Determining Agricultural Teacher Education Awareness of Biotechnology and the Future of Biotechnology Education in <state>

Dexter Wakefield I, Ph.D.
Assistant Professor
Texas State University
Department of Agriculture
wakephd@txstate.edu
601 University Drive
San Marcos, TX 78666, USA

Douglas Morrish, Ph.D.
Associate Professor
Texas State University
Department of Agriculture
dm43@txstate.edu
601 University Drive
San Marcos, TX 78666, USA

Antoine Alston, Ph.D.
Professor & Associate Dean
North Carolina A&T State University
1601 East Market Street
111 Webb Hall
Greensboro, NC 27411, USA

Abstract

The purpose of this study was to analyze agriculture teachers' awareness of biotechnology and the future of biotechnology education in <state>. The objectives of the survey were to analyze the awareness level of biotechnology, benefits, barriers, and the future of biotechnology education in <state> and the demographic characteristics of <state> agricultural education teachers surveyed in this study. The population for this study consisted of <state> Agricultural Educators in secondary schools.

When asked general statements regarding biotechnology, the majority of teachers answered 73% of the questions correctly. The research also revealed that the teachers were uncertain of the benefits of biotechnology, barriers to biotechnology and the future of biotechnology education in <state>. Generally, <state> agricultural education teachers were 44-year old Caucasian males with master's degrees. On average, the teachers had about 17 years of teaching experience. However, the respondents stated that they had no experience with biotechnology. Some respondents (n=13) did have practice with biotechnology, besides teaching. These respondents accounted for 6.38 years of biotechnology related experience. Recommendations from this study include incorporation of more biotechnology related curricula into the <state> State Learning Standards, in-service training for teachers, and partnering between educational institutions and private industry to improve awareness of biotechnology.

Keywords: biotechnology, business, teacher education, agriculture, economics

Introduction

Biotechnology is now a major contributor to the US economy. When comparing biotech and its economic impact to electronics, computing, utilities and mining, biotech supersedes all of these critical areas (Carlson, 2016). It is defined as the use of living organisms to develop products (Keener & Hoban, 2000). In 2000, Fernandez-Cornejo and McBride, of the Economic Research Service, defined agricultural biotechnology as a collection of scientific techniques, including genetic engineering, to create, improve, or modify plants, animals, and microorganisms. Recently, the public has turned their attention to biotechnology due to new developments in molecular biology (Keener, Hoban, & Balasubramanian, 2000). Many people find biotechnology to be beneficial from an economic and biological perspective (Conko, 2003; McGloughlin, 1999). Additionally, while there are many benefits to biotechnology, there are many barriers to its implementation (Van der Sluis, Diersen, & Dobbs, 2002).

Carlson (2016) stated in a recent article that "at least 20 countries have articulated strategies that explicitly identify biotech as critical to their future economic and employment growth." (p. 247). Many people use biotechnology on a regular basis without even realizing it. It is used when completing such simple tasks as baking bread, wine making and gardening. Biotechnology is a field which was greatly influenced by scientists such as Gregor Mendel and Louis Pasteur (Rhee, 1999a; Rhee, 1999b). Mendel utilized biotechnology when completing research about inheritance. During this experiment, he crossbred pea plants to determine which traits were inherited from the parent plant (Rhee, 1999). Pasteur also utilized biotechnology in many different areas. Perhaps, he is most widely known for his work on vaccinations against rabies and developing pasteurization. Pasteur's work has been very beneficial to mankind and for that, the world has changed and countless lives have been saved (Rhee, 1999). The work of these two researchers has inspired other scientists and geneticists to further their research. Their work has also been presented to students in introductory biology courses.

Economically, biotechnology has been adopted by American farmers. The Biotechnology Industry Organization (2004) stated that farmers have adopted products which have been modified utilizing biotechnology because these products decrease operating costs, input expenses, and boost yields. Farmers have boosted their incomes by $1.9 billion utilizing canola, corn, cotton, papaya, soybeans, and squash that were modified utilizing biotechnology. In 2003, the aforementioned crop yields were boosted by 5.3 billion and pesticide use decreased by 46.4 million pounds due to advances in biotechnology. These savings have resulted from reduced inputs of labor, capital, and depreciation on equipment. It also helps the economy because the world's food production must increase, to meet the higher demands, by 75% over the course of the next 25 years. The safest and most effective way to achieve this goal is to utilize agricultural biotechnology (US Soybean Board, 2004.)

Biologically, biotechnology has been utilized to protect water quality, strengthen crop resistance to pesticides, and produce healthier foods (US Soybean Board, 2004.) These are beneficial because the nation's water supply is vital for survival. Americans are more concerned about their health and are therefore skeptical about the amount of herbicides and pesticides used on their foods. In the same respect, they are also skeptical about the utilization of biotechnology to improve foods, though many are eating genetically modified crops when eating organic foods. Biotechnology is especially beneficial to food scientists and farmers. Food biotechnology allows for consumption products and their packaging to be improved either by taste, freshness, nutritional value, fat content, and or biodegradability of packaging (Keener & Hoban, 2000). Farmers benefit from biotechnology because crop land can remain fertile as a result of a reduction in the amount of chemicals used to produce crops. This allows the farmland to be used longer without using conservation practices such as no-till farming or crop rotation. According to the US Soybean Board (2004), biotechnology is used when developing edible vaccines which are administered through bananas, tomatoes and potatoes. Allergies are very prevalent in the American community. By utilizing biotechnology, the gene within the food which causes the allergy can be removed (Keener, Hoban, 2000).

Barriers to biotechnology include public reactions, lack of education and labeling. The public is concerned that scientists will cross ethical boundaries, like those related to human cloning. Consumers are also concerned with the foods that they are eating and are requesting that foods created utilizing biotechnology ingredients be labeled (Keener and Hoban, 2000.) The consumer's lack of acceptance of biotechnologically derived products is a concern for industry, but they recognize that these concerns stem from a lack of education. Consumers express confidence in the science involved, as well as the regulatory processes used to ensure safety (Keener, Hoban, & Balasubramanian, 2000.)

