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ILLINOIS AGRICULTURE TEACHER ACCEPTANCE OF AGRICULTURE BIOTECHNOLOGY

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ABSTRACT

Some nations have strictly regulated the cultivation of GMO crops, while critics have tried to raise the alarm on potential risks, environmental impact, social justice and ethical concerns regarding certain aspects of biotechnology. Given the recent advances and the benefits to those countries engaged in implementing biotechnology, and the scope of its use in so many countries, it is important that U.S. citizens understand what it is, and how it is employed. This descriptive study sought to assess agricultural teachers' acceptance of agriculture biotechnology by determining teacher knowledge, beliefs about, resources, and opinions on curriculum regarding biotechnology topics. Further, agricultural teachers' perceptions of biotechnology in the curriculum, and their self-efficacy as a teacher of biotechnology were determined. 453 agricultural teachers were surveyed in Illinois, with a response rate of 25.4%. It was found that ag teachers had a positive attitude toward biotechnology; but that they were not familiar with certain biotechnology topics. To achieve teaching success of biotechnology, more remains to be done.

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INTRODUCTION

The advancements of biotechnology in agriculture have improved drastically over the past three decades. The first GMO (genetic modified organism) to be commercialized was the FLAVR SAVR tomato in 1994 (Kramer and Redenbaugh, 1994). The case of FLAVR SAVR resulted in scientific success, and a temporary sales success. However the product failed commercially due to the cost of production and distribution being high (Bruening and Lyons, 2000). Insect resistant Bt corn and Bt cotton, as well as herbicide resistant/tolerate soybeans and oilseed rape, have had greater success (Lucht, 2015). From 1996 to 2016, an accumulated 2.15 billion hectares of biotech crops have been grown commercially, these consist of 1.04 billion hectare of biotech soybean, 0.64 billion hectare of biotech maize, 0.34 billion hectare of biotech cotton and 0.13 billion hectare of biotech canola (ISSA, 2017). Prior to 2011, the global area of biotech crops were evenly distributed between developing countries and industrial countries. In 2017, the global hectarage of biotech crops was 189.8 million hectares, this was led by the United States with 75 million hectares, Brazil with 50.2 hectares, and Argentina with 23.6 hectares. Farmers who grew biotech crops attested to the multiple benefits of growing biotech crops, which include, increased productivity that contributes to global food, feed, and fiber security; self-sufficiency on a nation's arable land; conserving biodiversity, precluding deforestation and protecting biodiversity sanctuaries; mitigating the challenges associated with climate change; and improving economic, health, and social benefits (ISAAA, 2017). The European Union (EU) has one of the strictest regulations regarding cultivating GM crops; currently, the insect resistant Bt maize MON810 is the only authorized GM crop allowed in EU. Five EU countries (Spain, Portugal, Czech Republic, Romania, and Slovakia) currently grows the MON810 and farmers have reported having good experience with the efficacy of Bt maize against the corn borer in infested regions (Gómez-Barbero *et al*. 2008; Lefebvre *et al*. 2014; Lucht 2015). Even in countries that do not cultivate GM crops, farmers have reported having a positive attitude towards GM crops in survey based studies (Areal *et al*. 2011; Jones and Tranter 2014; Lucht 2015). Critics of GM crops generally focus on the potential risks, environmental impact, social justice and ethical concerns (Sandin and Moula 2015). The negative attitude towards GM crops has been associated with insufficient knowledge of GM crops, the lack of trust in developers and/or relevant regulations, poor- risk benefit communications, and ethical concerns (Lucht 2015; Siegrist 1999; Siegrist *et al*. 2012; Tanaka 2004; Wunderlich and Gatto 2015; Ishii and Araki 2016). Numerous negative results regarding GM crops have been published over the past few years; some feeding experiments, for example, often involved feeding assays with different mammals (rats or pigs) (Séralini *et al*. 2014; Carman *et al*. 2013). In a recent study, researchers raised concerns over the claim that the scientific community had achieved consensus over the safety of GM crops. The researchers highlighted several debates and concluded that there was no consensus over the safety of GM crops (Hilbeck *et al*. 2015). Research about consumer-related issues have primarily focused on three topics, (a) public perception and attitude, (b) risk perceptions, (c) willingness to pay for GM/non-GM food (Moon and Balasubramanian, 2007). Knowledge of GMOs is an important area of interest due to the fact that it may affect consumer opinions, attitudes, and behavior. The status of consumer knowledge about GMO food has been widely researched. In a survey conducted by the Food Policy Institute at Rutgers University, it was found that approximately 48% of the US consumers were aware of GMOs being available in the supermarket and only 31% believed that they had likely consumed a GMO product. In the study, 48% self-rated their knowledge of GMO to be poor, and 16% reported that they felt they knew nothing at all. However, 30% reported that they knew a fair amount and 5% reported that they knew a great deal (Hallman *et al*. 2004; Wunderlich and Gatto, 2015). A more recent study conducted by Rutgers University reported that only 43% knew that GMO products were sold in supermarkets, 26% believed that they have consumed GMO food, 54% reported they knew little or nothing at all, and 25% reported that they had never heard of them. In addition, those who reported knowing about GMO food were often misinformed about the products sold in the US; 59% of the consumers knew about GMO soybeans being sold in the US, but over 50% were mistaken that GMO tomato, wheat and chicken were available in the supermarket (Hallman *et al*. 2013). The public's perception and attitude towards biotechnology varies based on the source of information and whether they are familiar with the subject (Mowen *et al*. 2007; Wunderlich and Gatto 2015). In a survey conducted on adult supermarket consumers in New Jersey, there was a slight correlation between knowledge and attitude ($r= 0.41$, $P<0.001$), in the study consumers with higher GMO knowledge measured by a self-reported familiarity with the term and ability to define it, had slightly more positive attitude towards non-GMO products (Vecchione *et al*. 2014). Consumers with high self-reported GMO knowledge have also shown lower willingness to pay for GMO products compared with low self-reported knowledge, based on a study involving the auction of GMO and non-GMO consumer goods (Wunderlich and Gatto 2015).

