THE USE OF PLANT TISSUE CULTURE IN AGRICULTURAL EDUCATION IN THE NORTHWESTERN STATES

by

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APPROVAL

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This professional paper has been read by each member of the graduate committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

The purpose of this study was to determine how secondary agriculture educators in the Northwestern states are using plant tissue culture to teach the application of scientific concepts.

To accomplish the purpose and objectives of this project a one page questionnaire was mailed to all of the secondary agriculture educators (595) in Idaho, Montana, North Dakota, Oregon and Washington to determine the population for the study. The questionnaire gathered data about teachers who had and had not done plant tissue culture, inservice they had attended on tissue culture and if they were not doing tissue culture the reasons why they were not. From a questionnaire return rate of 57.8% (344) the research population was determined to be 152 agriculture education teachers. A plant tissue culture research survey was mailed to the questionnaire respondents from each state who had done or were planning to do plant tissue culture during the 1992-93 school year. Responses were obtained from 63.1% (96) of the agriculture teachers. A follow up postcard was sent to the survey nonrespondents. Fourteen days after the postcard a follow up letter and another survey were sent to those who still had not responded.

The major findings include: 1. The African violet is the most common plant used for tissue culture. Carrot and potato plants are also frequently used for tissue culture. The potato is the most common plant used by agriculture education teachers for tissue culture in Montana. 2. The plastic transfer chamber and prepackaged media from a supplier are used most frequently for sterile tissue culture transfers. 3. The most popular instructional method of teaching tissue culture is the demonstration, and students actually doing tissue culture. 4. Explant type tissues are used most often by students when doing plant tissue culture. 5. Agriculture educators are in the early stages of learning about and providing instruction in plant tissue culture at the high school level. 6. Agriculture education teachers can expect about one half of their students' tissue cultures to show evidence of contamination. This level of contamination will be viewed by the students as part of the learning process, and thus can be used as a tool for teaching about microorganisms. 7. Plant tissue culture can be used to teach plant propagation and at least sixteen specific science competencies using equipment and supplies that can be purchased on a budget of less than $300 per year.

CHAPTER 1

THE PROBLEM

Introduction

Tissue culture has been recognized as a method of plant propagation for over 50 years but it has only been in the last 20 years that the techniques have been used to reproduce complete plants (Knorr, 1990). The idea of cultivating plant cells in vitro was conceived and the technique was put into practice by Haberlandt in 1902. In the 1970's tissue culture propagation expanded to commercial laboratories and nurseries (Hartman, 1990). Research facilities, laboratories and universities have used the tissue culture technique for plant propagation with great success for years. These institutions have compiled a great deal of research on the growth media required for specific plants, aseptic techniques of in vitro micropropagation, genetic engineering and plant breeding using tissue culture.

Tana Kappel, M.S.U. News Service, and Doyle Conner, Florida Department of Agriculture and Consumer Services, reported that tissue culture has now begun to make its way into high school classrooms. Many secondary

teachers and students have experienced the excitement and learning potential involved with doing plant tissue culture propagation. After visiting with his students, agriculture education teacher Bruce Ketchum found that "tissue culture will add enthusiasm to the plant science unit" (Ketchum, 1991). The excitement comes from performing successful experiments and watching small parts of plants (explants) grow into whole new plants (totipotency). Students enjoy learning about plants using this method of propagation because it is a hands on approach to learning.

Excitement and learning potential can be lost when problems are encountered doing tissue cultures. Problems such as contamination of the culture with bacteria, fungus, or mold can spoil a student's experiment. Venier stated that "learning to prevent contamination will help to minimize the potential for experiment failure" (Venier, 1991 page 2). Many times the tissue cultures are free of contamination but the plantlets will not grow. This could be due to such things as incorrect growth media or improper incubation temperature. Mapston indicated that he had problems getting the plants to grow so he switched to commercial growth media and solved the problem. He also reported having some problems with contamination (Mapston, 1991).

Teaching plant tissue culture in the high school classroom has potential as a teaching tool, but many teachers do not have an adequate understanding or training in the process of tissue culture. There is a need for information on solving problems encountered while doing tissue culture. Likewise the

successful application of tissue culture in the high school classroom needs to be shared with others. Inservice education and training workshops need to focus on solving specific problems encountered while doing tissue culture in the high school classroom. Information on which tissue culture techniques work well and what types of plants to use in the high school setting are needed by teachers who are trying to teach plant tissue culture.

Statement of the Problem

The purpose of this study was to determine how secondary agricultural educators in the Northwestern states were using plant tissue culture to teach the application of scientific concepts.

Specific Objectives

The objectives of this study were to: (1) determine what sterile techniques, equipment, plants and teaching methods are used by students in doing plant tissue culture in the high school setting and the amount of time spent; (2) identify plant growth problems and determine how they affect the attitudes of students toward doing plant tissue cultures; (4) determine what science competencies are applied and taught when doing plant tissue cultures; and (5) determine the agriculture teachers rationale for incorporating tissue culture into the local curriculum.

Need for the Study

Agriculture has become an increasingly scientific field requiring people with an understanding of and an ability to apply scientific principles and techniques. Yet, many people have noted the deficiencies in science education in the United States in terms of student preparation and performance. Inadequate science education has been a source of concern in the United State's efforts to sustain international competitiveness (Understanding Agriculture, New Directions for Education, National Research Council 1988). Plant Tissue culture, with its scientific background and its application to agriculture, is a great way to help bridge the gap between teaching about agriculture and science. "In addition to demonstrating a method of plant propagation, tissue culture affords practice in aseptic techniques and the opportunity to study the applications and effects of plant growth substances" (Haldeman, 1988). "Traditional science teaches theory. We (agriculture education) teach the application of science" says Mark Lalum, agriculture education teacher from Kalispell High School (Kappel, 1991a).

Tissue culturing is a method of in vitro plant propagation which is widely used in agricultural research and applied areas of plant science. One such application of tissue culture is in the propagation of orchids. Kalfered Yee reported that the Bangkok Orchid Growers Cooperative which is owned by 500 orchid growers farming 6000 acres, grossed well over 30 million dollars annually with tissue culture facilities employing 25 workers (Yee, 1982).

Jolene Brush, supervisor of the Montana State University Seed Potato Laboratory reported that they produce 60,000 disease free tissue cultured potato plants per year, worth $.65 each for a total of $39,000. The laboratory employs one person year around and six to eight seasonal people in the spring. In addition to this lab, there are five producer-owned potato tissue culture labs operating in Montana (Brush, 1991). These are examples of the diverse opportunities in plant tissue culture propagation. Thus, tissue culturing is an appropriate laboratory technique to teach in the high school agriculture education classroom.

In March of 1990, 33 Montana agriculture education teachers attended a plant biotechnology workshop in which tissue culturing of potatoes was taught. Many high school teachers have received inservice training on tissue culture techniques, and some have begun to incorporate teaching units on tissue culture experiments into their programs.

To provide optimal and successful learning experiences, agriculture education instructors need information to better equip their laboratories and prepare themselves to teach plant tissue culture. Agriculture teacher Dale Godfrey said "I have had little success with tissue culture because of contamination, the student interest has been high in this area, but we need success to keep them going" (Godfrey, 1990). There is a need for information to solve some problems teachers may encounter while trying to teach tissue

culture techniques. New ideas, techniques and teaching methods need to be identified so that teachers can have success with tissue culture experiments.

Assumptions

The assumptions for this study were: 1. Some teachers from the Northwestern study states have tried tissue culture in their classrooms and have had success, while others have had problems in teaching plant tissue culture. 2. Teachers from the Northwestern study states were teaching and applying scientific concepts when they taught plant tissue culture.

Limitations

The population for this study was limited to agriculture education teachers in the states of Montana, Oregon, Washington, Idaho, and North Dakota who had tried plant tissue culture in their classrooms prior to or during the 1992-93 school year.

Definition Of Terms

Tissue Culture — A general term that encompasses and is concerned with the study of cells, tissues, and organs maintained or grown in vitro for more than 24 hours.

Four different types of plant tissue culture are:

1. Cell Culture — The growth in vitro of cells that are no longer organized into tissues of their natural origin. Often grown in liquid suspension.

2. Callus Culture — In vitro growth of tissue arising from a large mass of disorganized cells from segments of plants. Callus cultures are usually grown as a mass of cells on a solid medium.

3. Explant Culture — The maintenance or growth of tissue fragments or segments (explants) in vitro; not specifically designed to maintain original or characteristic tissue architecture.

4. Organ Culture — The maintenance or growth of whole or parts of a particular plant structure in vitro. Specifically designed to allow differentiation and maintenance of the original architecture and/or function.

Aseptic	Free from pathogenic microorganisms, however, when used in reference to in vitro procedures, it means free from all microorganisms.
Clone	A population of cells derived from a single parent cell or plant and reproduced exclusively by asexual propagation.
Contamination	The appearance and growth of microorganisms such as bacteria, fungi or mold within the tissue culture.
Explant	Living tissue removed from its normal environment and transferred to an artificial medium for growth.
Hormone	A natural chemical that exerts strong controlling effects on growth, development or metabolism.
In vitro	Living outside the organism, under laboratory conditions or in an artificial environment.

Meristem	The meristem is a dome of undifferentiated tissue whose cells can divide and differentiate to form specialized tissues. It is about 0.1 mm in diameter and 0.25 mm long in size.
Apical Meristem	A mass of undifferentiated cells capable of division at the tip of a root or shoot. These cells differentiate by division, allowing the plant to grow in depth or height.
Successful Tissue Culture	The growth of explant tissues where by shoot and root development occurs in vitro, without contamination from bacteria, fungi, or mold.
Suspension Culture	A type of culture in which the cells proliferate without being attach to an inert surface.
Tissue Culture Problems	Difficulties encountered while doing tissue culture which prohibit or inhibit the growth or development of a contamination free explant.

Totipotent — Each cell of a plant carries all the genetic information it needs to become a whole new plant.

Methodology

The researcher requested three sets of mail labels from the state agriculture education supervisors in each of the study states, listing the agriculture education teachers in their states. From the three sets of mail labels, one was used to send the cover letter and questionnaire (appendix A), the second was used to send a reminder follow-up postcard to nonrespondents (appendix D), and the third was kept and used as a master list. A list of the agriculture education teacher's names, addresses and phone numbers was compiled from the returned questionnaires. The questionnaire was written to determine: a. which agriculture education teachers had taught plant tissue culture in their classroom; b. which agriculture education teachers were planning to teach plant tissue culture during the 1992-93 school year; c. if the teachers had not tried plant tissue culture, the reasons why they had not; and d. if teachers had ever attended an inservice workshop or presentation on plant tissue culture.

The questionnaire and a cover letter were sent to all 595 agriculture education teachers in the five states at the end of February 1993. Names,

addresses and phone numbers of all teachers in the five state study area were typed into a WordPerfect Mail Merge file and used to generate mailing labels for the research survey. A follow up postcard reminding the teachers to complete and return the questionnaire was sent out 14 days after the questionnaire was mailed. The questionnaires were sorted according to how they responded to the following questions: (1) have you taught plant tissue culture in your classes, and (2) are you planning to teach plant tissue culture during this school year. The respondents who answered yes to either question were included in the survey population. By March 1993, a list of teachers from the five state study area who had or were planning to do plant tissue culture during the 1992-93 school year was completed.

The plant tissue culture survey instrument (appendix C) was developed during the spring of 1993. It contained questions regarding: a. successes in doing plant tissue culture; b. problems encountered while doing plant tissue culture; c. new ideas, techniques, experiments and teaching methods being used in teaching plant tissue culture; and d. science competencies taught. The survey instrument was reviewed three times by my graduate committee to examine the content and validity. Following approval of the graduate committee the instrument was reproduced with a return address, stamped with the proper postage and mailed with a cover letter (appendix C) to the agriculture education teachers who had or were planning to do plant tissue culture. The survey instrument was mailed in May of 1993, and subsequent

follow-up postcards, letters (appendix D) and phone calls were made every 14 to 18 days until mid June 1993. Hand and computer tabulation of results along with writing of final chapters took place during the summer of 1993. The MSUSTAT statistical analysis program was used to look at any possible correlations of data from survey questions number 5, 6, 7, 8 and 9B. Due to low numbers of data on some questions it was difficult to note any correlations. Data were reviewed by the Montana State University Agriculture and Technology Education faculty.