In the State of <state> Agricultural Education programs, biotechnology is included in the curriculum. According to the <state> State Board of Education (2003), biotechnology is included in State Goals 12 and 13. According to State Goal 12, "students should have an understanding of the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences." State Goal 13 encourages "students to have an understanding of the relationships among science, technology and society in historical and contemporary contexts." Teachers are responsible for making sure that students understand these goals and can present the information to them in a clear, concise manner. Biotechnology standards needed by teachers for presentation to students are also included in Science – A Common Core of Standards (<state> State Board of Education, 2003). An example of this is the Guidebook for Science Safety (<state> State Board of Education, 2003) which has dedicated Section 13.4 to Biotechnology. It lists procedures for ensuring the safety of those conducting experiments related to microorganisms, DNA and biogenetic experimentation.

In 2005, the biotechnology industry contributed 50.7 billion dollars in revenue to the United States economy. There are over 1,400 biotechnology companies, in which about 330 of them are private (Biotechnology Industry Organization, 2007). As a result of the great impact that biotechnology has had in the past, and will have on the future economy, it is imperative that it remain incorporated in the curriculum. With the economic and biological implications that the biotechnology industry as a whole has for the United States, America's public education system will be a major player in preparing its future workforce and promoting biotechnological literacy among its future consumer base. Given the aforementioned concerns about the benefits and barriers related to biotechnology, it is imperative that public school educators, grades K-12, are knowledgeable and informed about the biotechnology discipline and industry. Teachers have a great impact on the future leaders of this country. Therefore, their attitudes about biotechnology need to be researched.

Background of the Study

General Awareness of Biotechnology

Influences on awareness and acceptance are influenced by cultures and socioeconomic status. Fritz, Husmann, Wingenbach, Rutherford, Egger, and Wadhwa (2003) stated that perceptions are influenced by family, friends, class and culture. They further stated that cultural attitudes may result in limited understanding of biotechnology.

Hoban (1998) conducted a study in which respondents were asked to indicate their awareness and understanding as it related to biotechnology. From 1992 to 1996, Hoban's results showed no change in the awareness levels among United States consumers. In 1997, however, there was a significant increase. This increase was attributed to the media attention about a sheep, which was cloned. It was also stated that other countries, in 1995, were more aware than the United States.

Wilson, Kirby and Flowers (2001) conducted a study in which respondents were asked about their personal perceived levels of science competencies. They indicated that they were fairly knowledgeable, especially when it related to basic genetics and the agriculture-biotechnology relationship. About half of the educators in this study, when given a multiple choice test about "Biotechnology and Agriscience Research," answered 70% of the items accurately.

Benefits of Biotechnology

Many benefits from biotechnology exist. Numerous authors across disciplines have addressed these benefits. Hoban (1998) stated that the promise of agricultural biotechnology is becoming a reality. It was a notion that has been presented for the past two decades. Farmers are raising crops that are protected from insects and require the use of fewer pesticides. Advocates of biotechnology argue the benefits by stating that it reduces herbicide use, increases yields, produces healthier foods, decreases disease, and causes plants to adapt to their environments (Trexler & Meischen, 2001).

Kalaitzandonakes (1999) stated plants, that are insect resistant, have improved yields, utilized fewer pesticides and were also tolerant to extreme conditions, are being developed to battle input shortfalls. Bioengineered crops can also be a means of administering pharmaceuticals and vaccinations. By utilizing crops in this manner, it expands the range of other benefits.

McGloughlin (1999) authored an article entitled *Ten Reasons Why Biotechnology Will Be Important to the Developing World*. In this article, McGloughlin (1999) challenged misconceptions about biotechnology as addressed by Altieri and Rosset (1999).

The misconceptions addressed by Altieri and Rosset (1999) include the application of genetic engineering in the development of transgenic crops, the enhancement of food security, and moving agriculture away from its dependence on chemicals to lessen environmental problems. McGloughlin (1999) include lower returns for the farmer due to the integration of chemical pesticides and seed usage, risks associated with eating bioengineered foods, and that bioengineered varieties of seeds will eventually fail as pests develop resistance to the toxins.

In an article by Datta (2004), the emphasis of the importance of rice was discussed. Datta stressed that rice feeds more thm,an two billion people worldwide. Additionally, it was stated that rice provides 40-70% of total calories consumed in Asia. Rice is also beneficial in Asia economically for the income of rural people and serves as a means of feeding animals. Engineered rice contains genes for β-carotene biosynthesis, *pmi* (phosphomannose isomerase) which can reduce deficiency of Vitamin A.

Other benefits of biotechnology are addressed by Conko (2003). Conko (2003) stated that farmers are allowed to grow significantly more food on less land due to biotechnological advances. Productivity could also be increased as a result of crop plants being modified to resist plant diseases and tolerate extreme environmental conditions. Conko (2003) included information about *Monsanto's Roundup Ready soybean*. This soybean is resistant to the herbicide Roundup. Other varieties of plants, such as canola, corn, cotton, flax, rice and sugar beets, have also been genetically engineered to be resistant to herbicides. Reduced pesticide use is also beneficial to farmers who practice conservation tillage (Conko, 2003). The practice of conservation tillage is defined as the growth of crops on soil that has been minimally cultivated. Weeds, therefore, are controlled by utilizing cover crops (Peet, 2001). Without added worry of damaging crops, production agriculturalists are more apt to adopt varieties of herbicide tolerant crops in an effort to compliment their conservation practices (Conko, 2003).

Van der Sluis, Diersen and Dobbs (2002) stated that the benefits and costs related to agricultural biotechnology is limited. The majority of the technology is related to the environment and food safety, while industrial structure has yet to be seen. Agricultural productivity, as a result of new technology, could increase relative to non-land inputs and result in production cost decreases.

Barriers to Biotechnology

Although biotechnology has many different benefits, it also faces many barriers. Opponents believe that it is a threat to the environment (Trexler & Meischen, 2001). Datta (2004) said that intellectual property rights should not be a barrier for advancing biotechnology because it is beneficial for all human beings.

