DISCOVERY

The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Vol. 21 Fall 2020

Fifth Generation Farmer Clayton Parker Hopes to Use His Agribusiness Degree to Help Run His Family Farm and to Help Other Arkansas Farmers

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DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

UNIVERSITY OF ARKANSAS
Dale Bumpers College of Agricultural, Food and Life Sciences

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Undergraduate Research Articles

Cover: Features the research of Bumpers student Clayton Parker, an agribusiness major, who looked at the economics of on-farm rice drying in Arkansas. Clayton is a fifth generation farmer on his family farm in Carlisle, Arkansas. Clayton hopes to apply his knowledge to his farming operation and also use it to help other Arkansas farmers.

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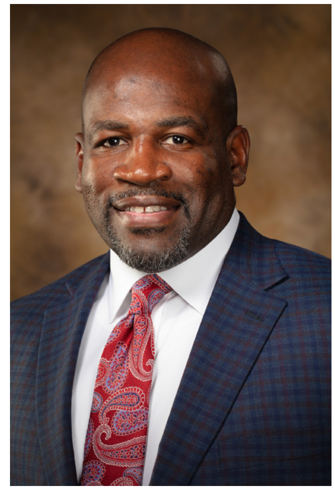
Letter from the Dean



Deacue Fields

When talking to current students, prospective students, industry partners, friends, supporters, or others, we often mention the multiple directions our graduates can choose for careers with a degree from the Dale Bumpers College of Agricultural, Food and Life Sciences.

That holds true for research, too, and this year's *Discovery* undergraduate journal is a great example. Of the 12 projects featured this year, 7 different departments and concentrations are represented, showing the versatility, range, and scope of our majors.

As Dean of Bumpers College, it is encouraging and inspiring to see the issues tackled by our students as they strive to answer questions and solve problems that have a far-reaching impact on society.

We are here to serve the people of Arkansas, across the country and around the world, and by tackling the subjects represented here, our students are doing just that. Our innovative programs, faculty experts, and outstanding students are improving the quality of life for everyone as graduates become scientists, innovators, managers, policymakers, entrepreneurs, educators, and most importantly, difference makers.

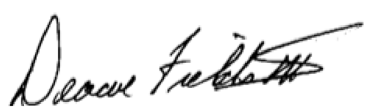
Our students are in the process of launching successful careers, conducting meaningful research, and sharing fact-based findings. *Discovery* highlights the efforts of just a few of our talented students as well as expert faculty. Our faculty work with them to produce what you see here because they care about our students and their development, as well as the research.

In this issue, you'll find projects by students and their mentors from the Department of Agricultural Economics and Agribusiness; the Department of Animal Science; the Department of Crop, Soil and Environmental Sciences; the Department of Food Science; the Department of Horticulture; and the human nutrition and dietetics, and human development and family sciences concentrations in our School of Human Environmental Sciences.

We encourage undergraduate research by awarding undergraduate research grants. Our students compete for research and travel grants awarded by the University of Arkansas Honors College and the Arkansas Department of Higher Education Student Undergraduate Research Fellowship grants program.

Projects may be designed to meet requirements for an honors project in the Bumpers College Honors Program. One of our goals is to prepare students to be responsible leaders with strong communication skills and problem-solving abilities. Inside this issue, you will find studies that highlight and exemplify those qualities in our student researchers and future leaders.

Congratulations to the student authors on completing your project. And thank you to the faculty mentors and editors who worked with them to make this collection possible. As a college, we are pleased and proud to present their work in a citable publication as a service to them and our readers.



Deacue Fields, Dean
Dale Bumpers College of Agricultural, Food
and Life Sciences

Letter from the Faculty and Managing Editors

Beth Kegley
Faculty Editor

This represents the second year that I have had the honor of serving as editor of this publication. I continue to be impressed with the broad scope of projects that students are conducting in the Dale Bumpers College of Agriculture, Food and Life Sciences, in conjunction with the University of Arkansas System Division of Agriculture's Arkansas Agricultural Experiment Station.

This year we would like to acknowledge the efforts of the Division and college faculty who mentor undergraduate students conducting these research projects. In particular, we want to give a big THANK YOU to Dr. Mary Savin who in addition to teaching, conducting environmental science research, supervising graduate students, and actively mentoring undergraduate students who desire research experience, was the longest-serving faculty editor of Discovery for 9 years, from 2010 to 2018.

She succeeded the first and second editors, Dr. John Clark (editor from 2000 to 2006) and the late Dr. Teddy Morelock (editor from 2007 to 2009) who laid the foundation for the strong and dynamic publication we have today. Dr. Savin successfully guided the publication through changes in the types of projects that were required of Honors students, changes to the funding model for the publication, and in her last year, helped the Managing Editor to transition journal management to the UAScholarWorks website. She devoted countless hours to working with students from across the college on their first trip through the publication process. She is a master of giving students critical guidance and forcing them to meet our high standards for publication. No one forced her to take this role—she volunteered—and her efforts are immensely appreciated. She continues as a faculty mentor, acting in that capacity for three articles in this issue alone.

All the faculty represented in these pages 'volunteered' to take on this extra responsibility of mentoring these undergraduate students. This publication reflects untold hours of commitment on the faculty's part reviewing proposals, assisting with data collection, going through statistical analyses, and finally reading and rereading manuscripts. Time is often my most valuable commodity, and I do not think I'm unique; so thank you to Dr. Savin and all the faculty who took the time to work with students whose work is presented in these pages.

Beth Kegley, Faculty Editor, Discovery Journal and
Professor, Department of Animal Science

Gail Halleck, Managing Editor, Discovery Journal

Bumpers Students with Lifelong Passions for Agriculture Use Their Research to Better the World

In science-driven disciplines like those in the Dale Bumpers College of Agricultural, Food and Life Sciences, research is key to ensuring students receive the highest quality education. Most of the teaching faculty in Bumpers College are also scientists in the Arkansas Agricultural Experiment Station, the research arm of the University of Arkansas System Division of Agriculture. Their research goes straight into the classroom, inspiring the next generation of scientists who will make vital contributions to civilization. The brightest of these students, many of whom are represented in these pages, are already contributing to society.

The undergraduate research reports you will read in this journal are not simply paper-cutter laboratory exercises with no greater purpose than to earn a grade. These are genuine scientific inquiries that add to the Arkansas Agricultural Experiment Station's tree of knowledge. Each research project recorded here is an essential rung on a ladder of discovery that will help feed the world and improve the quality of life for this generation and those that follow.

Take honors student Clayton Parker, whose photo is featured on this issue's cover. Since childhood, when he rode the tractor with his father on the family farm at Carlisle, he has been on a lifelong trajectory toward discovery. After high school, he enrolled in Bumpers College to pursue a degree in agribusiness. He came seeking the knowledge and expertise to succeed as a businessperson and leader in Arkansas' agricultural industry. His research, on page 69, investigated the economics of on-farm rice drying in Arkansas.

"The experiences in the classroom and as a researcher have helped me gain the skills to create what I hope are valuable tools for other farmers in Arkansas," Clayton said. "Upon graduation, I plan to return home to the farm and start the fifth-generation of our operation alongside my father and grandfather."

While still in high school, Rachel Barry developed a passion for politics and policy and understanding how they affect production agriculture. She channeled her passion into action in FFA and Farm Bureau. "American Farmers and Ranchers deserve informed, dedicated, and effective advocates who can ensure that production agriculture is protected through legislation," she said. You can read about her research on the political preferences of Arkansas farmers and ranchers on page 8.

Rachel graduated Magna Cum Laude from Bumpers College in May 2020 with a degree in agricultural business marketing and management. She plans to work in the grain industry where she wants to work toward increasing supply chain efficiency and empowering farmers to utilize risk management tools to protect their businesses.

Hailey Hilfiker, a native of Piggott, Arkansas, grew up showing cattle in local, regional, state, and national competitions. She developed a passion for large animals and began raising purebred Shorthorn cattle. Hailey began her undergraduate career at the University of Arkansas as an animal science major with a pre-professional concentration. She became interested in beef nutrition and reproduction, and her Honors Program research focused on those areas. You can read about it on page 43.

Her interests led her to participate in the Block and Bridle Club, where she served as the livestock activities chair. She also served as a Bumpers College student ambassador. Upon graduating Magna Cum Laude, she was accepted into the University of Missouri's veterinary medicine program.

Research and education are helping Clayton, Rachel, Hailey, and the other nine student researchers whose work is recorded in these pages, grow into the next generation of world citizens who will build a better society.

Fred Miller,
Division of Agriculture Communications

5th GENERATION FARMER: Clayton Parker (left) pictured on his family farm in Carlisle, Arkansas, with his dad and grandfather.

A PASSION FOR ANIMALS: Hailey Hilfiker on her family farm in Piggott, Arkansas, with two of her Shorthorn heifers that she showed and has since added to her herd.

Discovery on ScholarWorks@UARK

Journal management and submissions are facilitated through ScholarWorks@UARK, the institutional research repository for the University of Arkansas:

https://scholarworks.uark.edu/discoverymag/

Bumpers College undergraduate student research reaches a worldwide audience via this powerful database, with its extensive search engine and analytics, and ease in downloading individual articles. Here's a peek at readership distribution across the globe and most popular *Discovery* articles by download in recent months.

Table 1. Download history for all *Discovery* issues from the period of 14 July through 12 October 2020.

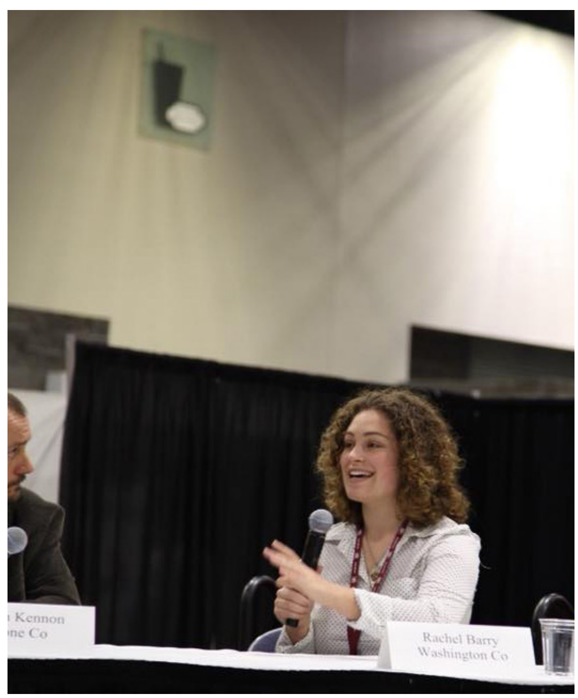
Title	Downloads
Growth and Performance of Broiler Chicks During the Starter and Grower Phases in Phase-Feeding	277
Love-bombing: A Narcissistic Approach to Relationship Formation	96
Investigating the Utilization of Silica Gel Packets in Drying Research-Scale Rough Rice Samples	78
Properties of Gluten-Free Pasta Prepared from Rice and Different Starches	73
Propagation of Thornless Arkansas Blackberries by Hardwood Cuttings	65
Eco-cosplay: Upcycling as a Sustainable Method of Costume Construction	63
Discovery: The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences - Volume 19 2018	43
The Characteristics of Consumers and Producers Using Farmers' Markets	41
Soil Particle-Size Analysis: A Comparison of Two Methods	39
A Comparison of Recently Introduced Instruments for Measuring Rice Flour Viscosity	33

The political preference of Arkansas farmers and ranchers

Meet the Student-Author

Rachel Barry

I am a Spring 2020 Magna Cum Laude graduate of the Dale Bumpers College of Agricultural, Food and Life Sciences with a degree in Agricultural Business Marketing and Management. While at the University of Arkansas, I was an active member of the Collegiate Farm Bureau, the Agricultural Business Club, and the Sigma Alpha Sorority, serving as an officer in all three. I represented Arkansas at the Young Farmers and Ranchers Collegiate Discussion meet in 2019, where I was a sweet sixteen finisher. I was active in both FFA and Farm Bureau in high school, which is where I developed a passion for politics and understanding how policy and legislation affect production agriculture. American Farmers and Ranchers deserve informed, dedicated, and effective advocates who can ensure that production agriculture is protected through legislation. After graduation, I will go to work in the grain industry with the goal of increasing supply chain efficiency and empowering farmers to utilize risk management tools to protect their businesses. I want to extend a huge thank you to Dr. Donna Graham for her guidance and support throughout this process. I also want to thank Drs. Nathan Kemper and Lanier Nalley for serving on my thesis committee, as well as the rest of the Agribusiness department faculty for their support and encouragement throughout my undergraduate career.



Rachel competing at the Young Farmers and Ranchers Collegiate Discussion Meet in 2019.

Research at a Glance

- Arkansas farmers and ranchers should be attentive to political activity at the State and National levels as those engaging in production agriculture are more likely to have their livelihood affected by policy or legislation development than the average American.
- Arkansas Farmers and Ranchers typically rely on information obtained through face-to-face interaction to make decisions about what candidates to support and to evaluate policy.
- The Arkansas Farm Bureau and University Cooperative Extension/Government are sources frequently consulted by farmers and ranchers in a political context.
- Farmers and Ranchers prioritize issues and candidate qualities based on conservative ideology.

The political preference of Arkansas farmers and ranchers

Rachel J. Barry and Donna Lucas Graham†*

Abstract

Access to information is critical to improving production efficiency, but little is known about how farmers are informed on the policy or issues influencing programs related to farming. This research sought to determine the sources of communication used by farmers and ranchers to form opinions about agricultural policy and candidates, identify the issues important in voting, and their level of participation in the political process. Face-to-face interaction was the preferred form of communication in farm organization meetings, with friends, or farm agencies. Magazines were the preferred source of print communication, and university/extension websites were preferred for internet sources. Broadcast media and social media were the least preferred sources for policy information, yet were consulted more often for information about candidates. Friends and family were also the preferred source used to gather information about candidates, along with meet-the-candidate events. The Farm Bureau was the most frequently preferred source of published information. Farmers and ranchers have higher than average levels of voter turnout and typically prefer to take political action by writing letters to their elected representatives. The candidate's values were the most important characteristic when choosing to support a candidate. While farm advocacy groups are producing information on policy and candidates, this information is frequently shared through friends. Additional research is needed to determine the trusted opinion-leaders who convey the information from community meetings or publications to other producers through face-to-face interactions.

* Rachel Barry is a senior honors student, with a major in Agribusiness Marketing and Management.
† Donna Graham, the faculty mentor, is a University Professor and Graduate Coordinator, Agricultural Education, Communication, and Technology.

Introduction

"America's farmers and ranchers make an important contribution to the U.S. economy by ensuring safe and reliable food supply, improving energy security, and supporting job growth and economic development" (United States Congress, 2013). Yet, new government mandates and regulations, specifically trade, environmental regulations, and land use, are the top issues facing the operation expansion and growth of the rural economy according to producers (Case IH, 2011; CoBank, 2020).

Policy directives contained in a legislative act, known as a farm bill, regulate agriculture in the United States (USDA-ERS, 2019). Early farm bill programs supported family farms, while recent regulations are more comprehensive in support of broader initiatives influenced by environmental, energy, consumer, business, and agricultural interest groups (Reimer et al., 2016). For these reasons, farmers must be more attentive to legislation as their plight is consistently tied to the policy that affects production.

The economic rationale for farmers' access to information is to enable them to manage the risks and uncertainties regarding production and marketing their products. The Extension Service has a long history of providing useful, unbiased, science-based production information. However, as production technology has rapidly changed, farmers have turned toward agribusinesses consultants, sales associates, governmental agencies, and crop consultants for information Gloy, et al., 2000; Arbuckle Jr. et al., 2012; Borrelli et al., 2018). Information is retrieved using smartphones and tablets, accessing the internet five or more times a week, and social media at least once a week (Farm Journal, 2019). Adults under age 50 access news from online sources, while adults over age 65 obtain news from a newspaper (Mitchel et al., 2016).

While the sources of information for production and marketing decisions are known, research is limited on how farmers get information related to voting. Little is known about whether farmers research and evaluate candidate positions or the issues that may impact agricultural policies. This study sought to understand the information sources and preferences that influence decisions before voting. The objectives of this study were to:

1. Determine the sources of information used by farmers to form opinions about agricultural policy and candidates.
2. Determine the issues farmers consider important when voting.
3. Determine the level of participation of farmers in the political process.

Materials and Methods

This study used a quantitative, nonexperimental design to describe the characteristics and political preferences of Arkansas farmers and ranchers. This approach was a convenience sample of agricultural producers attending the Arkansas Farm Bureau state meeting or the Young Farmers and Ranchers Conference.

The instrument consisted of 14 questions to ascertain a farmer's preferences for information sources and channels used for forming an opinion on agricultural policy and candidates, the issues most likely considered when developing a personal voting position, past political involvement, and preferences for discussing and sharing information with peers and acquaintances. Five sources of communication, including internet sources, face-to-face communication, print media, social media, and broadcast media, were rated by frequency of use as sources of information consulted on policy and candidates. Typical hubs of activity in rural areas were identified to indicate places farmers and ranchers were likely to discuss politics or political concerns. Issues identified by state and national polls as important to voters were listed for farmers to classify the importance of when considering candidates for voting. Means and standard deviation were calculated for all items ranked on a scale.

Demographic information was collected on farm size and type, farmer age, years of experience in agricultural production, and agricultural leadership positions. Institutional approval was given by the University of Arkansas Institutional Review Board.

Results and Discussion

Population

The survey population of 90 respondents was farmers and ranchers who were actively engaged in production agriculture. They were mostly split between the ages of 18 and 35 (46.4%) and those over age 50 (38.1%), with only 15.5% between the ages of 36–50. Respondents tended to be livestock producers (67.5%), with roughly one-third of the respondents being row crop or produce farmers. The respondents reported between 3 to 60 years of experience in farm production, with the most frequent category being 26 to 50 years of experience (42.2%). The most frequent (43.4%) farm size, a combination of leased and owned land, was 40.9 hectares (101 acres) to 202 hectares (500 acres). Fourteen respondents (16.9%) reported farm operations of 40.5 hectares (100 acres) or less, while 11 respondents (13.25%) reported farming over 809 hectares (2000 acres). Of these 90 respondents, 68% had served in a leadership role of an agricultural group.

Information Sources Used

Most respondents (70.0%) used face-to-face communication as a primary source of information to evaluate policy (Table 1), followed by print media (28.4%) and internet sources (27.8%). The least used source was social media (22.2%). Respondents remarked they often felt social media was too biased to use as a source for important information.

Face-to-face communication (78.7%) occurred in farm organization meetings and commodity groups to gather information about policies (Table 2). Friends (58.9%) and Extension and Government Agency personnel (58.9%) were equally consulted as the next most utilized form of contact. Farmers and ranchers rely on family (41.1%) the least for information about policies.

The most frequent source of print media consulted on policy information was magazines (48.9%), followed by newsletters (26.7%) and newspapers (24.4%). Respondents who used internet sources (distinct from the use of social media) primarily used university-based sources (51.1%). Of internet sources, the least used sources were news websites (28.9%), with industry sites used only slightly more frequently (31.1%). Respondents used both radio broadcasts (53.3%) and television (41.1%) broadcasts as a source of information on policies. Social media was the least selected source of information, with Facebook (62.2%) noted as the most frequently used social media source (Table 2).

Producers rely more on face-to-face communication (78.9%) when evaluating a candidate than when evaluating public policy (Table 3) and more on broadcast (37.8%) and social media (33.3%) when assessing a candidate's position. Internet sources were the least frequently consulted of all types of sources for candidate information.

Of all face-to-face sources, friends (60.0%) and family (51.1%) were most often consulted to gather information about candidates (Table 4). Other face-to-face communication included other producers (36.7%), candidates (33.3%), and interaction at community meetings (31.1%). With such a preference for face-to-face information, additional study is needed to identify the opinion leaders who convey the information from community meetings or publications to other producers.

When researching candidates, television (53.3%) and radio (40.0%) were used often as broadcast media sources. More than half obtained candidate information from social media.

Facebook (50.0%) was the most popular social media site with other reported sources as the candidate's social media account (14.4%) and Twitter (12.2%) (Table 4). Many respondents stated that broadcast media was too biased to be used as a legitimate source of information, even though they are tuned in for information.

Of all print media used for candidate information, the most frequent source consulted to help make decisions was newspapers (33.3%), campaign material produced by candidates (21.1%), and magazines (20.0%). Respondents

Table 1. Communication sources consulted for policy decisions (n = 90).

Sources used	Number of responses	Percent
Face to Face	63	70.0
Print Media	26	28.4
Internet	25	27.8
Broadcast Media	21	23.3
Social Media	20	22.2

Note: the percentages will total more than 100% as respondents selected all sources of media consulted.

Table 2. Type of communication sources consulted for policy information (n = 90).

Face to face sources	Percent
Meetings	78.7
Extension/governmental agencies	58.9
Friends	58.9
Other producers	50.0
Family	41.1
Print media sources	
Magazines	48.9
Newsletters	26.7
Newspapers	24.4
Internet sources	
University/Extension	51.1
Industry	31.1
News Organizations	28.9
Broadcast media sources	
Radio	53.3
Television	41.1
Social media sources	
Facebook	62.2
Twitter	16.7
Blogs	6.7

Note: the total can equal more than 100% as respondents selected all forms of media consulted within each source.

Table 3. Communication sources consulted for candidate decisions (n = 90).

Sources used	Number of responses	Percent
Face to face	71	78.9
Broadcast Media	34	37.8
Social Media	30	33.3
Print Media	26	28.9
Internet Sources	17	18.9

Note: the percentages will total more than 100% as respondents selected all sources of media consulted.

indicated that they use internet sources (distinct from social media) the least of all communication sources to gather information about candidates. Sources used were news websites (27.8%) and industry websites (17.8%) (Table 4). Research is needed to identify the farm magazines farmers and ranchers read, and how the publications support candidates that align with farmer values.

Most respondents (57.3%) participated in activities designed to help candidates meet the constituency. These included meet-the-candidate events hosted by county Farm Bureau organizations, town hall meetings, campaign stops, and similar events. These choices align closely with their preference for face-to-face interaction.

When asked about the confidence level of information gathered from these sources, a majority (54.1%) of respondents felt 'mostly informed' when casting votes for candidates. Twenty-two respondents (25.9%) indicated that they were "very informed" before voting. Additional study is needed to understand how candidate values are determined from the communication sources consulted.

The respondents reported they rely on information published by Farm Bureau (79.0%), university sources (63.0%), and commodity groups (61.0%) for both policy and candidates (Table 5). The USDA was consulted for information less than half the time (40.0%).

By far, the most frequently selected location for face-to-face discussion of politics or political issues was at farm organization meetings (86.0%), another's home or farm (73.3%), and at the respondent's own house or farm (67.4%).

