al., 2013; USDA APHIS, 2014). Florida lost more than 216 million boxes of citrus, $4.54 billion in economic output, and 8,257 jobs from citrus greening from the 2006-2007 citrus season to the 2010-2011 citrus season (Hodges & Spreen, 2012). "Despite everyone's best efforts, HLB now literally threatens the survival of Florida citrus and is a potential threat the entire U.S. citrus industry" (USDA ARS, 2016, para. 2).

The science of genetic modification (GM science) has been identified as one of the potential solutions to citrus greening (Korves, 2015; Mahgoub, 2016) and has already been used to save the papaya industry in Hawaii (Gonsalves, Ferriera, Manshardt, Fithc, & Slightom, 2000). Papaya ringspot virus (PRSV) was devastating papaya production in Hawaii, and traditional treatments were unable to stop the spread of PRSV. Genetically modified (GM) papaya was found to be a viable solution, and more than half of the papaya grown in Hawaii was GM by 2006 (Lemaux, 2008). The U.S. government has invested more than $380 million dollars in finding a solution to citrus greening (USDA, 2016), with GM science being the most promising solution to save the industry (Bove, 2012). However, consumers have not typically viewed GM science as favorable (Frewer, Scholderer, & Bredahl, 2000), which has made "… consumer acceptance of biotechnology a critical issue for stakeholders in all nations" (Irani, Sinclair, & O'Malley, 2001, p. 7). According to Funk and Rainie (2015), 57% of American adults believe foods produced using GM science are not safe for consumption, yet science has found food produced using GM science to be safe and unrelated to health issues (National Academy of Sciences, 2016; Nicolia, Manzo, Veronesi, & Rosellini, 2014).

Consumer acceptance of new technology is essential for the success of a product (MacFie, 2007). Understanding consumer perceptions of food produced using GM science provides insight to the potential acceptance and success of citrus produced through GM science. Clough (2011) stated "…knowledge, accurate or not, is what citizens use when assessing public issues involving science and technology" (p. 701). Once an individual has completed formal education, media becomes their main source of information about science and science-related topics (Nisbet et al., 2002). Therefore, it is important for educational institutions both at the secondary and post-secondary levels to educate students using an interdisciplinary approach to public issues involving science and technology, so that they are able to respond to real-world problems as they enter adulthood (DiBenedetto, Lamm, Lamm, & Myers, 2016). In addition, current undergraduate students in colleges of agriculture and life sciences will be serving as the future leaders of the agricultural industry; therefore, their ability to address society's changing demands (DiBenedetto et al., 2016) and understanding of science as it relates to food production practices is extremely important. Lamm, Lamm, and Strickland (2013) identified changing cultures and increased pressures on the land-grant system as challenges that need to be addressed in the classroom as agricultural educators prepare future leaders. The land-grant mission supports innovative ideas and technological advacements, while translating science and research to the public; however, little is known about how undergraduate students within colleges of agriculture and life sciences think about and make decisions regarding the use of GM science.

Adults, both young and old, have been found to have similar beliefs about the safety of GM food (Funk & Rainie, 2015). Additionally, Ruth, Gay, Rumble, and Rodriguez (2015) found that college students were generally unsure about the risks and benefits related to GM food. Most of today's college students are part of the Millennial generation. Those in the Millennial generation were born between 1980 and 2002 (Elmore, 2010; Howe & Strauss, 2007; Payment, 2008; Taylor, & Ketter, 2010) and make up 23% of the United States' population (American Community Survey, 2014). The Millennial generation has been identified as having more buying power than previous generations (Hais & Winograd, 2011), further extending the need to educate this generation about GM science and GM food. Additionally, research has shown that college students form attitudes about issues throughout the course of their collegiate studies (Sears, 1986), thus making them an important population to study (Goodwin, 2013). This study sought to determine if GM science has diffused among Millennial students in a college of agriculture and life sciences at a land-grant university and if they would be willing to consume citrus from a tree developed with GM science. This research directly aligns with priority two of the American Association for Agricultural Education's National Research Agenda, which calls for research that examines adoption decisions associated with new technologies, practices, and products (Roberts, Harder, & Brashears, 2016). By further understanding the diffusion of GM science, agricultural educators can enhance educational methods that will assist undergraduate students in making informed decisions about GM science as it relates to the future of agricultural production.