Hoban (1998) stated that labeling plays a large role in being a barrier to biotechnology. It was stated that the end consumer was not willing to pay an additional amount for foods that are a result of biotechnology. This is due in part to the fact that consumers are not aware of what products are direct results of biotechnology. The article suggested labeling products, such as fresh fruits and vegetables, with biotech labels and those that are blended or mixed should be left alone. Items that could be left alone were items like ketchup.

While Van der Sluis, Diersen and Dobbs (2002) stated several benefits in their article, they also listed barriers. They stated that risks which can be associated with health, food safety, and environment are major concerns. These risks can be associated with the potential costs of genetically modified technologies.

Curriculum

Wilson, Kirby and Flowers (2002) conducted a study identifying and describing factors related to the intent of agricultural educators to adopt biotechnology curriculum and assist them in curriculum adoption. Their study surveyed 173 North Carolina teachers. The researchers stated that the lack of support for educational reform is a contributing barrier to the integration of a new curriculum. The researchers concluded that teachers' lack of the perceived knowledge of biotechnology, lack of training, and external factors were prevalent barriers to biotechnology education. External factors, as identified by teachers, were funding, equipment, and instructor knowledge.

Wilson (2003) examined the attitudes of high school agricultural and science educators about biotechnology. Wilson compared the responses of teachers who had attended a biotechnology-related training to the responses of teachers who had not attended the training. The researcher stated that although many high school agricultural education programs encompass biotechnology instruction, the level of instruction is not keeping up with the advances being made in biotechnology. Others still believe that they are not teaching biotechnology related concepts, even after the definition of biotechnology has been explained to them.

Wilson (2000), as cited by Wilson and Flowers (2002), stated that teachers are more apt to adopt biotechnology curriculum if they have had training. They are also likely to adopt the curriculum if it is perceived as beneficial to their program.

Training

Wilson's study (2003) also revealed that as a result of training, the attendees were extremely aware of biotechnology, in comparison to their counterparts who had not attended the training. The respondents indicated that while the utilization of biotechnology is acceptable for the improvement of plants and animals in agriculture, it is unacceptable for use in the improvement of foods and recreational wildlife. The respondents also did not approve of the use of biotechnology for the transferring of genes from humans to animals. The respondents who attended the training, however, were more tolerant of the gene transfer from humans to animals.

Thompson and Balschweid (1999) conducted a study to determine Oregon agricultural science and technology teachers' attitudes about the integration of science into their curriculum. They found that teachers' antagonistic attitudes towards integration with agricultural education programs as being a major barrier. The barrier with the highest level of agreement was lack of equipment, followed by lack of adequate funding.

Future of Biotechnology Education

In a study conducted by Rudd and Hillison (1995), which sought to determine Virginia middle school teachers' attitudes, knowledge and expectations toward agriscience and to determine a predictive model for curriculum adoption related to agriscience. It was determined that the teachers had high positive attitudes towards biotechnology and were knowledgeable about the agriscience curriculum. The researchers also determined that these predictors were significant as it related to the adoption of curriculum about agriscience.

Wilson, Kirby and Flowers (2001) also posed questions related to the adoption of biotechnology related courses. In this study, respondents indicated that about half would adopt the curriculum and about thirty percent were not sure. The remainder of the population would not adopt the course, even if no barriers were present.

Purpose and Objectives

The purpose of this study was to analyze agriculture teachers' awareness of biotechnology and the future of biotechnology education in <state>. In order to accomplish the aforementioned purpose, the following objectives were developed:

1. To determine the awareness level of <state> agriculture teachers in relation to biotechnology.
2. To determine the benefits and barriers to biotechnology as perceived by <state> agricultural education teachers.
3. To determine the future of biotechnology education in <state> as perceived by <state> agricultural teachers.
4. List the demographic characteristics of <state> agricultural education teachers.

Significance of the Problem

The significance of this study was the provision of baseline data regarding the knowledge level of agricultural educators in relation to biotechnology, and their attitudes towards the future of biotechnology education in <state>' agricultural education curriculum. By conducting this study, agricultural education stakeholders and policy makers will be able to gauge the potential impact that teachers' knowledge and attitudes could have on the biotechnology career aspirations and biotechnology consumer decisions of their students.

Methods

The design of this research was descriptive in nature, utilizing a researcher-designed mail survey. Descriptive statistics provide information about variable distributions. It includes measures of central tendency, variability around the mean and normal deviation (George and Mallery, 2006). Glass and Hopkins (1996) stated that descriptive statistics is a tool for summarizing, describing and reducing the data to a manageable format. The mailing of the survey was conducted based upon methodology designed by Dillman (2000).

The population of this study consisted of <state> agricultural education teachers as identified by the <state> Association of Vocational Agricultural Teachers (IAVAT) Directory (N=377). However, in an effort to obtain an optimal representation of the population, a stratified random sample was used (N=100).

The IAVAT Directory has divided their directory into sections which are grouped into five (5) districts. Each respective district is represented by the percentage of the state's IAVAT population that they comprise. Therefore, District 1 represented 15.7% (n=15) of the population of the study, District 2 represented 23.6% (n=24) of the population of the study, District 3 represented 18.8% (n=19) of the population of the study, District 4 represented 18% (n=18) of the population of the study and District 5 represented 23.9% (n=24) of the population of the study. The overall response rate for the study was 38% (N=38). However, District 1 returned 28.571% (n=4) of the surveys sent to their district. District 2 returned 37.5% (n=9) of the surveys sent to their district. District 3 returned 42.105% (n=8) of the surveys sent to their district. District 4 returned 33.333% (n=6) of the surveys sent to their district. District 5 returned 45.833% (n=11) of the surveys sent to their district.

Table 1. Return Rate

District	Participants	Respondents	%
I	15	4	28.571
II	24	9	37.500
III	19	8	42.105
IV	18	6	33.333
V	24	11	45.833
Total	100	38	

Thirty-eight of the original 100 surveys were returned for a final return rate of 38%.