Issues Farmers Consider Important When Voting

Sixteen social issues were rated by respondents on a scale of importance considered on the ballot from 1 = critically important to 4 = Not important. Abortion [Mean (M) = 1.48, standard deviation (s.d.) = 0.72] and gun control (M =1.48, s.d.= 0.80) were rated as the most important social issues when voting (Fig. 1). Taxes (M = 1.52, s.d. = 0.60) and property rights (M = 1.53, s.d. = 0.68) were rated third and fourth in importance while policies on inheritance (M = 2.16, s.d. = 0.96) were the least important issue for the respondents, yet still considered very important.

When considering the characteristics of candidates, values held by the candidate were the highest-rated characteristic when deciding to support a candidate (M = 1.24, s.d. = 0.50). The gender of the candidate (M = 3.62, s.d. = 0.69) was considered the least important but still in the range as somewhat important, followed closely by the income and wealth of the candidate (M = 3.60, s.d. = 0.64).

Level of Involvement

Voting was the most frequently exercised political activity, with 68.5% of respondents reporting that they vote in every election and another 23.6% reporting that they

Table 4. Type of communication sources consulted for candidate information (n = 90).

Face to face sources	Percent
Friends	60.0
Family	51.1
Other producers	36.7
Candidates	33.3
Community meetings	31.1
Broadcast media	
Television	53.3
Radio	40.0
Social media	
Facebook	50.0
Twitter	12.2
Candidate's Social Media	14.4
Blogs	3.3
Print media	
Newspaper	33.3
Campaign Material	21.1
Magazines	20.0
Newsletters	13.3
Internet sources	
News websites	27.8
Industry websites	17.8

Note: the total can equal more than 100% as respondents selected all forms of media consulted within each source.

Table 5. Publishers of information consulted about policy and candidates (n = 90).

Publisher	Percent
Farm Bureau Federation	79.0
University sources	63.0
Commodity groups	61.0
USDA	40.0
Federal government agencies	37.0
Agricultural advocates	32.0
Corporate owned news organizations	29.0
State agencies	21.0
Industry	21.0
Congressional representative or elected officials	21.0
Public television or radio	20.0
Other	4.0

Note: the percentages can total more than 100% as respondents could select all publishers consulted.

vote most of the time. Other than voting, most respondents participated in one or more political activities with the most usual ways of engaging being writing a letter to an elected official (59.5%) and advocating for the passage of legislation (55.7%). The category with the least involvement of political activities was protesting (3.8%). Respondents indicated they were often motivated to act because a proposed bill would affect them or their family and friends directly. Examples of such issues cited included right-to-farm, EPA water regulations, or property rights.

Respondents to this study favor conservative values based on the values identified as important for voting and hold a unique social connection to other farmers with the same beliefs. Rural voters have tended to favor Republican candidates even when policies may negatively impact their economic interests. Mason (2018) explained that farmers are more attached to the social impact of their chosen label (liberal or conservative) than the ideology on issue positions when supporting candidates. The undercurrent of conflict between these ideological groups is apparent in social and mass media. Additional study is needed on whether farmers are voting on party lines or ideologies.

Limitations

The sample size and make-up for this study limits extrapolating results to the general population. It was concentrated with livestock producers in contrast to row crop farmers and was not representative of the farmer and rancher populations in Arkansas. Additionally, the respondents were members of the Farm Bureau and likely engaged in political activities of the organization where policy and candidate positions are discussed.

Conclusions

The findings of this study indicate that Arkansas farmers and ranchers are a very engaged constituency. They tend to prioritize social issues and vote according to a more conservative agenda. Face-to-face communication is preferred for obtaining information about both policy and candidates. They view more popular forms of media (broadcast media, social media, internet sources) as too biased to be reliable. Most farmers and ranchers feel informed when they approach the ballot box and are confident with their choices when casting a ballot. The Farm Bureau organization has a developed process of policy development and communication that is a trusted source for these respondents. This research should empower advocacy groups to transmit information to farmers and ranchers more efficiently and use their limited resources to advocate on behalf of the farmer to address issues most important to this population.

Acknowledgments

The authors would like to acknowledge funding for this project from the University of Arkansas Bumpers Honors Undergraduate Research Grant pool. We appreciate the Arkansas Farm Bureau's willingness to allow us to administer the survey at their meetings.

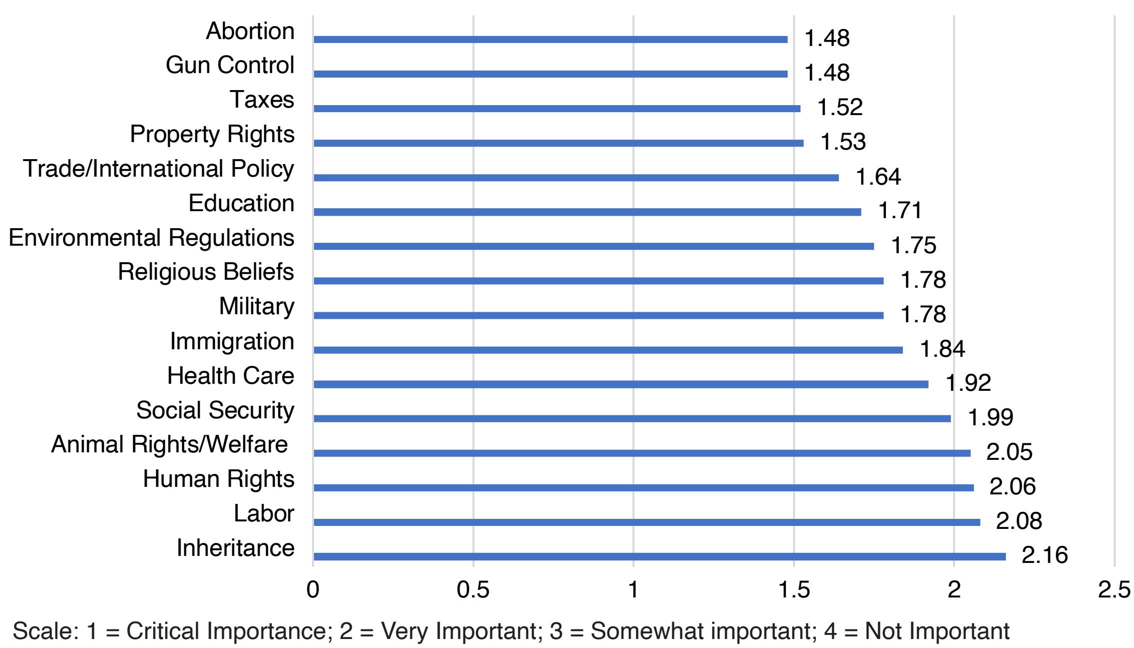


Fig. 1. Mean score of social issues important to Arkansas farmers and ranchers when voting.

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Estimation of additive and dominance effects of a mutant glutathione S-transferase gene on anthocyanin content in muscadine grape (*Vitis rotundifolia*)

Meet the Student-Author

Autumn Brown

I am from Mammoth Spring, Arkansas. I will be graduating with honors from the University of Arkansas in the Fall of 2020 with a degree in Horticulture and minors in History and Crop Biotechnology. While at the University of Arkansas, I have learned about research and horticulture in ways I never imagined. I have been working in the Fruit Breeding Lab, under the direction of Dr. Margaret Worthington, since freshman year, during which time I have learned invaluable skills and made many networking connections. I attended the Southern Region and National American Society for Horticultural Science conferences and won first place in the undergraduate oral research presentation competitions at both meetings. In the summer between sophomore and junior year, I interned at Edward Vinson Ltd. in Faversham, England. This helped spur my interest in study abroad, and since then, I studied in Belize and became a Study Abroad Mentor. I served for two years on the Bumpers Honors Student Board. I want to thank my amazing mentor, Margaret Worthington, for her help in this project and my entire college career. I also want to thank Lacy Nelson, Aruna Varanasi, Cindi Brownmiller, Renee Threlfall, Luke Howard, John Clark, the fruit breeding team, and the Horticulture Department for their countless hours of support. Lastly, I want to thank my mother and father for helping me with everything and always offering me their unwavering support.

Autumn with her mentor Margaret Worthington accepting her first place award for undergraduate student paper at the Southern Regional American Society for Horticultural Science.

Research at a Glance

- VrunGST4 is a dominant gene controlling berry color and anthocyanin content in muscadine grapes.
- Berry skin color is not a good indicator of total anthocyanins in black-fruited muscadine grapes.
- The average anthocyanin content in the two mapping populations was very different. This suggests that other genes may also contribute to variation in total anthocyanin content in muscadine grapes.

Estimation of additive and dominance effects of a mutant glutathione S-transferase gene on anthocyanin content in muscadine grape (*Vitis rotundifolia*)

Autumn Brown,[*] Margaret Worthington,[†] Aruna Varanasi,[§] Lacy Nelson,[‡] Renee T. Threlfall,[¶] and Luke R. Howard[#]

Abstract

The skin color of muscadine grapes (*Vitis rotundifolia*) is typically classified as black or bronze. A glutathione S-transferase, *VrunGST4*, has been identified as a candidate gene for berry skin color in muscadine grapes. A molecular marker was developed within *VrunGST4* to distinguish between muscadine genotypes (cultivars and selections) with bronze (T:T), heterozygote black (C:T), and homozygote black (C:C) berries. The objectives of this study were to determine whether there was a correlation between berry skin color and total anthocyanin content and to calculate additive and dominance effects of *VrunGST4* in determining total anthocyanins in the berries of two biparental F_1 muscadine populations with the intragenic *VrunGST4* marker. No correlation was found between the berry skin color measurements of hue and lightness and anthocyanin content of black-fruited genotypes in either population. However, there was a slight correlation (r = 0.64) between anthocyanin content and chroma in one of the populations. There was no difference in total anthocyanin content of homozygote black (C:C) and heterozygote black (C:T) genotypes in either population, indicating that *VrunGST4* had completely dominant gene action. The total anthocyanin content of the berry skins from black-fruited genotypes in one population was approximately four times greater than black-fruited genotypes in our other population. This finding suggests that other genetic loci may contribute to variation in total anthocyanin content in black-fruited muscadine grapes.

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[†] Margaret Worthington is the faculty mentor and an Assistant Professor in the Department of Horticulture.
[§] Aruna Varanasi was a Postdoctoral Associate in the Department of Horticulture and is now a scientist at Bayer Crop Science.
[‡] Lacy Nelson is a Program Associate in the Department of Horticulture.
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Introduction

Muscadine grapes (*Vitis rotundifolia*) have been cultivated since the mid-18th century and are native to the Southeastern United States, where winter temperatures do not drop below -12 °C (Conner, 2009). They have a very distinctive fruit, thick skin, large seeds, and a unique fruity and musky aroma. Muscadines are valuable for their fresh-market fruits, wine, and juice production. Most commercial muscadine production goes into juice or winemaking (Morris and Brady, 2007).

Muscadines contain many different phytochemicals, most of which are found in their skins and seeds (King and Young, 1999). Anthocyanins are phenolic pigments responsible for giving many different plants their blue, purple, or reddish color (Wrolstad, 2006). Anthocyanin content in bunch grapes and black muscadine skins vary widely, ranging from 1000 $\mu g.g^{-1}$ to over 5000 $\mu g.g^{-1}$ fresh weight (Conner and MacLean, 2013).

The total amount of anthocyanins in the berry and the relative proportion of the individual anthocyanins affect muscadine juice color quality and stability (Conner and MacLean, 2013). Delphinidin is the most prominent type of anthocyanin in muscadine grapes, with malvidin found in very small amounts, partly responsible for the poor color stability of muscadine juice and wines (Conner and MacLean, 2013). Muscadines form diglucosidic anthocyanins, which have a decreased ability to form polymeric pigments, making them more prone to oxidation and browning (King and Young, 1999).

In general, muscadine grapes have two main skin colors: black and bronze. Nearly all wild muscadines produce a dark purple, almost black-colored berry. Bronze (light green-brown) berries are present in a much lower amount in the wild, though many bronze cultivars have been developed for fresh market and processing. Our research group recently constructed the first saturated genetic linkage maps of muscadine in two F_1 biparental populations segregating for berry color, 'Black Beauty' × 'Nesbitt' and 'Supreme' × 'Nesbitt' (Lewter et al., 2019). All three parents were heterozygous for black color, and the progeny in both populations segregated at an expected 3:1 ratio for black and bronze berry color (Fig. 1). The muscadine berry color locus mapped to a region on linkage group (LG) 4 aligning to 11.09–11.88 Mbp on *V. vinifera* chromosome 4 (Lewter et al., 2019). There were 21 predicted genes in this interval, including *VviGST4*. Glutathione S-transferases (GST) are required for transporting anthocyanins from the cytosol into the vacuole, where they are sequestered.

Our team sequenced the *VrunGST4* gene in several bronze and black muscadine cultivars and found a non-synonymous single nucleotide polymorphism (CCG/CTG), resulting in proline to leucine substitution in bronze muscadines. We also developed an intragenic Kompetitive Allele Specific PCR (KASP) marker that can distinguish between homozygote black (C:C), heterozygote black (C:T), and bronze (T:T) genotypes (cultivars and selections) and used it to genotype the mapping population and progeny (Varanasi et al., 2020; Fig. 2). It is unknown whether homozygote black genotypes have significantly higher an-

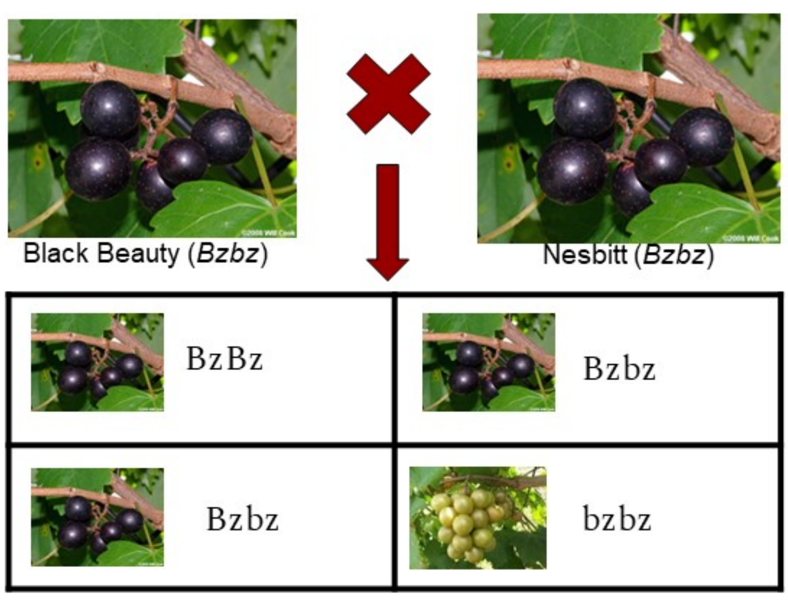

Fig. 1. The expected 3:1 segregation ratio of black (BzBz and Bzbz) and bronze (bzbz) progeny in the 'Black Beauty' x 'Nesbitt' muscadine grape mapping population.

thocyanin content than heterozygote black genotypes. Both genotype classes appear black, but color is not always a good predictor of nutraceutical content. Allele dosage plays a major role in determining anthocyanin content in *V. vinifera*. Most phenotypic variation in grape anthocyanin content has been attributed to additive effects, with dominance playing a minor role (Fournier-Level et al., 2009).

Now that we can accurately discern which progeny are heterozygote black and homozygote black, it is possible to determine whether allele dosage (additive genetic variation) at V*runGST4* plays a significant role in determining anthocyanin content in muscadine skins. If homozygote black progeny have significantly higher anthocyanin content, breeders can use the intragenic *VrunGST4* KASP marker to select progeny with high anthocyanin production for processing and nutraceutical industries (Varanasi et al., 2020).

There were two main objectives for this research: (1) to assess whether individual anthocyanin content varies between homozygote and heterozygote black muscadines, and (2) to determine if there is a correlation between berry skin color and total anthocyanin content in muscadines.

Materials and Methods

Harvest

Fruit from selected progeny in the 'Black Beauty' × 'Nesbitt' and 'Supreme' × 'Nesbitt' mapping populations was harvested from vines grown at the University of Arkansas System Division of Agriculture Fruit Research Station in Clarksville on 13 September 2018. Forty-eight progeny, 16 from each genotype class (C:C, C:T, T:T), with sufficient fully colored mature fruit on the date of harvest were selected from each population. Harvested plants were selected by walking both populations and taking notes on which vines had adequate amounts of ripe fruit. Sixteen plants from each genotype class were randomly selected from the list of plants with adequate ripe fruit.

Color Analysis

Five berries were collected from each progeny vine, transported back to the Department of Food Science, Fayetteville in coolers, and stored in a cold room (2 °C). The next day, skin color was measured at the equator of each in-

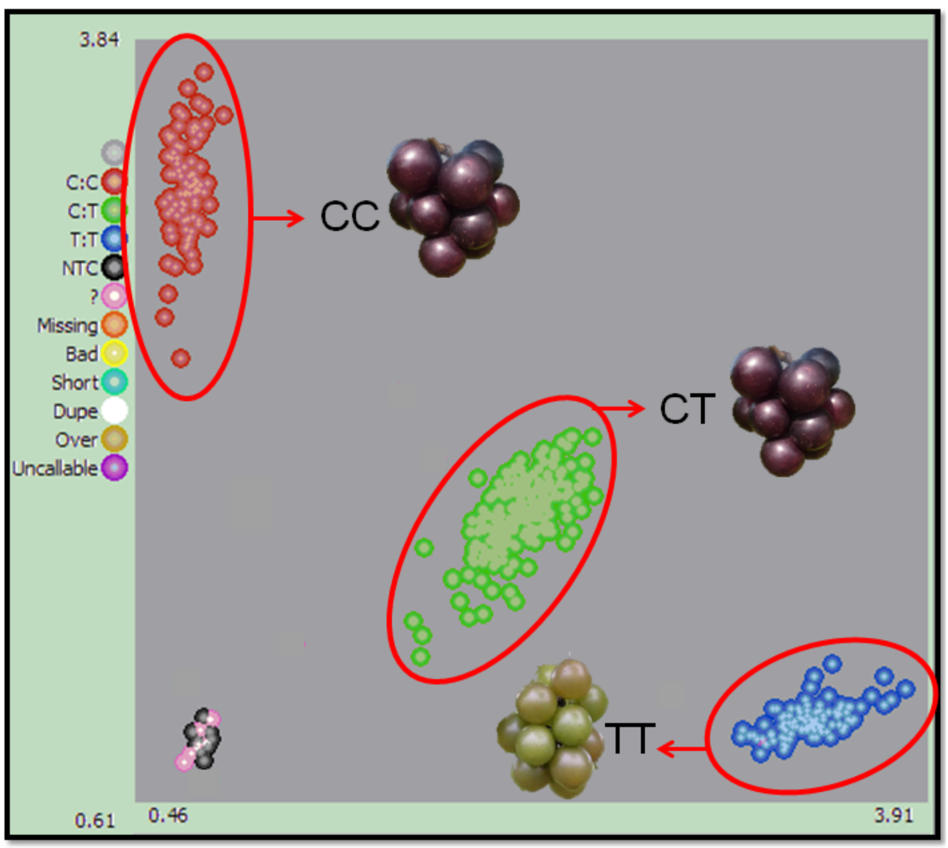

Fig. 2. Kompetitive Allele-Specific (KASP) PCR cluster plot showing clusters of bronze (T:T), heterozygote black (C:T), and homozygote black (C:C) progeny from the 'Supreme' x 'Nesbitt' and 'Black Beauty' x 'Nesbitt' muscadine grape mapping populations.

dividual berry using a CR 400 colorimeter (Konica Minolta, Ramsey, New Jersey). Color was measured as L* (lightness), a* (green-red), and b* (yellow-blue) coordinates. Coordinates a* and b* were transformed into chroma (C*) and hue angle (h°) using the equations: $C^* = (a^{*2} + B^{*2})^{1/2}$ and $h° = tan−1(b^*/a^*)$ following (McGuire, 1992). After color measurements were completed, the flesh was removed from the slipskin fruit (pulp releases easily from the skin), and seeds were extracted. The skins were frozen (-20 °C) for anthocyanin analysis.

Total Anthocyanins

Anthocyanins were extracted by homogenizing the grape skins (3.5 g) in the extraction solution, methanol/water/formic acid (60:37:3 v/v/v), with a Euro Turrax T18 Tissuemizer (Tekmar-Dohrman Corp, Mason, Ohio) for approximately 1 min. The samples were then centrifuged for 5 min at 10,000 rcf , and filtered through miracloth into a 100-mL or 200-mL volumetric flask. This process was repeated with 25 mL of extraction solution containing acetone/water/acetic acid. The entire process was repeated until all color was removed from the residue. Total anthocyanins were then measured using the pH differential method and quantified as cyanidin-3-glucoside equivalents following Giusti and Wrolstad (2001). Absorbance was measured spectrophotometrically at 510 and 700 nm and at pH 1 and pH 4.5.