Demographic Data

The plant tissue culture questionnaire was sent to 595 agriculture education teachers in Idaho, Montana, North Dakota, Oregon and Washington. The questionnaire return rates are shown in Table 1.

Table 1. Questionnaire return rate by state.

State	Number Sent	Number Returned	Percent Returned
Idaho	85	46	54.1
Montana	71	54	76.0
North Dakota	87	52	59.7
Oregon	110	59	53.6
Washington	242	133	54.9
Total	595	344	57.8

The data in Table 1 show that 344 (57.8%) of the 595 agriculture education instructors returned the questionnaire. Fifty four (76.0%) of the Montana teachers returned the questionnaire. The return rate for the other states ranged from 59.7% (52) for North Dakota, 54.9 (133) for Washington, 54.1% (46) for Idaho and 53.6% (59) for Oregon.

The questionnaire was also used to collect data on the number of teachers who had attended an inservice workshop or presentation on plant tissue culture. The data analyzed in Table 2 show the number of respondents by state who had attended an inservice workshop or presentation on plant tissue culture. Of the 344 respondents, 177 or 51.4% indicated they had attended an inservice workshop or presentation on plant tissue culture.

The questionnaire collected data as to why teachers had not taught plant tissue culture. The data in Table 3 show the respondent's reasons for not teaching plant tissue culture. Lack of training in plant tissue culture was reported by 67.3% (124) of the questionnaire respondents as a reason why they had not taught plant tissue culture. Lack of information was next at 55.45% (102), followed by lack of funds at 33.6% (62) and does not fit the present curriculum at 31.5% (58).

Table 2. A comparison by state of the agriculture education teachers who had attended an inservice workshop or presentation on plant tissue culture.

State	Total Questionnaires Returned	YES, Respondents who have done or are planning to do plant tissue culture.		NO, Respondents who had not done and did not plan to do plant tissue culture.		Total number of teachers attending inservice training	Total percent of teachers attending inservice training
		Teachers Doing plant tissue culture	Teachers who have attended inservice training	Teachers not doing plant tissue culture	Teachers who have attended inservice training		
Montana	54	25	20	29	13	33	61.1
North Dakota	52	30	19	21	11	30	57.0
Oregon	59	31	16	28	7	23	38.9
Washington	133	61	46	68	38	84	63.1
Idaho	46	8	2	38	5	7	15.2
Total	344	155	103	184	74	177	51.4

Table 3. The reasons why teachers have not taught plant tissue culture.

	States											
	Idaho N=38		Montana N=29		N.Dakota N=21		Oregon N=28		Washington N=68		Totals N=184	
Reasons	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Lack of training	32	84.2	17	58.6	15	71.4	20	71.4	40	58.8	124	67.3
Lack of information	28	73.6	15	51.7	12	57.1	21	75.0	26	38.2	102	55.4
Lack of funds	13	34.2	8	27.5	10	47.6	7	25.0	24	35.2	62	33.6
Does not fit the present curriculum	10	26.3	14	48.2	3	14.2	5	17.8	26	38.2	58	31.5

CHAPTER 2

REVIEW OF RELATED LITERATURE

Historical View of Tissue Culture

Plant tissue culture is not a new idea. In 1902 the German botanist Gottlieb Haberland was the first to place leaf tissue into a nutrient solution for observation (Oki, 1978). Although he was unsuccessful in his attempts to culture cells, he foresaw that they could provide a means of studying morphogenesis (the cellular organization, interrelationships and properties of plant cells) (Oki, 1978).

Successful embryo tissue culture was achieved by Manning in 1904 (Oki, 1978). However tissue culturing made little progress until the early 1930's when technical developments introduced by a number of investigators led to the successful aseptic culture of several plant species (Oki, 1978). By 1939, three investigators, Nobecourt and Gautheret in France and White in the United States, reported independently the indefinite culture of plant callus tissue on an artificial medium (Hartmann, 1990). In 1946, Ball obtained

complete plants from shoot tip tissue culture (Oki, 1978). In 1957, Skoog and Miller discovered a fundamental principle upon which all tissue culture and micropropagation depends. The two researchers found that differentiation of plant organs in tobacco callus was controlled by the interactions between auxins and cytokinins (Oki, 1978). By 1960, Norel described the first commercially applicable methods of tissue culture for rapid vegetative propagation of orchids (Oki, 1978). In 1970, Smith achieved the first true apical meristem tissue culture which led to the development of virus and disease free plant tissue culture (Oki, 1978).

Dr. Murashige reported in the 1974 Annual Review of Plant Physiology that:

> "there are four areas in which applications of plant tissue culture are possible, either presently or in the near future: 1. production of pharmaceuticals and other natural products; 2. the genetic improvement of crops; 3. the recovery of disease-free clones and preservation of valuable germplasm; and 4. rapid colonel multiplication of selected varieties." (Murashige, 1974 p.136)

Through Murashige's work, the basic principles and procedures of tissue culture were made available to commercial horticulturists. His work led to the development of commercial tissue culture laboratories in the 1970's and 80's. Dr. Murashige is recognized today as one of the foremost plant tissue culture experts of the world (Debergh, 1990).

The Future of Plant Tissue Culture

The plant tissue culture industry is currently in a maturation phase, experiencing consolidation and market development (MCCown, 1989). During the second half of the last decade the tissue culture industry has experienced slowed growth in the United States. The largest gains are in the tissue culture propagation of woody ornamentals, shade trees, and fruit crops (MCCown, 1989). Through the creation and development of new technologies the tissue culture industry has tremendous potential. Future growth of the tissue culture industry will be stimulated by several technological factors. One way to stimulate growth is to reduce the cost per unit. " Tissue culture is a labor intensive industry and thus has had to rely on a high dollar per unit return to make a profit" (MCCown, 1989 p. 463) This explains the greater industry growth in the woody ornamentals, shade trees, and fruit crops, because they bring a higher dollar return than do foliage plants. Tissue culture plantlets are, in general roughly ten times more expensive than seedlings produced with a semi-automated plug seeding production system. Even though tissue cultured plantlets are high priced there is still a great demand in the horticulture industry for them because of their many advantages (Debergh, 1990). If techniques existed to reduce the dollar per unit costs, then markets could open up, for annuals, vegetables and forest crops (MCCown, 1989). Some progress has been made to automate growth media preparation and handling of culture vessels (MCCown, 1989).

Plant breeding by way of tissue culture is used in the production of new hybrids. This can be done by way of protoplast fusion. The cell walls of two different plant cells can be dissolved with enzymes, and the nuclei from the different cells can then be fused to produce double , triple or four nuclei cells.

> "A triploid or three nuclei plant is often a better grower and gives a higher crop yield than a diploid type. This kind of triploid plant is difficult to use for hybridization, and it reaches a dead end for most breeding work. That's where tissue culture comes into play again." (Yee, 1983 p.7)

When reliable propagation techniques are developed, large new markets will be opened in the tissue culture propagation of conifers such as temperate pine, spruce, and fir (Debergh, 1990). These species as well as monocots such as corn, wheat and other cereal grains have not proven adaptable to shoot culture methods. One technique being explored by research laboratories is somatic embryogenesis. This is the development of true seed-like embryos in a sterile culture which are exact clones. Somatic embryos are encapsulated in a gel-like substance to prevent desiccation until plantlets are established. The hope is that these embryos could be handled much like true seeds. The first successful report of this technique for conifers was reported in 1985 (Debergh, 1990).

Today, plant tissue culture has become one of the key research tools of plant biotechnology with concentration on the in vitro propagation of valuable crops and on the biosynthesis of high value biochemicals. The current interest and demand for natural food ingredients have spurred additional research

activities in this field. The potential of plant tissue culture for food flavor and pigment production is tremendous. For example:

> "the world supply of natural vanilla beans does not satisfy the demand for vanilla flavor and the in vitro biosynthesis of natural vanilla flavor would alleviate this problem" (Knorr, 1990 p.71).

Why Use Tissue Culture To Propagate Plants?

The propagation of plants by tissue culture has some advantages and disadvantages. Advantages of using tissue culture include; rapid clonal multiplication of difficult-to-propagate cultivars, elimination of viruses from infected plants, maintenance of a nuclear stock of healthy plants, reduction in the number of nursery stock plants, importation and exportation of plant material, and genetic engineering of new cultivars. Disadvantages of using tissue culture include: expensive setup and operating costs, skilled staff is required, often lengthy research and development is required, and the potential for some mutation to occur (Callaghan, 1989). "To justify the expense of using plant tissue culture, the original "mother plant" must have special attributes" states Brian Callaghan (Callaghan, 1985 p.371). Seed potato producers in Montana and other states in the Northwest are justifying the use of tissue culture to produce high value disease-free seed potatoes. Because of the disease-free attributes of the "mother plant" seed potato producers are using tissue culture to rapidly multiply disease-free parent stock. Potato producer Dan Lake from Ronan became one of the first producers in the state of

Montana to build his own tissue culture lab in 1983. He stated that "in just five months he can turn five plants into 20,000 and tissue culture plants are almost certainly disease-free, if handled properly" (Jones, 1991 p.7). Potato microtubers produced in a bioreactor culture system also hold exciting promise for seed potato producing areas of the United States. Another reason that tissue culture is used to propagate some plants is because "many plants such as orchids, rhododendrons, azaleas, tuberous begonias and Gerber daisies are hard to propagate using conventional techniques, but can be easily mass produced in vitro" (McNabola, 1989 p.165).

The Application of Tissue Culture

Imagine the applications of the tissue culture: triploid plant propagation, virus-free potatoes, millions of orchids, genetic engineering, biosynthesis of high value food ingredients, and lipstick color pigment are all possible examples. The majority of tissue cultured plantlets are marketed in the ornamental segment of the horticulture industry. Orchids were probably the first horticultural plants to be propagated by tissue culture (Debergh, 1990). Kalfred Yee explains how orchids, which are normally a difficult plant to propagate using traditional methods can be multiplied from one explant to 1,953,125 plants in 12 months time using the technique of meristem tissue culture as a means of vegetative propagation (Yee, 1983).

"Boston ferns, Gerber daisies, strawberries, and orchids are some of the plants that have proven capable of producing literally millions of plants from one explant in a years time" (Yee, 1983 p.6). The sugarcane industry is the largest user of tissue culture plantlets among the agronomic crops. Most of the tissue culture work in agronomic crops is currently limited to research and plant breeding of alfalfa, cotton, rice, soybeans and sugarbeets (Debergh, 1990). Fruit crop production has used tissue culture since about 1980, and most of the laboratories located in Oregon, Washington and British Columbia work in nursery and tree crop propagation as well as small fruits such as raspberries, blackberries, strawberries and grapes. (Debergh, 1990). In the United States approximately 100 to 150 organizations are in the business of producing tissue culture plants. Excluding orchids, production volume ranges from 66 to 75 million units with gross sales of around $24 million annually. The earliest commercial laboratories were started in Florida and California. These two states remain leaders in terms of the number of commercial laboratories and total production capacity. Washington, Oregon and the province of British Columbia, have become industry centers in recent years (Debergh, 1990).

Why Teach Tissue Culture?