Data Collection Instrument

A previous version of this survey instrument was jointly developed by the researcher and her undergraduate advisor at <university), Department of Agribusiness, Applied Economics and Agriscience Education in order to accomplish objectives of a similar study. In order to accomplish the objectives of this study, questions from the aforementioned survey instrument were combined with new variables. Based upon the results of the previous study, a new instrument was created to accomplish the objectives of this new research venture. The new instrument and variables were developed after an exhaustive review of literature.

Brown (1983) defined content validity as "the degree to which items on a test representatively sample the underlying content domain" (p 487). Brown recommended using <university>, reviewed the instrument for content validity. These experts consisted of one professor of agricultural education at <university>, and two professors of agricultural education at <university>. In order to test the reliability of this instrument, a pilot study was conducted upon a similar group of agricultural teachers in a neighboring state.

The survey instrument for this study consisted of five sections. The sections are entitled: Section I: General Awareness of Biotechnology, Section II: Benefits of Biotechnology, Section III: Barriers to Biotechnology, Section IV: Future of Biotechnology Education in <state>, and Section V: Demographics. Sections one and two have fifteen questions, section three consists of ten questions and four consists of twenty questions. The questions in section one are multiple choice in nature. Respondents were given the opportunity to, using given answers, choose which item best represented the answer. Section two questions were posed in a manner which would allow for each question to be assigned a level of importance, from 1-10. One was listed as being of least importance while ten was seen as very important. Sections three and four utilized a five-point Likert-type scale with the following responses: 1=Strongly Disagree, 2=Disagree, 3=Uncertain, 4=Agree and 5=Strongly Agree. Section five utilized a combination of closed and open-ended responses to eight questions concerning demographics.

Data Collection

Elements of Dillman's Total Design Method (2000) were utilized to achieve an optimal return rate. The first round consisted of <state> secondary agricultural education teachers receiving a cover letter, consent form, survey, and a return self-addressed stamped envelope from the researcher and the researcher's major professor outlining the purpose of the research. Utilizing three one-week intervals, teachers were given the opportunity to respond. The second round consisted of all non-respondents receiving a follow-up email stressing to them the importance of returning the survey for data analysis purposes and to strengthen the study.

The third round consisted of all non-respondents receiving all of the items received in the first round, with another week to respond.

In order to control for nonresponse error, Miller and Smith (1983) recommended comparing early to late respondents. Research has shown that late respondents are often similar to non-respondents. Thus, one way to eliminate the nature of the replies of non-respondents is through late respondents. Late respondents were statistically compared to early respondents using the evaluation data to justify generalizing from the respondents to the sample.

In an effort to test the reliability of the instrument, a post hoc reliability test was conducted upon conclusion of the research study. Brown (1983) defined reliability as "how consistently a test measures over time, occasions, or samples of items; the degree to which test scores are influenced by measurement errors. Indices include reliability coefficients and the standard error of measurement" (p. 494). The reliability of each section was completed. The reliability test assures the dependability or precision of the instrument. In this study, a Chronbach's alpha was used as the measure of reliability. Nunnally (1967) recommended that an alpha of 0.5 to 0.6 is high enough in early stages of research. The 0.8 measurement is commonly utilized. If precision is needed, measurements of 0.9 may not be high enough. The alpha's for the previous survey instrument, in sections which were only slightly modified were, Section Three = .9096 and Section Four = .9500. For this study, Chronbach's alpha reliability coefficients were as follows: Section Two = .881, Section Three = .612 and Section Four = .889.

Data Analysis

The data collected from the participants was coded, entered, and analyzed using the researcher's personal computer. Data was analyzed using the Statistical Package for Social Science (SPSS), Personal Computer Version 10.0. The analysis of data included frequencies, means, and standard deviations.

Results/Findings

The purpose of this study was to analyze agriculture teachers' awareness of biotechnology and the future of biotechnology education in <state>. Therefore, it is important to gauge the public school teachers' knowledge and perceptions of biotechnology and the impact that it will have on the future of the country. Knowing the teacher's perceptions and knowledge is vital to the success of this subject because they are the ones who have to teach the subject. If they are not knowledgeable or have adverse feelings about biotechnology, it could be detrimental to children's education.

To accomplish the aforementioned purpose, four research objectives were developed. The objectives were as follows:

1. To determine the awareness level of <state> agriculture teachers in relation to biotechnology.
2. To determine the benefits and barriers to biotechnology as perceived by <state> agricultural education teachers.
3. To determine the future of biotechnology education in <state> as perceived by <state> agriculture teachers.
4. To identify the demographic characteristics of <state> agricultural education teachers.

Response Rate

Table two shows the districts and number of participants from each that were surveyed. It gives the number of initial participants as well as the actual respondents for the survey. Participants were randomly selected from the predefined districts within the state.

Table 2. Return Rate

District	Participants	Respondents	%
I	15	4	28.571
II	24	9	37.500
III	19	8	42.105
IV	18	6	33.333
V	24	11	45.833
Total	100	38	

Thirty-eight of the original 100 surveys were returned for usable response rate of 38%. In order to control for nonresponse error, Miller and Smith (1983) recommended comparing early to late respondents. Research has shown that late respondents are often similar to non-respondents. Thus, one way to eliminate the nature of the replies of non-respondents is through late respondents. Using the Method 1, for comparing early and late responders, established by Linder and Wingenbach (2002), late respondents were statistically compared to early respondents using the evaluation data to justify generalizing from the respondents to the sample. Thirty-three early responders and five late responders were analyzed for differences. The analysis confirmed no significant differences existed between early and late respondents and the data of the two groups were combined to obtain the 38% response rate.

Research Objective One and Discussion

Respondents were asked questions designed to gauge the awareness level of agricultural education teachers regarding biotechnology. Table 3 shows the biotechnology statement posed, percentages, and frequencies of how many respondents answered the question correctly for each of the fifteen questions posed. Each column, A, B, and C, represent the answer choices given. The columns display the frequencies and percentages of responses for each statement. Responses in the “D” column represent the questions that were left blank and by how many respondents. The frequencies and percentages of the respondents who correctly answered the questions are shaded in gray.