Agricultural Teacher Perspectives Toward Biotechnology: An increase in biotechnology literacy can be achieved through agricultural education, by educating students in the classroom regarding biotechnology issues. Students may understand the risk and benefits even though they may not be directly involved in some of the processes. Through service learning and agricultural education, students may impact public opinion about world hunger and the role of biotechnology in the food, fiber, and natural resources. Public perception and acceptance are critical to the success of the agricultural biotechnology industry and its products; therefore, quality agricultural education should respond to the students, industry, and community needs (Kirby, 2002; Mowen *et al*. 2007). Research has shown that agriculture teachers generally have a positive attitude towards agricultural biotechnology; however, many indicated the need to incorporate biotechnological subjects into classroom curricula (Iverson 1998; Hughes, 2001; Mowen 2007). In a study conducted among agricultural educators in North Carolina, teachers reported that they lack biotechnology knowledge but they support its importance and recognize the benefits of an integrated curriculum in agricultural education. Teachers perceived that funding equipment and teacher knowledge were the largest barriers to adopting integrated science curriculum (Wilson *et al*. 2002). In a similar study conducted among West Virginia agricultural educators, the teachers reported that they had a positive attitude towards biotechnology but lacked the resources and knowledge to incorporate the subject into the curriculum (Boone *et al*. 2006). In a study conducted among Texas agriculture educators, teachers reported that the likeliness of a topic being taught in a classroom was associated with their self-perceived knowledge of the specific biotechnology topic. Equipment was perceived as the main barrier; whereas, administration support and community support were considered as minor barriers. Teachers also acknowledged responsibilities for educating consumers, farmers, and students about biotechnology and involving students in biotechnology related SAE projects. Teachers disagreed that it was their role to develop instructional materials and lesson plans on biotechnology and workshops, video tapes, and internet were the preferred sources of knowledge (Mowen *et al*. 2007a; Mowen *et al*. 2007b). Modernizing the current curriculum regarding agriculture biotechnology is critical, yet challenging, due to biotechnology being a multidisciplinary field. The principles of biotechnology are excellent tools, however, to determine how effectively biotechnology is being taught or can be taught. Investigating teacher knowledge and perspective is critical (Mowen *et al*. 2007a). Several studies have shown that agriculture teachers have a positive attitude towards biotechnology but also pointed out some challenges they've encountered (Wilson *et al*. 2002; Boone *et al*. 2006; Mowen *et al*. 2007a; Mowen *et al*. 2007b). It is important to examine a teacher's confidence in teaching agriculture biotechnology, their belief in roles of teaching, and the barriers they encounter (Mowen *et al*. 2007b).