"One of the surest ways to get students involved in learning is to involve them in the activity" (El-Mallakh, 1991 p.26). Education is struggling to teach young people the science competencies and skills which numerous studies have shown are necessary to keep our nation competitive. How do you get students interested, motivated and turned on especially with difficult science competencies and skills? Show them the application of the competencies and give them a hands-on application of the skills, and you're on your way. This is the basis of experiential learning. Webster, defines experiential as "a participating in or living through an event, knowledge from doing" (Franklin Electronic Publishers Inc., 1990). "For many students laboratory activities provide the first contact with the real, living, growing elements of agriculture" (Pritchard, 1982 p.4). Plant tissue culture can bring a plant science unit to life through a combination of teaching methods and practical hands-on experiences. This point is emphasized by David Sawyer in an article titled Hands-on Labs in an Academic High School. He states "vocational education's most valuable resource and its best kept secret is its teaching methodology. Hands-on experience in real world laboratory setting allows students to reach into their storehouse of potential and explore their abilities" (Sawyer, 1986 p.50). This type of learning can be applied to any subject area. Hallman sites the value of an applied teaching approach to mathematics. "The value to students in using mathematics in vocational classes is that it becomes relevant when applied in

the laboratory experience. Thus the student gains a higher level of competency than may be possible in a regular mathematics class" (Hallman, 1986 p. 4). Plant tissue culture can be used to teach a wide variety of competencies and skills, from science to safety, math, and writing. "Students need to apply what they learn" (Lonza, 1988 p. 2). Plant tissue culture taught in the agriculture laboratory can provide relevance to the other subjects students are studying. For example english and writing skills can be brought to life through the writing of laboratory reports and research papers on plant tissue culture.

Agriculture education teachers need inservice training, curriculum materials and experience in the use and application of tissue culture. Shelhamer notes that "generally, inservice training will result in major instructional changes within instructional topics" (Shelhamer, 1982 p.57). It is just as important for the inservice instruction to be relevant and applied to teachers as it is for the students. Shelhamer goes on to state "the instructional techniques used during inservice training can influence the instructional method used by vocational agriculture teachers and can affect whether or not the training is incorporated into the local agriculture program" (Shelhamer, 1982 p.57). "Contemporary academic curricula lack real-world applications due to the lack of hands-on methodology and the lack of real-world applied experiences of facility within their academic field" (Lonza, 1988 p. 2). Justification for the use of tissue culture and other hands-on learning experiences can be summed up by the following statement motivation is

to the teaching and learning process. Early American educator Horace Mann made this point clear when he stated that; "A teacher who is attempting to teach without inspiring the pupil with a desire to learn is hammering on cold iron" (Johnson, 1992 p.19).

CHAPTER 3

RESULTS OF THE STUDY

The objectives of this study were to: (1) determine what sterile techniques, equipment, plants and teaching methods were used by students in doing plant tissue culture in the high school setting and the amount of time spent; (2) identify plant growth problems and determine how they affect the attitudes of students toward doing plant tissue culture; (3) determine types and sources of information and/or inservice training agriculture education teachers have received with regards to doing plant tissue culture; (4) determine what science competencies are taught and applied when doing plant tissue culture; and (5) determine the agriculture teachers rationale for incorporating tissue culture into the local curriculum. The findings related to these objectives are presented in the remainder of this chapter. It is important to note that when examining the data in the tables the percentages may not add up to one hundred, because the respondents could choose more than one response.

Demographic Data

The data in Table 4 show the number of respondents who received a plant tissue culture research survey. A total of 152 agriculture education teachers from five states were sent a survey instrument, of which 96 (63.1%) returned the survey. Eighteen surveys were rejected due to unusable data. Most of the unusable surveys were left blank or only filled out in part. Because of the low number of usable surveys from Idaho (4), their data were excluded from the study. Therefore, the data analyzed consisted of 78 (51.3%) respondents from four states. The usable response rate varied from a high of 76.0% (19) for Montana to a low of 43.3% (13) for Oregon.

Table 4. Response By States.

State	Number Sent	Number Returned	Percent Returned	Number Usable Surveys	Percent Usable Surveys
Montana	25	23	92.0	19	76.0
North Dakota	28	19	67.8	18	64.2
Oregon	30	14	46.6	13	43.3
Washington	61	35	57.3	28	45.9
Total	152	96	63.1	78	51.3

The data in Table 5 show the number of different times the respondents had taught tissue culture. More than half, (53.2%), (41) of the teachers had only taught tissue culturing 1 or 2 times. Another 29.8% (23) of the respondents had taught tissue culturing 3 to 4 times, 6.4% (5) had taught it 5 to 6 times, 3.8% (3) had taught it 7 to 8 times, 5.1% (4) had taught it 9 to 10 times. Four respondents indicated having taught tissue culturing 10 times (the highest number reported). On the average, respondents from the four states reported teaching plant tissue culture 2.8 times.

Table 5. The number of times respondents have taught tissue culture.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=27		Totals N=77	
Frequency	No.	%	No.	%	No.	%	No.	%	No.	%
1-2	9	47.3	11	61.1	7	53.8	14	51.8	41	53.2
3-4	5	26.3	5	27.7	6	46.1	7	25.9	23	29.8
5-6	3	15.7	0	0.0	0	0.0	2	7.4	5	6.4
7-8	0	0.0	1	5.5	0	0.0	2	7.4	5	6.4
9-10	2	10.5	0	0.0	0	0.0	2	7.4	4	5.1
	Average Number									
Average number of times taught per state.	3.4	-	2.4	-	2.3	-	3.4	-	2.8	-

The data in Table 6 show the number of hours the responding agriculture teachers spend in the classroom or laboratory each year on tissue culture. The greatest number of respondents, 44 (57.1%), spend from 1 to 10 hours per year, however, 24 (31.1%) spend from 11-20 hours per year. The number of hours spent per year drops off sharply with 6 (7.7%) spending 21 to 30 hours and 1 (1.2%) respondent spending 40 hours per year. On the average, responding agriculture teachers spend 11.8 hours per year on their plant tissue culture unit.

Table 6. Hours spent on plant tissue culture unit each year.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=27		Totals N=77	
Hours	No.	%	No.	%	No.	%	No.	%	No.	%
1-10	11	57.8	4	22.2	9	69.2	20	74.0	44	57.1
11-20	7	36.8	8	44.4	3	23.0	6	22.2	24	31.1
21-30	1	5.2	5	27.7	0	0.0	0	0.0	6	7.7
31-40	0	0.0	0	0.0	0	0.0	1	3.7	1	1.2
	Average Number									
Average # of hours taught per state.	11.5	-	17.5	-	8.0	-	10.4	-	11.8	-

The data in Table 7 reveal that 53.8% of the research survey respondents use the African violet plant to demonstrate plant tissue culture. The respondents from North Dakota, Oregon and Washington use the African violet at 55.5%, 69.2% and 57.1%, respectively. However, Montana teachers use the potato most frequently at 89.4% of the time. Other plants used by the respondents included; cauliflower (6), miniature rose (5), geranium (4), strawberry (2), hops (2), Boston fern, corn, and avocado, mint, beans and rhododendron.

Table 7. Plants used to demonstrate plant tissue culture.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=28		Totals N=78	
Plants	No.	%	No.	%	No.	%	No.	%	No.	%
African Violet	7	3.6	10	55.5	9	69.2	16	57.1	42	53.8
Carrot	5	26.3	14	77.7	3	38.4	7	25.0	29	37.1
Potato	17	89.4	2	11.1	2	15.3	6	21.4	27	34.6
Other Flowers	0	0.0	3	16.6	3	38.4	7	25.0	13	16.6
Other Vegetables	0	0.0	4	22.2	2	15.3	4	14.2	10	12.8
Other	1	5.2	1	5.5	0	0.0	3	10.7	5	6.4
Orchids	0	0.0	0	0.0	0	0.0	2	7.1	2	2.5
Tobacco	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

An examination of the data in Table 8 reveals the different types of plant tissue culture taught in the respondents' classrooms. Explants (small vegetative cuttings) were used at a frequency of 79.2% (61) by the respondents. The next most frequent type of culture done is callus culture (small group of cells) at 37.6% (29). Organ (flower or reproductive part) culture was used by only 11.6% (9) of respondents. In order to have successful tissue culture propagation in the high school classroom the proper plants need to be selected. Almost 80% of the respondents use an explant culture, which is often the easiest to do. However it is interesting to note that 37.6% of the respondents had done callus type tissue culture, which is slower to develop and often more difficult. Carrots, which are most often cultured from a callus, were used as a plant source by 37.6% respondents. The data in Table 7 and Table 8 show that the respondents from the state of Oregon used carrots 38.4%, of the time and callus culture 41.6% of the time. They also reported the lowest level (15.3%, Table 24) of student excitement as a reason for doing tissue culture.

Table 8. Different types of plant tissue culture done in the classroom.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=12		Washington N=28		Totals N=77	
Types of culture	No.	%	No.	%	No.	%	No.	%	No.	%
Explant	18	94.7	12	66.6	8	66.6	23	82.1	61	79.2
Callus	5	26.3	12	66.6	5	41.6	7	25.0	29	37.6
Cell	2	10.5	3	16.6	1	8.3	5	17.8	11	14.2
Organ	3	15.7	3	16.6	2	16.6	1	3.5	9	11.6

The data in Table 9 show that 69.7% (53) of the respondents use a prepackaged plant growth media from a supplier. The respondents who used prepackaged media were asked in the survey to list the supplier. Almost 50% listed Carolina Biological Supply. Other suppliers also listed by the respondents include; Wards, Frey, Nasco, Sigma and Hobar. By comparison, the data show that 26.3% (20) of the respondents mix their own growth media. Three respondents (3.9%) listed other sources of obtaining plant growth media, experiment station, university and a hospital laboratory.

Table 9. Sources of plant growth media.

	States									
	Montana N=18		N.Dakota N=18		Oregon N=12		Washington N=28		Totals N=76	
Growth media	No.	%	No.	%	No.	%	No.	%	No.	%
Prepackaged from a supplier	12	66.6	14	77.7	8	66.6	19	67.8	53	69.7
Mix your own	6	33.3	3	16.6	4	33.3	7	25.0	20	26.3
Other	0	0.0	1	5.5	0	0.0	2	7.1	3	3.9

The data in Table 10 show the percentage of teachers who use different types of sterile transfer chambers and/or methods to do plant tissue culture. The largest number, 31, or 39.7% of the teachers use a plastic box transfer chamber to do plant tissue culture in their classrooms. Seventeen (89.4%) of the Montana teachers used the plastic box transfer chamber compared to 22.2% of the North Dakota teachers, 30.7% of the Oregon and 21.4% of the Washington teachers. A clean table top method was used by 21.7% of the teachers. A wooden box was used by 14.1% of the teachers, and 14.1% used a laminar flow hood. Washington (28.5%) was the leading state using a laminar flow hood.

Table 10. Tissue culture transfer equipment used.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=28		Totals N=78	
Equipment	No.	%	No.	%	No.	%	No.	%	No.	%
Plastic box chamber	17	89.4	4	22.2	4	30.7	6	21.4	31	39.7
Clean table top	2	10.5	2	11.1	4	30.7	9	32.1	17	21.7
Laminar flow hood	0	0.0	1	5.5	2	15.3	8	28.5	11	14.1
Wooden box chamber	0	0.0	4	22.2	2	15.3	5	17.8	11	14.1
Other	0	0.0	2	11.1	1	7.6	1	3.5	4	5.1

Table 11. Student work area and tool sterilization methods.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=28		Totals N=78	
Methods	No.	%	No.	%	No.	%	No.	%	No.	%
Clorox® Solution	8	42.1	9	50.0	9	69.2	20	71.4	46	58.9
Alcohol	17	89.4	16	88.8	7	53.8	19	67.8	59	75.6
Combinations	6	31.5	1	5.5	2	15.3	14	50.0	23	29.4
Distilled Water	2	10.5	6	33.3	2	15.3	3	10.7	13	16.6
Washing in Water	3	15.7	4	22.2	0	0.0	0	0.0	7	8.9
Other	2	10.5	0	0.0	0	0.0	0	0.0	0	0.0

The data in Table 11 show the frequency of different work area and tool sterilization methods used by the respondents' students. Alcohol and Clorox® were the most frequently used sterilization methods in each of the states. The data show a total respondent usage of 75.6% for alcohol and 58.9% for Clorox® solution. Clorox® solution was used more frequently in Oregon (69.2%) and Washington (71.4%) while alcohol was used by 89.4% of the Montana teachers and 88.8% of the North Dakota respondents.

The data in Table 12 show the frequency of different explant sterilization methods used by the respondents' students. The data show a total respondent usage of 56.4% for Clorox® solution and 35.8% for alcohol. A combination of sterilants were the least used sterilization method at 6.4%.