Table 3. General Awareness of Biotechnology (N=38)

Biotechnology Statement	A		B		C		D	
	f	%	*f*	%	*f*	%	*f*	%
1. Biotechnology is defined as the use of molecules and cells from living organisms to ______________.	7	18.4	26	68.4	3	7.9	2	5.3
2. Biotechnology makes it possible for scientists to ________ plants and animals by taking parts of the genes of one plant or animal and inserting them into another.	3	7.9	32	84.2	2	5.3	1	2.6
3. Human, animal, plant and microbial genes can be altered with __________ biotechnology techniques.	35	92.1	1	2.6	2	5.3	0	0
4. _______ control visible and invisible characteristics of living organisms.	33	86.8	3	7.9	2	5.3	0	0
5. A ____is a specific sequence of DNA that serves as a unit of inheritance.	63	94.7	1	2.6	1	2.6	0	0
6. Most consumers in the United States have ________ products created through biotechnology.	28	73.7	5	13.2	1	2.6	4	10.5
7. Forensic ___________ allows the analysis of DNA to help solve crimes.	2	5.3	32	84.2	4	10.5	0	0
8. ______________ currently market drugs developed using biotechnology.	2	5.3	33	86.8	1	2.6	2	5.3
9. ______________ can regenerate whole plants from individual plant cells.	15	39.5	19	50.0	4	10.5	0	0
10. Cloning of a plant or animal creates a(n) ___________copy.	33	86.8	4	10.5	0	0	1	2.6
11. Genetically-modified animals are ______________ normal.	12	31.6	3	7.9	22	57.9	1	2.6
12. The ______________________ regulates all biotechnology products.	3	7.9	15	39.5	20	52.6	0	0
13. Biotechnology products are _______ based on their use rather than on the method by which they were produced.	24	63.2	13	34.2	1	2.6	0	0

Table 3. General Awareness of Biotechnology (N=38) (Continued)

Biotechnology Statement	A		B		C		D	
	f	%	*f*	%	*f*	%	*f*	%
14. Genetically-modified bacteria, fungi, and plants can clean up toxic waste sites in a process called ______________.	26	68.4	1	2.6	11	28.9	0	0
15. Pesticide-producing genes can be directly incorporated into crop plants so the need for additional pesticide application ______________.	35	92.1	1	2.6	2	5.3	0	0

Objective one sought to determine the awareness level of <state> agriculture teachers in relation to biotechnology. The respondents answered seventy-three percent (73%) or 11 of the 15 questions correctly. The percentage of correct responses means that the teachers, on average, are somewhat knowledgeable about biotechnology. On individual questions, there was a wide range of responses. The researcher assumed that the variation in responses could be attributed to the question being too easy or the respondents being extremely confident in a particular answer choice.

Research Objective Two and Discussion

Respondents were asked questions regarding their perceived benefits of biotechnology. Table 4 shows the means, standard deviations, and rankings for the fifteen statements regarding the benefits of biotechnology. For the purpose of data analysis, readers should utilize the following specifications when interpreting the scale for table three: 1=Lowest Importance and 10=Highest Importance. Table 4 also shows the rank of each response to show the importance of each statement to the agricultural education teacher in <state>. The rank of each item was determined based on the means of each statement.

Table 4. Benefits of Biotechnology (N=38)

Benefits of Biotechnology	**Mean**	**SD**	**Rank**
1. Reduced need for chemical pesticides.	7.24	3.392	6
2. Protection of groundwater supplies and more effective waste treatment techniques.	8.03	2.802	1
3. Economic savings for consumers and new fuel sources.	6.84	2.968	11
4. Better animal health management.	6.39	2.498	13
5. More nutritious, better tasting foods and alleviation of malnutrition.	7.05	2.667	8
6. Improved human medical care.	7.63	2.627	3
7. Development of unique products from aquatic sources.	4.95	3.079	14
8. Reduced environmental impact of industrial activities and improved soil conservation.	7.41	2.900	5
9. Improved fabrics.	4.83	3.116	15
10. More effective pharmaceuticals.	6.97	2.667	9
11. More accurate criminal investigations.	6.81	2.614	12
12. Increased crop yields that can be realized on less land and greater economic profitability for farmers.	7.42	2.832	4
13. Improved methods to fight bioterrorism.	7.65	2.783	2
14. Valuable technology for the citizens of the United States.	6.97	2.618	10
15. Increased quality of life for people in developing countries.	7.23	2.095	7

Respondents view the protection of groundwater supplies and more effective waste treatment techniques as the most important to them as it related to the benefits of biotechnology. This is followed by improved methods of fighting bioterrorism. The variable of least importance to the teachers as a benefit of biotechnology was the improved fabrics.

Respondents were asked questions regarding the barriers of/to biotechnology education in <state>. Table 5 shows the means and standard deviations for the ten statements regarding the future of biotechnology education in <state>. For purpose of data analysis, readers should utilize the following specifications when interpreting the scale for table four: 1-1.49=Strongly Disagree, 1.50-2.49=Disagree, 2.50-3.49=Uncertain, 3.50-4.49=Agree, and 4.50-5=Strongly Agree.

Table 5: Barriers of/to Biotechnology (N=38)

Barriers of/to Biotechnology	**Mean**	**SD**
1. The perception regarding the safety of genetically engineered foods is a major barrier to biotechnology.	4.24	.751
2. Biotechnology can have negative ecological impacts which reduce its acceptance.	2.81	1.050
3. The economic cost of biotechnology research is a barrier to its widespread practical daily implementation.	3.24	1.101
4. Lack of education leads to resistance toward biotechnology products.	4.39	.823
5. Issues concerning the labeling of genetically modified foods can have a major impact upon the agricultural industry.	4.08	.712
6. Ethical issues regarding biotechnology are a major barrier to its extensive use on a global scale.	3.97	.726
7. Religious concerns are a major barrier to biotechnology acceptance.	3.16	.916
8. From a socio-economic perspective, biotechnology can affect the relationship between, and relative power of, different groups in society.	3.45	.860
9. Equal access to the benefits of biotechnology will not be realized by all sectors of society.	3.50	1.059
10. Legislation is a major barrier to broad biotechnology implementation throughout society.	3.68	1.016

Scale: 1=Strongly Disagree, 2=Disagree, 3=Uncertain, 4=Agree, 5=Strongly Agree

In the section about the barriers of/to biotechnology, the means of all responses ranged from uncertain (M=2.81) to agree (M=4.39). The teachers agreed that the major barriers to biotechnology, were that a lack of education leads to resistance toward biotechnology products (M=4.39) and that the perception regarding the safety of genetically engineered foods is a major barrier to biotechnology (M=4.24). The teachers were uncertain that biotechnology can have negative ecological impacts which reduce its acceptance (M=2.81). Generally, the teachers agreed (M=3.652) that the barriers from the study were barriers of/to biotechnology.