Individual Anthocyanins

Aliquots (7.5 mL) of five extracts (chosen randomly from each genotype class and mapping population) were dried using a Speed Vac concentrator (ThermoSavant, Holbrook, New York) and then re-suspended in 1 mL of 5% formic acid. The samples were passed through 0.45-mm polytetrafluoroethylene (PTFE) syringe filters (Varian Inc, Palo Alto, California) before High-Performance Liquid Chromatography (HPLC) analysis. Anthocyanin analysis by HPLC was performed following a procedure from Cho et al. (2004). All samples were analyzed using a Waters HPLC system equipped with a model 600 pump, a model 717 Plus autosampler, and a model 996 photodiode array detector. Separation was carried out using a 4.6 mm × 250 mm Symmetry® C_{18} column (Waters Corp, Milford, Massachusetts) preceded by a 3.9 mm × 20 mm Symmetry® C_{18} guard column. The mobile phase was a linear gradient of 5% formic acid and methanol

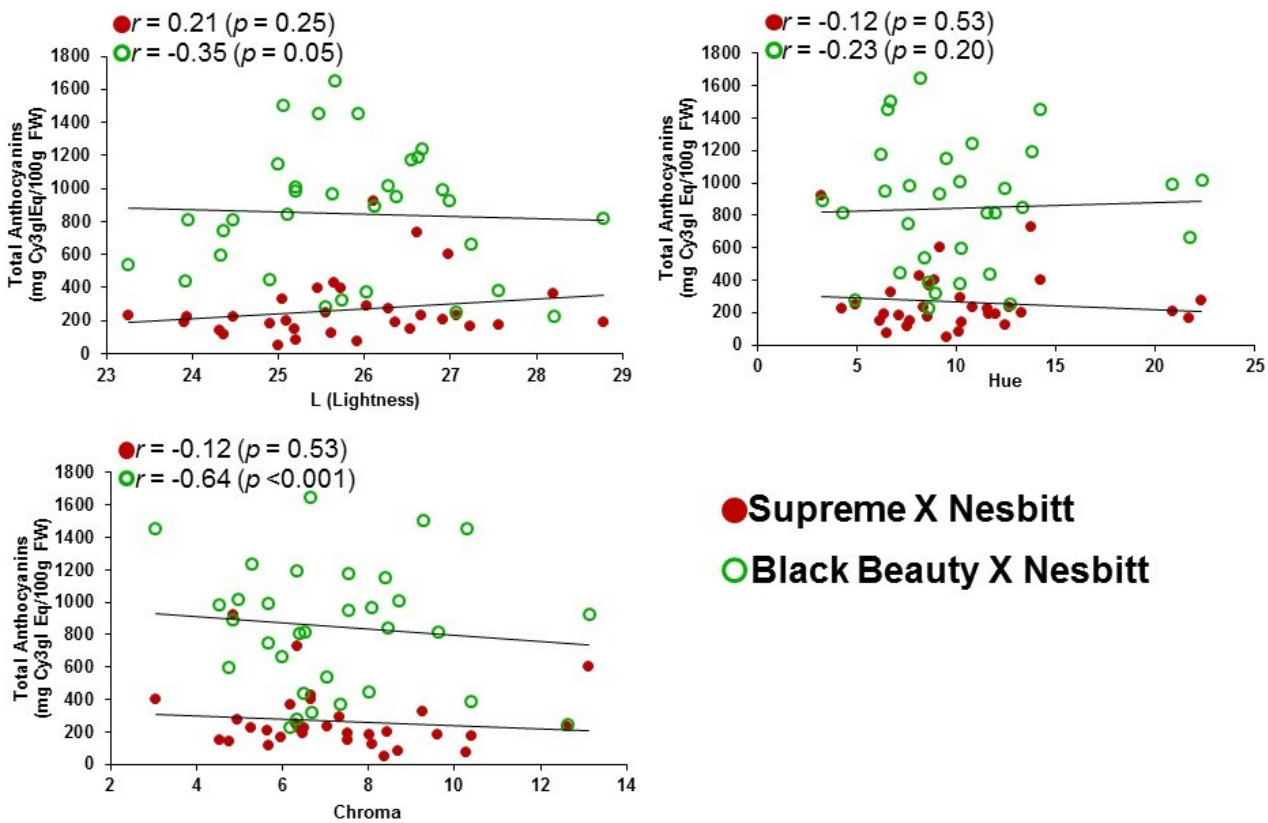

Fig. 3. Correlation between the anthocyanin content in black muscadine grape berry skin and color attributes, (a) lightness, (b) chroma, and (c) hue, in the muscadine mapping populations. The 'Supreme' x 'Nesbitt' and 'Black Beauty' x 'Nesbitt' mapping populations are indicated with black and hollow dots, respectively.

from 2% to 60% for 60 min at 1 mL/min. The system was equilibrated for 20 min at the initial gradient prior to each injection. The anthocyanin peaks were quantified at 510 nm with results expressed as mg cyanidin-3-glucoside equivalents per 100 g fresh fruit weight.

Statistical Analysis

Statistical analyses were performed in SAS 9.4 (SAS Institute, Inc., Cary, N.C.). Pearson's correlation coefficient was used to test for the significance of the correlation between color and total anthocyanins in black (C:C and C:T) genotypes. PROC GLM was used to perform an analysis of variance to test whether total anthocyanins differed among C:C, C:T, and T:T genotype classes in the two mapping populations.

Results and Discussion

Berry Skin Color and Total Anthocyanins

There was no correlation between total anthocyanins and the berry skin color attributes (lightness, hue, or chroma) in the 'Supreme' × 'Nesbitt' population (Fig. 3). In the 'Black Beauty' × 'Nesbitt' mapping population, there was no correlation between total anthocyanins and lightness or hue. However, total anthocyanins were negatively correlated with chroma in the 'Black Beauty' × 'Nesbitt' mapping population (r = -0.64, P < 0.001). Other researchers have also found that color is not a good indication of nutraceutical content. A 2014 study determined that color was not a good indicator for beta carotene in maize (*Zea mays*), with no significant correlation between color and nutraceutical content (Muthusamy et al., 2014).

Total Anthocyanins

The *VrunGST4* gene was determined to have dominant gene action, with no difference between the C:C and C:T genotypes in either population (Fig. 4). In the 'Supreme' × 'Nesbitt' mapping population, C:C genotypes had an average of 263.8 mg/100 g total anthocyanins, while the C:T genotypes averaged 265.4 mg/100 g total anthocyanins. The T:T genotypes averaged 9.43 mg/100 g total anthocyanins. In the 'Black Beauty' × 'Nesbitt" population, the C:C genotypes averaged 890.2 mg/100 g total anthocyanins, the C:T population had 883.1 mg/100 g total anthocyanins, and the T:T genotypes averaged 18.6 mg/100 g total anthocyanins. This finding is in contrast to the *V. vinifera* Myb color genes, which have an additive effect (Fournier-Level et al., 2009).

The greater average anthocyanin content of black-fruited progeny in the 'Black Beauty' × 'Nesbitt' mapping population than in the 'Supreme' × 'Nesbitt' progeny could be attributed to many different factors, including general ripeness when the berries were picked. The large difference between the means of the black-fruited genotypes in the two mapping populations suggests that there may be other loci contributing to total anthocyanin content in addition to *VrunGST4*. Anthocyanin content in the skins of black-fruited muscadines has previously been shown to range from less than 100 mg/100 g to over 500 mg/100 g (Conner and MacLean, 2013). Further investigations are needed to determine which other loci contribute to this large range in total anthocyanin content in black-fruited muscadines.

Individual Anthocyanins

By performing HPLC analysis, we determined the percentage of each individual anthocyanin in three genotype

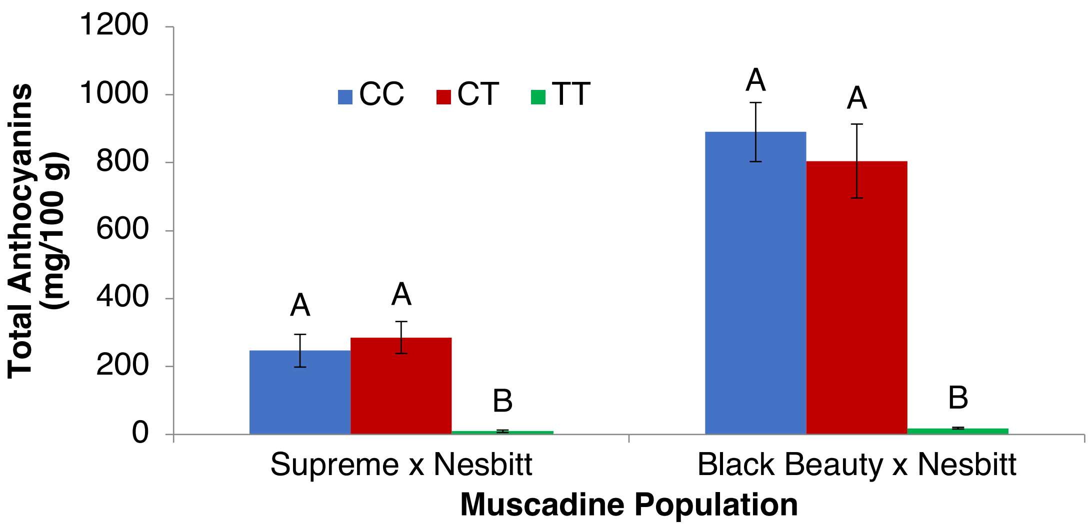

Fig. 4. Total anthocyanin content of skin extracts in three different muscadine grape genotype classes; homozygous black (C:C), heterozygous black (C:T), and homozygous bronze (T:T) in the 'Supreme' x 'Nesbitt' and 'Black Beauty' x 'Nesbitt' mapping populations.

classes (C:C, C:T, and T:T) of both mapping populations. Conner and MacLean (2013) previously reported that delphinidin was the predominant individual anthocyanin in both black and bronze berries from both mapping populations. Our results were similar, with delphinidin as the most abundant anthocyanin making up 22.21% to 37.72% of total anthocyanins in the C:T, C:C, and T:T genotype classes in both mapping populations (Fig. 5). The order of importance of the other individual anthocyanins was petunidin (9.9–12.7%), peonidin (7.08–9.61%), cyanidin (6.4–9.3%), and malvidin (2.68–5%).

Conclusions

For both total and individual anthocyanins, we found a dominant gene action regarding the *VrunGST4* gene, with no difference in anthocyanin content between homozygous black (C:C) and heterozygous black (C:T) muscadines. We also determined that berry skin color is not a good indicator of total anthocyanins in black-fruited muscadine grapes. The *VrunGST4* KASP marker is still predictive for berry color and will be useful for breeding purposes. Further research is needed to determine what other possible genes or loci affect anthocyanin content in muscadines.

Acknowledgments

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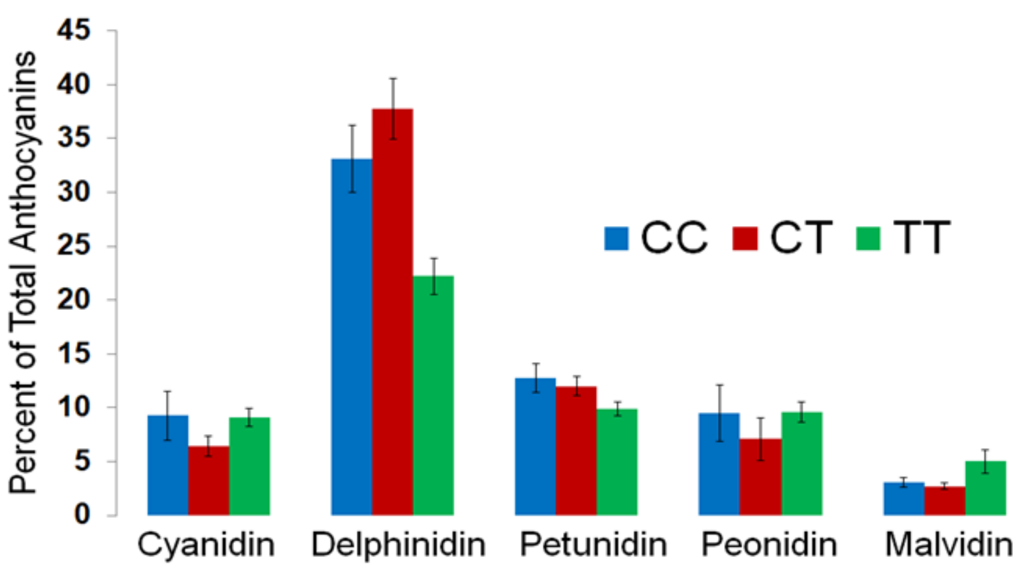

Fig. 5. Individual anthocyanins (percent of total anthocyanins) in homozygous black (C:C), heterozygous black (C:T) and homozygous bronze (T:T) muscadine grape genotype classes in the 'Supreme' x 'Nesbitt' and 'Black Beauty' x 'Nesbitt' mapping populations.

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Food accessibility related to the Double Your Dollar Program

Meet the Student-Author

Julia Carlson

Research at a Glance

- This study aims to determine if the Double Your Dollar (DYD) program had an impact on users' food accessibility and how the program could be improved for the future.
- Current DYD users were surveyed about the type, amount, and change of food purchases and shopping patterns they had at local farmers markets.
- Incentive programs, like DYD, are beneficial to low-income individuals in increasing their healthy food purchases and potentially improving nutrition status.

While beginning my degree in Human Nutrition and Dietetics at the University of Arkansas, I quickly discovered my passion for nutrition and its implications within my community. I was involved in a campus club called The Wells Project and also taught cooking classes to university students through Cooking Matters. These experiences gave me insight into the importance of accessible, healthy foods for all individuals. Classroom learning opened my eyes to food insecurity in the state of Arkansas, specifically and how necessary it is to provide and promote healthy food to low-income individuals. Post-graduation, I will be completing my Dietetic Internship at Vanderbilt University Medical Center. This research has helped me discover what I can do as a Registered Dietitian and has given me excellent experience in an area of nutrition that I could continue to better within my future career. I was introduced to the Double Your Dollar program by Heather Friedrich and Curt Rom. I would like to thank them both for their continued support and guidance on this project as well as my thesis mentor, Mechelle Bailey, for her instruction and encouragement. I would also like to thank the market managers of the Northwest Arkansas Farmers Markets for their aid in survey distribution throughout the duration of this project.

Julia Carlson at the Food and Nutrition Conference and Expo, where she explored dietetic internship options and learned about current issues and topics in the nutrition field.

Food accessibility related to the Double Your Dollar Program

Julia Carlson, Heather Friedrich,† Mechelle Bailey,§ and Curt Rom‡*

Abstract

The Double Your Dollar (DYD) Program is a program that gives Supplemental Nutrition Assistance Program (SNAP) beneficiaries and Senior Farmers Market Nutrition Program (SFMNP) participants match dollars to spend at local farmers markets. The DYD's goal is to incentivize healthy eating among individuals of low income and promote spending at farmers markets. Food insecurity affects over 60,000 individuals in Washington and Benton counties in Arkansas. The aim of this study was to assess how the DYD program impacted users' food accessibility and how the program could be improved for the future. A survey was used to address basic demographics, type, frequency, and change of food purchases, and customer shopping patterns. Eighty DYD users were surveyed at farmers markets in Washington and Benton counties. The results indicated that the vast majority of current DYD users had increased purchases of fresh fruits and vegetables, which is a marker for improved nutritional status. The main motivations for shopping at the farmers market included the ability to buy fresh, healthy, and quality foods. This study indicates that food assistance programs such as DYD could be replicated throughout the country to improve local food accessibility and, as a result, potentially improve nutritional status among individuals of low income. Future studies should assess the awareness of the program within the community since this study only assessed those already participating.

* Julia Carlson is a 2020 honors program graduate with a major in Human Nutrition and Dietetics in the Department of Human Environmental Sciences.

† Heather Friedrich is a project/program manager in the Department of Horticulture.

§ Mechelle Bailey, the faculty mentor, is a clinical instructor and Director of the Didactic Program in Dietetics in the Department of Human Environmental Sciences.

‡ Curt R. Rom is the Associate Dean for International Education in the Graduate School.

Introduction

Millions of Americans each year are faced with the issue of food insecurity. In 2018, 11.1% (14.8 million) of households were classified as food insecure (USDA-ERS, n.d.). Food security is not just the availability of food itself. It exists when, "… all people, at all times, have the physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 2008).

The Supplemental Nutrition Assistance Program (SNAP) was created for the purpose of aiding in the purchasing of food for low-income families (SNAP to Health, n.d.). Because Arkansas has the second-highest rate of food insecurity in America (Map the Meal Gap, 2019) and the third-highest rate of obesity in the nation (Explore Obesity in the United States, 2019), nutrition assistance programs are especially important.

Multiple studies (Gibson, 2003; Townsend et al., 2001; Jones, 2018) have concluded that current nutrition assistance program users were significantly more likely to be obese than non-users. Additionally, participants were more likely to be obese long-term and continually gain weight over an extended period of time (Gibson, 2003). Obesity and multiple year weight gain has been linked to an increased risk for developing Type II Diabetes, stroke, coronary heart disease, hypertension, cancer, and premature death (Colditz et al., 1995; Rexrode, 1997; Huang et al., 1998). Even with efforts towards helping those of low income increase the quantity of their food, the quality of that food is lacking, which is leading to poorer health status and other negative effects (USDA-ERS, n.d.).

Fruits and vegetables have become relatively more expensive than energy-dense foods, such as highly processed grain and corn products, prepackaged meals, fast-food, and sugar-sweetened beverages (Fields, 2004). The USDA suggests that half of each plate should include fruits and vegetables because daily consumption can lower the risk for developing Type II Diabetes, heart attack, stroke, and some cancers (USDA ChooseMyPlate, n.d.). Lower-income individuals, however, are more likely to purchase these highly processed foods because of the price and convenience.

The population for this study consisted of participants in Double Your Dollar (DYD) programs at six farmers markets in Washington and Benton counties in Arkansas. The objectives of the study were to (1) determine participants' self-reported use of the DYD program in purchasing locally grown foods; (2) determine if DYD program participation changed self-reported food purchasing outcomes; and (3) assess DYD participants' motivations for and perceived obstacles to shopping at local farmers markets. The results of this study may provide a model for other farmers markets desiring to improve similar incentive programs.

Materials and Methods

In a free option survey, feedback was obtained from Washington and Benton county DYD users, which included individuals receiving SNAP dollars as well as seniors participating in SFMNP. The surveys were distributed, after receiving approval from the University of Arkansas' Institutional Review Board (IRB), to users at six Northwest Arkansas farmers markets that had the greatest SNAP sales throughout previous years. These markets included Fayetteville, Bella Vista, Bentonville, Rogers, Downtown Rogers, and Springdale. Individuals who were at farmers markets doubling their dollars or attending events where they could receive DYD tokens were asked to participate in a survey that assessed how the DYD program had impacted them. Any participant that gave verbal consent to participate was given a survey. Surveys were distributed using an iPad with one-to-one interaction between the customer and the researcher. Assistance was offered to participants who were not comfortable using the iPad. For the first two months of distribution, only iPads were used to complete the surveys. During the last month of distribution, printed copies of the survey were used to obtain responses in addition to the iPad. This was done to help improve the efficiency of gaining survey responses. The completed paper surveys were then entered into Qualtrics by the researcher.

The survey was created using Qualtrics Survey software (www.qualtrics.com) and contained basic demographic questions, including age, gender, race, household composition, and approximate living distance from farmers markets vs. grocery stores. Additional questions assessed customer's regular food purchases, change in food purchases, main motivations and obstacles for shopping at the farmers market, and ways in which to make the farmers market more accessible. The survey contained two questions, including a 5-point hedonic scale, multiple-choice, check all that apply, and one optional open-ended question. The questions were used to determine the impact the DYD program had on the user's type, amount, and change of food purchases, while also analyzing individuals shopping patterns and preferences.

Data collection occurred between mid-June through September. Qualtrics Survey software was used to analyze correlations between questions. Graphs were created using Excel. Data were compared between the age of respondents, living distance from farmers markets and grocery stores, and the length of participant usage of the DYD program. A total of 80 survey responses were obtained.

Results and Discussion

The main types of food purchased at the farmers markets were fruits and vegetables (Fig. 1). Of the respondents, 77 out of 80 stated that one of the main products they regularly purchased was vegetables. Sixty-four out of 80 respondents selected fruits.

The survey question stated in Table 1 was asked to determine changes in food purchases and nutrition status through the increase of fresh food purchases. Fifty-nine out of 94 (63%) responses indicated that purchases of produce had slightly or significantly increased while 12 out of 94 (13%) responses indicated that purchases did not change (Table 1). With an increase in fruit and vegetable purchases, it can be inferred that consumption was also increasing. While no data were obtained of customers' physical or nutritional status, it is known that increased fruit and vegetable consumption has been shown to correlate with improved health and decreased risk for many diseases.

Users' strongest motivations for shopping at the farmers markets included healthier, higher quality, fresher food, and the ability to use DYD tokens (Fig. 2). Eighty-seven percent of responses indicated that healthier options were either somewhat significant or very significant reasons for shopping at the farmers market. Eighty-two percent of responses indicated higher quality food, 85% reported fresher food, and 85% reported using DYD tokens. Surprisingly, special dietary needs and medical conditions were of more significance for younger individuals than for seniors (ages 65+).

The biggest obstacles for individuals shopping at the farmers markets included the price of products and types of food offered (Fig. 3). Fifty-three percent of responses identified that the obstacle of higher pricing was either somewhat or very significant in shopping at the farmers market. Forty percent of responses indicated that type of food offered was a significant obstacle. For seniors, the convenience of the farmers market and hours of operation were less of an issue than for younger individuals.

The survey results indicated that recipe ideas would be the best way to make the farmers markets more accessible to DYD users (Table 2). Forty-two respondents marked that recipe ideas would help make using DYD easier for them. Twenty-six respondents marked cooking demonstrations and 23 marked cooking classes and

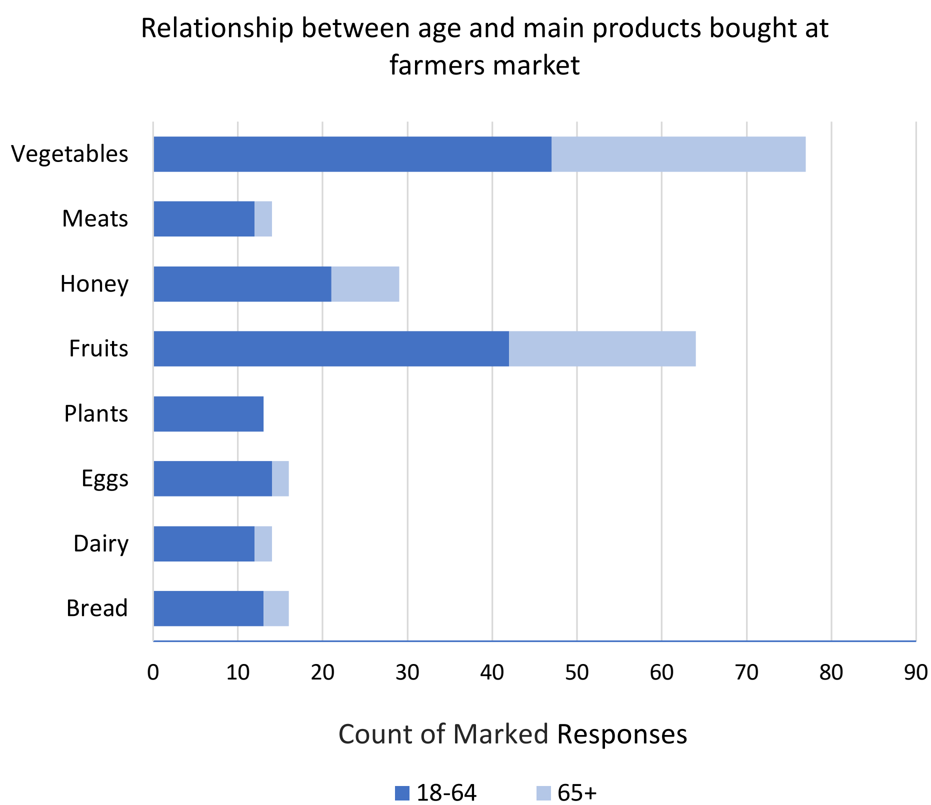

Fig. 1. The frequency of product category purchases by two broad age groups of Double Your Dollar survey participants at six farmers markets in Northwest Arkansas in 2019.

Table 1. The relationship between the Double Your Dollar survey participants' age group and the difference in food purchases at six farmers markets in Northwest Arkansas in 2019.

Survey Question: Since using Double Your Dollar, have you noticed a difference in the type of food you buy at the farmers market? Select all that apply

Marked responses	Total	Additional comments	No, my purchases have not changed	Yes, slightly more local produce	Yes, significantly more local produce	Yes, slightly more local eggs, meat, dairy	Yes, significantly more local eggs, meat, dairy
Total Count	94	10	12	16	43	0	13
Total Percentages[a]	80	12.5%	15%	20%	53.8%	0%	16.3%
Responses ages 18-64 (count)	60	8	5	9	27	0	11
Responses ages 65+ (count)	34	2	7	7	16	0	2
Respondents ages 18-64[a]	49	16.3%	10.2%	18.4%	55.1%	0.0%	22.4%
Respondents ages 65+[a]	31	6.5%	22.6%	22.6%	51.6%	0.0%	6.5%

[a] Respondents were instructed to select all that apply, thus, percentage totals exceed 100%.

