Comparison of the Economics of *Vitis aestivalis* 'Norton/Cynthiana' Propagation by Cuttings and Tissue Culture

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Abstract

The *Vitis aestivalis* or the “Norton”/ “Cynthiana” grape is a very hardy grape that possesses unique qualities, like being disease resistant and producing high yields. Normally propagated though traditional, time consuming methods, the Norton grape is very difficult to reproduce. For this study, a survey about traditional propagation methods was sent out to 72 producers and the response rate was low. The development of a propagation method that will cut down on time, labor, and resources will be economically beneficial to the grape industry. The use of tissue cultures to produce viable plantlets will be revolutionary and generate more revenue for producers. Although research surrounding the use of tissue culture propagation has been unsuccessful up to this point, the research needs continue because of the gross profit potential that will be generated from discovering new propagation methods.

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Introduction

Most commercial grape varieties are native to the Fertile Crescent and have been grown in Europe for so long that they are also referred to as "European grapes." As the Europeans began their colonization of the New World, they took their grapes with them, spreading them around the World. As with almost every other edible plant, grapes from different regions were crossbred to produce new varieties with an array of tastes and purposes. Selective breeding helped the wine industry take root in America, an industry that is completely dependent upon grape production. Likewise, products, such as jams, jellies, juices, and raisins, depend upon grape production.

In 2017, Tennessee's grape industry accounted for $1.9 billion and employed 16,000 individuals (Tennessee Wines, 2017). This indicates that this simple, yet extraordinarily complex fruit has a significant impact on the Tennessee economy and the agricultural production industry. Agritourism, including tours of vineyards and wineries, accounts for $89.1 million in tourism expenditures (Tennessee Farm Wine Growers Association, 2019; Tennessee Wines, 2017). Grape production on the 1,128 acres of vineyards planted in Tennessee peaks in the months of September through October (Hatcher, 2018; Tennessee Farm Wine Growers Association, 2019). If *Vitis aestivalis* grapes could be propagated more cost efficiently, there would inevitably be more acreage planted, more jobs created, and more economic value to the state of Tennessee.

The *Vitis aestivalis* grape commonly called "Norton" or "Cynthiana," is principally produced in the mid-west region of the United States, but it is known to be

difficult to vegetatively propagate. Decreasing the cost of propagation of this grape variety has the potential to significantly impact its range of production as well as its use in producing a wide variety of consumer products.

The domestication of grape vines by Native Americans and the introduction of new varieties brought to the New World by European explorers led to the development of the grapes we now call "*Vitis aestivalis"* (Clift, 2005; Krochmal, A., & Grierson, W., 1961). Over time, this grape has gained popularity in many Midwestern states and is currently the state grape of Missouri (Mouer, 2019). The *Vitis aestivalis* grape is principally grown in the Midwest because of its capability to adapt to a wide variety of environments and its ability to consistently produce fruit even in the worst of seasons.

The Norton or Cynthiana grape was named after Dr. Daniel Norborne Norton. The story of the grape's origin is on the same scale of the discovery of Penicillin. Dr. Norton happened across a seedling growing in his experimental vineyard and soon discovered its extraordinary qualities (Mouer, 2019). These qualities include production of high-quality wine with a popular taste and resistance to different diseases and pests. This means that the *Vitis aestivalis* can be produced with less pesticides used to grow other European varieties (Clifford, 2013).

Dr. Norton saw a chance to make some income by selling this grape, so he began to reproduce it using traditional propagation methods. There are three ways to traditionally propagate grapes. First there is cutting a dormant stem and planting it directly into the ground, which creates a plant identical to the mother plant. Second, the

individual can lay dirt over a long shoot from the mother plant, then grows roots and can be separated from the mother plant. This is also an identical copy of the mother plant. Third, one can simply plant seeds from the fruit of the plant. While seeds seem to be the most practical method, there is no way of knowing what grape variety pollinated the flower, so there is no guarantee of growing the same identical plant from a seed. Traditional propagation, therefore, typically involves only the first two techniques.

Traditional methods of grape propagation are the most commonly used techniques for producing grape plants for sale at a large scale. However, they require large amounts of time, space, and labor to produce a new plant. They also involve extensive care and maintenance of the mother plant from which they are produced. The mother plants are the source of the cuttings and they must be conserved to have stock for the productions of the next year's supply. If anything were to happen to the mother plants, like flooding, pest, or infection, the entire operation could have to start over from scratch.