Research Objective Three and Discussion

Respondents were asked questions regarding the future of biotechnology education in <state>. Table 6 shows the means and standard deviations for the twenty statements regarding the future of biotechnology education in <state>. For the purpose of data analysis, readers should utilize the following specifications when interpreting the scale for table five: 1-1.49=Strongly Disagree, 1.50-2.49=Disagree, 2.50-3.49=Uncertain, 3.50-4.49=Agree, and 4.50-5=Strongly Agree.

Table 6: Future of Biotechnology Education in <state> (N=38)

Future of Biotechnology Education in <state>	Mean	SD
1. Industry leaders should aid in biotechnology curriculum development in <state>' public schools.	4.18	.563
2. Biotechnology education can help alleviate negative public perceptions regarding the industry.	4.34	.534
3. The <state> General Assembly should provide funding to develop and infuse biotechnology curriculum into the public school system.	3.76	1.065
4. <state>' universities should have a major impact on the infusion of biotechnology at the secondary level of education.	3.89	.727
5. The infusion of biotechnology into <state>' State Learning Standards will require teacher education programs to revise and plan more rigorous baccalaureate degree programs.	3.61	1.028
6. Universities should offer advanced placement courses concerning biotechnology at the secondary level.	3.50	.980
7. Programs should be developed to link secondary level education in biotechnology with current community college biotechnology programs.	3.82	.766
8. Internships should be provided in biotechnology-related organizations as an option for "College Tech Prep" work-based experience requirements.	3.79	.741
9. Public schools should increase their curriculum offerings in this area.	3.74	.795
10. Biotechnology should be offered as a general science option for the core curriculum.	3.87	.875
11. Special programs concerning biotechnology should be implemented for students hoping to enter the biomanufacturing workforce after high school graduation.	3.61	.755
12. Industry and university biotechnology specialists should be utilized to teach special biotechnology topics in the public school systems.	3.46	.836
13. The supply of qualified teachers to teach biotechnology will be very low.	3.55	1.132
14. In service workshops concerning biotechnology, curriculum should be provided for teachers.	4.26	.554
15. <state> students will be interested in enrolling in biotechnology courses and programs.	3.47	.922

Table 6: Future of Biotechnology Education in <state> (N=38) (Continued)

Future of Biotechnology Education in <state>	Mean	SD
16. Biotechnology, which is currently a part of the secondary agricultural education curriculum in <state>, should be integrated into other subject matter areas.	3.71	.867
17. Public school administration, overall, should be supportive of biotechnology education.	4.11	.559
18. Industry grants should be provided to public school systems to infuse biotechnology education into their respective curricula.	3.89	.667
19. There will be great public support for biotechnology education at the secondary level in <state>.	3.13	.963
20. Biotechnology education can help enhance public perceptions regarding the industry.	4.24	.675

Scale: 1=Strongly Disagree, 2=Disagree, 3=Uncertain, 4=Agree, 5=Strongly Agree

Objective three sought to determine the future of biotechnology education in <state> as perceived by <state> agriculture teachers. The responses in this section ranged from uncertain (M=3.13) to agree (M=4.34). Generally, the teachers agreed (M=3.7965) with the statements of the study regarding the future of biotechnology education in <state>.

The teachers agreed that biotechnology education can help alleviate negative public perceptions regarding the industry (M=4.34). The teachers were uncertain if there will be great public support for biotechnology education at the secondary level in <state> (M=3.13).

Research Objective Four and Discussion

The respondents in this study were asked to complete demographic characteristics. Table 7 presents the means and percentages for the demographics.

Table 7: Demographic Characteristics of <state> Agricultural Education Teachers (N=38)

Demographics	N	Mean or Percent
1. Age	33	44.7
2. Highest Degree Earned		
Bachelor’s	16	42.1%
Master’s	19	50.0%
Specialist	1	2.6%
Doctorate	1	2.6%
3. Years of professional experience in public education	36	17.2 years
4. Gender		
Male	28	73.7%
Female	8	21.1%
5. Race/Ethnicity		
Asian		
Black	3	7.9%
Caucasian	33	86.8%
Latino(a)		
Native American		
Other ________		
6. Teaching experience besides biotechnology		
Yes	13	34.2%
No	23	60.5%
7. Years of experience with biotechnology	13	6.4 years

The mean age for the respondents was about 44 years old. In terms of explaining the level of education of the participants in this study, approximately 42% had obtained a bachelor’s degree, 50% had obtained a master’s degree, about three percent had become specialists in a field and about three percent had obtained a doctorate degree. The mean year of experience for the teachers was seventeen years. Regarding the gender in this study, about 74% were male and approximately 21% were female. Regarding the race/ethnicity of the respondents, about eight percent of the respondents were Black and 89% were Caucasian. The respondents were also asked a question about their teaching experience with biotechnology and 34.2% stated that they had some teaching experience and 60.5% said that they did not have any teaching experience with the subject. The respondents (n=13) who indicated that they have had experience teaching biotechnology accounted for 6.38 years of biotechnology related experience. In question eight, respondents with such experience were asked an open-ended question about the type of experience that they had with biotechnology. Responses included farming, coursework, research, tech support, field trips to and employment with Monsanto™, utilizing GMO seeds, plant genetics, plant breeding experience, plant genetics, planting biotech corn and soybeans, personal interests, readings, ag science, and participation in the state task force for chemical training.