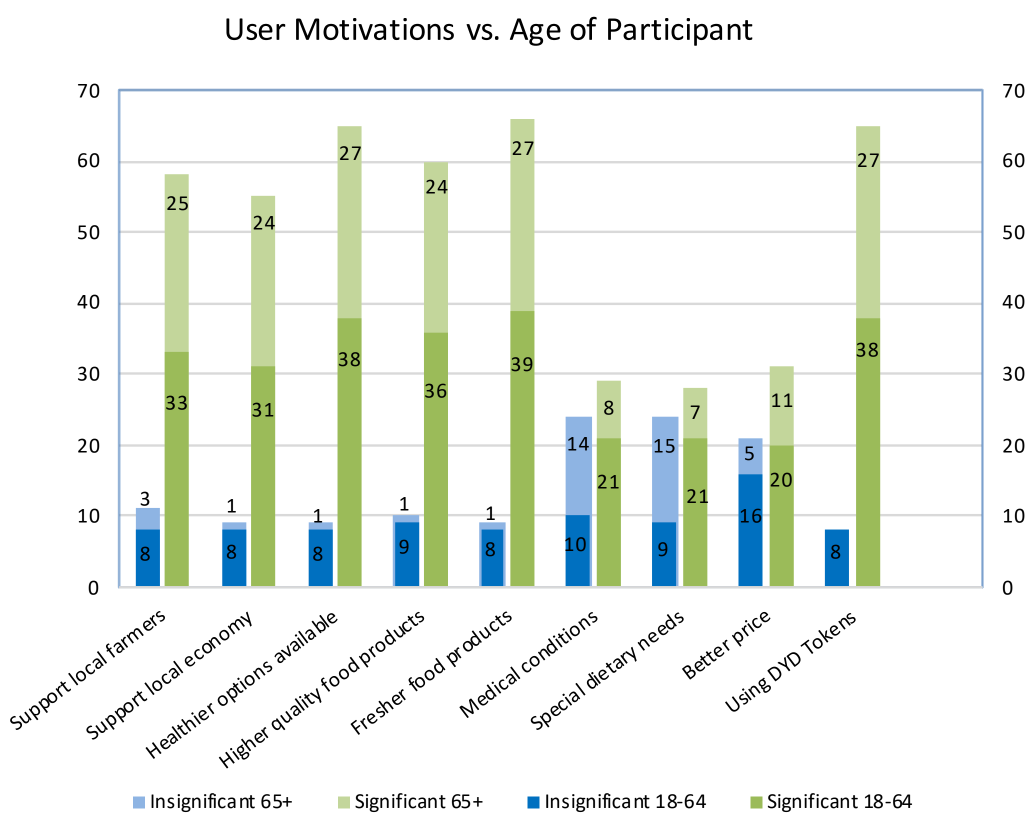

Fig. 2. The relationship between the age of Double Your Dollar survey respondents on motivations of using farmers markets at six farmers markets in Northwest Arkansas in 2019. The graph does not include 'Neutral' option choice.

expanded food options. Some of the markets have already implemented cooking demonstrations and recipe ideas. This may mean that the advertisements of these resources are not reaching DYD users. The ability of these resources to reach DYD users needs to be made through a wider variety of communication and contact.

In an open response question asking, "How has the DYD program impacted your food stability," 23 out of the 61 responses included the word "fresh" or "quality" referring to produce. Sixteen of 61 responses included the term "more," mostly relating to more fresh produce and food. However, the phrase "more choices" and "more access" were also used. There was a surprising emphasis on how much people valued the quality of their food. It is also notable that this program has changed the way some users think about their food choices. One open response indicated, "I think more about what I buy and eat." The DYD program also helped users' children venture to try new, healthy foods. One respondent stated, "I love this program, kids have new things to try." Other statements in the open response section included, "this is a lifesaver for us" and, "I would not be able to afford farmers market food at this time without double your dollar."

Conclusions

The DYD impact survey showed that the majority of users were purchasing mainly fruits and vegetables at the six Northwest Arkansas farmers markets. The survey respondents preferred fresh, locally sourced food. More than half of the survey participants noticed an increase in the amount of fresh produce they purchased, which is notable because it is a marker for improved nutritional status. Additionally, providing more recipe ideas, cooking demonstrations, and increasing the communication to users of where and when to utilize these resources would be areas that the DYD program could improve. This study suggested that the DYD program made a positive impact on how often users were able to shop and make healthy food purchases at farmers markets, which has aided in improved food accessibility.

Acknowledgments

I would like to thank the University of Arkansas Dale Bumpers College of Agricultural, Food and Life Sciences, the University of Arkansas Honors College, and the University of Arkansas System Division of Agriculture for their generous funding on this project.

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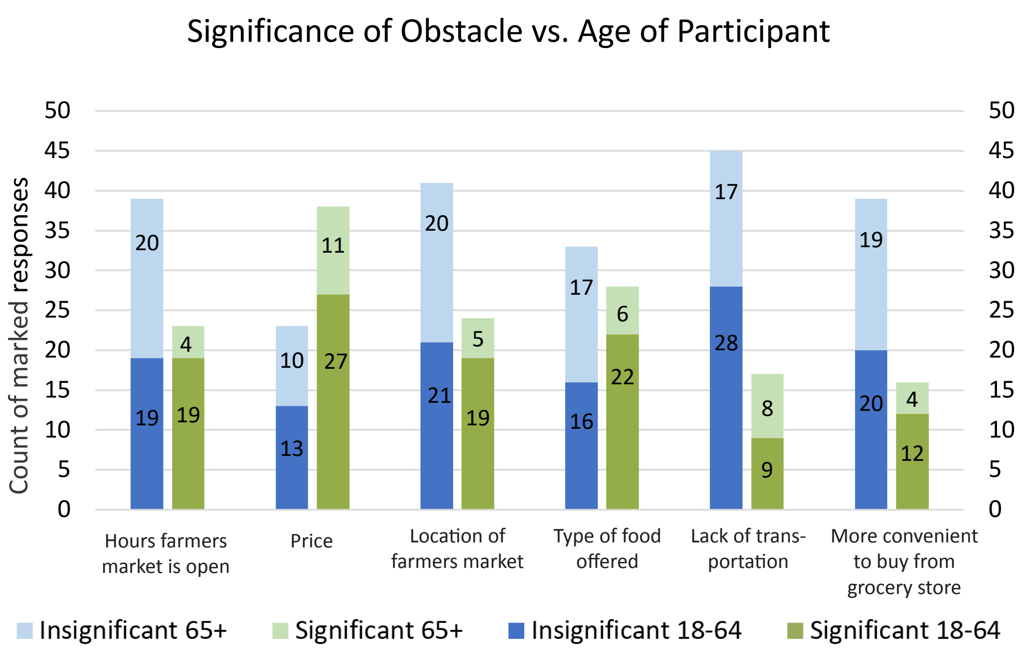

Fig. 3. The relationship between the age of DYD survey respondents and perceived obstacles to shopping at the farmers market at six farmers markets in Northwest Arkansas, 2019. The graph does not include 'Neutral' option choice.

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Table 2. The relationship between the age of the Double Your Dollar survey respondents and farmers market accessibility preferences at six Northwest Arkansas farmers markets, 2019.

Survey Question: What are some ways that would make using SNAP or Double Your Dollar at the farmers market easier for you? Select all that apply

Marked responses	Total	Recipe ideas	Product price list	Increased public transportation	Expanded food options	Cooking demonstrations	Cooking classes
Total Count	147	42	20	13	23	26	23
Responses ages 18-64 (count)	116	28	16	9	19	23	21
Responses ages 65+ (count)	31	14	4	4	4	3	2

The biofiltration ability of *Asparagus densiflorus* to remove sulfur dioxide from the indoor atmosphere

Meet the Student-Author

Rhiannon de La Rosa

As a student from Burlington High School, Iowa, aspiring to become a horticulturist, I fell in love when I visited the University of Arkansas. Once enrolled, I felt right at home in both the horticulture program and as a Bumpers Honors student. Soon I was a Bumpers Honors Student Mentor, President of the Horticulture Club, and working as a research assistant on berry budgets for the extension service. With countless opportunities such as taking any and all classes that interested me, assisting in a plant pathology lab, and volunteering with the Watershed Conservation Resource Center to help optimize propagation of native plants, I have kept myself busy these past four years. Now that I have completed my honors thesis, I feel that I was given a chance to prove how much I have grown as a person and as a student here at the University of Arkansas. I would like to thank my mentor, Dr. Mary Savin, and her lab group for their tireless work as sounding boards and proofreaders, as well as my fantastic committee members Dr. Garry McDonald and Dr. Lisa Wood.

Research at a Glance

- Plants have been known to take up air pollutants from the air. The capacity of uptake varies among both pollutants and plant species.
- *Asparagus densiflorus*, a common houseplant, was used in this study in order to take up the air pollutant sulfur dioxide in an airtight container.
- Removal of sulfur dioxide was statistically significant, though too variable to draw any definite conclusions.

Rhiannon in the Horticulture Club Greenhouse with the *Asparagus densiflorus* plants used in her research.

The biofiltration ability of *Asparagus densiflorus* to remove sulfur dioxide from the indoor atmosphere

Rhiannon de la Rosa* and Mary Savin†

Abstract

Sulfur dioxide is an inorganic compound (IC) and air pollutant that causes health risks in humans. The buildup of sulfur dioxide (SO_2) in enclosed indoor spaces is, therefore, a concern to human health, especially since the average person spends 90% of his/her time indoors. This study focused on decreasing SO_2 concentration in a cost-effective and simple way—by using botanical biofiltration, or the uptake of pollutants by plants. Research in biofiltration has focused mostly on the remediation of volatile organic compounds (VOC). However, research has also shown that plant species that remediate VOC efficiently also have the potential for efficient IC remediation. *Asparagus densiflorus*, which has a superior capacity for VOC uptake, has not yet been tested for the uptake of SO_2. In order to fill that research gap, this study measured the difference in the amount of SO_2 after 3 hours in an airtight container in the presence of an *Asparagus densiflorus* plant divided by the amount of SO_2 present in the absence of the plant. This result was considered the fraction of SO_2 remediated by the plant. The results in this experiment, although showing significant fractions of SO_2 removal, were too variable to be conclusive about the amount of SO_2 removed from an enclosed atmosphere and, therefore, of the biofiltration ability of *A. densiflorus*. Nonetheless, further research using a different research design is recommended to investigate whether *A. densiflorus* is more efficient than other plants at removing SO_2 from the atmosphere and, therefore, could be used in biofilters.

* Rhiannon de La Rosa is a 2020 Honors Program graduate in Horticulture, Landscape, and Turf Sciences.
† Mary Savin, the faculty mentor, is a professor in the Department of Crop, Soil, and Environmental Sciences.

Introduction

According to surveys conducted in 1989 and 2001, the average American spends about 90% (or 22 hours a day) of his or her time indoors (USEPA, 1989; Klepeis et al., 2001). For urban residents, from 58% to 78% of their time is in a building with air that is considered contaminated to some extent (Compton, 2011). Therefore, indoor air quality should be a priority concern for all individuals who spend this much time within buildings and sealed structures.

Two main chemical categories contribute to indoor air pollution: volatile organic compounds (VOC) such as benzene and toluene, as well as inorganic compounds (IC), including sulfur dioxide (SO_2). Both contribute to many health risks and are regulated in order to protect individuals. If a limit of one of these compounds were to be exceeded, the options for remediation could be very expensive: repairing ventilation systems, replacing faulty appliances, or even remodeling structures. A more cost-effective way to reduce pollutants is botanical biofiltration—the removal of contaminants from the environment using green plants (Soreanu et al., 2013).

Pollutant uptake in botanical biofiltration has been predicted to occur by any combination of the following mechanisms: rhizosphere degradation via soil microorganisms, phytoextraction (plant-liquid extraction), stomatal uptake (plant-gas extraction), phytodegradation via the enzymes within plant tissue, and/or phytovolatilization by means of evaporation from leaves or plant transpiration (Soreanu et al., 2013). The activity in the rhizosphere is the main mechanism of pollutant remediation, though this experiment excludes the soil in order to focus mainly on stomatal uptake.

Previous research has focused mostly on VOC, though it is evident in the literature that plants efficient in the uptake of VOC may also be efficient in the uptake of IC (Esguerra et al., 1982; Wolverton et al., 1985; Yang et al., 2009). One plant that has been categorized as superior in VOC remediation is *Asparagus densiflorus*, a common houseplant known as asparagus fern with bushy, needle-like foliage (Fig. 1) (Yang et al., 2009). However, it has not been used widely in IC remediation studies and has not been investigated for the uptake of SO_2.

The objective of this experiment was to determine the amount of SO_2 a single *A. densiflorus* plant could absorb from a closed system in three hours. The null hypothesis was that SO_2 measured in a defined empty volume (i.e., in the absence of *A. densiflorus*) after 3 hours of exposure to a source of 10 mg/L SO_2 would be the same as the SO_2 measured in the presence of an *A. densiflorus* plant in the same defined volume after 3 hours of exposure to the same source of 10 mg/L SO_2.

Fig. 1. One of the *Asparagus densiflorus* plants used in the experiment prior to exposure to sulfur dioxide. Shown with plastic wrap used to prevent soil uptake of sulfur dioxide during the experiment.

Materials and Methods

The experiment was modeled after Hochheiser's (1964) gas sampling train, with modifications to incorporate an airtight box that contained the *A. densiflorus* plant and a fan to ensure uniform mixing of the air (Fig. 2). In addition, a safety trap was added before the vacuum pump to ensure that all SO_2 was captured. The SO_2 at an original concentration of 10 mg/L from a tank was pulled through the box and into an impinger filled with 0.3 N hydrogen peroxide absorbing solution. The impinger (Fig. 3) bubbled the incoming air through 75 mL of the 0.3 N hydrogen peroxide solution, which captured all SO_2 before the cleaned air broke the surface of the 0.3 N hydrogen peroxide solution. This absorption is based on the chemical reaction of sulfur dioxide and hydrogen peroxide to form sulfuric acid. The cleaned air was pulled from the impinger through the side port into a safety trap filled with approximately 200 mL of 0.3 N hydrogen peroxide, which acted much like a large impinger, in order to ensure there was no remaining SO_2 in the air before it was pulled through the vacuum pump and released into the atmosphere.

The modified gas sampling train was assembled and smoke-tested for airtightness before beginning the experiments testing four treatments: 1) ambient air with no plant present, 2) ambient air in the presence of a plant, 3) SO_2 with no plant exposed to a source of 10 mg/L SO_2 in a defined volume for three hours, and 4) SO_2 with the plant present exposed to a source of 10 mg/L SO_2 in a defined volume for three hours.

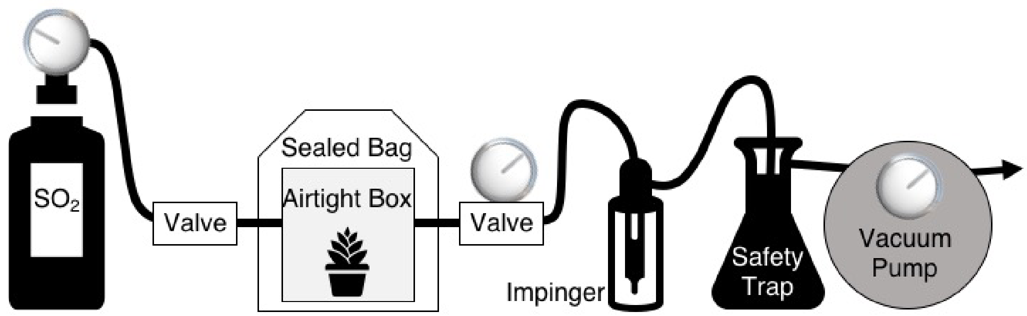

Fig. 2. The experimental setup used to evaluate *Asparagus densiflorus*' ability to take up SO_2 from the atmosphere in a defined volume. The airtight system was attached first to a safety trap in order to absorb any overflow of SO_2, then to a vacuum pump in order to control the flow through the system.

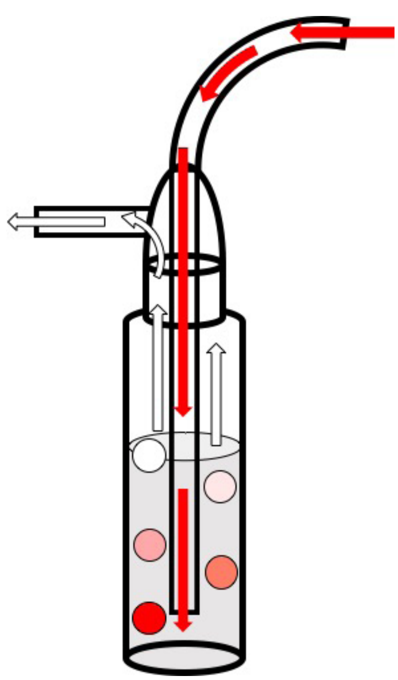

Fig. 3. A schematic of how the hydrogen peroxide solution-filled impinger collects SO_2. Air containing SO_2 (shown as red arrows) flows down the impinger tube and to the bottom of the hydrogen peroxide solution. As bubbles of SO_2-contaminated air are formed in the solution (red circles), they react with the hydrogen peroxide in order to form sulfuric acid and remove all SO_2 from the bubbles until there is none within them (white circles) before they break the surface of the solution and the cleaned air is pulled through the outer port.

The source of SO_2 (10 mg/L SO_2, balance air) was obtained from AirGas USA, LLC (Durham, N.C.). The 0.3 × 0.3 × 0.3 m^3 airtight acrylic box was placed in a sealed glove bag during the experiment (Fig. 4). These components were attached to the flow control, impinger, safety trap, and vacuum pump with Tygon tubing and plastic connectors.

Four *A. densiflorus* plants (Lowe's, Fayetteville, Ark.) were purchased, acclimated in the Horticulture Department greenhouse for four months, divided into 12 plants in potting soil, and maintained with regular watering for four additional months to regulate physiological processes before the experiment (Fig. 1).

At the beginning of each treatment, the airtight box was latched with the fan, and plant if applicable, inside. The plant pots were encased in plastic wrap to ensure soil reactions were excluded from SO_2 uptake. The bag was sealed around the box, and the connections were checked to ensure attachment to the rest of the sampling train. The impinger was filled with 75 mL of the 0.3 N hydrogen peroxide solution and connected via Tygon tubing to a valve, which controlled outflow from the airtight box. The safety trap was filled with approximately 200 mL of the 0.3 N hydrogen peroxide solution. Once all components were confirmed in the sampling train, the SO_2 tank (if applicable) was set to have an output of 34.47 kPa while the vacuum was set at a suction pressure of 33.86 kPa. The treatment was run for 3 hours. The SO_2 tank was then detached, the vacuum was shut off, and the 75 mL of 0.3 N hydrogen peroxide solution in the impinger was collected and transferred to a beaker. The 0.3 N hydrogen peroxide solution in the safety trap was checked regularly for the presence of SO_2 from possible overflow, and none was ever detected.

In order to determine the amount of SO_2 collected during each run, 4 drops of the mixed indicator bromocresol green and methyl red in methanol were added to the 0.3 N hydrogen peroxide solution from the impinger (or safety trap) that was stirred continuously with a magnetic stir bar. The 0.002 N sodium hydroxide titrant was added dropwise via a 50-mL burette until the solution turned green. The amount of SO_2 (mg) was found by multiplying the total sodium hydroxide titrant used by 64.07, as calculated based on the equation below.

$$\frac{x\ L\ NaOH}{1} \chi \frac{0.002\ mol\ NaOH}{1L} \chi \frac{1\ mol\ H_2SO_4}{2\ mol\ NaOH} \chi$$

$$\frac{1\ mol\ SO_2}{1\ mol\ H_2SO_4} \chi \frac{64.07\ g\ SO_2}{1\ mol\ SO_2} \chi \frac{1{,}000\ mg\ SO_2}{1\ g\ SO_2}$$

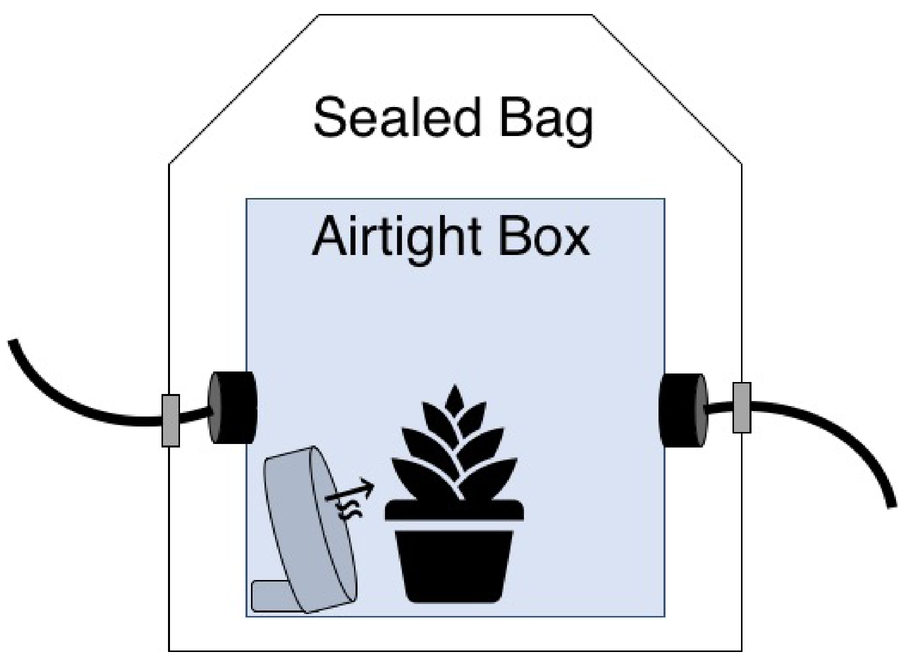

Fig. 4. The airtight box used in the experiment to test the presence or absence of atmospheric SO_2 is surrounded by the sealed bag, with tape-reinforced inlets and outlets for the Tygon tubing. Box contains either no plant or one plant and a fan regardless of the presence or absence of the plant.

Treatments 1 (ambient air with no plant present) and 2 (ambient air in the presence of a plant) were replicated four times. Treatment 3 (SO_2 with no plant exposed to a source of 10 mg/L SO_2 in a defined volume for three hours) was replicated six times. In order to evaluate replicability in treatment 3, treatment 3b consisted of six additional replicates. Treatment 4 (SO_2 with the plant present exposed to a source of 10 mg/L SO_2 in a defined volume for three hours) was replicated six times.