Theoretical Framework

The theoretical framework for this study stems from Rogers' diffusion of innovation theory (2003). According to Rogers (2003), an innovation is, "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p. 12). In this study, GM science represents the innovation. Rogers described five characteristics that determine the rate of adoption for an innovation: (a) Relative advantage, (b) compatibility, (c) complexity, (d) trialability, and (e) observability. Relative advantage is "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 2003, p. 229). Compatibility pertains to how easily an individual can fit the innovation into his/her life and if the innovation is consistent with his/her values and needs (Rogers, 2003). Complexity describes how easy an innovation can be understood and used. Trialability is how the innovation can be experimented with by adopters and is positively related to rate of adoption. Lastly, observability is defined as "the degree to which the results of an innovation are visible to others" (Rogers 2003, p. 16). Higher rates of adoption are observed when relative advantage, compatibility, trialability, and observability are high and complexity is low.

Diffusion of innovation theory (Rogers, 2003) has been used extensively in agricultural education research and provides a strong foundation for diffusing an innovation such as GM science (e.g., Bowen, Stephens, Childers, Avery, & Stripling, 2013; Murphrey & Dooley, 2000; Rollins, 1993). Murphrey and Dooley (2000) recommended increasing diffusion of an innovation, in an educational setting, by using incentives to boost relative advantage; increasing compatibility by tying the innovation to "existing values, past experiences, and needs of potential adopters" (Murphrey & Dooley, 2000, p. 48); reducing complexity by focusing on less complicated components of the innovation and providing technical expertise for more complicated components; providing the opportunity for individuals to start the diffusion process to boost trialability; and by increasing observability through the recognition of innovation success.

Diffusion of innovation theory has also been applied to the adoption of GM food. Weick and Walchi (2002) assessed the five factors of diffusion to identify how to make GM food successful in the consumer marketplace. Environmental risks associated with growing GM food, perceived health risks, and ethical concerns were expected to negatively impact relative advantage of GM food. The researchers concluded that GM science should be compatible with United States consumers due to the culture's ability to embrace technology and science. The complexity of GM food was determined to be high because of consumers concerns with the effects of the GM food, how it is produced, and the science involved in GM food development. Since the current societal benefits of GM food had not directly benefited the United States consumer at the time of the study, the researchers indicated that trialability of GM food was limited. When assessing observability, the researchers reflected upon Enriquez and Goldberg's (2000) suggestion that consumers focused more on the risks of GM food because the benefits could not be directly seen by consumers. The researchers concluded that the five factors had either a neutral or negative effect on the adoption of GM food. In a similar study, Klerck and Sweeney (2007) predicted the attitudes toward GM food would have to be positive for the innovation to be viewed as having a greater relative advantage compared to other food products. Further research is necessary to understand the adoption of GM science as an innovation, particularly in a context like citrus greening where it may be one of the best possible solutions.

Purpose and Objectives

The purpose of this study was to determine if the acceptance of GM science has diffused among Millennial students in a College of Agriculture at a land-grant university and if they would be willing to consume citrus from a tree developed with GM science. The strength of the diffusion will allow educators to identify a need to further enhance educational methods to translate GM science throughout formal education. The following research objectives guided the study:

1. Describe undergraduate students' perceived relative advantage, compatibility, complexity, trialability, and observability of GM science.
2. Describe undergraduate students' likelihood of consuming citrus products made with GM science.
3. Determine if undergraduate students' perceived relative advantage, compatibility, complexity, trialability, and observability of GM science predicts their likelihood to consume citrus products developed from GM science.

Methods

The study's population was undergraduate students, 18 and older, enrolled in the College of Agriculture and Life Sciences at the University of Florida. The population was sampled through a convenience sample of two general education courses offered to undergraduate students in the College of Agriculture and Life Sciences at the University of Florida ($N = 175$). Both courses were focused on research and business writing. A convenience sample was suitable due to practical restraints, efficiency, and ease of access to students in the College of Agriculture and Life Sciences (McMillan & Schumacher, 2010). However, the use of a convenience sample limits the generalizability of the results (McMillan & Schumacher, 2010).