Purpose and objectives: The purpose of this study was to assess agricultural teachers' acceptance of agriculture biotechnology. The specific objectives were:

1. Determine Illinois agricultural teachers' knowledge of plant biotechnology topics.
2. Determine Illinois agricultural teachers' belief in the role of plant biotechnology topics in the secondary agricultural education curriculum.
3. Determine Illinois agricultural teachers' sources of knowledge in plant biotechnology.
4. Determine Illinois agricultural teachers' opinions on curriculum regarding plant biotechnology topics.

Theoretical Framework: This study employed Bandura's Social Cognitive Theory and the construct of self-efficacy (Bandura, 1986). Bandura (1986) proposed that the locus of agency in humans is interactive and shares a reciprocal relationship between determinants, action and environmental factors; termed, reciprocal determinism. This led Bandura to conceptualize how people develop belief in their ability to succeed, or self-efficacy. This is used to explain Teaching Success in teaching biotechnology through Cognitive/Personal Factors (determinants), Behavioral and Environmental Factors, Teacher Behavior, and Teaching Success of Biotechnology in the Ag Curriculum (teacher self-efficacy); see Figure 1. Ulmer, *et al*. has reported that student teaching and teacher success has been closely linked to teacher efficacy (2013). He further points out that personal teaching efficacy had been employed to predict teacher behavior (Ulmer, *et al*., 2013; Ashton, Webb, & Doda, 1983).

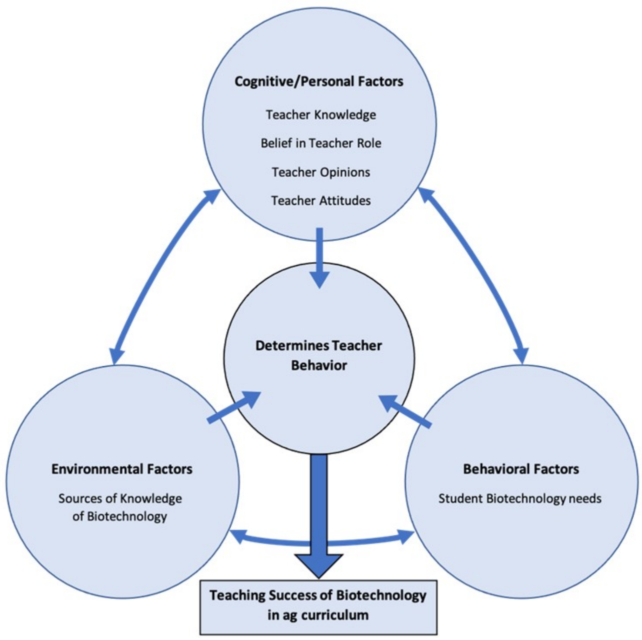

Fig. 1. Adaptation of Bandura's Social Cognitive Theory in teacher acceptance and teaching success with Biotechnology in the Agricultural Education curriculum (Bandura, 1986)

METHODS AND METHODS

A descriptive survey research method was designed to collect data from 453 Illinois agriculture teachers; an Illinois agriculture teacher was defined as the teacher listed on the Illinois agriculture education directory. The survey was designed and modified from an existing questionnaire in a similar study (Wilson *et al.* 2002; Boone *et al.* 2006; Mowen *et al.* 2007a; Mowen *et al.* 2007b). The survey consisted of three sections; in the first section, teachers were asked to describe their demographic information. The second section consisted of 15 questions in which teachers self-assessed their knowledge and awareness of biotechnology. The section was divided into four categories: seven questions for plant biotechnology research techniques, five questions for plant biotechnology products, including two definitions of common terms and one current issue in the industry. The third section was designed to assess the teachers' attitudes on four subjects; four questions regarding the teacher's belief in his/her role, five questions regarding the sources of knowledge, four questions regarding the teacher's opinion on the current curriculum, and four questions about students. The data was collected through an internet survey following Dillman (2000) recommendations and included a cover letter explaining the purpose of the study and the survey. To increase the response rate, an optional gift card draw was provided to the teachers who completed the survey. An initial contact with a link to the internet survey was emailed to the teachers to inform them of the study. To address survey fatigue, three additional contacts were sent as reminders. One section was randomly selected from the Illinois agriculture directory to test the instrument; 7 out of 18 teachers responded in that section (38.9%). A Chronbach Alpha test was used to test the reliability of the instrument; acknowledging a small sample size of 7, the Chronback Alpha yielded a reliability coefficiency of 0.957. This was deemed to be sufficient indication that the instrument was reliable, and the survey proceeded with a census sample of the study's population.