The descriptive statistics, including the mean, median, first and third quartiles, minimum, maximum were calculated for the SO_2-no plant (treatments 3 and 3b) and SO_2-plant treatment (treatment 4) and displayed in a box plot. Percent relative difference was calculated for a pair of SO_2-no plant runs. Standard deviation and relative standard deviation were calculated for the SO_2-no plant (treatments 3 and 3b) and SO_2-plant treatments (treatment 4).

The SO_2-no plant (treatment 3b, SO_2^N) and SO_2-plant treatments (treatment 4, SO_2^P) were run in pairs (n = 5) and used to determine SO_2 uptake for the purposes of the study as shown in the equation below.

$$\text{Percentage uptake} = \frac{SO_2^N - SO_2^P}{SO_2^N} \times 100$$

The distribution of the total of 12 replications of SO_2-no plant (treatments 3 and 3b) was plotted in a histogram (data not shown). After a log transformation in order to normalize the distribution of samples, a paired t-test was run to evaluate the significance of SO_2 removal among paired treatments of SO_2-plant and SO_2-no plant.

Results and Discussion

The SO_2 content of treatments 1 and 2 was expected to be 0 mg. For four replications of treatment 1 (ambient air, no plant) and treatment 2 (ambient air, plant), all runs had 0 mg SO_2. Repeated sampling is generally expected to follow a normal distribution. Statistical analyses are often based on that normal distribution, and those tests are parametric tests. A histogram was created of the 12 samples of SO_2 in the absence of the plant (treatments 3 and 3b) to determine if samples followed a normal distribution. Sample distribution was found to be strongly right-skewed (data not shown).

Regardless of sample distribution, results demonstrated that amounts of SO_2 were variable (e.g., treatments 3 and 3b, Fig. 5). The mean of the first six replications of SO_2 in the absence of the plant (i.e., treatment 3) was less than the mean of the second six replications within the

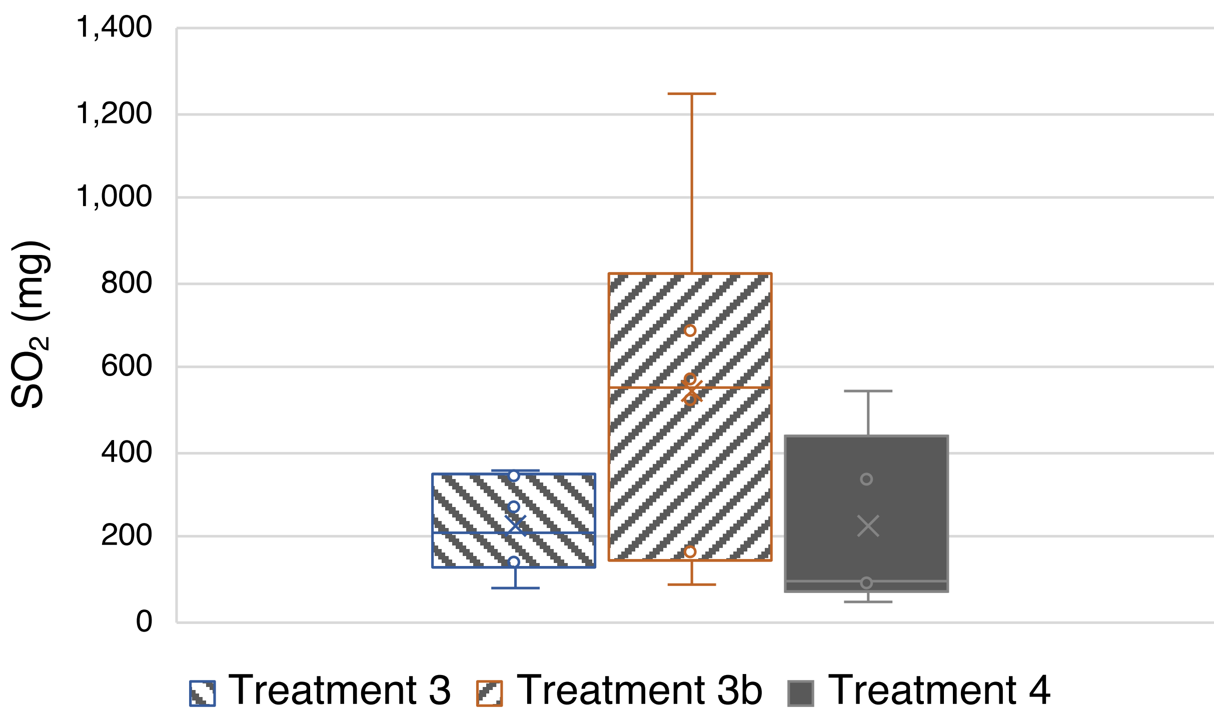

Fig. 5. The amount of SO_2 in mg when pulled at an original concentration of 10 mg/L at 33.9 kPa negative pressure for 3 hours in a space of 28 liters in the absence of *Asparagus densiflorus*, evaluated twice (Treatments 3 and 3b, n = 6), and in the presence of *Asparagus densiflorus* (Treatment 4, n = 5).

same treatment (i.e., treatment 3b). The median is a robust measure of central tendency; however, the median was also much larger (2.6 times larger) in the second six replicates (i.e., treatment 3b) compared to the first six of the same treatment (i.e., treatment 3). The range of values was more than 4 times greater in the second six replicates compared to the first six. Even in the presence of plants, treatment 4, the range of values was 1.8 times greater than in the absence of plants from the original six replicates (treatment 3). In order to analyze the data despite variability among the means, coefficient of variation (CV) or relative standard deviation was used (Table 1). The CV varied between the first six and second six replicates in the SO_2 treatment in the absence of a plant, treatments 3 and 3b, respectively, and compared to the presence of a plant, or in treatment 4. However, a repeated run of SO_2 in the absence of the plant yielded a percent relative difference between duplicates of 17.3% (data not shown), which is within generally accepted values of less than 20%.

Due to the variability among replications within a treatment, the first six replicates in the presence of SO_2 and absence of a plant (treatment 3) were disregarded and the second six (treatment 3b) were paired with each replicate of treatment 4 (i.e., presence of SO_2 and plant). A failure in data collection resulted in a total of five paired replications being included in the analysis of percent removal instead of six replications. The percentage of SO_2 removal from the atmosphere ranged from 35% to 84%, with a mean removal rate of 53% (Table 1) and a median of 46% (data not shown). A paired t-test indicated significant percent removal of SO_2 from the enclosed atmosphere under these defined conditions for 3 hours ($P = 0.011$). However, while there was a significant difference in SO_2 removal with the presence of the plant, the data are too widely variable to make a definitive statement about the removal capacity of *Asparagus densiflorus*. While the pairs of treatment 3b and treatment 4 each indicated a certain percentage of removal, up to 84%, the inherent variability of the data creates an issue in claiming to what extent the plant may remediate SO_2.

There are potential sources of error that contributed to variability in SO_2 measured in treatments 3 and 4, one of which was the original concentration of 10 mg/L SO_2 could not be confirmed as the same concentration in the airtight box. The liters of air flowing through the system could not be measured, and thus a concentration within the system could not be determined. Ideally, at any given time, there would have been 280 mg of SO_2 in the 28 L box, yielding a concentration of 10 mg/L.

The mean removal capacity of *A. densiflorus* may have been 296 mg SO_2 in three hours, or 99 mg SO_2 per hour. These results differ from other studies where remediation capacity was reported in other units. Yang et al. (2009) found *A. densiflorus* took up VOC at 2.65 to 11.40 μg of pollutant • m^{-3} container volume • m^{-2} leaf area per hour, and Hörmann et al. (2018) measured *A. densiflorus* to take up VOC at 1.7 to 4 L pollutant • m^{-2} leaf area per hour. Esguerra et al. (1982) found an uptake range from 0.15 to 2.77 μg SO_2 • m^{-2} leaf area • s^{-1} for three hours. All these measurements were taken in relation to exposed leaf area, and all experiments covered the soil surface in order to isolate effect on pollutant concentration by aboveground plant tissue.

In the case of a standard houseplant that had the soil exposed to the atmosphere, the uptake measured in this study would increase, though it should not be attributed to the actual remediation of *A. densiflorus* but instead remediation by the soil and related microbes performing soil rhizosphere transformation of SO_2 (Soreanu et al., 2013). Soreanu et al. (2013) also summarized research that suggested that phytoremediation is a collective effort between plants and soil microorganisms, which depends on interactions with each other.

Table 1. Statistical analysis of SO_2 (mg) in a 28-L airtight container after being exposed to a source of 10 mg/L SO_2 for 3 hours in the presence or absence of *Asparagus densiflorus*, and found percent removal of SO_2

	Statistical Analysis		
Property	**Mean**	**SD[a]**	**CV[b]**
SO_2 (mg) in absence of *Asparagus densiflorus*[c] (Treatment 3, n = 6)	223.2	115.6	51.8
SO_2 (mg) in absence of *Asparagus densiflorus*[d] (Treatment 3b, n = 6)	546.7	419.2	76.7
SO_2 (mg) in presence of *Asparagus densiflorus* (Treatment 4, n = 5)	223.0	213.7	95.8
Percent Removal of SO_2 (n = 5)	52.5	19.5	37.2

[a] SD = Standard Deviation.

[b] CV = Coefficient of Variation (relative standard deviation expressed as a fraction of mean divided by the standard deviation).

[c] First six replicates, Treatment 3, data were disregarded in paired treatments.

[d] Second six replicates, Treatment 3b.

It also must be accepted that in experiments such as this, the closed, modified environment used to measure uptake cannot be compared to uptake in a normal indoor condition. Similarly, the closed box increased the concentration of SO_2 around the plant and therefore created a greater concentration gradient. A concentration gradient will eventually cause sulfur levels in both plant tissue and air to equalize, stopping uptake until the sulfur is metabolized and transported elsewhere (Hörmann et al., 2018). This greater concentration would, therefore, create the appearance of greater or faster uptake in comparison to within a large room in which the amount of SO_2 may be the same, but the concentration itself would be substantially lower.

However, hypothetically speaking, if the mean 99 mg SO_2 per hour rate found in this study was to be used as a calculation, a standard 4 by 4 by 4 cubic meter room at 5 mg/L SO_2 would require 20 plants to remediate all SO_2 in a week. Calculations such as these are difficult to substantiate when the remediation rate is not only determined from variable data, but also from an experiment lasting only three hours in a closed system with conditions unlike that of a larger room. These challenges also compound when scaling up remediation rates to incorporate into a larger biofilter system.

Conclusions

In conclusion, it was determined that the experimental design resulted in data that were too variable to assess *Asparagus densiflorus*' uptake of sulfur dioxide confidently. Any repetitions of the experiment would require a more constant and reliable method of delivery of SO_2 and measurement of plant uptake of SO_2.

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Intercultural competence among early childhood educators

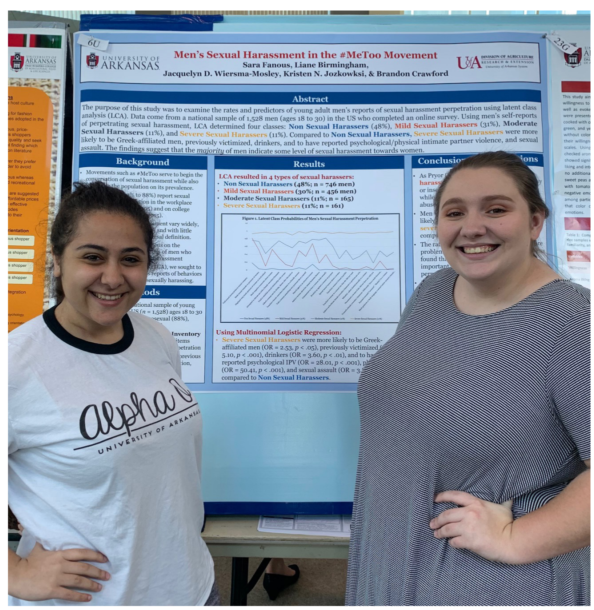
Meet the Student-Author

Sara Fanous

Research at a Glance

- As society continues to diversify, the call for intercultural competence among educators is increasingly more important.
- The educators at a child development center were asked to take the Intercultural Development Inventory Assessment (IDI) to determine where they land on the IDI continuum.
- An individual's intercultural competence is something that a person can work on and improve.
- Diversity promoting toys, books, and posters in classrooms have the capability of promoting intercultural competence and make a more accepting place for all children to learn.

As a child, I always knew my future career would be in pediatrics. Coming to the university, I knew I wanted to be a Child Life Specialist at a children's hospital. Until I began working alongside professors and taking classes, I didn't realize that to be great in this career path, it is not enough to work well with children. There were so many skill sets that I didn't realize were important. One of the subjects that sparked interest the most was intercultural competence. Being born and raised in the United States, yet living in an Egyptian household was an everyday struggle for me growing up. It was almost as if every morning I would wake up and make the conscious decision as to whether I wanted to be the All-American girl I would see around me or the Egyptian girl my parents wanted me to be. Through these courses, I began to find my identity. This inspired me to mesh the two interests of child development and intercultural competence into a research project. I am thankful that I have been part of the Honors College and pursued a degree in Human Development and Family Science. Working with Dr. Jacquelyn Mosley, not only as my thesis advisor but in several other capacities, was one of the greatest blessings. I can honestly say that none of this would have been possible without her. Finally, I would also like to thank the rest of my thesis committee: Shelley McNally, Laura Herold, Donia Timby, and Brande Flack.



Sara with an Honors student in Psychology, Liane Birmingham, at the Bumpers Honors Poster Competition in April 2019 presenting another research project.

Intercultural competence among early childhood educators

Sara M. Fanous, Jacquelyn D. Wiersma-Mosley,† Laura Herold,§*
Donia Timby,‡ Shelley McNally,¶ and Brande Flack#

Abstract

The purpose of this study was to assess and develop intercultural competence among early childhood educators. Intercultural competence is an integral part of creating a welcoming environment for all students in a classroom. It is not only the acknowledgment of individual differences but the acceptance and celebration of what makes each person an individual and member of a cultural group. This project assessed the intercultural competence of 24 early childhood educators and staff at a child development center in the mid-south. Participants completed the Intercultural Development Inventory (IDI) as pre- and post-assessments. In between assessments, our team conducted a cultural competence training workshop to advance the educators' intercultural development skills. Based on the training and conversations with the educators, diversity books and toys were purchased and implemented into the classroom. On average, intercultural competence increased significantly over time. Overall, most educators scored in the *Minimization* orientation, which is the most common orientation among adults. In order to advance beyond the *Minimization* orientation to the *Acceptance* orientation, educators need additional educational opportunities, which may aid them in understanding concepts regarding power and privilege, as well as other crucial differences between cultures.

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¶ Shelley McNally is the Director of the Jean Tyson Child Development Center.
# Brande Flack is the Director of Retention Programs for the Multicultural Center.

Introduction

The purpose of this study was to examine the intercultural competence of early childhood educators. During recent years, the discussion of intercultural competence in the school system and the workplace has grown exponentially. This may be because diversity in schools is on the rise. In 2014, the United States' public schools reached a "minority-majority milestone" in which the number of Latino, Asian, and African American students have surpassed the number of White students (Maxwell, 2014). The rise in diversity means that there will be more responsibility for childcare centers to not only prepare children for the diversity in future schooling but in the real world as well. However, there is little to no research that has been done to examine the prevalence of diversity inclusion before entering grade school. Unfortunately, this is a population that is often overlooked by researchers due to the misconception that children between the ages of birth and five years do not understand cultural identity. Many people believe that because several of the children in this age group are not able to use language like adults, then they cannot be affected by monoethnic toys or non-representative posters. However, children begin stereotyping and profiling quite young. "Children begin to notice differences and evaluate others at a very early age. By the age of three, children begin to show signs of being influenced by societal norms and biases and may exhibit 'pre-prejudice' toward others on the basis of gender or race or being differently abled" (Derman-Sparks, 1989). Intercultural competence may help toward raising awareness as well as making environments more welcoming for everyone.

Intercultural Competence

To some degree, we all lack intercultural competence. It is not something that you are born with; rather it is a process that continues over the course of a lifetime (Marteev and Merz, 2014). Intercultural competence is an awareness of one's cultural identity and the ability to interact effectively and appropriately with people from other cultures (Deardorff, 2011). There are numerous ways to measure, define, and model intercultural competence. Spitzberg and Chagnon (2009) identified five basic models that include compositional (i.e., attitudes, knowledge, and skills), co-orientational (i.e., symbolic meanings across interactions), developmental (i.e., chronological process of change or evolution), adaptational (i.e., extend from an individual perspective to a dyadic or group perspective), and causal (i.e., quantitative test for predictions of outcome and interaction processes). The Intercultural Development Inventory (IDI; Hammer, 2008) was developed to measure individuals' lenses of cultural similarities and differences along a continuum from monocultural to intercultural worldviews. The IDI is an appropriate instrument for assessing educators because of the nature of the developmental process that can be supported through learning and experiences.

A typical way to conceptualize intercultural competency using the IDI is along a continuum of five stages (Hammer, 1998): *Denial, Polarization, Minimization, Acceptance*, and *Adaptation*. *Denial* (approximately 3% of people) reflects limited experience and capability understanding and responding appropriately to cultural differences in values, beliefs, perceptions, emotional responses, and behaviors. *Polarization* (approximately 16% of people) uses an "us vs. them" mindset either through Defense (seeing cultural differences frequently as divisive and threatening to one's way of doing things) and Reversal (valuing other cultural practices while denigrating one's culture group). *Minimization* (approximately 65% of people) is highlighting commonalities too much that can mask a deeper understanding of cultural differences (i.e., color blindness, "I don't see color"). *Acceptance* (approximately 15% of people) is the recognition and appreciation of patterns of cultural differences and commonality in one's own and other cultures, but with the inability to adapt to cultural differences. Lastly, *Adaptation* (approximately 2% of people) is when one has a deep cultural bridging across diverse communities using an increased repertoire of cultural frameworks and practices in navigating cultural commonalities and differences. For intercultural competence to develop, three major domains must be addressed: (1) identity development (i.e., self-awareness), (2) learning about cultural differences, and (3) bridging or adapting behavior with different groups.

The current study examined the intercultural competence of educators at a child development center focused on early childhood development, specifically with children aged 8 weeks to 5 years old (pre-K). The goals were to investigate their current intercultural competence using the IDI, to then train them and provide additional tools to further their intercultural competence, to provide items for the classroom that promote diversity, and finally to post-assess their intercultural competence and changes (if any) over time. The research questions were: (1) What is the average intercultural competence of early childhood educators? and (2) Is there a notable change in the educators' intercultural competence between the pre- and post-assessment based on intercultural competence training?

Materials and Methods

Participants and Procedures

Data came from 24 early childhood educators and staff at a child development center in the mid-south. The majority of the participants identified as white women with a bachelor's degree or are currently in a bachelor's program in child development or related field. For this project, all educators volunteered to participate, and an institutional review was deemed expedited by the primary institution of data collection. In December 2019, the Intercultural Development Inventory assessment was sent to each teacher via email, and educators were given one week to complete the assessment. As an incentive, the educators were awarded a $30 Walmart gift card for completing the pre-assessment. In January 2020, a 3-hour training workshop was held during the educators' professional development day by two licensed IDI administrators from the research team. During the presentation, intercultural competence theories and definitions were reviewed, as well as research on implicit bias. During the training, each teacher was provided the group average and their individual results. The overall group results were then discussed as well as what it meant to belong in each development orientation, and some steps that can be taken to increase intercultural competence. This presentation was adapted to the needs of the group of educators to focus specifically on children. The educators were asked to walk around every classroom in the center to look for items that promote diversity or books that had a variety of cultural representation. Then educators were asked to create lists of items that promote the diversity that they wish to see in their classrooms. This assisted the team with the purchasing of new toys and items in February 2020 (i.e., books on gender, disability, race/ethnicity) that were implemented into the classroom. Finally, the post-assessment was administered in March 2020; educators were again incentivized with $30 Walmart gift cards to participate. The pre- and post-results were analyzed in order to see if educators' intercultural competence increased significantly over three months.

Measures

IDI Assessment. The Intercultural Development Inventory is a cross-cultural assessment of intercultural competence used by companies, organizations, and schools all over the world. The assessment (costing $12/student; $18/non-student) consists of 50 multiple choice questions that extend from a monocultural mindset to a multicultural mindset in order to scale where an individual is in achieving intercultural competence. Items include intercultural experiences in terms of participants' (a) cross-cultural goals, (b) challenges that they confront while navigating cultural differences, (c) intercultural incidents that they face when they encounter cultural differences, and (d) ways they address those cultural differences. The IDI ranges from a score of 50 to 145 that individuals are rated with for their Developmental Orientation (DO), which was used for this study. The DO indicates a participant's primary orientation toward cultural differences and commonalities along a continuum. The DO is the perspective that the person is most likely to use in situations where cultural differences and commonalities need to be bridged. Scores of 55 to 70 indicate *Denial*, 70 to 85 indicate *Polarization*, 85 to 115 indicate *Minimization*, 115 to 130 indicate *Acceptance*, and 130 to 145 indicate *Adaptation*.

Results and Discussion

The data were first analyzed as a group to measure the intercultural competence of the educators as a whole, examining the average Development Orientation (DO). Then, the pre- and post-assessments of the group DOs were compared to determine if there was a significant change within the three months of taking the assessment, using a t-test. For the pre-IDI assessment, the average development orientation (DO) for 24 educators and staff was 96.29, indicating most were in the *Minimization* stage. Within each DO, 8 educators were in *Polarization*, 13 were in *Minimization*, 1 was in *Acceptance*, and 2 were in *Adaptation*. For the post-IDI assessment, the average DO for 21 educators and staff was 101.89 (also *Minimization*). Within each DO, 4 were in *Polarization*, 11 were in *Minimization*, and 6 were in *Acceptance*. Using a paired t-test, the group significantly increased in their DO, $t = 2.26$, $P < 0.05$.

Overall, most educators scored in the *Minimization* orientation, which is the most common orientation among adults and comprises 65% of the population. In order to advance beyond the *Minimization* orientation to the *Acceptance* orientation, educators need educational opportunities that aid them in understanding concepts regarding power and privilege, as well as other crucial differences between cultures.

The present study's participants were primarily white women living in a White community in the mid-south. However, some research (Hu and Kuh, 2003; Loes et al., 2012; Pascarella et al., 2001) indicates that white individuals benefit more in critical thinking development when they are exposed to diversity educational training. A limitation to the present study is that the IDI assumes individuals become more interculturally competent in a linear progression and forces individuals into stages without allowing for the possibility that individuals can express multiple, complex, and conflicting aspects of intercultural competence (see Perry and Southwell, 2011 for a review).

Conclusions

Increasing intercultural competence is essential to educators. Therefore, it is important that educators for all ages systematically make changes in their curriculum, assessment, policies, and environments (Wiersma-Mosley, 2019). Future research should seek to measure the effects of intercultural competence longitudinally, rather than just a month, as with any development, this skill may take additional effort and time to fully form. Additional qualitative data using reflections and interviews would help capture the full extent of educators' learning and intercultural competence growth. As society becomes more interconnected and multicultural, it is imperative to develop and assess intercultural competence among educators. This study indicated that intercultural competence could significantly increase with educational and professional training.