The data in Table 13 reveal which instructional methods were used by teachers in teaching plant tissue culture. Demonstrations were used by 91.0% of the respondents while lecture and notes were used by 87.1%. This is closely followed by 85.8% of the students actually doing plant tissue culture. Teachers used video presentations as a method of teaching tissue culture 61.5% of the time. Field trips were used by only 6.4% of the teachers as a method of instruction to teach plant tissue culture.

Table 12. Explant sterilization methods.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=28		Totals N=78	
Methods	No.	%	No.	%	No.	%	No.	%	No.	%
Clorox® solution	10	52.6	9	50.0	6	46.1	19	67.8	44	56.4
Alcohol	6	31.5	9	50.0	5	38.4	8	28.5	28	35.8
Distilled water	3	15.7	7	38.8	5	38.4	6	21.4	21	62.9
Washing in water	7	3.6	4	22.2	1	7.6	3	10.7	15	19.2
Combination	1	5.2	0	0.0	3	38.4	1	3.5	5	6.4
Other	1	5.2	0	0.0	0	0.0	1	3.5	2	2.5

Table 13. Instructional methods used to teach plant tissue culture.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=28		Totals N=78	
Methods	No.	%	No.	%	No.	%	No.	%	No.	%
Demonstrations	17	89.4	15	83.3	12	92.3	27	96.4	71	91.0
Lecture and notes	13	68.4	16	88.8	11	84.6	28	100	68	87.1
Students doing tissue culture	18	94.7	17	94.4	9	69.2	23	82.1	67	85.8
Video presentations	8	42.1	17	94.4	6	46.1	17	60.7	48	61.5
Field trips	0	0.0	1	5.5	0	0.0	4	14.2	5	6.4

The data in Table 14 show the perceived level of enthusiasm demonstrated by the students while doing plant tissue culture. Respondents were asked to rate the level of enthusiasm on a scale of 1 to 10, with 10 meaning the students were very excited. Thirty-five percent (27) of the teachers reported an 8 on the enthusiasm scale. The data also show 33.7% (26) of the teachers felt their students demonstrated a 7 on the enthusiasm scale. None of the teachers reported student enthusiasm lower than a 5, while only 5.1% (4) indicated a 10 (very excited) on the scale.

It is interesting to compare the data from Table 13 with the data from Table 14: a low percentage (25.0%) of the respondents from Oregon indicated an 8 on the enthusiasm scale. When compared with the data in Table 13 that show few Oregon respondents 69.2% (9) had students doing plant tissue culture, the reason for a lower level of enthusiasm might be explained.

Table 14. Level of student enthusiasm.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=12		Washington N=28		Totals N=77	
Enthusiasm	No.	%	No.	%	No.	%	No.	%	No.	%
10 Very excited	1	5.2	0	0.0	1	8.3	2	7.1	4	5.1
9	2	10.5	1	5.5	0	0.0	2	7.1	5	6.4
8	7	36.8	7	38.8	3	25.0	10	35.7	27	35.0
7	7	36.8	6	33.3	4	33.3	9	32.1	26	33.7
6	2	10.5	4	22.2	2	16.6	4	14.2	12	15.5
5 No change	0	0.0	0	0.0	2	16.6	1	3.5	3	3.8
4	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
2	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
1 Disliked	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

The data in Table 15 show 96.1% (75) of the responding agriculture education teachers had contamination in their plant tissue culture. This is compared with 3.8% (3) of the respondents who reported no contamination.

Table 15. Contaminated tissue culture.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=28		Totals N=78	
Contamination	No.	%	No.	%	No.	%	No.	%	No.	%
Yes	19	100	17	94.4	12	92.3	27	96.4	75	96.1
No	0	0.0	1	5.5	1	7.6	1	3.5	3	3.8

Table 16. Causes of contamination.

	States									
	Montana N=19		N.Dakota N=17		Oregon N=13		Washington N=27		Totals N=76	
Causes	No.	%	No.	%	No.	%	No.	%	No.	%
Mold	11	57.8	11	64.7	5	38.4	15	55.5	42	55.2
Bacteria	8	42.1	8	47.0	2	15.3	9	33.3	27	35.5
Do not Know	5	26.3	8	47.0	4	30.7	6	22.2	23	30.2
Fungus	7	36.8	5	29.4	2	15.3	6	22.2	20	26.3
Combinations	6	31.5	4	23.5	2	15.3	3	11.1	15	19.7
Other	1	5.2	0	0.0	0	0.0	0	0.0	1	1.3

The data in Table 16 reveal that 55.2% (42) of the teachers reported that mold was the cause of contamination in their tissue culture. Bacteria were reported 35.5% (27) of the time as the cause of contamination. Fungi were reported as the cause of contamination 19.7% (15) of the time. A need for inservice education is revealed by the data that show only 30.2% (23) of the teachers know the type of contamination their culture had.

The data in Table 17 show the percent of contamination in the respondents' tissue culture. One should be cautious when examining the data in this table because the respondents were not actually asked to count and calculate the percentage of contamination also the low number of respondents could effect the results. The majority of respondents, (66.1%), 47 (13+17+17) out of 71, reported contamination levels from 1 to 60%. Seven (9.8%) of the respondents reported contamination of 61% to 80%, while 14 (19.7%) reported contamination of 81% to 100%. The average level of tissue culture contamination for the responding teachers was 51.6%. Montana teachers reported the highest level of contamination at 63.8% (17) and Oregon teachers reported the lowest levels at 44.2% (11).

Table 17. Percent levels of contamination.

	States									
	Montana N=17		N.Dakota N=16		Oregon N=11		Washington N=27		Totals N=71	
Level	No.	%	No.	%	No.	%	No.	%	No.	%
1-20%	1	5.8	2	12.5	4	36.3	6	22.2	13	18.3
21-40%	4	23.5	4	25.0	2	18.1	7	25.9	17	23.9
41-60%	3	17.6	5	31.2	2	18.1	7	25.9	17	23.9
61-80%	2	11.7	3	18.7	0	0.0	2	7.4	7	9.8
81-100%	7	41.1	2	12.5	3	27.2	5	18.5	14	19.7
	Average Percent									
Average % contamination	-	63.8	-	51.8	-	44.2	-	46.8	-	51.6

The data in Table 18 show how contaminants were perceived by respondents to affect student attitudes toward tissue culture. Over one fourth of the respondents reported that plant growth problems can cause some students to become discouraged. The largest group of teachers 56.1% (41) reported that students view contamination as part of the process. Seventeen (23.2%) of the respondents indicated that their students became interested in learning more about the contaminants. The data show that only 9.5% (7) of the students became indifferent as to what caused the contamination.

Thirty-five (20 + 15) or 47.8% (27.3% + 20.5%) of the respondents reveal that contamination caused their students to become discouraged or react negatively.

Table 18. Student attitudes toward contamination.

	States									
	Montana N=19		N.Dakota N=17		Oregon N=10		Washington N=23		Totals N=73	
Attitudes	No.	%	No.	%	No.	%	No.	%	No.	%
View contamination as part of the process	9	47.3	12	70.5	6	60.0	14	51.8	41	56.1
Become discouraged	4	21.0	5	29.4	4	40.0	7	25.9	20	27.3
Become interested in the contamination	6	31.5	2	11.7	2	20.0	7	25.9	17	23.2
React negatively	2	10.5	6	35.2	2	20.0	5	18.5	15	20.5
Become indifferent	3	15.7	0	0.0	1	10.0	3	11.1	7	9.5

Table 19 present data regarding how agriculture education teachers learned to do plant tissue culture. Most teachers (75.6%) learned to do tissue culture by attending an inservice workshop. Others learned to do tissue culture by having someone show them (20.2%), viewing videos (21.6%) and by reading (36.4%). Very few (5.4%) of the teachers learned to do tissue culture from industry.

Table 19. How teachers learned to do tissue culture.

	States									
	Montana N=18		N.Dakota N=17		Oregon N=12		Washington N=27		Totals N=74	
Learn	No.	%	No.	%	No.	%	No.	%	No.	%
Inservice / workshop	17	94.4	12	70.5	5	41.6	22	81.4	56	75.6
Readings	3	16.6	6	35.2	9	75.0	9	33.3	27	36.4
Videos	2	11.1	5	29.4	6	50.0	3	11.1	16	21.6
Someone showed	3	16.6	5	29.4	3	25.0	4	14.8	15	20.2
College	2	11.1	1	5.8	1	8.3	5	18.5	9	12.1
Industry	0	0.0	2	11.7	0	0.0	2	7.4	4	5.4

The data in Table 20 indicate that materials from Carolina Biological Supply were used the most frequently by the respondents at 61.0% (47) for student lab instructions. The data show that 49.3% (38) of the teachers use inservice materials and 42.8% (33) use self developed materials. The higher percent (66.6%) of Oregon teachers using self developed materials is supported by data in Table 18 which reveal that 75% (9) of Oregon respondents learned by completing readings. The Montana teachers (78.9%) relied heavily on materials received during inservice. Purchased lab manuals and books were used by only 5.1% (4) and 3.8% (3) of the respondents respectively.

Table 20. Teaching materials used for student tissue culture labs.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=12		Washington N=28		Totals N=77	
Materials	No.	%	No.	%	No.	%	No.	%	No.	%
Carolina Biological	9	47.3	15	83.3	6	50.0	17	60.7	47	61.0
Inservice materials	15	78.9	8	44.4	2	16.6	13	46.4	38	49.3
Self developed	6	31.5	6	33.3	8	66.6	13	46.4	33	42.8
Lab manual	2	10.5	1	5.5	0	0.0	1	3.5	4	5.1
Books	0	0.0	2	11.1	1	8.3	0	0.0	3	3.8
Other	0	0.0	3	16.6	0	0.0	0	0.0	3	3.8
Journals/Magazines	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

The data in Table 21 show similarity with the data in Table 20 regarding where teachers get information for doing plant tissue culture. Carolina Biological Supply materials were used most frequently 67.5% (52) as a teacher information reference. Inservice materials were used by 64.9% (50) of the teachers. Montana teachers 78.9% (15) relied on inservice materials at a higher rate than the other states. A high number of teachers from North Dakota 14 (77.7%) and Oregon 9 (75.0%) relied on information from Carolina Biological Supply. Self developed materials were used by 25.9% (20) of the

respondents. The reported use of journals, purchased lab manuals and books were only 3.8% (3), 5.1% (4) and 9.0% (7), respectively.

Table 21. Teacher reference materials used.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=12		Washington N=28		Totals N=77	
Materials	No.	%	No.	%	No.	%	No.	%	No.	%
Carolina Biological	10	52.6	14	77.7	9	75.0	19	67.8	52	67.5
Inservice materials	15	78.9	11	61.1	6	50.0	18	64.2	50	64.9
Self developed	6	31.5	5	27.7	2	16.6	7	25.0	20	25.9
Books	1	5.2	2	11.1	3	25.0	1	3.5	7	9.0
Lab manual	1	5.2	3	16.6	0	0.0	0	0.0	4	5.1
Journals/Magazines	0	0.0	1	5.5	1	8.3	1	3.5	3	3.8
Other	0	0.0	2	11.1	0	0.0	1	3.5	3	3.8

The data in Table 22 indicate the areas in which agriculture teachers feel they need additional training regarding plant tissue culture. Over three fourths (76.6%) of the teachers reported that controlling contamination was the area of training where they needed the most help. The respondents from North Dakota and Oregon reported needing help with controlling contamination

82.3% and 84.6% respectively. Preparation of growth media (55.8%) was the second area of greatest need. Obtaining sterile plant stock is a problem for about one half (50.6%) of the teachers. Montana teachers (36.8%) reported the lowest need for additional training in preparation of plant tissue culture growth media. Obtaining sterile plant stock does not appear to be an area of great need for the teachers from Washington with only 35.7% reported needing help in this area.

Survey question numbers 17 and 17a asked if the respondents had helped other teachers get started doing tissue culture. The data from these questions was not put into table format. Only 27.2% of the respondents indicated they had helped other teachers get started doing tissue culture. This may be in part due to the lack of experience doing tissue culture as reported in Table 5.