RESULTS

Demographics: In this study, 115 out of 453 surveys were collected (25.4%), and one survey was discarded due to incompletion. Of the 114 surveys, 13 reported to be in the 19-24 age group (11.50%), 35 in the 25-34 age group (30.97%), 24 in the 34-44 age group (21.23%), 24 in the 45-54 age group (21.23%), and 17 in the 55-64 age group (14.04%), one respondent did not specify the age. For the years of teaching experience, 37 reported to have 0 to 5 years of teaching experiences (32.45%), 15 for 6 to 10 years of teaching experiences (13.15%), 16 for 11 to 15 years of teaching experiences (14.03%), 17 for 16 to 20 years of teaching experiences (14.91%), 7 for 21 to 25 years of teaching experiences (6.14%), 10 for 26 to 30 years of teaching experiences (8.77%), and 12 for more than 31 years of teaching experiences (10.52%). There were 53 female respondents and 60 male respondents; one respondent did not specify his/her gender. Overall, 68 respondents had Bachelor degrees, 44 held Master degrees, and two had PhDs.

Self-assessment of plant biotechnology: Illinois agricultural teachers were asked to fill out a self-assessment report based on how knowledgeable they were regarding four topics in biotechnology. The teachers were comfortable with defining the two common terms conventional plant breeding and genetically modified crops (M=3.71 SD=0.75; M= 3.77 SD=0.75). Definitions had the highest overall mean score among the four categories (M=3.75 SD=0.75). Current Issues in the biotech industry had the second highest overall mean score (M=3.24 SD=1.03). In general, teachers were somewhat familiar with the plant biotechnology products (M=3.18 SD=1.10), with roundup ready soybean having the highest score (M=3.83 SD=0.78) followed by Bt corn (M=3.70 SD=0.89). FLAVR SAVR tomato were the least familiar product (M=2.48 SD=1.02). The teachers reported that they were not familiar with the research techniques (M=2.51 SD=1.02), five out of the seven research techniques had a score below 3. CRISPR cas-9 and RNAi technology had the lowest scores (M=1.87 SD=0.83, M=2.00 SD= 0.88). Overall, Roundup ready soybeans (M=3.83 SD=0.78) and Bt corn (M=3.70 SD=0.89) were the most familiar items; whereas, Crispr cas9 (M=1.87 SD=0.83) and RNAi technology (M=2.00 SD= 0.88) were the least familiar items.

Table 1. Illinois agriculture teacher self-assessments in four aspects of plant biotechnology

Knowledge	M	SD
Research techniques:		
CRISPR-cas9	1.87	0.83
RNAi technology	2.00	0.88
Genomic tools	2.29	0.82
Mutation breeding	2.36	0.80
Genome editing	2.45	0.77
Plant tissue culture	2.98	1.01
Plant hybridization	3.62	0.83
Summed scale mean:	2.51	1.02
Plant biotechnology products		
FLAVR SAVR tomato	2.48	1.02
Liberty/Ignite	2.79	1.14
DICAMBA	3.11	1.01
Bt corn	3.70	0.89
Roundup ready soybeans	3.83	0.78
Summed scale mean:	3.18	1.10
Common terms		
Conventional plant breeding	3.71	0.75
Genetically modified crops	3.77	0.75
Summed scale mean:	3.75	0.75
Current issues in the biotech industry		
Bayer/Monsanto deal	3.24	1.03

1= Not at all familiar, 2= Not so familiar, 3= Somewhat familiar, 4= Very familiar, 5= Extremely familiar

Belief in roles of agricultural teacher: Illinois agricultural teachers neither agreed or disagreed on the statement that it is an agricultural teacher's job to develop SAE programs regarding plant biotechnology (M= 3.00 SD= 0.95). They agreed on the statements that the teacher's knowledge and attitude towards plant biotechnology will affect the student's perspective and interest (M= 4.20 SD= 0.68, M= 4.22 SD= 0.60). Overall, the teachers agreed that the teacher plays an important role in teaching plant biotechnology.