Many pests and diseases are transmitted in nurseries, and because nurseries are hubs for their dispersal across national and international boundaries, pest and disease control are critical (Troley, 2014). As a result, there is demand for plants that are stronger and more resistant to pests and diseases and produce high yields. *Vitis aestivalis* is inherently more resistant to disease and produces good yields but is very difficult to propagate. Researchers are, therefore, working on its propagation because this variety of grapes offers everything the industry demands and presents the industry with qualities not found in European grapes growing in most of the US.

Middle Tennessee State University (MTSU) researchers have investigated the use of tissue culture techniques to propagate *Vitis aestivalis* grapes for over 6 years to date. The MTSU team of scientists have developed a protocol for generating callus tissue from the native plants, which they also discovered internally host a fungus which had not been known before (Wilson et al, 2016) . Through support provided in grants from the USDA and Tennessee Department of Agriculture, the scientists have found that callus can be generated from a variety of plant tissues, but they have not yet succeeded in generating plantlets from. Eventually this research project will evaluate the crop's resistance and production traits when produced from plants created from these callus tissues. Because tissue culture has the potential to produce a lot of plants in a little space, the cost of production is projected to be much lower than traditional propagation methods.

Methodology

This study sought to compare the cost of *Vitis aestivalis* production by traditional techniques to that of tissue culture propagation of the grape. Information was gathered by contacting nurseries and vineyards via email and phone, requesting they complete a simple, seven question survey about their traditional propagation costs. The survey was projected to take 10 minutes to complete. Participants were also asked to provide contact information on additional producers of this grape to expand the database of information available. After the initial contact, the same email was sent out again two weeks later.

After collecting the completed surveys, the cost of traditional propagation was compared to the cost of tissue culture propagation (received from MTSU faculty advisors). This research was conducted as part of a grant received by Middle Tennessee

State University professors Dr. Tony Johnston (Agriculture) and Dr. John Dubois (Biology) supporting the development of tissue propagation of *Vitis aestivalis* grapes.

This survey was designed to gather information on the producer's production cost at the time of gathering new root stock for the upcoming year's production. The questions addressed technology used, cost per vine, vendor of root stock purchased, labor, and number of plants planted for the upcoming year. In the effort to get an idea of the size and scope of their operation, the survey provides a glimpse of the grape industry, overall, in the United States. It is hoped that this information may lead producers to try new propagation techniques and technologies which will improve their yields and the grape industry, overall. The survey instrument is included in the appendix.

Results

Contact information for root stock nurseries and vineyards, who produce the Norton grape was found via the internet and other networking platforms such as grape forum websites. The survey was emailed to 69 producers across the United States. In addition, three producers were called, but they declined the request to fill out the survey. After emailing and calling a total of 72 producers, I followed up with each producer two weeks after the initial contact. Only one survey was returned.

Table 1

Traditional Propagation Data Collected from Survey of Nurseries and Vineyards Propagating Norton/Cynthiana Grape Variety

NAME OF PRODUCER	SALE PRICE OF ROOTSTOCK	LABOR HOURS	STARTING PLANT NUMBER
Commercial Nursery Owner A	$6 per vine and $3.95 per 500	25	10,000 hardwood cuttings
Arkansas Grape Extension and Research Station 2005	$2.25	N/A	680 plants/ac.

Commercial nursery owner A reported that their numbers were based on their annual production. Their response stated that they planta total of 10,000 hardwood cuttings each year. Only 50% of those cuttings successfully make it to the selling stage of maturity. They also included a list of equipment used. Unfortunately, with only Producer A's production costs available, averages could not be calculated.

One additional source of data was identified: the Arkansas Grape Extension and Research Station. A report published by the Arkansas Research Station stated that the cost to produce each Norton plant is $2.25 (Alman, 2016). This report did not, however, define the number of labor hours each plant required in the root stock stage. To calculate the cost of plants per acre, the authors divided the total area of an acre by 64 square feet (the area one plant is allocated based on a row and plant spacing of 8' x 8') and multiplied that number by $2.25. Based on 64 square feet per plant, 680 plants can be produced per acre. Assuming a replant rate of 5% of the 680 plants, 34 plants (at $2.25 each) would need to be replaced each year, resulting in a total plant replacement cost of $76.50 per acre for a grower. These calculations do not include maintenance costs for the

vineyard, which vary with the variety planted. As previously stated, *Vitis aestivalis* grapes are naturally resistant to disease and are, therefore, less expensive to produce.