Table 22. Areas in which teachers feel they need additional training:

	States									
	Montana N=19		N.Dakota N=17		Oregon N=13		Washington N=28		Totals N=77	
Training	No.	%	No.	%	No.	%	No.	%	No.	%
Controlling contamination	14	73.6	14	82.3	11	84.6	20	71.4	59	76.6
Preparation of growth media	7	36.8	11	64.7	8	61.5	17	60.7	43	55.8
Obtaining sterile plant stock	11	57.8	10	58.8	8	61.5	10	35.7	39	50.6
Equipment sterilization	4	21.0	7	41.1	5	38.4	9	32.1	25	32.4
Use of equipment	5	26.3	11	64.7	2	15.3	5	17.8	23	29.8
Understanding lab manuals	3	15.7	7	41.1	2	15.3	4	14.2	16	20.7
Other	1	5.2	0	0.0	0	0.0	2	7.1	3	3.8

The data in Table 23 a and b list the scientific competencies which were taught by respondents in their tissue culture unit of instruction. Two competencies were listed by over 80% of the respondents: describe different methods of plant reproduction by 81.8% and demonstrate the safe use of laboratory equipment and supplies by 89.6%. Four competencies were listed

by 70% to 80% of the respondents; aseptic techniques 70.1%, plant anatomy 71.4%, identify environmental conditions necessary for plant germination and growth 71.4%, and describe the life cycle of plants 75.3%. Six science competencies were reported by 50% to 70% of the responding teachers; classifying and identifying plants according to their parts 59.7% and explain photosynthesis 63.6%, the competency of distinguishing between different kinds of plant tissue was reported by 54.5% of the respondents. There were three competencies taught by 51.9%, prepare and mix chemical solutions, identify the primary and secondary nutrients required by plants, and explain how light influences the growth rate of plants. Four science competencies were listed in the 40% to 50% frequency range and include explaining plant transpiration 44.1%, recording growth patterns of plants 45.4%, using a microscope to observe plant growth and development, and describing and testing pH, each at 49.3%. The remaining three competencies were selected by less than 25% of the respondents and include explaining plant and seed dormancy 24.6%, identifying the three major groups of plant hormones 20.7%, and lowest response was performing basic metric conversions 16.8%. In addition to the nineteen science competencies listed in Table 23 a, and 23 b, the respondents listed 43 other competencies being taught or applied in their tissue culture unit (appendix E).

Table 23 a. Frequently taught science competencies.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=27		Totals N=77	
Competencies	No.	%	No.	%	No.	%	No.	%	No.	%
Demonstrate the safe use of laboratory equipment and supplies.	17	89.4	18	100	11	84.6	23	85.1	69	89.6
Describe different methods of plant reproduction.	14	73.6	13	72.2	10	76.9	26	96.2	63	81.8
Describe the life cycle of plants.	15	78.9	15	83.3	8	61.5	20	74.0	58	75.3
Identify environmental conditions necessary for plant growth.	14	73.6	12	66.6	9	69.2	20	74.0	55	71.4
Plant anatomy.	15	78.9	13	72.2	9	69.2	18	66.6	55	71.4
Aseptic techniques	12	63.1	15	83.3	9	69.2	18	66.6	54	70.1
Explain photosynthesis	13	68.4	13	72.2	7	53.8	16	59.2	49	63.6
Classify and identify plants according to their parts.	13	68.4	11	61.1	7	53.8	15	55.5	46	59.7
Distinguish between different kinds of plant tissues.	11	57.8	10	55.5	4	30.7	17	62.9	42	54.5

Table 23 b. Frequently taught science competencies, continued.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=27		Totals N=77	
Competencies	No.	%	No.	%	No.	%	No.	%	No.	%
Identify the primary and secondary nutrients required by plants.	8	42.1	13	72.2	6	46.1	13	48.1	40	51.9
Explain how light influences the growth rate of plants.	9	47.3	10	55.5	5	38.4	16	59.2	40	51.9
Prepare and mix chemical solutions.	12	63.1	11	61.1	6	46.1	11	40.7	40	51.9
Use microscope to observe plant growth and development.	8	42.1	8	44.4	6	46.1	16	59.2	38	49.3
Describe and test pH.	10	52.6	7	38.8	6	46.1	15	55.5	38	49.3
Record the growth patterns of plants.	8	42.1	7	38.8	7	53.8	13	48.1	35	45.4
Explain plant transpiration.	9	47.3	9	50	6	46.1	10	37.0	34	44.1
Explain plant and seed dormancy.	3	15.7	10	55.5	2	15.3	4	14.8	19	24.6
Identify the three major groups of plant hormones.	2	10.5	6	33.3	2	15.3	6	22.2	16	20.7
Preform basic metric conversions.	2	10.5	3	16.6	2	15.3	6	22.2	13	16.8

When asked about science teachers teaching tissue culture, nine (11.8%) respondents reported that their science departments taught plant tissue culture. The majority of respondents 63, (82.8%) reported their science departments did not teach tissue culture. The remaining 4 respondents or 5.2% reported they did not know if their science departments taught tissue culturing.

The data in Table 24 reveal the reasons why responding agriculture education teachers teach plant tissue culture. The most frequently reported reasons were; to teach science skills 67.5%, teach plant propagation 62.3%, have a hands on activity in the plant science unit 61.0%, and teach aseptic laboratory techniques 44.1%. Listed under other reasons, seven respondents reported to teach biotechnology and two reported teaching tissue culture because the science department does not teach it.

Table 24. The reasons teachers teach plant tissue culture.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=27		Totals N=77	
Reasons	No	%	No.	%	No.	%	No.	%	No.	%
To teach science skills and competencies	9	47.3	15	83.3	10	76.9	18	66.6	52	67.5
To teach plant propagation	9	47.3	10	55.5	10	76.9	19	70.3	48	62.3
To have a hands on activity during the plant science unit	15	78.9	10	55.5	8	61.5	14	51.8	47	61.0
To teach aseptic techniques	6	31.5	9	50.0	6	46.1	13	48.1	34	44.1
The students get excited	8	42.1	7	38.8	2	15.3	9	33.3	26	33.7
Other	2	10.5	3	16.6	1	7.6	3	11.1	9	11.6

The data in Table 25 show the instructional unit titles under which plant tissue culture was taught. Plant propagation (77.9%) stands out from all of the titles used by respondents. When the respondents reported other titles plant science was listed three times (3.8%).

Table 25. Instructional units in which plant tissue culture is taught.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=27		Totals N=77	
Unit	No.	%	No.	%	No.	%	No.	%	No.	%
Propagation	14	73.6	11	61.1	11	84.6	24	88.8	60	77.9
Genetics	4	21.0	9	50.0	1	7.6	3	11.1	17	22.0
Germination	4	21.0	2	11.1	3	23.0	1	3.7	10	12.9
Other	3	15.7	2	11.1	1	7.6	2	7.4	8	10.3

The data in Table 26 show the course titles within which agriculture education teachers teach plant tissue culture. The most common course title was horticulture at 45.4%. The next most frequently selected course titles were agriscience at 25.9% and Vo-Ag II or Ag-Ed II at 23.3%. A review of the data seem to indicate that plant tissue culture is taught in the early years of high school particularly the sophomore year. One might hypothesize that some difficulties reported by teachers may be the result of teaching tissue culture

material to younger students prior to their having sufficient background in science. It is interesting that Montana teachers include tissue culture in the instructional program for a greater number of their younger students. Montana freshman or Vo-Ag I/Ag-Ed I (15.7%) and sophomore Vo-Ag II/Ag-Ed II (52.6%) students received plant tissue culture instruction more frequently than reported by other states for the same course titles. When referring back to Table 17 it is noted that Montana reported the highest total levels of contamination at 63.8% compared with a total of 51.6%.

Table 26. The common course titles under which plant tissue culture is taught.

	States									
	Montana N=19		N.Dakota N=18		Oregon N=13		Washington N=27		Totals N=77	
Titles	No.	%	No.	%	No.	%	No.	%	No.	%
Horticulture	1	5.2	4	22.2	8	61.5	22	81.4	35	45.4
Agriscience	5	26.3	5	27.7	1	7.6	9	33.3	20	25.9
Vo-Ag or Ag-Ed II	10	52.6	3	16.6	3	23.0	2	7.4	18	23.3
Vo-Ag or Ag-Ed IV	2	10.5	4	22.2	2	15.3	1	3.7	9	11.6
Vo-Ag or Ag-Ed III	5	26.3	2	11.1	0	0.0	1	3.7	8	10.3
Vo-Ag or Ag-Ed I	3	15.7	0	0.0	0	0.0	2	7.4	5	6.4
Other	2	10.5	5	27.7	1	7.6	3	11.1	11	14.2

The survey instrument also asked the respondents if they knew of better ways to teach similar science skills. The resulting data were not put into table form; however, seventy-one (92.2%) of the respondents had not found better techniques than plant tissue culture to teach similar science skills. Six respondents (7.7%) reported having found a better technique to teach similar skills. Of these six respondents, three reported that fast plants were superior to tissue culture in teaching similar science competencies.

Seventy-one (92.2%) of the responding teachers plan to keep tissue culture as part of their curriculum while six (7.7%) will not continue with tissue culture. The reported reasons why agriculture education teachers will discontinue teaching plant tissue culture include lack of proper facilities, and lack of training or inservice education.

The data in Table 27 show the amount of money spent by teachers for chemicals, supplies and growth media per year to do plant tissue culture. The greatest number of respondents, 32 (42.1%), spend from 0 to $100. Twenty (26.3%) of the responding teachers reported spending from $101 to $200 and 18 (23.6%) spend from $201 to $300 per year.

Table 27. Money spent per year on chemicals, supplies and growth media.

	States									
	Montana N=18		N.Dakota N=18		Oregon N=13		Washington N=27		Totals N=76	
Amount	No.	%	No.	%	No.	%	No.	%	No.	%
$ 0-100	11	61.1	6	33.3	6	46.1	9	33.3	32	42.1
$ 101-200	5	27.7	3	16.6	5	38.4	7	25.9	20	26.3
$ 201-300	4	22.2	4	22.2	2	15.3	8	29.6	18	23.6
$ 301-400	0	0.0	1	5.5	0	0.0	0	0.0	1	1.3
$ 401-500	0	0.0	2	11.1	0	0.0	2	7.4	4	5.2
$ 501-1000	0	0.0	2	11.1	0	0.0	1	3.7	3	3.9
$ 1001->	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

The data in Table 28 show the amount of money spent per year by teachers for equipment to do plant tissue culture. A total of 25 or (39.1%) of respondents spent between 0 and $100. Thirteen (17.5%) of the respondents spent between $201 and $300. It is interesting to note that 13.5% of the respondents spent $1,000 or more on equipment. Data show that Montana respondents reported spending less than the respondents from other states. North Dakota 5 (27.7%) and Washington 4 (16%) had the most respondents spending over $1,000.

Table 28. Money spent per year on equipment to do plant tissue culture.

	States									
	Montana N=18		N.Dakota N=18		Oregon N=13		Washington N=25		Totals N=74	
Amount	No.	%	No.	%	No.	%	No.	%	No.	%
$ 0-100	10	55.5	6	33.3	7	53.8	6	24.0	29	39.1
6$ 101-200	6	33.3	1	5.5	1	7.6	5	20.0	13	17.5
$ 201-300	1	5.5	2	11.1	2	15.3	4	16.0	9	12.1
$ 301-400	1	5.5	1	5.5	0	0.0	2	8.0	4	5.4
$ 401-500	0	0.0	2	11.1	1	7.6	0	0.0	3	4.0
$ 501-1000	0	0.0	1	5.5	1	7.6	4	16.0	6	8.1
$ 1001->	0	0.0	5	27.7	1	7.6	4	16.0	10	13.5

The researcher was interested in ascertaining if different methods of doing tissue culture would result in lower levels of contamination. The data in Tables 29, 30 and 31 compare equipment, and sterilization techniques with the respondents reported level of tissue culture contamination. Usable data were obtained from 71 teachers and reported in Tables 29 through 33.