Acknowledgments

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Impact of phosphorus intake on beef heifer growth performance and conception rates

Meet the Student-Author

Hailey Hilfiker

I am originally from Piggott, Arkansas, where I grew up showing cattle on a local, regional, state, and national level. From these experiences, I developed a passion for large animals and began raising purebred Shorthorn cattle. I began my undergraduate career at the University of Arkansas as a major in Animal Sciences with a pre-professional concentration. I have served as the livestock activities chair for the Block and Bridle Club in the animal science department and a student ambassador through the college. I have also had the opportunity to study through the Bumpers Honors College and gain hands-on experiences through my research. In the summer of 2019, I began my research on beef nutrition and reproduction. I graduated Magna Cum Laude and was recently accepted to the University of Missouri's College of Veterinary Medicine, where I will obtain my doctor of veterinary medicine degree. My time at the University of Arkansas has been made possible by many individuals. I would like to thank Dr. Beth Kegley for serving as my honors mentor and for her confidence in me and continual support throughout this project. I also would like to thank Dr. Jeremy Powell and Dr. Rick Rorie for serving on my thesis committee and their help throughout this process. To my family, thank you for your continual encouragement and support while achieving my goals.

Hailey collecting blood samples from heifers for her study at the University of Arkansas System Division of Agriculture's research farm at Savoy.

Research at a Glance

- Phosphorus is an important mineral for growth and performance in beef cattle and is thought to be linked to reproductive performance.
- Data did not show any negative effects of removing phosphorus from free choice mineral but was not advantageous with regard to fertility and growth performance.
- Producers in the area where pastures have been fertilized with livestock manure could purchase mineral with or without phosphorus.

Impact of phosphorus intake on beef heifer growth performance and conception rates

Hailey Hilfiker, [*] Beth Kegley,* [†] Rick Rorie,* [§] and Jeremy Powell* [‡]

Abstract

In Northwest Arkansas, soil phosphorus concentrations have increased where livestock manures have been repeatedly applied, leading many to question if supplementing phosphorus in this area is necessary. The effects of phosphorus intake on beef heifer growth performance and conception rates were investigated. In this study, crossbred Angus heifers (n = 72), approximately 30 days after weaning, were stratified by body weight (average initial weight 251 ± 3.9 kg) and allocated randomly into 8 groups. Groups were assigned randomly to 1 of 2 treatments. Treatments were delivered through either a free-choice-mineral mix that contained no supplemental phosphorus (CON), or a free-choice-mineral mix with 4% supplemental phosphorus and identical concentrations of other supplemental minerals (4PMIN). Heifers grazed 2.42 ha mixed grass pastures with a history of livestock manure application and were supplemented with soy hulls (0.5% of body weight) daily. Data were analyzed using the mixed procedures of SAS with group as the experimental unit. Total mineral intake through day 112 did not differ ($P = 0.55$) between treatments. On days 84 and 112, any heifers greater than 273 kg body weight (n = 58) had an ultrasound evaluation of their reproductive tract. Reproductive tract score (1, infantile to 5, corpus luteum present) did not differ ($P = 0.65$) due to treatment. Body weights were not different ($P \geq 0.59$) through day 264, 409 ± 6.0 kg and 412 ± 6.0 kg for CON and 4PMIN, respectively. When grazing pastures with a history of livestock manure application, heifers did not need supplemental phosphorus throughout the breeding season.

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[§] Rick Rorie is a committee member and a Professor in the Department of Animal Science.
[‡] Jeremy Powell is a committee member and a Professor in the Department of Animal Science.

Introduction

Nutrition has a major influence on the growth and productivity of livestock. To help an animal achieve its genetic potential, a well-balanced diet of protein, vitamins, and minerals is a necessity. While there are different nutrient requirements for each stage of an animal's life, it is well known that phosphorus is a crucial component to the feed ration of any livestock species. In recent decades, producers have used livestock manure as a fertilizer for their pastures, leading many to believe phosphorus concentrations in those areas are higher than average. Because of this, there has been much discussion on whether it is truly beneficial to add phosphorus to the diets of beef cows. The environmental aspect of this conversation is supported by excess phosphorus in the soil. While price discourages some producers from adding phosphorus to feed rations, studies have shown that well-balanced diets provide shorter anestrus cycles, or when the animal is not cyclic (Ciccioli et al., 2003). Furthermore, nutritionally compromised cows have difficulty maintaining adequate body condition scores to exhibit estrous (Hess et al., 2004). As an industry, cattle producers are in need of nutritional programs to increase and maintain fertility in their herds. In order to achieve a highly concentrated period of calving, early onset of puberty in replacement females is crucial (Diskin and Kenny, 2016).

Phosphorus is a crucial nutrient in animal health and well-being, with over three-fourths of the mineral being found in the body and is abundant in the bones and teeth of many species (Karn, 2001). The benefits of feeding phosphorus include increased cellular growth, development of musculoskeletal growth, and maintenance of body weight. Not only has phosphorus been shown to be vital to animal growth and well-being, but deficient amounts can cause reproductive problems, with previous studies finding that beef heifers fed higher levels of phosphorus continue to cycle later in the season over heifers that were fed diets lower in phosphorus (Call et al., 1978).

This study aims to examine the effects of phosphorus intake on weanling beef heifer growth performance and conception rates. One group was grazed on pasture with a decades-long history of livestock manure application, fed grain with minimal amounts of phosphorus, and given no supplemental phosphorus in a mineral mix, while the other was grazed on pasture with the same type of forage, fed the same grain, and given supplemental phosphorus in their mineral mix.

Materials and Methods

Animals and Management

For this experiment, heifers (n = 72) were weaned in May 2019 from the University of Arkansas System Division of Agriculture's Cow-Calf Unit in Fayetteville. Approximately 30 days after weaning, heifers were weighed, stratified by body weight, and divided into eight groups. Following this, groups were assigned randomly to one of two dietary treatments. Group A was supplemented with phosphorus, and group B was given no supplemental phosphorus. Treatments were delivered through free choice mineral (Table 1). All groups had identical mineral feeders in their pasture, mineral was constantly available, and mineral feeders were moved with groups as they rotated pastures every 28 days. Feeders were checked daily, and mineral additions were recorded. Every 28 days, the mineral remaining in feeders was weighed, and mineral disap-

Table 1. Composition of free choice minerals for heifers.

Ingredient	Control	Supplemental P
Calcium, %	20	20
Phosphorus, %	0	4
Salt, %	24 to 26	24 to 26
Magnesium, %	0.2	0.2
Potassium, %	0.1	0.1
Copper, mg/kg	2,500	2,500
Selenium, mg/kg	26	26
Zinc, mg/kg	10,000	10,000
Vitamin A, IU/kg	440,000	440,000
Vitamin D3, IU/kg	22,000	22,000
Vitamin E, IU/kg	22	22

pearance for each group was calculated and expressed on a grams/heifer each day basis. Heifers remained in 8 groups except during the breeding season (days 168 to 223); during this period, heifers were kept in 2 groups (1 group/treatment). Heifers remained on their appropriate mineral treatment, and mineral intakes were recorded; however, they were not used in the statistical analyses because of a lack of replication.

Cattle were examined daily to detect morbidity and received antibiotic treatment as required for pinkeye (n = 6) and mastitis (n = 1). Heifers were given a pinkeye vaccine on day 1 and were treated with a pour-on for ectoparasites (Standguard, Elanco, Greenfield, Indiana) on days 1, 27, 84, 112, and 252. Heifers were treated for endo- and ectoparasites on day 196 (Cydectin Pour-on, Bayer Livestock, Shawnee Mission, Kansas).

As the breeding season approached, heifers were allotted to treatments in a concurrent research project investigating the use of sexed semen in a short-term fixed-timed artificial insemination protocol. This project had a 2 × 2 × 2 factorial arrangement of treatments, and heifers on this pre-existing nutrition project were stratified across these new experimental treatments to be bred by artificial insemination. In brief, on day 151, half the heifers were administered 5 mL of prostaglandin$_{2\alpha}$ ($PGF_{2\alpha}$); 7 days later, controlled internal drug release (CIDR) intravaginal progesterone inserts and 2-mL gonadotropin release hormone (GnRH) were administered to all heifers. After 7 days, all CIDRs were removed, and all heifers were administered 5 mL $PGF_{2\alpha}$. Heifers were inseminated at either 54 or 72 hours after CIDR removal (days 167 and 168) with either sexed or conventional semen. When inseminated, the heifers also received 2 mL of GnRH. On day 179, heifers were exposed to fertile bulls (1 bull/treatment, bulls had passed a breeding soundness exam within 21 days of use), bulls were rotated between groups on day 196. On day 214, a bull was found to be injured and was replaced with a third fertile bull. Bulls were removed on day 224.

Collection Periods and Description

Cattle were grazed on 8 ha mixed bermudagrass and fescue pastures throughout the summer months and supplemented at 0.5% of their body weight with soybean hulls, a low phosphorus feed product. This diet met or exceeded protein and energy requirements. Soil samples were taken in February 2020 and were analyzed at the University of Arkansas System Division of Agriculture's Marianna Soil Test and Research Laboratory. Two soil samples were taken per pasture on a transect to a depth of 4 inches. Soil phosphorus concentrations were extracted with Mehlich-3 and determined by inductively coupled argon plasma (ICAP). Concentrations ranged from 130 to 259 ppm. Forage samples were taken on day 0 and approximately every 28 days thereafter for a total of 6 dates. Samples were collected by walking pastures and taking grab samples at random points throughout the paddock. Forages were stored in a freezer at -20 °C until analyzed (Table 2). In order to measure concentrations of minerals in the diet, samples were taken from free choice minerals as well as the pelleted soybean hulls.

Reproductive Tract Scoring and Pelvic Area Measurements

After day 84, any heifers that weighed greater than 273 kg began monthly ultrasound evaluations. Heifers were rectally palpated and evaluated using real-time B-mode ultrasonography to determine the uterine horn and ovary size. Reproductive tract scores (RTS) were given on a scale of 1 to 5. A score of 1 was given if uterine horns were <20 mm and no palpable follicles were on the ovaries, while a score of 5 was assigned when the uterine horns were ≥30 mm and >10 mm follicles present as well as a visible

Table 2. Forage composition of pastures (dry matter basis).

Date	NDF[a]	ADF	CP	Ash
	%	%	%	%
June, day 0	67.23	35.15	14.94	8.41
July, day 27	66.71	30.65	12.31	7.51
August, day 56	69.47	32.81	12.81	7.36
September, day 84	68.23	30.09	14.06	7.67
October, day 112	68.06	31.38	15.38	7.93
November, day 140	72.67	34.23	11.31	6.19
Hay	68.99	31.43	13.13	6.85
Soyhull pellets	67.99	48.83	10.69	5.13

[a] NDF = neutral detergent fiber; ADF = acid detergent fiber; CP = crude protein.

corpus luteum (Pence et al., 2000). Heifers weighing >273 kg initially were given a score, while on day 112, a second data collection was completed to obtain data on any heifers that did not meet the weight requirements on day 84 and on those heifers that had an RTS of <4 on day 84. On day 112, pelvic area measurements were taken using a Rice pelvimeter. This device was used to measure the internal area of the pelvis, and area was determined by multiplying the height by the width of the pelvic opening. Height was measured using the linear distance from the middle of the pubic bone to the bottom of the mid sacrum, while width was measured using the linear distance between the ilia (Deutscher, 1987). These data allow producers to detect heifers that could potentially experience dystocia due to small pelvic area.

Statistical Analysis

Mineral intakes were analyzed using the MIXED procedure of SAS (SAS Institute, Inc., Cary, N.C.). Replicate was a random effect, and group was the subject. Treatment, period, and their interaction were fixed effects. Body weights, average daily gains, and reproductive tract scores were analyzed using the MIXED procedure. Pregnancy data were analyzed using the GLIMMIX procedure. Binary distribution and the compound symmetry covariance structure were specified. In all analyses, replicate was a random effect, and group was the subject. Treatment was the fixed effect. For the purpose of this study, $P < 0.1$ are considered significant.

Results and Discussion

The supplemental phosphorus group consistently had a greater daily mineral intake compared to the control group (Table 3; $P = 0.06$). It is important to note that during breeding season (occurring over two periods from days 166 to 224), bulls and heifers were combined into one replicate per treatment. During this time, the control group experienced a higher mineral intake. This is potentially due to decreasing the number of groups from eight to two.

Forage samples were taken and analyzed to determine neutral detergent fiber (NDF), acid detergent fiber (ADF), crude protein (CP), and ash. Table 2 illustrates a consistent NDF forage value until day 140, where it was greatest at 72.67%. Compared to other dietary sources, soyhull pellets had a significantly greater percentage of ADF. Percent ash values varied during the study, with the largest percentage coming from the initial data collection on day 0.

With soils rich in phosphorus concentrations, forages consequently take up the mineral and have large concentrations available for grazing animals. In addition to pasture grass, heifers were given soyhull pellets at 0.5% of their body weight to supplement dietary needs. It can also be noted that with the phosphorus concentration of the soyhull pellets combined with forages, heifers were well over their specific requirements. During the winter months, heifers were fed hay and continued to receive soyhull pellets. It is worth noting that the hay consisted of 0.39% phosphorus, a value greater than any concentrations heifers had grazed earlier in the season. While the concentration of phosphorus in the soyhull pellets was 0.10%, heifers were receiving a small portion of their body weight. In order to achieve maximum efficiency and performance, growing beef cattle need approximately 0.25% of their diet to consist of phosphorus. Table 4 demonstrates that the phosphorus concentrations of the forages alone were above the minimum requirement for growing heifers.

Table 3. Mineral intake of heifers (g/day).[a]

				P-value		
Date	**Control**	**Supplemental P**	**SE**	**Treatment**	**Period**	**Treatment × Period**
Days 0 to 27	76.35	91.98	7.34	0.06	< 0.001	0.41
Days 28 to 56	72.3	84.64				
Days 57 to 84	55.89	64.76				
Days 85 to 112	54.95	66.11				
Days 113 to 140	62.19	69.75				
Days 141 to 165	74.54	88.1				
Days 225 to 252	56.52	74.84				
Days 253 to 263	82	123.27				
Overall	66.84	82.93				

[a] During 2 periods when with bulls, heifers were housed in 1 replicate/treatment, consumption was as follows: days 166 to 196 = 105.79 and 60.26 g/day; days 197 to 224 = 80.6 and 76.84 g/day for control and supplemental P, respectfully. These data were not included in the above statistical analysis. SE = standard error.

Soil analysis showed the concentrations of phosphorus to range from 130 ppm to 259 ppm. Soils with phosphorus concentrations between 36 to 50 ppm are considered ideal for maintaining optimal forage growth, while those above 50 ppm are considered above optimum. Grasses in this area are excellent consumers of phosphorus. Plant tissue phosphorus will increase if soil concentrations are high in the mineral. Because of this, forages in this area have larger phosphorus concentrations compared to other pastures that do not have a history of livestock manure application.

Heifers in both groups were consistent in their average daily gains (Fig. 1 and Table 5), with the exception of days 84 to 112 where both groups experienced a decrease in weight gain, but the control group gained more than the supplemental phosphorus heifers ($P = 0.04$). This overall decrease is most likely due to heat stress from summer conditions. During days 141 to 168, heifers in the supplemental phosphorus group tended to have a greater daily gain ($P = 0.08$) compared to those in the control group; however from days 169 to 196, heifers in the control group tended to experience a greater rate of gain compared to the supplemental phosphorus group ($P = 0.07$).

On day 84, all heifers weighing >273 kg were given an ultrasound to determine size of their uterine horns and ovaries, and to check for presence of a corpus luteum (Table 6). There was not a difference ($P = 0.65$) between the groups, with the supplemental phosphorus group having an average score of 3.07 compared to the control group's

Table 4. Feed mineral composition.

Date	P	K	Ca	Mg	S	Fe	Mn	Zn	Cu
	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg
June, day 0	0.36	2.32	0.39	0.18	0.23	269	95	63	9
July, day 27	0.36	2.20	0.40	0.20	0.23	97	118	56	7
August, day 56	0.37	1.90	0.43	0.20	0.24	175	98	91	12
September, day 84	0.34	2.10	0.44	0.20	0.25	194	67	63	8
October, day 112	0.37	1.91	0.47	0.20	0.26	237	96	206	16
November, day 140	0.28	1.26	0.39	0.15	0.19	171	103	99	8
Hay	0.39	1.52	0.49	0.36	0.25	123	97	94	9
Soyhull pellets	0.10	1.17	0.64	0.23	0.09	393	26	44	7

P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; Fe = Iron; Mn = manganese; Zn = zinc; and Cu = copper.

Table 5. Average daily gain of heifers.

Date	Control	Supplemental P	SE[a]	*P*-value
Days 0 to 27	0.71	0.70	0.040	0.76
Days 28 to 56	0.62	0.59	0.049	0.65
Days 57 to 84	0.29	0.39	0.042	0.13
Days 84 to 112	0.17	0.01	0.041	0.04
Days 113 to 140	0.50	0.51	0.042	0.84
Days 141 to 168	0.41	0.62	0.069	0.08
Days 169 to 196	1.11	0.95	0.059	0.07
Days 197 to 224	0.65	0.68	0.041	0.58
Days 225 to 252	0.97	1.01	0.067	0.76
Days 253 to 264	0.48	0.58	0.174	0.70
Days 0 to 264	0.60	0.61	0.015	0.70

[a] SE = standard error.

value of 2.89. On day 112, there was still no difference ($P = 0.35$) in RTS. From these data, it can be determined that there was little statistical evidence that phosphorus played a role in the growth and development of heifer reproductive tracts. In addition to ultrasonography, pelvic area measurements were taken on day 112. Between the control and supplemented phosphorus groups, there was little variation ($P = 0.51$).

The control group had 35% of heifers bred to the supplemental phosphorus group's 31% rate ($P = 0.73$). A blood sample to determine whether heifers were bred early in the natural mating season found that 74% of open heifers in the control group versus 52% of the open heifers in the supplemental phosphorus group were bred ($P = 0.09$) early in the natural breeding season. After two months, bulls were removed from the groups, and breeding season concluded. A blood sample was taken from any heifers open from the last blood draw and was tested again to determine pregnancy status to the bull via the entire natural service period. The results from this collection determined a final 89% and 78% pregnancy rate ($P = 0.19$) for the control and supplemental phosphorus groups, respectively.

Conclusions

Throughout this study, there were no negative effects of removing phosphorus from the free choice mineral; however, it still remains important to have adequate phosphorus concentrations in the total diet. Heifers in the control group performed as well, if not better, in several areas of this study, particularly in regard to pregnancy rates. Compared to the control group, the supplemental treatment had an 11% lower end of season pregnancy

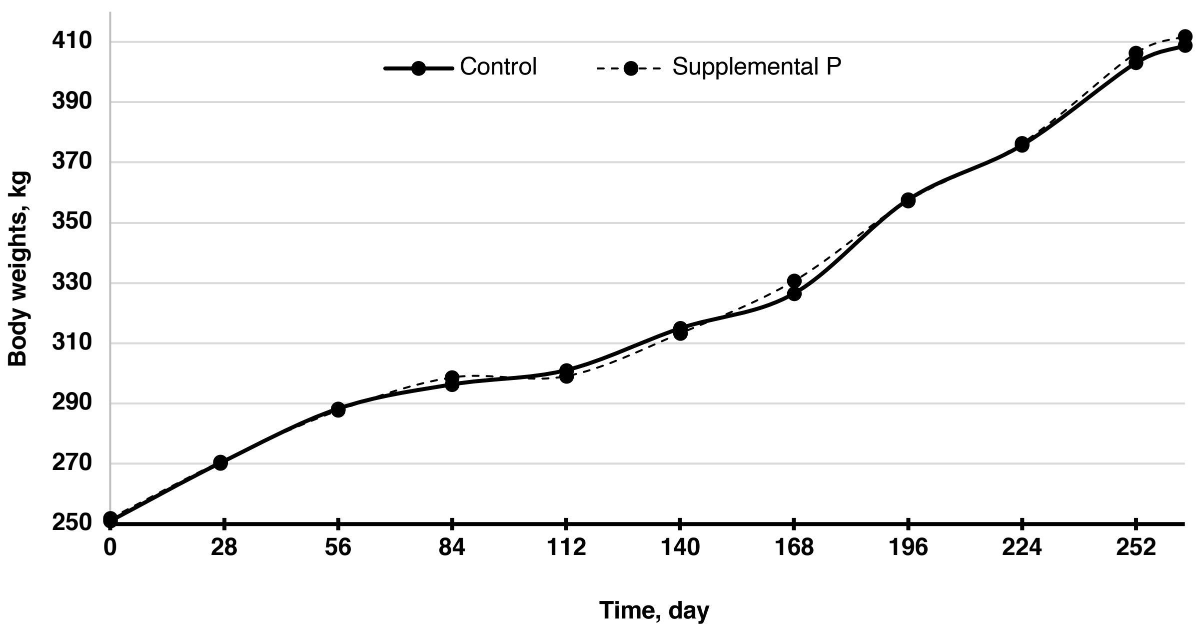

Fig. 1. Body weights of heifers.

Table 6. Reproductive data of heifers.

Evaluation	Day	Control	Supplemental P	SE	*P*-value
Reproductive tract score	84	2.89	3.07	0.27	0.65
	112	3.48	3.24	0.18	0.35
Pelvic area, cm^2	112	169	165	4.3	0.51
Pregnancy rate to synchronized breeding, %	196	35	31	10	0.73
Pregnancy rate for early bull bred, %	224	74	52	8.5	0.09
Pregnancy rate at end of breeding season, %	259	89	78	5.5	0.19

rate. When looking at other reproductive data, there was little variation between the two treatments. However, in the first attempt at breeding via artificial insemination, heifers in the control group had a higher rate of conception, and that trend continued during natural service. Producers in this situation, where the land had a history of manure application and forage concentration was 0.35% or greater, could either purchase mineral with or without phosphorus in it.

Acknowledgments

I would like to thank the University of Arkansas Dale Bumpers College of Agricultural, Food & Life Sciences, the University of Arkansas Honors College, and the University of Arkansas System Division of Agriculture for their generous funding.

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Microdialysis: a method for quantifying in situ nitrogen fluxes in soil microsites

Meet the Student-Author

Srusti Maddala

I am from Springdale, Arkansas, and graduated from Har-Ber High School in 2016. In May of 2020, I graduated from the University of Arkansas with a dual degree in Environmental, Soil, and Water Science and Chemistry (with a concentration in Biochemistry) and a minor in Biology. Funding for my undergraduate studies was generously provided by the Bodenhamer Fellowship and the Arkansas Governor's Distinguished Scholar scholarship. Funding to conduct and present research was provided by the Honors College, Bumpers College, and the Arkansas Department of Higher Education through a SURF grant.