The instructors generated a list of students' names and email addresses of those enrolled in their course. The questionnaire was administered using Qualtrics, an online survey development tool. The target population had access to the Internet, therefore an online survey instrument was used (Dillman, Smyth, & Christian, 2014). The instructors announced the upcoming survey in their course period prior to the launch of the survey. Each student was given an identification number and emailed a personalized link to the survey. Students had one week to complete the survey, with reminders sent on day six and day seven (Dillman et al., 2014). Extra credit in the course was given for completing the survey. The incentive of extra credit presents limitations to the study as it may have caused students to complete the survey only for the extra credit, paying little attention to the questions or providing much thought to their responses. A total of 123 students responded to the survey, achieving a response rate of 70.3%. Twenty-five of the respondents were removed from the sample due to age restrictions and incomplete data, reducing the number of usable responses to 98.

The survey was part of a larger research study, but for the purposes of this manuscript, six constructs were used for analyses, in addition to demographic questions (age, gender, race, and class rank). All questions and constructs were researcher developed. Prior to data collection, a panel of experts reviewed the final instrument to ensure face and content validity and IRB approval was obtained from the University of Florida. The panel of experts included the Associate Director of the UF/IFAS Center for Public Issues Education, an assistant professor focused on food production and well published in GM science, and an associate professor with extensive knowledge in survey design.

To measure undergraduates' perceived relative advantage, compatibility, trialability, complexity, and observability of GM science, researchers used a series of Likert-type and semantic differential scales. To measure undergraduate students' percieved relative advantage, compatibility, and trialability of GM science, a five-point Likert scale was used (1 = *Strongly disagree*, 2 = *Disagree*, 3 = *Neither agree nor disagree*, 4 = *Agree*, 5 = *Strongly agree*).

The construct measuring relative advantage included eight items with an alpha reliability of .88. The question in the construct asked about the advantages to GM science and included statements such as, "GM science enhances the taste of food" and "GM science increases the amount of food a farmer can grow." An index for relative advantage was created by taking the average of the items in the construct.

Compatibility was measured by six statements that asked about how GM science aligned with the respondent's beliefs and values. An example of some of the items in this construct included, "Developments in GM science help make society better" and "Overall, GM science does more harm than good." Negatively framed statements were reverse coded before data anlysis. The six items were found to be reliable ($\alpha = .88$). An average of the items was taken to create an index for compatability.

The construct measuring undergraduate students' perceived trialability of GM science included five items asking respondents about their interaction with or ability to try products made from GM science, such as "Food products that result from plants made with GM science are easy to try" and "The opportunity to try food products that result from plants made with GM science is not available to me." Negatively framed statements were reverse coded before data anlysis. The items had an alpha reliability of .58. However, after the removal of one of the statements, reliability increased to .71. The reliability of the construct was determined to be acceptable according to Baruch and Holtom (2008). An average of the remaining four items in the contsrtuct was calculated to create an index for trialability.

Complexity and observability of GM science were measured on five-point semantic differential scales. These questions asked the respondents to indicate how they felt about a statement by marking where they fell between two bipolar adjectives or statements. For both constructs, negative adjectives were assigned a 1 (e.g. "complex" or "invisible") and positive adjectives were assigned a 5 (e.g. "simple" or "visible"). Therefore, scores closer to one represent high complexity or low visibility, while scores close to five represent low complexity or high visibility. Six pairs of adjectives were used to measure complexity and had an alpha reliability of .77. The six pairs of adjectives were averaged to create an index. Six pairs of adjectives were used to measure observability and had an alpha reliability of .89. These items were averaged to create an index for observability.

The last question asked respondents to indicate their likelihood of consuming fruit or juice grown on a genetically modified tree. To measure their likelihood to consume, a five-point Likert-type scale was used (1 = *Extremely unlikely*, 2 = *Unlikely*, 3 = *Neither likely nor unlikely*, 4 = *Likely,* and 5 = *Extremely likely).*

Following the descriptive analysis of each construct (objectives one and two), the respondents' likelihood of consuming GM citrus was recoded into a dichotomous variable for analysis using logistic regression for objective three. Responses of extremely unlikely, unlikely, or neither likely nor unlikely were given a score of "0" and responses of likely or extremely likely were assigned a "1."