The data in Table 29 show transfer chamber contamination levels. Plastic box chamber and laminar flow hood show the lowest levels of contamination in the 81% to 100% range, with a contamination rate of 17.6% and 16.6% respectively. When eliminating the table cells containing one

response there is no noticeable difference in the percentage of respondents reporting different levels of contamination.

Table 29. Contamination levels of different transfer chambers and methods.

	Percent Contamination									
	0 - 20		21 - 40		41 - 60		61 - 80		81 - 100	
Equipment	No.	%	No.	%	No.	%	No.	%	No.	%
Wood box chamber N=15	2	13.3	4	26.6	3	20.0	2	13.3	4	26.6
Plastic box chamber N=34	8	23.5	7	20.5	8	23.5	5	14.7	6	17.6
Laminar flow hood N=12	1	8.0	4	33.3	4	33.3	1	8.0	2	16.6
Clean table top N=15	3	20.0	3	20.0	3	20.0	1	6.6	5	33.3

The data in Table 30 show the percent level of contamination for different types of work area and tool sterilization techniques. Sixty percent (33.3% + 27.7%) of the respondents who used an autoclave reported a contamination percentage of less than 40%. Using distilled water resulted in the highest levels of contamination. Fifty percent (25.0% + 25.0%) of the respondents who used distilled water for sterilization reported contamination

levels of 61% to 100%. No notable difference in percent between sterilization materials were revealed by the data in Table 30.

Table 30. Contamination levels for work area and tool sterilization.

	Percent Contamination									
	0 - 20		21 - 40		41 - 60		61 - 80		81 - 100	
Sterilization	No.	%	No.	%	No.	%	No.	%	No.	%
Clorox® N=48	9	18.7	11	22.9	12	25.0	6	12.5	10	20.8
Alcohol N=53	9	16.9	10	18.8	12	22.6	6	11.3	16	30.1
Distilled water N=12	1	8.0	3	25.0	2	16.6	3	25.0	3	25.0
Wash in water N=6	0	0.0	1	16.6	3	50.0	1	16.6	1	16.6
Autoclave N=18	6	33.3	5	27.7	2	11.1	1	5.5	4	22.2
Combination N=6	2	33.3	1	16.6	1	16.6	0	0.0	2	33.3

The data in Table 31 show the contamination levels for different methods of explant sterilization methods. Working in water (38.4%) and combination of sterilization (57.1%) led to the greatest number of problems and resulted in

an 81 to 100% contamination rate. Clorox® (N=48) and alcohol (N=53) are the most frequently used sterilant, data do not show a noticeable and consistent difference in percent of respondents reported level of contamination.

Table 31. Contamination levels for different explant sterilization methods.

	Percent Contamination									
	0 - 20		21 - 40		41 - 60		61 - 80		81 - 100	
Sterilization	No.	%	No.	%	No.	%	No.	%	No.	%
Clorox® N=48	6	14.6	9	21.9	13	31.7	3	7.3	10	24.3
Alcohol N=53	5	20.0	4	16.0	6	24.0	4	16.0	6	24.0
Distilled water N=12	5	29.4	5	29.4	0	0.0	3	17.6	4	23.5
Wash in water N=6	2	15.3	2	15.3	4	30.7	0	0.0	5	38.4
Combination N=6	1	14.2	1	14.2	0	0.0	1	14.2	4	57.1

When one examines the data in Tables 29, 30 and 31 a significant conclusion cannot be drawn from the data as to the cause of contamination. As a result a best means to prevent tissue culture contamination was not identified.

A closer examination of the raw data was undertaken to compare the level of contamination between different equipment and sterilants. The data in Table 32 reveal the percent levels of contamination for the four transfer methods when a combination of either Clorox® or alcohol sterilization was used. Ten respondents indicated using a clean table top and alcohol and also reported the highest levels of contamination (68.2%). The lowest level of contamination was reported by the teachers who used a laminar flow hood and alcohol (44.6%). An analysis of the data suggest there is no noticeable advantage of any combination of equipment and sterilant.

Table 32. Contamination levels of transfer methods and sterilization technique.

	Contamination Level	
Methods and Techniques	No.	%
Wooden box chamber and Clorox®	9	53.8
Wooden box chamber and alcohol	21	55.9
Plastic box chamber and Clorox®	21	46.3
Plastic box chamber and alcohol	28	52.9
Laminar flow hood and Clorox®	11	52.4
Laminar flow hood and alcohol	8	44.6
Clean table top and Clorox®	14	52.2
Clean table top and alcohol	10	68.2

The data in Table 33 show the student enthusiasm level as reported by the respondents using different teaching methods. It is interesting to note that higher levels of enthusiasm were reported when a video presentation was included in the instruction. Six respondents reported an average enthusiasm level of 8.3 (on a scale of 1 to 10) when using instruction which included a video presentation, lecture, notes and students actually doing plant tissue culture. There were ten additional combinations of instructional teaching methods not reported with the data in Table 33 because they had 5 or less respondents.

Table 33. Student enthusiasm level for different instructional methods.

Methods	Enthusiasm Level *
Video presentation, lecture, notes, demonstrations and students doing tissue culture. N=29	7.5
Video presentation, lecture and notes, and students doing tissue culture. N=6	8.3
Lecture and notes, and students doing tissue culture. N=14	6.9
Demonstrations and students doing tissue culture. N=6	7.0

* Note; enthusiasm level scale is 1 to 10, 1 is disliked, 5 is no change in enthusiasm and 10 is very excited.

CHAPTER 4

CONCLUSIONS, IMPLICATIONS, RECOMMENDATIONS AND SUMMARY

Conclusions

The purpose of this study was to determine how secondary agricultural educators in Idaho, Montana, North Dakota, Oregon and Washington were using plant tissue culture to teach the application of scientific concepts.

The objectives of this study were to: (1) determine what sterile techniques, equipment, plants and teaching methods were used by students in doing plant tissue culture in the high school setting and the amount of time spent; (2) identify plant growth problems and determine how they affect the attitudes of students toward doing plant tissue culture; (3) determine types and sources of information and/or inservice training agriculture education teachers have received with regards to doing plant tissue culture; (4) determine what science competencies were taught and applied when doing plant tissue culture; and (5) determine the agriculture teachers rationale for incorporating tissue culture into the local curriculum. The findings related to these objectives are presented in the remainder of this chapter.

Based on the analysis of data, the following conclusions relating to the

use of plant tissue culture in agriculture education in the Northwestern states have been drawn:

1. The African violet is the most common plant used for tissue culture. Carrot and potato plants are frequently used for tissue culture. The potato is the most common plant used by agriculture education teachers for tissue culture in Montana.
2. The plastic transfer chamber and prepackaged media from a supplier are used most frequently for sterile tissue culture transfers.
3. The most popular instructional method of teaching tissue culture is the demonstration, and students actually doing tissue culture.
4. Explant type tissues are used most often by students when doing plant tissue culture.
5. Agriculture educators are in the early stages of learning about and providing instruction in plant tissue culture at the high school level.
6. Agriculture education teachers can expect about one half of their students' tissue cultures to show evidence of contamination. This level of contamination will be viewed by the students as part of the learning process, and thus can be used as a tool for teaching about microorganisms.
7. Plant tissue culture can be used to teach plant propagation and

at least sixteen specific science competencies using equipment and supplies that can be purchased on a budget of less than $300 per year.

Implications

The following implications are offered as a result of this study:

1. The type of plants, equipment, supplies, references, growth media and sterilization techniques used by teachers are determined by the type of instructional methods used in inservice education received by teachers. This agrees with research done by Shelhamer 1982.
2. The undergraduate agriculture education teacher preparation should include more training in science and science methodology.
3. Agriculture education teachers need to work more closely with science teachers in their schools and support each others efforts to teach science competencies.
4. Agriculture education as a profession should develop closer ties with the tissue culture industry.

Recommendations

As a result of this study, the following recommendations are offered for the agriculture education profession:

1. Periodic teacher inservice sessions should be provided to update current users and to train and build the confidence levels of nonusers of plant tissue culture.
2. Industry professionals should be utilized as inservice instructors.
3. To develop additional curriculum materials on plant tissue culture for high school students, each state agriculture education teacher's association, teacher training department and state supervisors should identify and work with those teachers utilizing plant tissue culture to provide training and curriculum materials for other teachers.
4. Inservice training and curriculum materials should be shared with teachers in other states.
5. Secondary agriculture education teacher preparation programs should give students a brief exposure to tissue culture. During a designated college agriculture education course, prospective teachers should be assigned to a research lab or production tissue culture facility to do an 8 to 16 hour or 1 to 2 day internship in tissue culture usage and application.
6. An agriculture teacher inservice program should be developed to deal specifically with culture contamination sources and types of contaminants. Instructional emphasis should be given to identification of bacteria, mold and fungi.

7. Agriculture education needs to continue to explore other ways to teach science competencies.

Recommendations for Further Study

1. Research should be conducted and information gathered from other states to compare with the results of this study.
2. A study should be completed to ascertain the causes of tissue culture contamination and the sources of contamination.
3. Research should be conducted to identify the specific reasons why teachers are not teaching tissue culture.
4. Research should be conducted to gather information from high school students doing plant tissue culture.

Summary

Teachers planning to teach tissue culture should keep it simple. They should use prepared media, plastic transfer chambers, explant tissues, and use sterile plant sources from industry if possible. The teacher should practice sterile techniques with his/her students before doing any tissue culture.

BIBLIOGRAPHY

Bhojwani, Sant, S., Dhawan, Vibha, Arora. & Renu. (1990) Plant Tissue Culture A Classified Bibliography 1985-1989. Elsevier Science Publishing Company Inc. New York, NY.

Bottino, P. J. (1981) Methods In Plant Tissue Culture. Botany Department, University of Maryland, College Park.

Brush, Jolene. (July, 1991) (Interview with Jolene Brush, Montana State University Seed Potato Lab Supervisor. Bozeman MT.).

Burr, Randall. (1983) Progress and New Ideas in Tissue Culture Propagation. The International Plant Propagators Society v33.

Burton, DeVere, L. (1992) Agriscience and Technology, Delmar Publishing, Albany, New York.

Butcher, Dennis, N., Ingram, David, S. (1976) Studies in Biology no.65, Plant Tissue Culture, Edward Arnold Publishing Limited, Hill Street, London.

Callaghan, Brian, J. (1985) Tissue Culture: Is It The Ultimate In Asexual Propagation? The International Plant Propagators Society v35.

Center for Occupational Research and Development (1992). Applied Biology/Chemistry. Plant Growth and Reproduction. Waco, Texas: Author.

Cohen, D. (1980) Equipping A Plant Tissue Culture Laboratory. Massey University. Department of Horticulture and Plant Health Proceedings. 1980.

Conner, Doyle. (1980) Florida Student Clones Plants. Florida Market Bulletin. Tallahassee, Florida May 15, 1980 v.22 #10.

Debergh, P. C., Zimmerman, R. H., (1991) Micropropagation Technology and Application. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Dixon, R. A. (1985) Plant Cell Culture A Practical Approach, IRL Press, Oxford, England.

El-Mallakh, Rif., Wilson, John., & Silverman, Robert., (1991) Abuzz over Beekeeping, A hands-on approach to entomology. The Science Teacher v58.

Erickson, Deborah. (1991) Through the grapevine: tissue culture attacks a scourge of wine grapes. Scientific American v264 March 1991 p.111 (2).

Galston, Arthur., Davies, Peter., & Slatter, Ruth. (1980) The Life Of The Green Plant. Prentice-Hall Inc. Publisher, Englewood Cliffs, New Jersey.

Godfrey, Dale. (July, 1991) (Unpublished paper presented for Ag-Ed 500 credit at Montana Ag-Ed up-date conference, Dr. Shelhamer instructor. M.S.U.).

Haramaki, Chiko., Heuser, Charles. (1980) Plant Propagation The Future is Here. American Horticulturist, v59.

Haldeman, Janice H., Ellis, Jane, P. (1988) How-To-Do-It; Using Cauliflower to Demonstrate Plant Tissue Culture. Journal of American Biology Teacher, v50 n3 p154-59.