Growing up, I had always loved the natural sciences and was exposed to gardening at a young age. At the start of college, I knew I wanted to major in Chemistry, but also decided to major in Environmental, Soil, and Water Science because it seemed interesting. As I took courses in the Crop, Soil, and Environmental Sciences department, I began to see the beauty of the interdisciplinary nature of environmental science and how vital it was to conduct research. Over the course of my four years as an undergraduate at the University of Arkansas, I had the opportunity to conduct an honors thesis project that integrated my interests in both majors and provided me with invaluable research experience. I also was able to participate in study abroad programs in Belgium and Belize. Thank you to Dr. Savin for her guidance, Dr. Stenken for her support, and Dr. Wood for her assistance.

Srusti working on her greenhouse experiment at the University of Arkansas System Division of Agriculture's Altheimer Lab.

Research at a Glance

- Microdialysis data provide information about nutrient movement in the soil, which may improve understanding of soil processes and reform current fertilizer usage.
- An advantage of using microdialysis is that it can be used to sample nutrients without moving any soil particles from where they are around the plant.
- Through a series of experiments, we found the best flow rate to be 2.0 µL/min. We also discovered that we could measure multiple forms of nitrogen at the same time because we did not have to worry about the measurement of one form of nitrogen interfering with another.

Microdialysis: a method for quantifying in situ nitrogen fluxes in soil microsites

Srusti Maddala, Mary C. Savin,† Julie A. Stenken,§ and Lisa S. Wood‡*

Abstract

Microdialysis, a diffusion-based sampling technique commonly used in biomedical research, has recently been recognized as a candidate for monitoring chemical changes in the rhizosphere. The information it provides about nutrient diffusion may improve nitrogen use efficiency, leading to enhanced management and success of restoration projects. The objective of this study was to determine the efficacy of microdialysis sampling to quantify the relative recoveries (*RR%*) of nitrate-N and ammonium-N, the two inorganic nitrogen compounds typically found in soil. The effects of microdialysis flow rate, sample medium concentration, and the presence of both analytes in solution on the relative recoveries obtained from dialysate samples were investigated. In comparison to 3.75 and 5.0 µL/min, a flow rate of 2.0 µL/min resulted in an increased relative recovery for both nitrate-N and ammonium-N solutions, at 42.7% and 51.0%, respectively, and was determined to be an optimum rate for subsequent experiments using CMA 20 microdialysis probes. The *RR%* for both nitrate-N and ammonium-N did not display a statistically significant dependence on the concentration of analyte present in the sample medium. The analytes also did not exhibit interferences, and the presence of both nitrate-N and ammonium-N in the same solution did not influence the *RR%* of either analyte. The results obtained from this study will assist in validating a novel approach to measuring in situ nitrogen availability in soil with minimal disturbance.

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‡ Lisa S. Wood, a faculty mentor, is a professor in the Department of Crop, Soil, and Environmental Sciences and Assistant Dean of Honors and International Programs for the Dale Bumpers College of Agricultural, Food and Life Sciences.

Introduction

Microdialysis is a diffusion-based sampling method used for nearly three decades in the field of medicine and has been established as a major research tool in studying the effects of drugs and disease on brain tissue (Duo et al., 2006; Kehr, 1993; Stenken, 2006). The central component of the microdialysis device is a semipermeable membrane 500 µm in diameter and 10 mm in length (Fig. 1), which is very similar in size to 0.5-mm mechanical pencil lead. A perfusion fluid is passed through the inlet of the device at flow rates in units of µL/min, which drives diffusion of compounds from the sample medium into the probe according to their concentration gradient. These compounds of interest—in this study nutrients such as nitrate-N and ammonium-N—are then carried to the outlet to undergo chemical analysis (de Lange, 2013; Stenken, 2006).

In the soil, namely the rhizosphere (Fig. 2)—a zone of dynamic microbial activity and interconnecting relationships between microorganisms, plant roots, and the soil—microdialysis has the potential for providing real-time, in situ data with greater temporal and spatial resolution than current standard methods, which are highly destructive (Mulvaney, 1996). Comparatively, salt extractions using potassium chloride (KCl) and potassium sulfate (K_2SO_4) are the conventional methods of sampling nitrogen from the soil, which destroy soil structure and also require significant periods of time between sampling and analysis.

Recent studies have investigated applications of microdialysis to sample inorganic forms of N (nitrate-N and ammonium-N) and measure the chemical changes in the rhizosphere without removing soil or destroying the soil structure (Inselsbacher et al., 2011). The microdialysis technique measures N flux (rate of movement in space) over time, which can enhance the understanding of the mechanisms involved in the availability of nutrients to plants and nutrient diffusion. By discerning the patterns and the trends of fluxes of nitrogen in the rhizosphere, more efficient use of fertilizers is possible and can also improve the management and success of remediation projects.

While the overarching purpose of this research was to implement microdialysis sampling in the rhizosphere soil, initial optimization of the technique was required to ensure 1) acquaintance with the equipment and procedures involved with microdialysis, including equipment set-up, probe handling, and sample analysis using colorimetric assays and 2) acquisition of preliminary data regarding the efficiency of the sampling technique in solutions of nitrate-N and ammonium-N using percent relative recovery (*RR%*). This study focuses on optimizing the microdialysis technique in the laboratory setting for further application to the rhizosphere of plants. The results of this study could aid in identifying the most effective flow rate of perfusate and quantifying the effects of sample medium concentration and the presence of potential interferences the analytes may exhibit on one another.

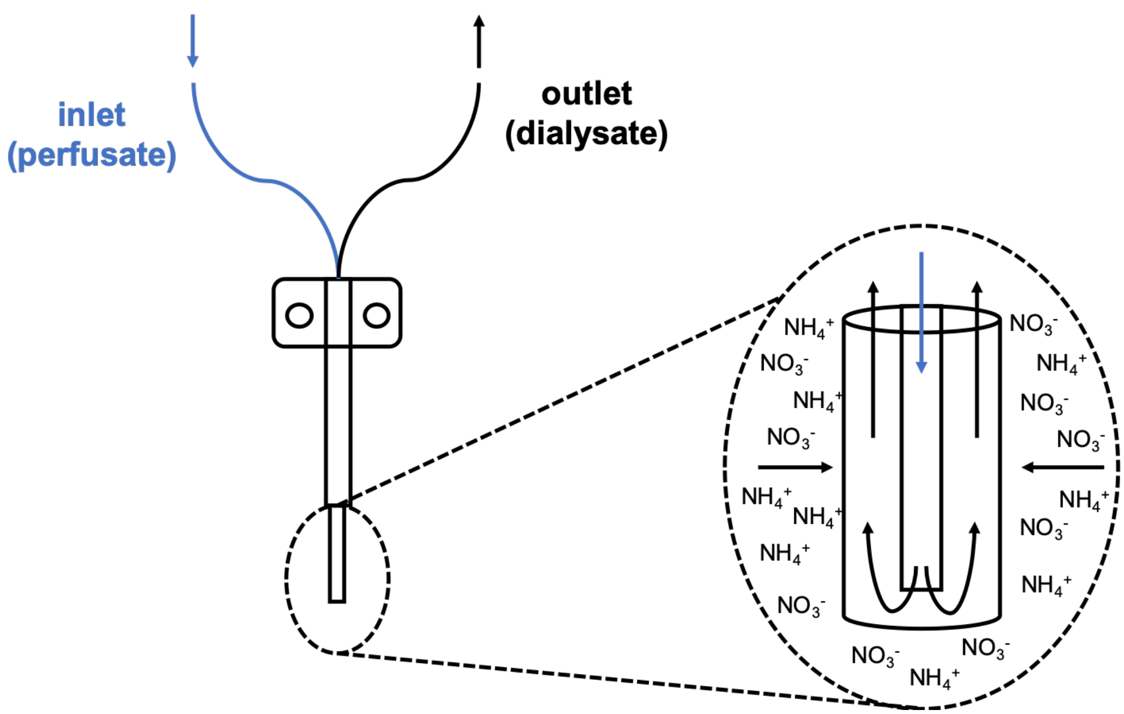

Fig. 1. An overview of the microdialysis device showing the potential for diffusion of nitrate and ammonium ions from soil solution through the probe membrane as an example in the expanded inset.

Materials and Methods

Microdialysis Set-Up

Four syringe pumps (MD-1001, BASi, Lafayette, Indiana) were equipped with a total of 12 gas-tight syringes (MDN-0250, 2.5 mL, BASi) that delivered the perfusate high performance liquid chromatography (HPLC)-grade water (VWR, Radnor, Pennsylvania) at the specified flow rates using a four-syringe drive pump controller (MD-1020, BASi). The HPLC-grade water was used ubiquitously as the perfusate for all microdialysis experiments in this study. Each syringe was connected to extra tubing (MF-5164, 1 meter, FEP (fluorinated ethylene propylene), 0.65 mm OD × 0.12 mm ID, BASi), which was connected to the inlet of a CMA 20 Elite probe (CMA8010436, 10-mm membrane length, PAES (polyarylethysulfone) membrane, and 20-kDa molecular weight cut-off, Harvard Apparatus, Holliston, Massachusetts). The equilibration time used at the beginning of every sampling was 15 minutes.

Determination of Optimum Flow Rate

A 10-µg/mL nitrate-N solution was prepared in HPLC-grade water using sodium nitrate (Mallinckrodt, St. Louis, Missouri), and three microdialysis probes were placed into the solution. Dialysates (180 µL) were collected in pre-weighed 0.5-mL microcentrifuge tubes at flow rates of 2.0, 3.75, and 5.0 µL/min (0.8, 1.5, and 2.0 µL/min on the pump controller). The relative recovery percent (*RR%*) was calculated at each flow rate using Equation 1:

$$RR\% = \frac{C_d}{C_{SM}} \times 100\% \qquad \text{Eq. (1)}$$

where C_d is the concentration of nitrate-N in the dialysate, and C_{SM} is the concentration of nitrate-N in the sample medium. An equilibration time of 15 minutes was used between changing flow rates. The same procedure was repeated with a 10-µg/mL solution of ammonium-N prepared using ammonium chloride (Mallinckrodt, St. Louis, Missouri).

Effects of Sample Medium Concentration on *RR%*

Standard solutions of 1, 3, 5, 8, and 10 µg/mL nitrate-N and ammonium-N were prepared in HPLC-grade water. Microdialysis sampling was performed in each solution using a 2.0-µL/min flow rate to collect 180 µL of dialysate. Equilibration times of 15 minutes were used between changing sample medium concentrations. The *RR%* was calculated for each sample medium concentration using Equation 1.

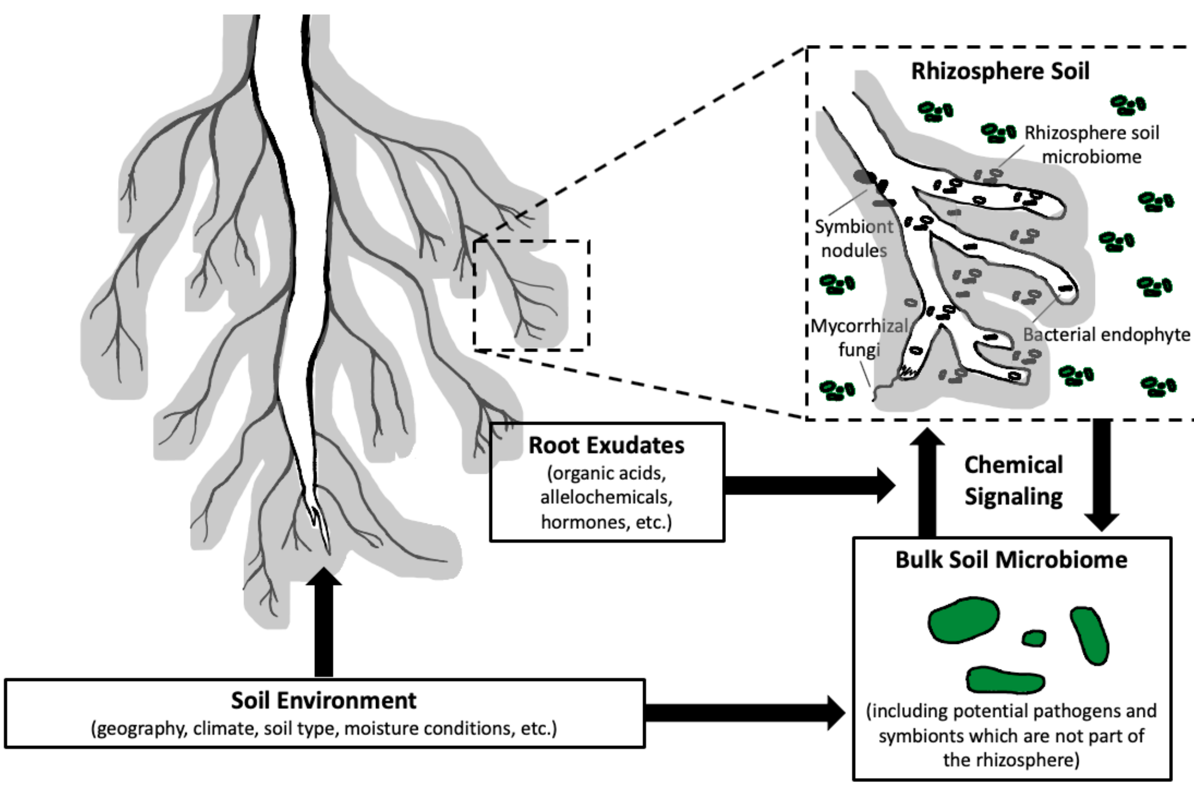

Fig. 2. The rhizosphere, a zone of dynamic symbiotic relationships at the plant root-soil interface.

Comparison of *RR%* in a Combined Solution of Nitrate-N and Ammonium-N

Standard solutions of 5 µg/mL nitrate-N and 5 µg/mL ammonium-N were prepared in HPLC water. Three microdialysis probes were placed into the 5-µg/mL nitrate-N solution and sampled for 30-minute intervals for a total of 90 minutes at 2.0 µL/min. Aliquots from the sample medium were collected before the initial collection and at the end of each 30-minute interval. Microdialysis was performed in the 5-µg/mL ammonium-N solution using the same sampling procedure. After dialysates were collected from each ion solution, 10-µg/mL nitrate-N and 10-µg/mL ammonium-N solutions were added to a 5-mL centrifuge tube in a 1:1 (v/v) ratio. The solution was vortex-mixed to ensure homogeneity, and microdialysis was performed at 2.0 µL/min for 60 minutes. The *RR%* for the individual ion solutions, as well as the combined solution, was calculated using Equation 1.

Nitrate-N Chemical Assay (Griess Reaction)

Nitrate-N in microdialysis samples was analyzed using vanadium chloride (VCl_3) and the Griess reaction based on the technique described by Miranda et al. (2001) and adapted to microplate analysis. A 0.05-M solution of VCl_3 (Strem Chemicals, Newburyport, Massachusetts) was prepared in 1M-HCl and filtered using a 0.2-µm Whatman syringe filter (GE Healthcare, Chicago, Illinois). Griess reagent 1 consisted of 1% (w/v) sulfanilamide (Tokyo Chemical Industry, Tokyo, Japan) prepared in 5% (v/v) phosphoric acid. Griess reagent 2 consisted of 0.1% (w/v) N-naphthylethylenediamine (Sigma-Aldrich, St. Louis, Missouri) in HPLC water. The assay for nitrate in a 96-well plate (3590, Corning Inc., Corning, New York) was as follows: 50 µL of sample or standard, 50 µL of VCl_3, 50 µL of Griess reagent 1, and 50 µL of Griess reagent 2. The plate was covered in aluminum foil and placed on a plate shaker at 200 RPM for 2.5 hours at room temperature.

Ammonium-N Chemical Assay (Indophenol Berthelot Reaction)

Ammonium-N in the dialysate samples was analyzed using the microplate adaptation of the Indophenol Berthelot reaction based on the technique as described by Baethgen and Alley (1989) and Willis et al. (1996). The plate was covered in aluminum foil and placed on a plate shaker at 200 RPM for 1.5 hours at room temperature.

UV-Vis Spectrophotometry

Absorbance values were measured using a Tecan infinite m200 plate reader (Tecan, Männedorf, Switzerland) at 540 nm and 650 nm for the Griess and Indophenol Berthelot reactions, respectively.

Statistical Analysis

Statistical analyses were performed using one-way analysis of variance (ANOVA) followed by Tukey's hon-

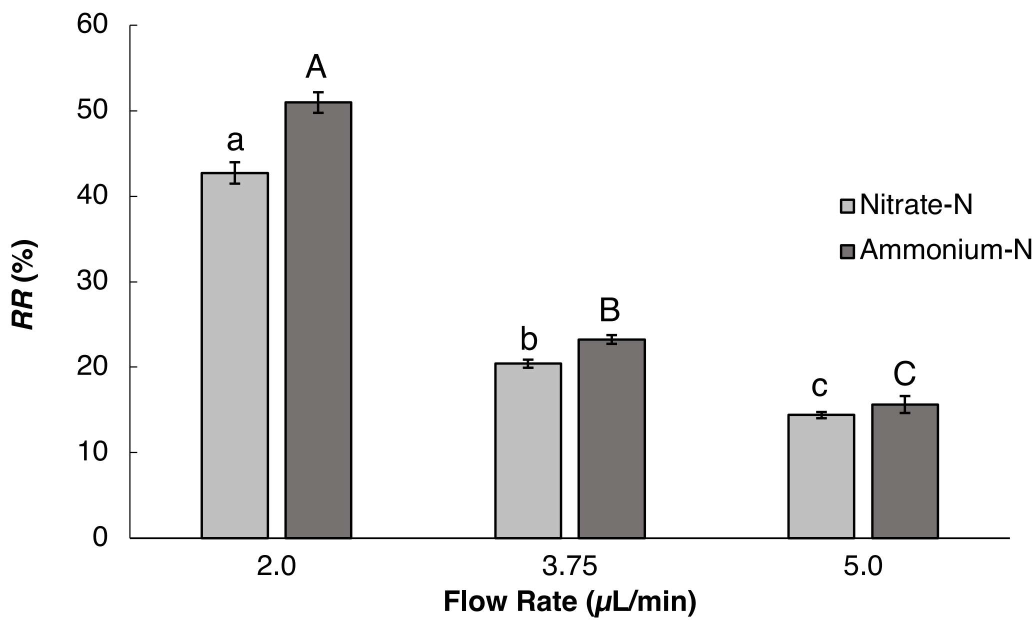

Fig. 3. The relative recovery percent (*RR%*) of nitrate-N and ammonium-N obtained from microdialysis sampling in solutions of 10 µg/mL at flow rates of 2.0, 3.75, and 5.0 µL/min. Nitrate-N and ammonium-N *RR%* were analyzed separately. Bars represent means ± SE (n = 3). Different lowercase letters indicate differences between *RR%* of nitrate-N ($P < 0.001$), and different uppercase letters indicate differences between *RR%* of ammonium-N ($P < 0.001$).

estly significant difference as a post-hoc test and Student's *t*-test using SigmaPlot 14.0 (Systat Software, Inc). All statistical analyses were performed using a 95% confidence interval; therefore, differences were considered statistically different at $P \leq 0.05$.

Results and Discussion

Optimum Flow Rate Determination

The effect of differing flow rates on the recovery of nitrate-N and ammonium-N was studied in order to determine the optimal flow rate for microdialysis sampling. The *RR%* of nitrate-N (denoted as mean ± SE) were 42.7 ± 1.3 %, 20.4 ± 0.5 %, and 14.4 ± 0.4 % for flow rates of 2.0, 3.75, and 5.0 µL/min, respectively (Fig. 3; n = 3). The recoveries yielded by the flow rates were all statistically different from each other, with 2.0 µL/min yielding the greatest *RR%* ($P < 0.001$).

The *RR%* of ammonium-N were 51.0 ± 1.2 %, 23.2 ± 0.5 %, and 15.6 ± 1.0 % for flow rates of 2.0, 3.75, and 5.0 µL/min, respectively (Fig. 3; n = 3). The recoveries yielded by the three different flow rates were all statistically different from each other, with 2.0 µL/min yielding the greatest *RR%* ($P < 0.001$).

Flow rate affects both recovery and sampling times: slower flow rates yield greater relative recoveries but also result in longer sampling times, which could be problematic to the microdialysis equipment such as the syringe pumps as they are exposed to heat, moisture, and a non-sterile environment for longer periods of time. Prior studies employ a flow rate of 5.0 µL/min and report low recoveries of target molecules from the soil (Buckley et al., 2017; Inselsbacher et al., 2014; Inselsbacher et al., 2011; Shaw et al., 2014).

A flow rate of 2.0 µL/min was determined to be an optimum rate for subsequent experiments using CMA 20 microdialysis probes (Fig. 3). Relative recoveries at 2.0 µL/min were significantly greater than the other two flow rates—twice greater than a flow rate of 3.75 µL/min—and would result in sampling times of 60 minutes in order to sample the needed volumes for nitrate-N and ammonium-N chemical analysis.

Effect of Differing Sample Medium Concentrations

The effect of compound concentration on the relative recoveries was studied in order to determine if the concentrations of analytes obtained in the dialysate samples were still proportional to the concentrations in the sample medium regardless of the magnitude of the actual concentration of the sample medium. Microdialysis was performed in solutions of 1, 3, 5, 8, and 10 µg/mL nitrate-N and ammonium-N, respectively, and the relative recoveries of the analytes from each sample medium were calculated. The relative recoveries of nitrate-N (denoted as mean ± SE) were 37.0 ± 3.1%, 31.0 ± 1.1%, 29.3 ± 1.7%, 38.2 ± 3.7, and 29.9 ± 0.3% in 1, 3, 5, 8, and 10 µg/mL solutions, respectively (Fig. 4; n = 3). Varying the concentration of the sample medium did not yield statistically different relative recovery percentages for nitrate-N ($P = 0.093$).

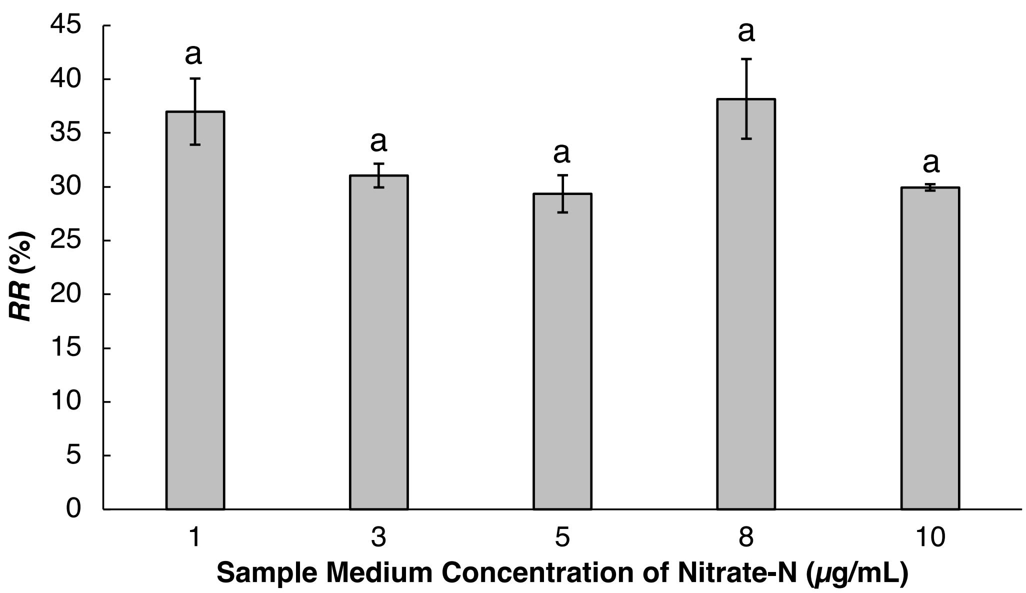

Fig. 4. The relative recovery percent (RR%) of nitrate-N obtained from microdialysis sampling in 1, 3, 5, 8, and 10-µg/mL solutions at 2.0 µL/min. Bars represent means ± SE (n = 3).