Results

Description of Respondents

Of the useable responses, 66.3% were female and 33.7% were male (see Table 1). The majority of respondents were Caucasian (85.7%), followed by Asian or Pacific Islander (10.2%), Black or African American (5.1%), and American Indian or Alaska Native (2.0%). Additionally, 18.4% considered themselves to be Hispanic, Latino, or Chicano. More than half indicated their age ranged between 21-25 years old (64.3%). When looking at college rank, most of the respondents were juniors (61.2%), followed by seniors (35.7%), and then sophomores (3.1%).

Perceived Relative Advantage, Compatibility, Complexity, Trialability, and Observability of GM Science

Respondents were asked to indicate their perceptions of the five characteristics of an innovation (Rogers, 2003) related to GM science. An index was created for relative advantage, compatibility, complexity, trialability, and observability of GM science. The mean and standard deviation for each index are in Table 2. The respondents perceived the relative advantage and compatability of GM science to be more favorable than the trialability, complexity, and observability of GM science. However, relative advantage was the only characteristic with a score falling more than .50 above or below the mid-point of the scale.

Table 1
Demographics

	n	%
Sex		
Female	65	66.3
Male	33	33.7
Race		
Black or African American	5	5.1
Asian or Pacific Islander	10	10.2
White/Caucasian (Non–Hispanic)	84	85.7
American Indian or Alaska Native	2	2.0
Other	7	7.1
Hispanic Ethnicity	18	18.4
Age		
18 - 20	30	30.6
21 - 25	63	64.3
26 - 29	3	3.1
30 - 34	2	2.0
School Rank		
Senior	35	35.7
Junior	60	61.2
Sophomore	3	3.1

Table 2
Diffusion of Innovation Characteristics (N = 98)

	M	SD
Relative Advantage	3.76	.69
Compatibility	3.46	.77
Trialability	3.21	.72
Complexity	2.72	.69
Observability	2.63	.92

Likelihood of Consuming Citrus Products made with GM Science

Table 3 displays the likelihood of respondents' consuming citrus fruit or juice grown from a genetically modified tree. Respondents identified their likelihood on a five point Likert-type scale. Respondents answered favorably to this question with 56.1% indicating they were likely or extremely likely to consume fruit or juice from citrus grown on a genetically modified tree.

Table 3

Likelihood of consuming fruit or juice from citrus grown on a GM tree (N = 98)

	Extremely Unlikely %	Unlikely %	Neither Likely nor unlikely %	Likely %	Extremely Likely %
Likelihood	4.1	13.3	26.5	36.7	19.4

Predicting Likelihood to Consume Citrus Products Developed from GM Science

A logistic regression model was run, using the dichotomous variable as the dependent variable, to determine if perceived innovation characteristics were significant predictors of likelihood to consume. The model was statistically significant (χ^2 = 45.59, p < .01) and could account for 50% of the variance in likelihood to consume GM citrus products (pseudo-R^2 = .50). Compatibility was found to be a statistically significant predictor of likelihood to consume GM citrus (Table 4). This result indicated that as respondents' perceptions of GM science being compatible with their beliefs and values increased by one unit, the odds of respondents being likely or extremely likely to consume GM citrus increased by 5.74. The remaining innovation characteristics were not significant predictors.

Table 4

Influence of perceived GM science innovation characteristics on likelihood to consume citrus products made with GM science

Index	B	Odds	p
Compatibility	1.75	5.74	.00**
Relative Advantage	.84	2.32	.15
Trialability	.61	1.84	.15
Complexity	.45	1.57	.33
Observability	-.05	.95	.88

Note. **p < .01. R^2 = .50.