Sources of knowledge: Overall, the teachers agreed that having lab experience will help teach plant biotechnology subjects (M=4.26 SD= 0.55). The teachers felt that attending workshops was the best way to gain knowledge (M= 4.23 SD=0.62) and a webinar was the least favorable method (M= 3.30 SD= 1.03). The teachers agreed on the statement that having a science background would help in teaching plant biotechnology subjects (M= 4.01 SD= 0.82).

Curriculum: The curriculum statements had the lowest scores in the questionnaire; the teachers disagreed on the statement that the schools have sufficient resources to teach plant biotechnology (M= 2.20 SD= 0.92), and that that the current curriculum covered enough plant biotechnology (M= 2.36 SD= 0.85). In addition, the teachers felt that the current curriculums were outdated (M= 2.46 SD= 0.78). The teachers did agree on the statement that it is necessary for students to have lab experience to learn well in the subject (M= 4.00 SD= 0.68).

Students: The teachers generally agreed on the statements regarding students; they felt that going on field trips to public universities and private companies were beneficial to the students (M= 3.75 SD= 0.80; M= 3.97 SD=0.64). In general, the teachers agreed that learning plant biotechnology is beneficial for the students (M= 4.19 SD= 0.54). The teachers were divided into two groups, under 15 years of teaching experience and 15 or more years of teaching experience. In the self-assessment report, teachers with 15 or more years of teaching experience reported that they were more familiar with research technologies. A similar trend was observed in the biotechnology product and definition section; overall, the teachers with 15 or more years of teaching experience felt that they were more familiar with the biotech products and the definitions of terms. No differences between the attitudes based on years of experiences were observed in this analysis.

Teachers with 15 or more years of experience reported to be more familiar with research techniques, compared to the teachers with under 15 years of experience; but overall, they were still not too

Table 3. Comparison among teaching experiences

	<15 years n=68		≥15 years n=46		Pr
Knowledge	M	SD	M	SD	
Research techniques					
CRISPR-cas9	1.81	0.83	1.96	0.84	>0.05
RNAi technology	1.81	0.81	2.30	0.92	0.05>
Genomic tools	2.17	0.76	2.46	0.91	0.05>
Mutation breeding	2.32	0.87	2.41	0.69	>0.05
Genome editing	2.41	0.77	2.52	0.78	>0.05
Plant tissue culture	2.75	0.90	3.33	1.10	0.05>
Plant hybridization	3.42	0.81	3.93	0.78	0.05>
Summed scale mean	2.39	0.97	2.70	1.07	0.05>
Plant biotechnology products					
FLAVR SAVR tomato	2.32	0.99	2.71	1.02	0.05>
Liberty/Ignite	2.67	1.18	2.98	1.06	0.05>
DICAMBA	3.07	1.02	3.17	1.02	>0.05
Bt corn	3.44	0.87	4.09	0.78	0.05>
Roundup ready soybeans	3.62	0.75	4.15	0.73	0.05>
Summed scale mean	3.02	1.08	3.42	1.10	0.05>
Common terms					
Conventional plant breeding	3.52	0.72	4.00	0.79	0.05>
Genetically modified crops	3.64	0.77	3.98	0.68	0.05>
Summed scale mean	3.58	0.74	3.99	0.73	0.05>
Current issues in the biotech industry					
Bayer/Monsanto deal	3.20	1.02	3.30	1.05	>0.05

Likert scale as follows: 1= strongly disagree, 2= Disagree, 3= neither agree or disagree, 4= Agree, 5= strongly agree

Table 4. Comparison among teachers with under 15 years of teaching experience and 15 or more years of teaching experience