Conclusions

The purpose of this study was to analyze agriculture teachers’ awareness of biotechnology and the future of biotechnology education in <state>. Therefore, it is important to gauge the public school teachers’ knowledge and perceptions of biotechnology and the impact that it will have on the future of the country. Knowing the teachers’ perceptions and knowledge is vital to the success of this subject because they are the ones who have to teach the subject. If they are not knowledgeable or have adverse feelings about biotechnology, it could be detrimental to students’ education.

The data from this research yielded many interesting findings that have implications not only for <state> secondary agricultural education programs, but also for agricultural education and the biotechnology industry as a whole throughout the United States.

Objective one sought to determine the awareness level of <state> agriculture teachers in relation to biotechnology. The respondents answered seventy-three percent (73%) or 11 of the 15 questions correctly. The percentage of correct responses means that the teachers, on average, are somewhat knowledgeable about biotechnology. On individual questions, there was a wide range of responses. The researcher assumed that the variation in responses could be attributed to the question being too easy or the respondents being extremely confident in a particular answer choice.

Objective two sought to determine the benefits and barriers as perceived by <state> agricultural education teachers. Respondents view the protection of groundwater supplies and more effective waste treatment techniques as the most important to them as it related to the benefits of biotechnology. This is followed by improved methods of fighting bioterrorism. The variable of least importance to the teachers as a benefit of biotechnology was the improved fabrics.

In the section about the barriers of/to biotechnology, the means of all responses ranged from uncertain ($\underline{M}$=2.81) to agree ($\underline{M}$=4.39). The teachers agreed that the major barriers to biotechnology, were that a lack of education leads to resistance toward biotechnology products ($\underline{M}$=4.39) and that the perception regarding the safety of genetically engineered foods is a major barrier to biotechnology ($\underline{M}$=4.24). The teachers were uncertain that biotechnology can have negative ecological impacts which reduce its acceptance ($\underline{M}$=2.81). Generally, the teachers agreed ($\underline{M}$=3.65) that the barriers from the study were barriers of/to biotechnology.

Objective three sought to determine the future of biotechnology education in <state> as perceived by <state> agriculture teachers. The responses in this section ranged from uncertain ($\underline{M}$=3.13) to agree ($\underline{M}$=4.34). Generally, the teachers agreed ($\underline{M}$=3.80) with the statements of the study regarding the future of biotechnology education in <state>. The teachers agreed that biotechnology education can help alleviate negative public perceptions regarding the industry ($\underline{M}$=4.34). The teachers were uncertain if there will be great public support for biotechnology education at the secondary level in <state> ($\underline{M}$=3.13).

Objective four listed the demographic characteristics of <state> agricultural education teachers. Generally, <state> agricultural education teachers were 44 year-old Caucasian males with Master's degrees. On average, the teachers had about 17 years of teaching experience. However, the respondents stated that they had no experience with biotechnology. Some respondents (n=13) did have practice with biotechnology, besides teaching. These respondents accounted for 6.38 years of biotechnology related experience.

After conducting this study, the researcher drew one main conclusion. In the state of <state>, biotechnology and related curricula need to be incorporated into the <state> State Learning Standards. This would be in addition to what is currently required by the <state> State Board of Education through State Goals 12 and 13. These goals require that "students have an understanding of the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences" and "have an understanding of the relationships among science, technology and society in historical and contemporary contexts."

Recommendations and Implications

Although the teachers answered the majority of the questions about General Awareness of Biotechnology, it does not mean that they are knowledgeable about the subject. The teachers, because the survey was conducted away from the researcher, had the opportunity to research the answers to the questions in an effort to obtain the correct answer. Given the aforementioned information, it is recommended that the current teachers receive in-service training about biotechnology. This way, they will be more informed about the subject. Teachers would, as a result of training, be more confident in the benefits of biotechnology, barriers of/to biotechnology and the future of biotechnology education.

Pre-service teachers, i.e. student teachers, should also be required to enroll in biotechnology related courses, regardless of their discipline. Biotechnology spreads across disciplines and the subject can be incorporated into lessons taught by each teacher.

The final recommendation would be to foster partnerships between educational institutions and public and private industry. These relationships need to be established as early as possible at the primary levels. This partnership would allow for improved awareness of biotechnology and would allow the future workforce to be better prepared. Teachers would benefit from this partnership because industry professionals would be able to assist them with classroom instruction in areas where their knowledge base is not as strong. With outside assistance in instructing courses, the teacher would become a student and would become knowledgeable enough to teach the subject without assistance.

This study can be used in future research and educational ventures to encourage biotechnology education. It serves as a method of improving the education that America's future workforce would receive. Biotechnology is important to the world, and it therefore is critical that the educational emphasis is not diminished, but heightened.

References

Altieri, M.A. & Rosset, P. (1999). Ten reasons why biotechnology will not ensure food security, protect the environment and reduce poverty in the developing world. *AgBioForum*, 2(3&4), 155-162.

Biotechnology Industry Organization. (2004). *Frequently asked questions on agricultural biotechnology*. Retrieved November 9, 2005, from http://bio.org/foodag/faq.asp

Biotechnology Industry Organization. (2007). *The guide to biotechnology 2007*. Washington, DC: Strickland.

Brown, F.G. (1983). *Principles of educational and psychological testing* (3rd ed). New York: Holt, Rinehart, and Winston.

Carlson, R. (2016). *Estimating the biotech sector's contribution to the US economy*. Nature Biotechnology, 34, 247-255. doi:10.1038/nbt.3491

Conko, G. (2003). *The Benefits of Biotech*. Retrieved March 3, 2005, from http://www.biotech-info.net/biotech_benefits.html

Datta, S. (2004). Rice biotechnology: a need for developing countries. *AgBioForum*, 7(1&2), 31-35.

Dillman, D.A. (2000). *Mail and internet surveys-the tailored design method*. New York: John Wiley and Sons.