Conclusions

Understanding undergraduate students' perceptions of GM science and likelihood of consuming a product made with GM science, is important to the future success of the technology (MacFie, 2007) as a solution to diseases such as citrus greening. Additionally, understanding undergraduates perceptions provides insight into how agricultural educators can develop curriculum that assists this audience in making informed decisions about GM science. This study used Rogers' (2003) five characteristics of an innovation to gain a deeper insight into the adoption of GM science and how the level of diffusion influenced the likelihood to consume citrus fruit and juice from a GM tree. The relative advantage of GM science was the only characteristic that the respondents viewed positively. Since the relative advantage of GM food has to be positively perceived for adoption (Klerk & Sweeney, 2007), undergraduate students in this study are likely to adopt GM food, if they have not done so already. This finding indicates students, who will be the future leaders of agriculture, are more accepting of GM science than the general public as Funk and Rainie (2015) found 57% of American adults believe foods produced using GM science are not safe.

However, the findings indicate there are still more barriers limiting the adoption of GM science among this audience. In fact, the respondents viewed the remaining four characteristics of GM science as neutral. Studies have already concluded that Millennials are unsure about GM food (Ruth et al., 2015), and this finding further supported that claim. Weick and Walchi (2002) concluded that trialability and observability of GM products are difficult for consumers to experience with GM products, which is reflected in the neutral characterization of the qualities. However, complexity was found to be neutral in this study, which conflicts with previous literature (Weick & Walchi, 2002). The respondents were students in the College of Agriculture and Life Sciences and may have been exposed to the GM science through their coursework. Learning about GM science in a formal setting may have decreased the perceptions of complexity when compared to the general public. Compatibility also was perceived as neutral by the respondents. Similar to observability and trialability, this characteristic may be difficult to experience, which likely led to the neutral responses.

More than half of the respondents reported they were likely or extremely likely to consume GM citrus fruit or juice in the future. This finding supported prior conclusions in this study that undergraduate students were likely to accept GM products as reflected by their positive perceptions of the relative advantage. This acceptance may stem from their knowledge of GM food or from generational differences in values. Even though relative advantage was the only positive adoption characteristic perceived by the respondents, it was not a predictor of whether they would consume GM citrus. The only predictor was compatibility, which was positively related to consuming GM citrus. The predictive relationship between compatibility and likelihood to consume GM citrus conflicted with prior research. Weick and Walchi (2002) concluded that the characteristics of adoption had either neutral or negative effects on the acceptance of GM food.

In this case, compatibility measured how closely GM science aligned with the respondents' beliefs and values. Since the respondents attended a large research institution and were enrolled in a college of agriculture and life sciences, they may have favorably viewed research and science in general. Their views on their compatibility with GM science likely differ from the general public and can explain this predictive relationship. Trialability, complexity, and observability were likely not predictors simply because they are difficult characteristics for students to comprehend in regards to GM science. However, the fact that relative advantage was not a predictor of adoption when it was the only positive characteristic does have implications. Even though the students perceived scientific, tangible qualities of GM science to be positive, this knowledge was not a predictor for adoption. Undergraduate students' values and beliefs were more important to the decision making process than the relative advantage of the science when examining their intended consumption of GM citrus.

Implications and Recommendations

Consumer acceptance of GM science will be essential for the future success of the citrus industry if the technology is used to combat citrus greening disease. Even though more than half of the respondents reported they were likely or extremely likely to consume GM citrus, the citrus industry and higher education will still need to identify ways to facilitate the diffusion of GM science if they want to encourage the consumption of citrus products produced from GM trees. A large effort should be put toward further educating college of agriculture and life sciences undergraduates about GM science since they will have large purchasing power in the future (Hais & Winogard, 2011) and will be serving as leaders within the agricultural industry (DiBenedetto et al., 2016; Lamm et al., 2013).

Compatibility of GM science with beliefs and values will be important to address since compatibility was the only predictive characteristic of GM citrus consumption. Agricultural educators at higher institutions can help to increase perceptions of compatibility through a variety of outlets. When coursework includes the topic of GM science, educators should seek to connect students' values, experiences, and needs with the science (Murphrey & Dooley, 2000). Various educational methods could be used to achieve this, such as discussion about GM science, how it is conducted, and what people think about it. Activities that could be used in the classroom to get students to engage in deeper reflection and discussion to activate values and needs could include think-pair-share activities or an assignment where students are asked to reflect on their values, experiences, and needs related to GM science and then asked to construct a review of popular and scientific literature to identify how the media and science aligns or misaligns with their thoughts.