The MTSU research team is still conducting their work. The labor hours associated with the grant are for the two professors and one research assistant conducting the physical propagation. The project totals 784 hours. Each professor contributes 52 hours of unpaid labor and the research assistant, who does the bulk of the physical work, accounts for 680 paid hours. The grant provided $10.00 per hour for the research assistant. The labor costs of student researchers are totaled $6,800.00 at this current point. The faculty's labor is not a factor included in the total cost of the research. The research is being conducted through the public education system and is, therefore, serving the public rather than an individual company. Table 2 presents all the supplies and equipment the MTSU research team has used during their research. Thus far, supply and equipment costs have totaled $2,804.00 and it is estimated that an additional $9,604.00 will be spent for supplies as propagation by tissue culture is further developed.

Table 2

MTSU Equipment Used for Tissue Culture Propagation

Item Description	Per-Unit Cost	# of Units/Pieces Purchased	Total Cost
Incubator	4,300/unit	1	$4,300
Petri Dishes	120.54/500	2 x 500	$241.08
Media Preparation - Lloyd & McCowan Media w/vitamins (L449)	9.49/10L	2 x 10L	$18.98
Media Preparation – Lloyd & McCown Basal Salts (L444)	7.34/10L	2 x 10L	$14.68
Media Preparation - Agar (A296)	124.5/500g	1 x 500g	$124.50
Media Preparation - Sucrose (S829)	20.50/Kg	1 x 1Kg	$20.50
Media Preparation - Thiamine (T390)	46.71/100g	1 x 100g	$46.71
Media Preparation - Casein (C184)	64.17/500g	1 x 500g	$64.17
Media Preparation - 2,4-D (D295)	45.63/500mL	1 x 500mL	$45.63
Media Preparation - Kinetin (K483)	29.25/500mL	1 x 500mL	$29.25
Media Preparation – Adenine Hemisulfate (A545)	54.33/25g	1 x 25g	$54.33
Media Preparation - Thidiazuron (T438)	34.71/100g	1 x 100g	$34.71
Media Preparation - Indole Butyric Acid (I538)	55.41/25g	1 x 25g	$55.41
Media Preparation - BA Solution (B130)	29.25/500mL	1 x 500mL	$29.25
Media Preparation - Phloroglucinol (P694)	151.51/100g	1 x 100g	$151.51
Media Preparation - Daconil 16 oz			$15.00
Shipping			$75.00

Tissue culture propagation is another way of producing a viable plant. The process starts in a lab. The container that the plants are grown in is called a Petri dish. The environment that the Petri dish is exposed to is controlled by an incubator. A standard Petri dish is 20mm deep and 100 mm in diameter, or 9.59 in^3. The volume of the Petri dish was calculated using the equation $V = \pi r^2 h$ where r is the radius and h is the height. The volume of the Petri dish was then used to calculate how many would fit into an incubator. Assuming that a standard Petri dish's volume is 9.59 in^3 and the volume of a 4.5 ft^3 incubator is 7,776 in^3, 810 Petri dishes can be placed in an incubator.

If one plate can produce on average 18 plantlets, 810 plates will yield 14,580 plants in one full incubator, which occupies a footprint of only 2.125 ft^2. This means that the tissue culture method of propagation can successfully produce a possible 14,580 rooted plantlets for the producer to plant and/or sell.

Discussion

In grape propagation, the mother plant is the foundation for the production of sellable plants and continuing the lineage of a crop. Each year, one mother plant can produce a maximum of 50 cuttings per year in a space of 80 ft^2 under traditional propagation methods. Based on the survey response received through this research project, only half of the plants produced by traditional propagation survive to maturity and can be sold. Therefore, a producer would yield only 25 sellable plants at an average value of $4.00 per plant from the 80 ft^2 of space each mother plant occupies. Additional space is required to root the cuttings. Assuming a pot is 6in in diameter, occupies an area 0.785 ft^2 per pot, and 50% production of viable plants with roots, the producer must set aside 50 x 0.785 ft^2 or 39.25 ft^2 of space per mother plant for rooting, only half of which will result in sellable plants. To further expand on this example, 1 acre of space in which plants could be prepared for sale will accommodate the production from 1110 mother plants. One acre of space is small for a nursery, but the 1110 mother plants would occupy an additional 2 acres.