	15> years n= 68		15<years n= 46		T-test
	M	SD	M	SD	
Belief in role					
I believe that it is the teacher's responsibility to develop SAE projects regarding plant biotechnology	2.97	0.97	3.07	0.93	>0.05
I believe that it is the teacher's responsibility to develop SAE projects regarding plant biotechnology I believe that the teacher's attitude towards plant biotechnology will affect the student's perspective	4.14	0.75	4.28	0.54	>0.05
I believe that the teacher's knowledge regarding the subject will draw interest to the student towards the field	4.25	0.65	4.18	0.53	>0.05
Summed scale mean	3.78	0.99	3.84	0.88	>0.05
Sources of knowledge:					
I feel that webinars are a good way for teachers to learn about the current plant biotechnology subjects	3.14	1.17	3.52	0.72	>0.05
Attending field days in public universities will help the teacher gain knowledge of plant biotechnology	4.01	0.70	3.87	0.75	>0.05
From my experience, having a science background helps in teaching plant biotechnology concepts	3.94	0.82	4.13	0.81	>0.05
I believe that attending workshops help the teacher have a better understanding of the current plant biotechnology subjects	4.26	0.63	4.17	0.62	>0.05
I believe that having lab experience in plant biotechnology will help the teacher explain the subject better	4.29	0.57	4.22	0.52	>0.05
Summed scale mean	3.93	0.90	3.98	0.73	>0.05
curriculum					
The school has enough resources to teach plant biotechnology labs	2.07	0.82	2.39	0.98	>0.05
I feel that there are sufficient materials in school that cover plant biotechnology subjects	2.20	0.81	2.59	0.86	>0.05
I believe the current curriculum are up to date regarding plant biotechnology subjects	2.48	0.83	2.43	0.69	>0.05
It is necessary for the students to have lab experience to learn well in plant biotechnology	3.97	0.69	4.04	0.67	>0.05
Summed scale mean	2.68	1.10	2.86	1.05	>0.05
Students					
From my experience, learning about plant biotechnology will impact the student's career choice	3.94	0.82	4.13	0.81	>0.05
Field trips to public university will encourage students to pursue a degree in plant biotechnology	3.82	0.89	3.78	0.66	>0.05
Field trips to private plant biotechnology companies will encourage students to pursue a degree in plant biotechnology	3.94	0.68	4.02	0.58	>0.05
Overall, learning about plant biotechnology is beneficial to the students	4.19	0.55	4.20	0.54	>0.05
Summed scale mean	3.87	0.75	3.95	0.62	>0.05

DISCUSSION

Overall, Illinois agricultural teachers reported that they were unfamiliar with the research techniques, but somewhat familiar with plant biotechnology products. Teachers were confident that they could define the common terms "conventional breeding" and "genetically modified crops." The teachers were aware of the current issues in the industry. The results were not surprising since the survey focused on plant biotechnology; whereas, many teachers may have had a more diverse background in other fields.

familiar (M= 2.70 SD= 1.07). A similar trend was observed in the biotech product section; teachers with 15 or more years of experiences felt that they were very familiar with Bt corn and roundup ready soybeans (M= 4.09 SD= 0.78; M= 4.15 SD=0.73). The third section of the study focused on the teachers' perspectives on various subjects; including their belief in roles, the sources of knowledge for plant biotechnology topics, the current plant biotechnology curriculum, and how plant biotechnology affected the students. Overall, the teachers agreed that the educator's attitude and knowledge played an important role; however, they neither agreed nor disagreed on the fact that it was the teacher's responsibility to develop SAE projects. The teachers favored attending actual trainings over online webinars, with workshops being the most favorable method (M= 4.23 SD=0.55) and webinars being the least favorable (M= 3.63 SD= 1.03). In general, the teachers felt that there were not enough plant biotechnology topics in the current curriculum, and having proper lab experiences was critical to learning the subjects. The teachers generally believed that learning plant biotechnology is important and has an impact on the students' careers. Overall, the years of teaching experiences did not affect the teachers' perspectives toward the statements; only one statement showed significant difference between the attitudes, but the score still indicated that the teachers disagreed to the statement that there were sufficient plant biotechnology topics covered in the curriculum. This study, conducted among Illinois agricultural teachers, agreed with the studies conducted in other states, that agricultural teachers generally have a positive attitude towards biotechnology. The teachers agreed that their knowledge and attitudes will have an impact on teaching the various topics in biotechnology. Mowen *et al*. (2007b) reported that the teachers were not very familiar with the biotechnology topics (M= 2.62 SD= 0.61 on a 1-4 scale); this observation was similar to this study regarding lab techniques (M= 2.41 SD= 1.02). The development in plant biotechnology has brought us various products over the past few years; this has not only contributed convenience to modern agricultural production, but also brought safety and ethical concern. The use of plant biotechnology products is still heavily debated; however, we cannot deny the fact that these products have become a part of our daily lives. It is important to educate consumers regardless of their beliefs on the subject. Agricultural teachers play an important role in educating the future generation, who may impact policies and acceptance of products in the future. Understanding these educators' knowledge and perspectives is critical in modernizing the current curriculum.

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