Additionally, agricultural education programs can develop an agriculturally based issues class that focuses on controversial industry topics. This course could be used to provide students with a more holistic understanding of topics in agriculture, including GM science. The coursework could focus on the non-science side of the issues, and allow students the opportunity to see the effect of GM science on society as a whole. If the course were offered to students outside of the agricultural education program, perceptions of compatibility may increase throughout the agricultural college.

Another way to increase compatibility would be to partner with the Cooperative Extension Service to host a forum-style event to allow students to interact with scientists, farmers, and consumers to learn more about GM science. Giving students the opportunity to express their own opinions would help to make them feel heard and allow agricultural educators, extension professionals, and communicators to address their concerns. Focusing on the values and beliefs students associated with GM science would help facilitate the adoption of GM citrus in the future.

Even though relative advantage, complexity, trialability, and observability were not significant predictors of consumption of GM citrus, they are still important characteristics in Rogers' (2003) diffusion of innovations theory. The relative advantage and complexity of GM science can be addressed through formal education classes. In classes, educators should make an effort to reduce the complexity of GM science by initially focusing on simple components of the science, similar to the recommendations of Murphrey and Dooley (2000). For example, starting with a discussion of the GM foods currently available to consumers (corn, soybeans, yellow squash, papaya, alfalfa, sugar beets, canola, potatoes, artic apples, cotton, and salmon) can spark interest and decrease cognitive dissonance. By starting with an initial discovery approach, students become interested and start asking questions. The technical expertise of GM science may be appropriate for students required or motivated to take an advanced genetics course, but for students not in those classes, reducing complexity by focusing the discussion less complicated components of the innovation is important (Murphrey & Dooley, 2000). Introductory agriculture or science classes should integrate content about GM science and GM food to expose undergraduate students to the topic early in their academic careers. Similar to the recommendation for compatibility, a forum could be used to help students interact with farmers, residents of developing nations, or consumers to see how using GM food has benefited them and increase perceptions of relative advantage.

Trialability and observability may be difficult for consumers to identify with GM food, but there are opportunities at universities for extension professionals and agricultural educators to promote these characteristics. Agricultural educators discussing GM science or GM food in their courses should look for experiential learning opportunities to accompany their lessons to help encourage the diffusion of these topics. For example, agricultural educators may be able to allow students to try a GM food or experiment with GM science in a laboratory setting.

Observability of GM food or GM science also could be increased by having students identify food products in a grocery store that are genetically modified or by taking a field trip to an on-campus laboratory where GM science could be observed. Tasting panels and educational booths can also be present at campus and community events as well as grocery stores to educate students on what foods are and are not developed by GM science. At campus dining halls, informational posters and signs can be included to help students understand which of the foods they are eating have used GM science and why.

Accompanying the results and conclusions of this study are limitations that should be considered. The convenience sample provided insight into the adoption of GM citrus by College of Agriculture and Life Sciences undergraduate students at the University of Florida, but cannot be generalized. To strengthen the findings, a simple random sample from a population of university students is needed. A replication of this survey with the general public would also add to the body of literature. There may be differences between the general public and undergraduate students, which would lead to alternate recommendations. Another limitation associated with this study was that it measured intent to consume GM citrus, which can be different than actual behavior. To gain a greater understanding of the adoption of GM citrus, an observability study will be necessary. Since GM citrus does not yet exist, one way to observe this behavior would be to offer research participants orange juice under the false pretense that the juice is a GM product, followed by a debriefing of the participants after the research.

A curriculum could also be developed to teach students about citrus greening and GM science. The effects of this curriculum on diffusion as well as likelihood to consume citrus products developed from GM science could then be assessed, perhaps through a pretest-posttest design. Future research also should test message frames to determine how to best promote the adoption of GM citrus. Based on the results from this study, frames should focus on promoting compatibility with GM science. These research recommendations could be used to study other potential GM foods, which have yet to reach the market.

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