Hallman, Patsy. (1986) Teaching Basic Academic Skills in Secondary Vocational Classes. Presented at the National Vocational Home Economics Education Conference. (Columbus, OH. February 1986).

Hartmann, Hudson, T., Kester, Dale, E., Davies, Fred, T. (1990) Plant Propagation Principles and Practices. (5th ed.) New Jersey, Prentice Hall.

Johnson, Donald, M. (1992) Laboratory Teaching: Presenting Effective Method Demonstrations. The Agriculture Education Magazine. v65 n5.

Jones, Sherry. (1991) MSU News Service, Bozeman Daily Chronicle. Tuesday April 2, 1991. page 7.

Kappel, Tana. (1991a) Montana Schools Apply Science to Ag. Education. The Prairie Star, March 1991.

Kappel, Tana. (1991b) Tissue Culture Used To Increase Plant Varieties. The Prairie Star, March 1991.

Ketchum, Bruce. (July, 1991) (Unpublished paper presented for Ag-Ed 500 credit at Montana Ag-Ed up-date conference. Dr. Shelhamer instructor, M.S.U.).

Knoor, D., Beaumont, M., Caster, C., Dornenburg, H., Gross, B., Pandya, Y. & Romagnoli, L. (1990) Plant Tissue Culture for the Production of Naturally Derived Food Ingredients. Food Technology v44 n6.

Kyte, Lydiane., Briggs, Bruce. (1972) A Simplified Entry Into Tissue Culture Production of Rhododendrons. The International Plant Propagators Society v29.

Lineberger, Daniel, R. (1980) Aspects of a Teaching Program for Plant Tissue Culture. The International Plant Propagators Society v30.

Lewis, Rosemary. (1982) Introducing Students To Plant Tissue Culture. The International Plant Propagators Society v32.

Lonza, Martin., (1988) What Should We Do About The Decline In Vocational Enrollment? Vocational education instructor, Wasco Union High School, Wasco, Califorina. (ERIC Documents Reporting Service No.Ed 301 692).

MCCown, Deborah, D., Ellis, David, D. (1989) Plant Tissue Culture - Where is it Going? The International Plant Propagators Society v39.

McNabola, Sharon. & Kitto, Sherry, L. (1989) How-To-Do-It Tissue Culture of Carrot Roots, The American Biology Teacher, v51, n3 p165-67.

MacQueen, Hilary. (1988) Biotechnology puts the squeeze on plants. New Scientist v118.

Mapston, Ken. (July, 1991) (Unpublished paper presented for Ag-Ed 500 credit at Montana Ag-Ed up-date conference Dr. Shelhamer instructor, M.S.U.).

Monette, Paul, L. & Kyte, Lydiane. (1983) An Inexpensive Laminar Air Flow Hood. The Plant Propagator, v29 n2 p5-7.

Murashige, Toshio (1974) Plant Propagation Through Tissue Culture. In:Annual Review of Plant Physiology Winslow R. Briggs. (ed.) v25.).

National Research Council. (1988) Understanding Agriculture: New Directions For Education. Washington, D.C.: National Academy of Science, National Academy Press.

Oki, George. (1978) Setting Up A Tissue Culture System. The International Plant Propagators Society v28.

Pietraface, William, J. (1988) How-To-Do-It: Plant Regeneration. Journal of American Biology Teacher, v50 n4 p234-35.

Pritchard, Jack., (1982) Using Learning Laboratories. The American Educational Magazine. v54 n12.

Sawyer, David, E., (1986) Hands-on Labs in an Academic High School. Journal of the American Vocational Association v60.

Shelhamer, Van, C., (1982) Impact of Agriculture Mechanics Inservice Training On Montana Vocational Agriculture Programs. (Doctoral dissertation, Colorado State University).

Stolz, Leonard, P. (1979) Getting Started in Tissue Culture - Equipment and Costs. The International Plant Propagators Society v29.

Torres, Kenneth, C. (1989) Tissue Culture Techniques for Horticultural Crops. New York: Van Nostrand Reinhold.

Venier, Steve. (July, 1991) (Unpublished paper presented for Ag-Ed 500 credit at Montana Ag-Ed up-date conference Dr. Shelhamer instructor, M.S.U.).

Wetter, L. R. & Constable, F. (1982) Plant Tissue Culture Methods, Second Revised Edition, National Research Council of Canada Prairie Regional Laboratory, Saskatoon, Saskatchewan.

Yee, Kalfred, K. (1983) Tissue Culture - From Theory To Practice. The Plant Propagator, v28 n4 p5-7.

APPENDICES

APPENDIX A:

AGRICULTURE EDUCATION TEACHER COVER LETTER AND QUESTIONNAIRE

MONTANA STATE UNIVERSITY
1893•CENTENNIAL•1993

Department of Agricultural and Technology Education
Cheever Hall
Montana State University
Bozeman, MT 59717-0374
406-994-3201 or 994-3691

December 21, 1992

Dear Fellow Agriculture Teachers,

Plant tissue culture is a widely used propagation method in the horticulture, agronomy, and plant research industries. Tissue culture propagation of plants is a hands-on activity which many teachers are beginning to use to teach a wide variety of plant science competencies and laboratory skills.

I need your assistance to complete my graduate program. I'm conducting research on the use of plant tissue culture as a teaching tool in high school agriculture education programs. I'm asking teachers from: North Dakota, Montana, Idaho, Washington and Oregon to participate in this project. The teachers who indicate that they have taught plant tissue culture in the past or will teach plant tissue culture during the 1992-93 school year will be sent a follow-up *Plant Tissue Culture Research Survey,* in the spring of 1993.

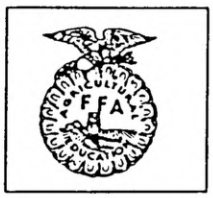
All responses will be treated confidential, and will not be used for any purpose unrelated to this study, nor will any individual or institution be identified. Will you please take a few minutes to complete, and return the enclosed self addressed, stamped questionnaire by January 30, 1993.

If you have any questions regarding the study, I will be happy to answer them if you will write or call. My telephone number is (406) 846-2757 school or (406) 846-1699 home. Thank you very much for your assistance.

Sincerely,

Bill Lombardi
Agriculture Education Teacher
Deer Lodge, MT.

Dr. Van Shelhamer
Committee Chairman
Montana State University



Plant Tissue Culture Questionnaire

Name _____
School _____
Address _____
City _____
State _____ Zip _____
Telephone Number _(___)_____

All information provided will be treated as confidential.

YES	NO	
____	____	Have you taught plant tissue culture in your classes.
____	____	Are you currently or planning to teach plant tissue culture during this school year.
____	____	Have you attended an inservice workshop or presentation on plant tissue culture.

I have not taught plant tissue culture for the following reasons. (check all that apply)

____ Lack of information.
____ Lack of training.
____ Does not fit the present curriculum.
____ Lack of funds.
____ Other reasons. _____

Please fold, staple, and **return by January 30, 1993.**

THANK YOU!

APPENDIX B:

QUESTIONNAIRE RESPONDENTS COMMENTS

QUESTIONNAIRE RESPONDENTS COMMENTS

Curriculum needs to be developed.
I'm a new teacher, no time yet.
Have not incorporated it yet.
Need a list of places to order materials.
Takes too much time.
The other ag teacher in our dept. teaches it.
New teacher.
Time.
Lack of facilities.
I need more information and training.
Lack of confidence.
Did not get to it.
Transferred to the science dept.
Above the high school student level.
State board of Vo-Ed does not see a need for tissue culture.
Not recognized as reimbursable vo-ed curriculum.
Hard to have successful percent in the classroom.
Lack of sterilization equipment.
Need curriculum.I teach a short unit on theory.
The other ag teacher in the dept teaches it.
Administration is opposed to it.
I need a hood.
Commercial supplies to expensive.
Lab not available.
Gone on maternity leave.
Materials lacking.
Starting a new ag program.
We had excellent results with miniature rose kit form Carolina Biological Supply.
Lack of success.
Lack of high school level materials.
Not teaching plant science.
Lack of a laboratory.
The other ag teacher is teaching it.
Lack of sterile environment.
Lack of space.
Works better at the college level.
To technical for my students.
Would need to take something out of the curriculum to make room.
Not 9th grade level.

APPENDIX C:

COVER LETTER AND SURVEY

AGRICULTURE EDUCATION

5-10-93

1~ 2~
3~
4~
5~ 6~ 7~

Dear 1~,

Thank you for filling out and returning the plant tissue culture questionnaire I sent you. You are an important part of agriculture education, with your continued help this survey will become an important educational tool which can provide information to other agriculture education teachers.

It is the intent of this research to identify new and useful techniques used in plant tissue culture education. I will compile this information and present it in a usable form to all agriculture education teachers interested in plant tissue culture.

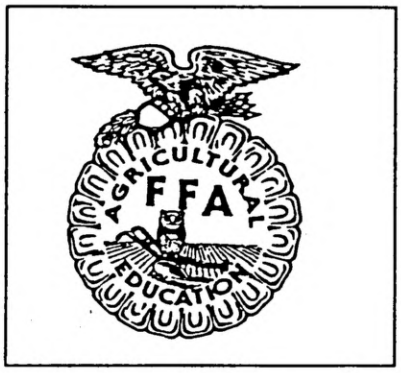
I do understand that each of you will go about teaching plant tissue culture in different ways and that you may be at different stages of teaching plant tissue culture. If you feel that the questions on the survey do not address an important aspect of plant tissue culture please write additional comments on the survey. Please fill out the survey to the best of your ability and return it to me by **May 25, 1993.** The information from this survey will be kept confidential as to its origin. Each survey is numbered for follow up purposes.

Sincerely,
Bill Lombardi

Ag-Ed/FFA Teacher
Deer Lodge, MT.

PLANT TISSUE CULTURE RESEARCH SURVEY

Research today, for tomorrow's agriculture.



By:
Bill Lombardi
Agriculture Education Instructor
Deer Lodge, MT.

In Conjunction With:
Montana State University
Ag and Tech Education Department



Plant Tissue Culture Research Survey

Instructions: Please read each question and place an X in the space provided next to the appropriate answer. ***Check all the answers that apply.*** Print clearly when filling in the blanks or providing additional information. When finished please staple, and mail the survey by **May 25, 1993.** Thank you.