By utilizing the tissue culture method, one mother plant can produce 14,580 plantlets in a space of 4.5 ft^3. Producers can be confident that this method will produce plantlets with roots, as opposed to the risk of failure associated with traditional

propagation. This makes the tissue culture method 10,600 times better than traditional methods. Producers can reduce the amount of space used in the greenhouse and double the amount of production in the nursery because producers are guaranteed rooted plantlets.

The cost for the tissue culture research thus far was used as the maximum cost to be expected for tissue culture propagation, due to the lack of any alternative information. Many different methods are being tested, but the methods found be to unsuccessful are being eliminated from further use. Although the solution is yet to be discovered, the total production cost will inevitably be significantly lower than the traditional propagation cost. The upfront cost of the tissue culture method will be higher, but in the long run the production rate of rooted plantlets will make the process significantly less expensive.

Response rates to surveys can be calculated by dividing the number of responses returned by the total number of surveys sent out (Fincham, 2008). For this research, one response was received out of 72 surveys delivered, resulting in a response rate of 1.3889%. This response rate is poor. Electronic surveys increase the number of potential respondents, but mailed surveys are noted to have higher response rates (Fincham, 2008).

This was a very small study with a limited scope. Many traditional propagation producers have worked through family generations to successfully produce a viable crop. The community of Norton producers are very secretive on the actual process of propagation. This is one of the key factors in having a low response rate. Since there was only one response to the survey, there was no way to compare the results, which was the most important use of the survey.

Sending the survey out via email, seemed to be the most quick and convenient way to gather information from Norton producers. Looking back, I wish I would have called more people and voiced the reasons for this research. Much like any kind of research, I wish I had more time to collect more data. I think this is a very important topic to be discussed and shared. When the research is completed, more producers can make more money producing this grape variety and possibly many other difficult to propagate plants. Future research should be pursued because it may reveal new propagation methods for other grapes. This will have a huge impact on the industry.

Conclusion

Vitis aestivalis is a very hardy grape variety that can be used for juice, jam, jelly, table grape and wine production. The purpose of finding a new method of propagating this grape is to extend its potential commercial utilization, shorten the time it takes to produce plantlets, and cut the cost of propagation. This grape consistently produces good yields, requires little maintenance, is disease resistant, and has the potential to become very popular in the wine industry. Although the response rate of the survey was low, the research needs to continue to make a difference in the grape industry. The development of a less expensive technique for reproduction would have an enormous economic value, with the potential to reduce the production cost by a factor of thousands. Grape producers are currently limited to traditional methods of propagation for this grape variety. Finding a new, easier way to propagate this grape will be groundbreaking. It will decrease overall time, labor, and resources, while boosting the economy for the entire grape industry.

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Appendix A

Survey for Nurseries and Vineyards Propagating Norton/Cynthiana Grape Variety.

Name of business:

Address:

Phone Number:

Email Address:

1. What kind of technology are you using to propagate the Norton/ Cynthiana?

2. If you replace your vines by purchasing new vines, rather than propagating them, approximately how much do you pay per vine and how many vines do you typically purchase in a given year?

3. Where do you get your original root stock? (If you have the contact information of your growers please include that in your response.)

4. What kinds of materials are you using to propagate methods are you using?
    a. Examples: Mist tables, heated beds, hydroponics, soil, artificial soil.

5. On average how many hours of labor are you using just for the Norton/ Cynthiana propagation?

6. How many plants do you start and what is your success rate in achieving rooted vines?

7. Do you know of any other nurseries that produce this grape variety? If so, can you include their contact information below?