Fernandez-Cornejo, J. and McBride, W. (2000). *Genetically engineered crops for pest management in U.S. agriculture*. AER-786. Retrieved June 23, 2004, from http://usda.mannlib.cornell.edu/usda/reports/general/aer/aer786.pdf#search='Genetically%20Engineered%20Crops%20for%20Pest%20Management%20in%20U.S.%20Agriculture'

Fritz, S., Husmann, D., Wingenbach, G., Rutherford, T., Egger, V., & Wadhwa, P. (2003). Awareness and acceptance of biotechnology issues among youth, undergraduates, and adults. *AgBioForum*, 6(4), 178-184.

Glass, G. D. and Hopkins, K. D. (1996). *Statistical methods in education and psychology* (3rd ed.). Boston: Allyn and Bacon.

George, D. and Mallery, P. (2006). *SPSS for windows step by step: A simple guide and reference* (6th ed.). New York: Pearson and Allyn and Bacon.

Hoban, T. J. (1998). Trends in consumer attitudes about agricultural biotechnology. *AgBioForum*, 1(1), 3-7.

<state> State Board of Education. (2003). *Guidebook for Science Safety*. Retrieved November 8, 2005 from, http://www.isbe.state.il.us/ils/science/pdf/science_safety.pdf

<state> State Board of Education. (2004). *Science-A common core of standards (*27.140). Retrieved November 8, 2005 from, *http://www.isbe.net/profprep/CASCDvr/Wd97/27140_sciencecore.doc*

<state> State Board of Education. (2004). *State Goal 12*. Retrieved November 8, 2005 from, http://www.isbe.state.il.us/ils/science/pdf/goal12.pdf

<state> State Board of Education. (2004). *State Goal 13*. Retrieved November 8, 2005 from, http://www.isbe.state.il.us/ils/science/pdf/goal13.pdf

Kalaitzondonakes, N. G. (1999). *Agrobiotechnology in the Developing World*. AgBioForum, 2, Retrieved April 24, 2006, from, www.agbioforum.org/v2n34/v2n34a01-editor.htm

Keener, K. and Hoban, T. (2000). *Biotechnology: answers to common questions*. Retrieved June 23, 2004, from http://www.ces.ncsu.edu/depts/foodsci/ext/pubs/biotech.html

Keener, K., Hoban, T. and Balasubramanian, R. (2000). *Biotechnology and its applications*. Retrieved June 23, 2004, from http://www.ces.ncsu.edu/depts/foodsci/ext/pubs/bioapp.html

MedicineNet.com, (2005). *Genetics definition*. Retrieved Dec. 14, 2005, from http://www.medterms.com/script/main/art.asp?articlekey=15390

Linder, J.R. & Wingenbach, G.J. (2002). *Communicating the handling of nonresponse error in the journal of extension research brief articles. Journal of Extension, 40(6).* Retrieved April 12, 2007 from http://www.joe.org/joe/2002december/rb1.shtml

McGloughlin, M. (1999). Ten reasons why biotechnology will be important to the developing world. *AgBioForum*, 2(3&4), 163-174.

Miller, L. E. & Smith, K. (1983). Handling Nonresponse Issues. *Journal of Extension.* September/October Edition.

Nunnally, J.C. (1967). *Psychometric theory*. New York, NY: McGraw Hill Book Co. Inc.

Peet, M. (2001). *Conservation Tillage*. Retrieved April 29, 2006, from http://www.cals.ncsu.edu/sustainable/peet/tillage/c03tilla.html

Rhee, S. Y. (1999). Access excellence @ the National Health Museum about biotech. Retrieved December 11, 2005, from Gregor Mendel (1822-1884). Web site: http://www.accessexcellence.org/RC/AB/BC/Gregor_Mendel.html

Rhee, S. Y. (1999). Access excellence @ the National Health Museum about biotech. Retrieved December 11, 2005, from Louis Pasteur (1822-1895) Web site: http://www.accessexcellence.org/RC/AB/BC/Louis_Pasteur.html

Rogers, E. M. (1971). *Communications of innovations: A Cross cultural approach.* The Free Press: New York.

Rudd, R. D. & Hillson, J. H. (1995). Teacher characteristics related to the adoption of agriscience curriculum in Virginia middle school agricultural education programs. *Journal of Agricultural Education*, 36(2), 19-27.

Thompson, G. W. & Balshweid, M. M. (1999). Attitudes of Oregon agricultural science and technology teachers toward integrating science. *Journal of Agricultural Education*, 40(3), 21-29.

Trexler, C. J., & Meischen, D. (2001). Prospective elementary teacher's understandings of agricultural technology and its effects on culture and the environment. *Proceedings of the 28th Annual National Agricultural Education Research Conference*, New Orleans, LA, *28*, 485-497.

University of Guelph, (2002). Pasteurization. Retrieved Dec. 14, 2005, from http://www.foodsci.uoguelph.ca/dairyedu/pasteurization.html

US Soybean Board, (n.d.). *Biotechnology facts - did you know?* Retrieved June 23, 2004, from http://www.talksoy.com/media/aBiotechFacts.html

Van der Sluis, E., Diersen, M. A., & Dobbs, T. (2002). Agricultural biotechnology: farm-level, market, and policy considerations. *Journal of Agribusiness*, 20(1), 51-66.

Wilson, E. (2003). An examination of agricultural and science educators' attitudes towards the use of biotechnology. *Journal of Southern Agricultural Education Research*, 53(1), 248-257.

Wilson, E.B. (2000). *Factors related to the intent of agricultural educators to adopt integrated biotechnology curriculum*. Unpublished doctoral dissertation, North Carolina State University.

Wilson, E. and Flowers, J. (2002). Secondary educators' confidence in teaching agricultural biotechnology after training**.** *Journal of Natural Resources and Life Sciences Education*, 31, 131-135.

Wilson, E., Kirby, B., & Flowers, J. (2001). Factors related to the intent of agriculture educators to adopt integrated agricultural biotechnology curriculum. *Journal of Southern Agricultural Education Research*, 51(1), 75-87.

Wilson, E., Kirby, B., & Flowers, J. (2002). Factors influencing the intent of North Carolina agricultural educators to adopt agricultural biotechnology curriculum. *Journal of Agricultural Education*, 43(1), 69-81.