1. What plant species do you use to demonstrate plant tissue cultures?
____ CARROT
____ POTATO
____ OTHER VEGETABLES, PLEASE IDENTIFY _____
____ AFRICAN VIOLET
____ ORCHIDS
____ OTHER FLOWERS, PLEASE IDENTIFY _____
____ TOBACCO
____ OTHER _____

2. What type(s) of plant tissue culture are you doing in your classes?
____ EXPLANT (small vegetative cutting)
____ ORGAN (flower or reproductive part)
____ CELL (individual cell)
____ CALLUS (small groups of cells)
____ OTHER _____

3. How do you obtain plant growth media?
____ PREPACKAGED FROM A SUPPLIER, SUPPLIERS NAME _____
____ MIX YOUR OWN
____ OTHER _____

4. What types of sterile transfer chambers and/or methods do you use?
____ WOODEN BOX
____ PLASTIC BOX
____ LAMINAR FLOW HOOD
____ CLEAN TABLE TOP
____ OTHER _____

5. How do students sterilize their work area and tools?
____ CLOROX SOLUTION
____ ALCOHOL
____ DISTILLED WATER
____ WASHING IN WATER
____ AUTOCLAVE OR PRESSURE COOKER
____ COMBINATION _____
____ OTHER _____

6. How do students sterilize their explant?
____ CLOROX SOLUTION
____ ALCOHOL
____ DISTILLED WATER
____ WASHING IN WATER
____ COMBINATION _____
____ OTHER _____

7. Which of the following instructional methods do you use in teaching plant tissue culture?
____ VIDEO PRESENTATION
____ LECTURE AND NOTES
____ FIELD TRIPS
____ DEMONSTRATIONS
____ STUDENTS DOING PLANT TISSUE CULTURE
____ OTHERS _____

8. What level of enthusiasm do your students demonstrate while doing tissue cultures?
(check your perception on the scale provided)

____ 10 VERY EXCITED
____ 9
____ 8
____ 7
____ 6
____ 5 NO CHANGE IN ENTHUSIASM
____ 4
____ 3
____ 2
____ 1 DISLIKED

9. Have you had contamination in your tissue cultures?

____ YES
____ NO, IF NO SKIP TO QUESTION NUMBER 12

9. A. If yes, what specifically caused the contamination?

____ MOLD
____ BACTERIA
____ FUNGUS
____ COMBINATIONS _____
____ OTHER
____ DO NOT KNOW

9. B. If yes, what percent of your tissue cultures became contaminated? _____

10. How does contamination affect student attitude toward doing plant tissue culture experiments?

____ THEY BECOME DISCOURAGED
____ THEY REACT NEGATIVELY TO ANY CULTURES WHICH BECOME CONTAMINATED
____ THEY VIEW CONTAMINATED CULTURES AS PART OF THE PROCESS
____ THEY BECOME INDIFFERENT AS TO WHAT CAUSED THE CONTAMINATION
____ THEY BECOME INTERESTED IN LEARNING MORE ABOUT THE CONTAMINATION
____ OTHER _____

11. Where did you learn to do plant tissue culture?

____ READINGS
____ VIDEOS
____ TEACHER INSERVICE OR WORKSHOP
____ SOMEONE SHOWED ME, PLEASE IDENTIFY BY PROFESSION _____
____ INDUSTRY
____ COLLEGE OR UNIVERSITY, PLEASE LIST THE COURSE, COLLEGE OR LOCATION OF TRAINING.
_____
_____

12. What type of <u>student</u> directions and/or instructions are used in your labs?

____ A PURCHASED LAB MANUAL, PLEASE IDENTIFY _____
____ INSERVICE MATERIALS
____ BOOKS, PLEASE IDENTIFY _____
____ JOURNALS OR MAGAZINES, PLEASE IDENTIFY _____
____ CAROLINA BIOLOGICAL SUPPLY MATERIALS
____ SELF DEVELOPED MATERIALS
____ OTHER _____

13. What type of <u>teacher</u> information and references are you using for your labs?

____ A PURCHASED LAB MANUAL, PLEASE IDENTIFY _____
____ INSERVICE MATERIALS
____ BOOKS, PLEASE IDENTIFY _____
____ JOURNALS OR MAGAZINES, PLEASE IDENTIFY _____
____ CAROLINA BIOLOGICAL SUPPLY MATERIALS
____ SELF DEVELOPED MATERIALS
____ OTHER _____

14. In what areas of plant tissue culture do you feel you need additional training?
____ CONTROLLING CONTAMINATION
____ USE OF EQUIPMENT
____ OBTAINING STERILE PLANT STOCK
____ PREPARATION OF GROWTH MEDIA
____ UNDERSTANDING LAB MANUALS
____ EQUIPMENT STERILIZATION
____ OTHER _____

15. How many different times have you taught plant tissue culturing? _____

16. How many hours of classroom/laboratory time do your students spend on the tissue culture unit each year? _____

17. Have you helped other teachers get started doing plant tissue culture?
____ YES, How many teachers? _____
____ NO

17. A. If yes, List the ways that you have given other teachers assistance.
_____
_____
_____

19. What specific scientific principles, or competencies are being taught, reinforced or applied in your plant tissue culture units?

_____ DEMONSTRATE THE SAFE USE OF LABORATORY EQUIPMENT AND SUPPLIES.

_____ DESCRIBE THE LIFE CYCLE OF PLANTS.

_____ CLASSIFY AND IDENTIFY PLANTS ACCORDING TO THEIR PARTS.

_____ IDENTIFY THE PRIMARY AND SECONDARY NUTRIENTS REQUIRED BY PLANTS.

_____ IDENTIFY ENVIRONMENTAL CONDITIONS NECESSARY FOR PLANT GERMINATION AND GROWTH.

_____ EXPLAIN PHOTOSYNTHESIS.

_____ RECORD GROWTH PATTERNS OF PLANTS.

_____ EXPLAIN PLANT TRANSPIRATION.

_____ DESCRIBE DIFFERENT METHODS OF PLANT REPRODUCTION.

_____ EXPLAIN PLANT AND SEED DORMANCY.

_____ EXPLAIN HOW LIGHT INFLUENCES THE GROWTH RATE OF PLANTS

_____ PERFORM BASIC METRIC CONVERSIONS.

_____ USE A MICROSCOPE TO OBSERVE PLANT GROWTH AND DEVELOPMENT.

_____ DESCRIBE AND TEST PH.

_____ PREPARE AND MIX CHEMICAL SOLUTIONS.

_____ DISTINGUISH BETWEEN DIFFERENT KINDS OF PLANT TISSUES.

_____ IDENTIFY THE THREE MAJOR GROUPS OF PLANT HORMONES.

_____ ASEPTIC TECHNIQUES

_____ PLANT ANATOMY

20. What other science competencies are being taught, reinforced or applied in your tissue culture units? Please list.

_____

_____

_____

_____

_____

21. Does the science department (in your school) teach a class where students study tissue culture or do tissue culture experiments?
____ YES
____ NO
____ DO NOT KNOW

22. Why do you teach plant tissue culture?
____ THE STUDENTS ARE EXCITED ABOUT IT
____ TO TEACH SCIENCE SKILLS AND COMPETENCIES
____ TO TEACH PLANT PROPAGATION
____ TO TEACH ASEPTIC LABORATORY TECHNIQUES
____ TO HAVE A HANDS ON ACTIVITY IN YOUR PLANT SCIENCE UNIT
____ OTHER _____

23. In which of the following instructional units do you teach plant tissue culture?
____ GENETICS
____ GERMINATION
____ PROPAGATION
____ OTHER _____

24. Under what course title do you teach plant tissue culture?
____ VO-AG OR AG-ED I
____ VO-AG OR AG-ED II
____ VO-AG OR AG-ED III
____ VO-AG OR AG-ED VI
____ HORTICULTURE
____ AGRISCIENCE
____ OTHER _____

25. Have you found other techniques which teach similar skills but are superior to tissue culture when teaching plant science?
____ YES, EXPLAIN _____
____ NO

26. Will plant tissue culture continue to be a part of your curriculum?
____ YES, IF YES SKIP TO QUESTION 28
____ NO

27. If no, what are some of the reasons that you will not teach plant tissue culture in the future?
____ LACK OF FUNDS
____ FACILITIES
____ DOES NOT FIT MY CURRICULUM
____ LACK OF TRAINING, INSERVICE AND EDUCATIONAL OPPORTUNITIES
____ SCIENCE DEPARTMENT IS TEACHING IT
____ OTHER _____

28. How much do you spend on chemicals, supplies, and growth media per year for plant tissue culture?

____ $0-100
____ $101-200
____ $201-300
____ $301-400
____ $401-500
____ $501-1000
____ $1000- >

29. Excluding chemicals and growth media, how much did the equipment you use for plant tissue culture cost?

____ $0-100
____ $101-200
____ $201-300
____ $301-400
____ $401-500
____ $501-1000
____ $1000- >

30. Other information you wish to provide.

_____

_____

_____

_____

_____

_____

_____

Thank you for your time and response to this survey. You have helped provide important information that will help agriculture education and the students it serves.

In Sincere Appreciation;

Bill Lombardi

Agriculture Education Instructor

Deer Lodge, MT.





Return To: **BILL LOMBARDI**
705 MILWAUKEE AVE.
DEER LODGE, MT. 59722

APPENDIX D:

FOLLOW UP LETTER AND POST CARD

AGRICULTURE EDUCATION

6-10-93

Dear Fellow Agriculture Teacher,

PLEASE, fill out and return the enclosed *Plant Tissue Culture Survey.*

You are an important part of agriculture education, with your continued help this survey will become an important educational tool which can provide information to other agriculture education teachers.

It is the intent of this research to identify new and useful techniques used in plant tissue culture education. I will compile this information and present it in a usable form to all agriculture education teachers interested in plant tissue culture.

I do understand that each of you will go about teaching plant tissue culture in different ways and that you may be at different stages of teaching plant tissue culture. If you feel that the questions on the survey do not address an important aspect of plant tissue culture please write additional comments on the survey. Please fill out the survey to the best of your ability and return it to me by **July 1, 1993.** The information from this survey will be kept confidential as to its origin. Each survey is numbered for follow up purposes.

Sincerely,
Bill Lombardi

Ag-Ed/FFA Teacher
Deer Lodge, MT.

Plant Tissue Culture Research

FROM:
Bill Lombardi
Agriculture Education Teacher
705 Milwaukee Ave.
Deer Lodge, MT. 59722

TO:

post card

URGENT REMINDER

5-26-93

Dear Fellow Agriculture Teacher,

I sent you a Plant Tissue Culture Research Survey two weeks ago. I need you to fill out the survey and mail it to me as soon as possible. The information provided by the survey will help me conduct important Ag-Ed Plant Tissue Culture research. Please return the completed survey to me by June 1, 1993. If you have sent in the survey then please disregard this reminder. If you have any questions or did not receive a survey please call me at (406) 846-2757 (W) or (406) 846-1699 (H).

Thank you,
Bill Lombardi
Ag-Ed/FFA Teacher
Deer Lodge, MT. 59722

APPENDIX E:

RESPONDENT LIST OF OTHER SCIENCE COMPETENCIES TAUGHT IN TISSUE CULTURE UNITS

RESPONDENT LIST OF OTHER SCIENCE COMPETENCIES TAUGHT IN TISSUE CULTURE UNITS

Montana

plant and cell development
tissue functions
genetics
cloning
measuring
lab methods
data interpretation
recording data
accuracy
asexual and sexual reproduction
marketing
greenhouse

North Dakota

biotechnology
biology
cell function in human anatomy
general plant science
biotechnology
bacteria growth
salinity effects of soil in inoculation of legumes
semen evaluation
biodegradation
ABC materials
effects of hormone ratios

Oregon

data gathering, (portfolios)
proper investigating technique
observation
write reports

RESPONDENT LIST OF OTHER SCIENCE COMPETENCIES TAUGHT IN TISSUE CULTURE UNITS, CONTINUED.

Washington

cooperative learning
job awareness
scientific procedure
recording
measuring
lab write-ups
interpreting data
make conclusions
safety
microbiology
pathology
equipment operation
scientific method
bio systems
problem solving
care and maintenance

APPENDIX F:

OTHER INFORMATION PROVIDED BY RESPONDENTS

OTHER INFORMATION PROVIDED BY RESPONDENTS

Montana

I found it easier to buy the kits and have the materials for each student. Our success rate is still very low but the students still enjoy the lab.

I am very frustrated by the lack of knowledge in this area. I have not had great success with my plants.

We had very little success with getting the tissue culture to work, the students get discouraged when that happens.

North Dakota

I am building up the Ag. Science area, so every year I try to focus on one large item, (with the science dept) for example a good microscope w/camera and TV, lab equipment (scales, thermometers, pH meters, etc.), in the near future a greenhouse, etc.

Oregon

I have found using plant tissue culture to be very discouraging for myself and my students. In fact I am already 0 for 2 and if I am not even partly successful this next time, I will probably not do it again.

Washington

Get Mobay, Monsanto or others to provide more inservice to Ag. teachers.

The best kit available that will provide a marketable horticultural crop is the Carolina biological Supply Miniature Rose Tissue Culture kit. The first time we used it we had 100% success. Mushroom culture is interesting and involves many of the same techniques. A good source is Fungi Perfect, P.O. Box 7634 Olympia, Wa. 98507.

I plan to allocate more of next year's budget to purchase more equipment (flow hoods).

I'm still experimenting with plant tissue culture. Ag./Horticulture in our state is still not recognized or granted a science credit for our students.

OTHER INFORMATION PROVIDED BY RESPONDENTS CONTINUED

Thanks for the chance to help. We don't share enough information between teachers. There needs to be a better way of improving our curriculum.

We had a new teacher this year and the tissue culture unit was put on hold for this past year.

This survey is appropriate and well written. I'm curious to see what results you get from the respondents!