Appendix B

Nurseries, Vineyards, and Universities Propagating Norton/Cynthiana Grape Variety Contacted in this Research

612 Vineyard	info@612vineyard.com
Adam Puchta Winery	info@adampuchtawine.com
An Enchanting Evening Winery	info@AnEnchantingEvening.com
Aspen Dale Winery at the Barn	reservations@aspendalewinery.com
Audrey's Corner	270-766-1672
August Hill Winery	info@augusthillwinery.com
Bates Nursery	Into@batesnursery.com
Black Silo Winery	info@blacksilowinery.com
Blumenhof Vineyards	info@blumenhof.com
Bottom Brothers Nursery	bottomsnrsy@blomand.net
Brimstone Hill Vineyard & Winery	bhvwine@frontiernet.net
Broadacres Nursery U Pick Grapes	broadacr@oregonsbest.com
Brooklyn Oenology	taste@brooklynoenology.com
Brookview Station Winery	sue@goold.com
Canterbury Hill Winery and Restaurant	sales@canterburyhill.com
Chateau Aux Arc Vineyards & Winery	Audreybhouse@gmail.com
Chateau Elan	chateau@chateauelan.com
Chateau LaFayette Reneau	clrwine@aol.com
Cherry Knoll Farm	cherryknollfarmp@peoplepc.com
Circle T Winery	john@circletwines.com
Claverach Farm and Vineyard	info@claverach.com
Cowie Wine Cellars & Museum	vintner@cowiewinecellars.com
Creekside Vineyards Winery & Inn	jen@creeksidevineyards.com
DeAngelis Cantina del Vino	stacey@deangeliscantina.com
Dionysus Wine and Brew	dionysuswinebrew@gmail.com
Double A Nursery	jillian.degolyer@doubleavineyards.com
Dr. Konstantin Frank Vinifera Wine Cellars	info@drfrankwines.com
Duck Walk North	info@duckwalk.com
Edg-Clif Farms and Vineyard	steffie@EDG-CLIF.com
Endless Summer Winery	info@endlesssummerwinery.com
Engelheim Vineyards	info@engelheim.com
Farmer & Frenchman Winery	info@farmerandfrenchman.com
Fenton Winery & Brewery	info@fentonwinery.com
Flying Otter Vineyard and Winery	info@flyingotter.com
Fox Creek Vineyards	wines@foxcreekwinery.com
Grape Exchange	hindsvillefarm@yahoo.com
Green Wood Nursery	info@greenwoodnursery.com
Holy Grail Winery	lonnie_2010@hotmail.com
Iowa Grape Vines	iowagrapevines@yahoo.com

Ison's Nursery	ison@isons.com
JKC Cellars	vintner@jkccellars.com
Justine Vanden Heuvel	justine@cornell.edu
Keels Creek Winery & Art Gallery	winery@keelscreek.com
Krieger's Nursery	office@kriegersnursery.com
Lehman's Orchard	stevelecklider@aol.com
Lohr Wine and Spirits	lohrdistributing.com
Magpie Farms	magpie@magpiemead.com
Martin's home and garden	Website
Mary Michelle Winery & Vineyard	walt500@aol.com
Millbrook Vineyards & Winery	millbrookwinery@millwine.com
Missouri State Fruit Experiment Station	statefruitexperimentstation@missouristate.edu
Montaluce	events@montaluce.com
Mount Bethel Winery	sales@mountbethel.com
Movie House Winery	mhwinery@hotmail.com
Pense Nursery	pensefarms1@hotmail.com
Pop Pop N Bears Nursery	812-653-1072
Post Winery	info@postfamilie.com
Professor Jacob Lahne, PhD	jlahne@vt.edu
Railway Winery	railwaywinery@trestle71-7.com
Raimondo Family Winery	870-424-0234
Renee Threlfall	rthrelf@vark.edu
River Bottom Winery at BoBrook Farms	bobrookfarms@gmail.com
Riverben Nurseries	Website
Sassafras Springs Vineyard	SassafrasSpringsVineyard@gmail.com
Shawnee Bluff Winery	larry@shawneebluffwinery.com
South Branch	info@southbranchnursery.com
St. Francois Vineyard	winevine@i1.net
Stone Hill Winery	Events@stonehillwinery.com
The Winery of Hot Springs	duckwaxwine@yahoo.com
Tontitown Winery	sales@tontitownwinery.com
Ty Ty Nursery	customerservice@tytyga.com
Vaughn Nursery	vaughnnursery@blomand.net