The relative recoveries of ammonium-N were 46.9 ± 1.3 %, 40.5 ± 3.3 %, 37.2 ± 1.9 %, 43.3 ± 2.8 %, and 45.1 ± 2.8 % in 1-, 3-, 5-, 8-, and 10-µg/mL solutions, respectively (Fig. 5; n = 3). Varying the concentration of the sample medium did not yield statistically different relative recovery percentages for ammonium-N ($P = 0.130$).

It was important to determine that the concentrations of nitrate-N and ammonium-N do not impact the precision of quantification of either compound. The concentration of N in the soil is a dynamic property and is constantly changing depending on microbial activity, precipitation, temperature, and other abiotic and biotic factors. The results of this study indicate that the recoveries of neither compound depended on concentration.

Comparison of *RR%* of Individual Analytes with *RR%* in Combined Solution

The presence of nitrate-N and ammonium-N in the same solution was studied in order to study the differences in microdialysis performance in the laboratory setting. Since the analytes are of opposite charges and different molecular weights, this study was performed to determine if the presence of both analytes imposed interferences or confounded measurement. Both forms of N are present in the soil environment and were sampled simultaneously during microdialysis sampling. In the 5-µg/mL nitrate-N solution, the average *RR%* (denoted as mean ± SE) was 39.9 ± 0.7 % (n = 3); while in the nitrate-N and ammonium-N combined solution, the average recovery was 41.2 ± 0.6 % (n = 3). The *RR%* obtained from the individual nitrate-N solution and *RR%* obtained from the combined solution were not statistically different ($P = 0.199$).

The average *RR%* in the 5-µg/mL ammonium-N solution and the combined nitrate-N and ammonium-N solution were 43.7 ± 0.8 % (n = 3) and 43.9 ± 1.1 %, respectively (n = 3). The recoveries yielded by the individual ammonium-N solution and the combined solution were not statistically different ($P = 0.863$).

Conclusions

This study revealed that a flow rate of 2.0 µL/min was optimum for subsequent rhizosphere studies, as it resulted in significantly greater recoveries of both nitrate-N and ammonium-N and would result in a sampling time of 60 minutes for collecting the volumes of dialysate required for colorimetric analysis. The concentrations of the analytes in the surrounding solution, as well as the presence of both analytes in the same solution, did not have a significant effect on the recovery of either analyte. The results of this study indicated that the nature of the analytes did not exert any significant effects on the recoveries; therefore, subsequent differences of recoveries observed in a soil-based sample medium can be attributed to analyte-soil-plant interactions.

Acknowledgments

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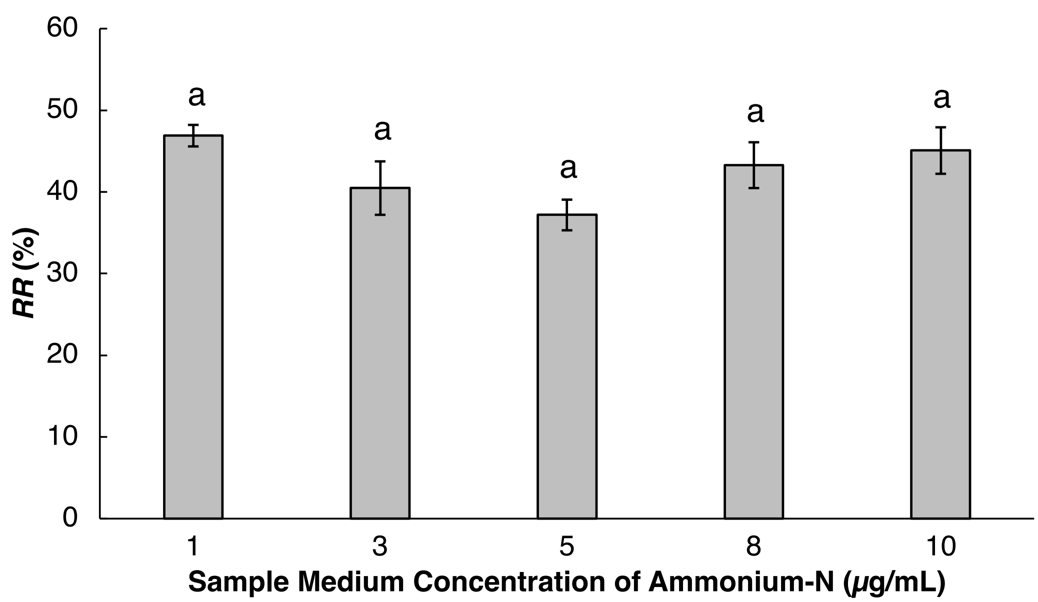

Fig. 5. The relative recovery percent (RR%) of ammonium-N obtained from microdialysis sampling in 1, 3, 5, 8, and 10-µg/mL solutions at 2.0 µL/min. Bars represent means ± SE (n = 3).

ship (SURF) grant, and a University of Arkansas Honors College grant for travel to the ASA-CSSA-SSSA Tri-Societies meeting to present this research.

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Characterization of jasmine rice cultivars grown in the United States

Meet the Student-Author

Anastasia Mills

Growing up in Benton, Arkansas, I was excited to attend the University of Arkansas. I graduated summa cum laude in May 2020 with a degree in Food Science and a Bachelor of Arts degree in Music. I play the oboe and have performed with the University Symphony Orchestra, the Wind Symphony, and the Razorback Marching Band Color Guard. During my time at the University of Arkansas, I have served as a Bumpers College Ambassador, Honors College Ambassador, and secretary for the Food Science Club. I had the opportunity to study abroad in Belgium, Austria, and France. Last summer, I worked as a Research and Development intern at Newly Weds Foods in Springdale. After graduation, I will attend the University of Wisconsin-Madison to pursue my master's degree on my path to a research and development career in the food industry. I would like to express my gratitude to my mentor Dr. Ya-Jane Wang for her patience and guidance on this project. I'd also like to thank my committee members Dr. Luke Howard and Dr. Philip Crandall for their insight, Dr. Benjamin Runkle, Dr. Andy Mauromoustakos, and Kevin Thompson for their assistance, and Dr. Sun-Ok Lee and Jia-Rong Jinn for their analysis. Thank you to the village of graduate students who worked with me along the way and helped me learn the skills I needed for this project—Annegret Jannasch, Ana Gonzalez Conde, Michelle Oppong Siaw, Seth Acquaah, and Wipada Wunthunyarat.

Measuring Arkansas jasmine rice in Dr. Wang's lab in the Department of Food Science.

Research at a Glance

- The research characterizes and compares the physical and chemical properties of newly developed U.S. jasmine rice from Arkansas, California, and Louisiana with jasmine rice samples from Thailand.
- The Californian jasmine rice sample was most similar to the Thai jasmine rice samples, while the Arkansas and Louisiana samples differed.
- These findings can help the U.S. rice industry to develop U.S. jasmine rice cultivars with properties closer to Thai jasmine rice.

Characterization of jasmine rice cultivars grown in the United States

Anastasia K. Mills and Ya-Jane Wang†*

Abstract

Jasmine rice from Thailand accounts for about 60% to 70% of U.S. imported rice, primarily due to its preference by ethnic Asians as well as the general American population. Recently new U.S. jasmine rice cultivars have been developed independently at three rice research stations in Arkansas, California, and Louisiana, but their properties have not been characterized. The objective of this research was to characterize and compare the physical appearance, chemical composition, thermal and pasting properties, cooked rice texture, and starch structures of the newly developed U.S. jasmine rice from Arkansas, California, and Louisiana, to be compared with jasmine rice samples from Thailand. In general, the U.S. varieties had smaller length/width ratios, darker color, and greater ash and lipid contents than the Thai controls. The Arkansas samples were similar to each other as well as one Louisiana sample, CLJ01 2017, and the other Louisiana samples were similar to each other; but rice of both origins was different from Thai jasmine. Calaroma-201 was found to be the most similar to the Thai jasmine rice out of the U.S. varieties from Ward's hierarchical cluster analysis of all attributes. These findings can help the U.S. rice industry to develop U.S. jasmine rice cultivars closer to Thai jasmine rice.

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† Ya-Jane Wang is the faculty mentor and a professor in the Department of Food Science.

Introduction

Rice (*Oryza sativa* L.) is the staple food of almost half of the world's population. While the U.S. accounts for only about 2% of global rice production, it exports more than 6% of global exports (USDA-ERS, 2019). The U.S. rice imports have increased over the past 30 years, and aromatic rice accounts for about 90% of U.S. rice imports (Suwannaporn and Linnemann, 2008a). Most rice imports are aromatic varieties from Asia, i.e., jasmine from Thailand and basmati from India and Pakistan. Thailand alone accounts for 60% to 70% of total U.S. imported rice. The demand for aromatic rice is expected to continue increasing in both domestic and international markets (Sakthivel et al., 2009).

Aromatic rice has characteristic taste, aroma, appearance, and texture that makes it desirable when compared with other nonaromatic varieties. Suwannaporn and Linnemann (2008a) found that eating quality attributes of hardness and stickiness were important factors in discriminating consumer preference. In another study by Suwannaporn and Linnemann (2008b) on consumer preferences, attitudes, and buying criteria toward jasmine, country of origin was frequently mentioned as an important criterion in buying rice when participants from rice-eating countries were surveyed. Currently, there are links between preferences and countries of origin in certain grain types such as Jasmine rice with Thailand.

Suwansri et al. (2002) evaluated 3 U.S. and 12 imported commercial jasmine rice varieties from Thailand using a trained sensory panel and 105 Asian families who lived in the State of Arkansas. They found that Asian consumers preferred imported Jasmine rice more than the domestic products, and the sensory characteristics most important to the acceptance of cooked Jasmine rice were color, followed by flavor, aroma, stickiness, and hardness. Suwansri and Meullenet (2004) further investigated the physiochemical properties of the same 15 jasmine rice varieties and found that the U.S. jasmine rice samples were associated with high amylose, high surface lipid, and high protein contents, resulting in cooked rice of harder texture, darker color, and inferior flavor.

Recently, several jasmine rice cultivars have been released from different states. There has been no study comparing jasmine rice cultivars grown in the U.S. with Thai jasmine. Therefore, the objective of this study was to characterize and compare the physiochemical properties and sensory attributes of these newly released jasmine rice cultivars to be compared with two commercial Thai jasmine samples.

Materials and Methods

Materials

Nine jasmine rice samples were used for this study, including seven from the United States and two from Thailand. The U.S. cultivars included ARoma17 from 2017 and RU1701105 from 2018, grown in Stuttgart, Arkansas, provided by Dr. Karen Moldenhauer of the University of Arkansas System Division of Agriculture's Rice Research and Extension Center (Stuttgart, Arkansas); Calaroma-201 from California from 2018 and grown in Richvale, California, Butte County provided by Dr. Kent McKenzie of the California Rice Experiment Station, California Cooperative Rice Research Foundation, Inc. (Biggs, California); and CLJ01 and Jazzman from both 2017 and 2018 crop years grown in Crowley, Louisiana provided by Dr. Adam Famoso of the Louisiana State University Agricultural Center, H. Rouse Caffey Rice Research Station, (Rayne, Louisiana). The two commercial Thai jasmine rice samples were Golden Phoenix purchased in Bangkok, Thailand, and Three Ladies Brand HOM MALI 105 purchased in Springdale, Arkansas, in 2018.

Kernel Appearance

Head rice color was measured by the $L^*a^*b^*$ color system (ColorFlex, Hunter Associates Laboratory, Reston, Virginia). Kernel dimensions (length, width, and thickness) were measured using a digital image analysis system (SeedCount 5000; Next Instruments, New South Wales, Australia).

Chemical Composition

Milled rice flour samples were obtained by grinding head rice with a laboratory mill (cyclone sample mill, Udy Corp., Ft. Collins, Colorado). The flour was used to determine apparent amylose content (Juliano, 1971), moisture content by Approved Method 44-15A (AACC, 2000), crude protein (AACC Method 46-13), lipid content (Soxtec Avanti 2055, Foss North America, Eden Prairie, Minnesota) according to AACC Method 30-20 with modifications by Matsler and Siebenmorgen (2005), and ash content (AACC method 08-03). Duplicate measurements were conducted for each flour sample. Starch was extracted from milled rice flour following the method of Patindol and Wang (2002).

2-acetyl-1-pyrroline and Hexanal Analysis

Samples were analyzed for levels of 2-acetyl-1-pyrroline (2-AP; Santa Cruz Biotechnology, Dallas, Texas) and hexanal (Sigma-Aldrich, St. Louis, Missouri) through solid-phase microextraction (SPME). Hexanal and 2-acetyl-1-pyrroline were quantified by performing linear regression from reference standards.

Characterization of Amylopectin Structure

The chain-length distribution of amylopectin was determined by high-performance anion-exchange chromatography with pulsed amperometric detection (HPAEC-PAD) according to Kasemsuwan et al. (1995) using a

Dionex ICS-3000 ion chromatography system (Dionex Corporation, Sunnyvale, California).

Gelatinization Properties

Milled rice flour gelatinization properties were determined with a differential scanning calorimeter (DSC; Pyris Diamond, Perkin Elmer Instruments, Shelton, Connecticut) following the method of Wang et al. (1992) with some modification. Onset, peak, and conclusion gelatinization temperatures (T_o, T_p, and T_c, respectively), and gelatinization enthalpy were calculated from each thermogram using the Pyris software.

Pasting Characteristics

Flour pasting properties were determined using a Rapid ViscoAnalyser (RVA; Model 4, Perten Instruments, Springfield, Illinois) according to AACC Method 61-02.01. The pasting properties measured include peak viscosity, hot paste viscosity (trough), final viscosity, breakdown, setback, and total setback.

Cooked Rice Texture

Rice was cooked and evaluated following a modified method of Sesmat and Meullenet (2001). Ten cooked rice kernels were compressed using a texture analyzer (TA. XT Plus Texture Analyzer, Texture Technologies, Hamilton, Massachusetts). The maximum compression force (peak force, g) and adhesiveness (area of negative force, g·s) were recorded as cooked rice hardness and stickiness, respectively. Six replications were performed for each cooked sample, and two cooked samples were prepared for each rice sample.

Results and Discussion

Kernel Appearance

Jasmine rice typically has translucent slender kernels. Calaroma-201 shared a similar kernel length with the two Thai jasmine rice samples (Golden Phoenix and 3 Ladies HOM MALI), which were greater than the others (Table 1). Apart from Jazzman 2017, the Louisiana cultivars were shorter than the other cultivars, with CLJ01 2018 being the shortest. The cultivar RU1701105 was wider than the others, whereas Calaroma-201 had a much smaller kernel width. The kernel thickness exhibited less variation, with Arkansas cultivars slightly thicker than the Golden Phoenix. Both commercial Thai jasmine rice samples had the greatest lightness (L^*) values, followed by Calaroma-201, whereas ARoma17 and Jazzman 2017 had the lowest lightness values. Calaroma-201 was lower in yellowness (b^*) than the other cultivars. The Federal Grain Inspection Service (FGIS) of the United States Department of Agriculture classifies milled rice with kernels having a length-to-width ratio (L/W) of greater than 3 as a long-grain type, and 2.0–2.9 as a medium-grain type (USDA, 2014). The L/W of RU1701105 was 2.63, which was smaller than the other cultivars and classified as a medium-grain type. Based on the kernel dimension and color, Calaroma-201 was most similar to Thai jasmine.

Chemical Composition

The cultivar RU1701105 had the greatest protein content, 1.8 percentage points greater than the next greatest one, CLJ01 2017 (Table 2), while Calaroma-201 and Jazzman 2018 had the lowest protein contents. The cultivars RU1701105 and Calaroma-201 had the greatest amylose

Table 1. Kernel appearance of jasmine rice samples from Thailand and grown in the U.S.

	Kernel Dimension				Kernel Color	
Sample	Length (L) (mm)	Width (W) (mm)	Thickness (mm)	L/W ratio	L^*	b^*
Golden Phoenix	7.22 ± 0.02 a[†]	2.14 ± 0.00 cd	1.84 ± 0.03 b	3.37 ± 0.01 a	75.2 ± 0.5 a	17.0 ± 0.6 ab
3 Ladies HOM MALI	7.22 ± 0.01 a	2.14 ± 0.01 cd	1.86 ± 0.02 ab	3.38 ± 0.01 a	73.9 ± 0.1 b	16.9 ± 0.2 b
ARoma17	6.80 ± 0.02 b	2.22 ± 0.01 b	1.95 ± 0.04 a	3.07 ± 0.00 b	68.8 ± 0.0 f	18.1 ± 0.3 a
RU1701105	6.73 ± 0.03 b	2.56 ± 0.01 a	1.95 ± 0.01 a	2.63 ± 0.03 c	70.4 ± 0.1 de	17.4 ± 0.2 ab
Calaroma-201	7.21 ± 0.06 a	2.07 ± 0.04 e	1.89 ± 0.00 ab	3.49 ± 0.09 a	72.2 ± 0.1 c	12.7 ± 0.0 e
CLJ01 2018	6.30 ± 0.01 d	2.11 ± 0.01 de	1.90 ± 0.01 ab	2.99 ± 0.00 b	69.6 ± 0.1 e	16.8 ± 0.2 bc
CLJ01 2017	6.48 ± 0.03 c	2.15 ± 0.01 cd	1.91 ± 0.05 ab	3.01 ± 0.01 b	70.9 ± 0.2 d	17.8 ± 0.4 ab
Jazzman 2018	6.53 ± 0.08 c	2.19 ± 0.02 bc	1.91 ± 0.02 ab	2.99 ± 0.01 b	71.0 ± 0.3 d	14.6 ± 0.3 d
Jazzman 2017	6.83 ± 0.05 b	2.21 ± 0.02 b	1.89 ± 0.02 ab	3.09 ± 0.01 b	68.6 ± 0.2 f	15.7 ± 0.5 cd

[†] Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

contents, while CLJ01 2018 had the lowest amylose content. Cultivars ARoma17 and RU1701105 had the greatest lipid contents, while the two Thai jasmine samples had the lowest. Jazzman 2018 had a lower lipid content than Jazzman 2017, while CLJ01 2018 and CLJ01 2017 were similar to each other, indicating cultivar and crop year interaction. Cultivar RU1701105 had the greatest ash content, followed by ARoma17, and the two Thai jasmine rice samples had the lowest ash contents. The two Arkansas cultivars generally had greater protein, lipid, and ash contents, whereas the two Thai jasmine rice samples had lower lipid and ash contents. Jazzman 2018 seems the closest to the Thai varieties out of all chemical characteristics, due to its relative similarity in 3 out of 4 chemical attributes. The Thai jasmine samples were commercial samples, which were likely milled to a greater extent, compared with the U.S. grown rice cultivars that were milled in the laboratory, thus resulting in lower protein, lipid, and ash contents, which could account for their lighter color (greater L^*). The greater b^* values (yellowness) of ARoma17, RU1701105, and CLJ01 2017 could be attributed to their greater protein contents (Wang et al., 2014). Calaroma-201 had the lowest protein content and exhibited the lowest b^* value among all the cultivars.

2-Acetyl-l-pyrroline and Hexanal

Buttery et al. (1982) identified and determined the concentration of 2-acetyl-l-pyrroline (2-AP) as an important compound contributing to a popcorn-like aroma in several Asian fragrant rice varieties, including jasmine rice. Calaroma-201 had the greatest level of 2-AP, followed by CLJ01 2017, while the two Thai samples had lower levels of 2-AP. The greatest amount of 2-AP in Calaroma-201 could be attributed to its genetic makeup, as certain alleles have been isolated to account for this compound, which Calaroma-201 may possess (Niu et al., 2008). Although the exact crop years of both Thai samples were unknown, it is speculated that their low 2-AP

Table 2. Chemical composition (%, dry basis) of jasmine rice samples from Thailand and grown in the U.S.

Sample	Protein	Amylose	Lipid	Ash
Golden Phoenix	7.61 ± 0.01 d†	16.08 ± 0.14 d	0.15 ± 0.00 g	0.26 ± 0.01 d
3 Ladies HOM MALI	7.65 ± 0.01 d	16.18 ± 0.07 cd	0.19 ± 0.00 f	0.23 ± 0.00 d
ARoma17	8.39 ± 0.02 c	16.65 ± 0.21 bc	0.56 ± 0.02 a	0.48 ± 0.01 b
RU1701105	10.89 ± 0.15 a	19.57 ± 0.07 a	0.54 ± 0.01 a	0.60 ± 0.02 a
Calaroma-201	6.99 ± 0.03 e	19.37 ± 0.14 a	0.31 ± 0.01 d	0.33 ± 0.00 c
CLJ01 2018	7.87 ± 0.01 d	14.13 ± 0.11 f	0.43 ± 0.01 bc	0.37 ± 0.00 c
CLJ01 2017	9.09 ± 0.02 b	16.76 ± 0.07 b	0.40 ± 0.01 c	0.34 ± 0.02 c
Jazzman 2018	6.87 ± 0.00 e	16.66 ± 0.21 bc	0.26 ± 0.01 e	0.36 ± 0.01 c
Jazzman 2017	8.41 ± 0.13 c	14.71 ± 0.11 e	0.45 ± 0.01 b	0.37 ± 0.01 c

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

Table 3. Hexanal and 2-acetyl-1-pyrroline (2-AP) in raw milled jasmine rice samples from Thailand and grown in the U.S.

Sample	2-AP	Hexanal
	(ng/g)	(ng/g)
Golden Phoenix	977.4 ± 54.6 fg†	344.8 ± 21.9 b
3 Ladies HOM MALI	396.2 ± 35.6 h	364.1 ± 9.9 b
ARoma17	1331.5 ± 68.1 cdef	197.8 ± 5.6 cd
RU1701105	1608.7 ± 88.7 c	44.1 ± 2.8 g
Calaroma-201	3434.3 ± 60.2 a	167.8 ± 9.7 def
CLJ01 2018	1385.1 ± 60.7 cde	233.9 ± 12.5 c
CLJ01 2017	2328.7 ± 191.8 b	437.6 ± 34.8 a
Jazzman 2018	1092.4 ± 28.0 efg	111.4 ± 8.4 f
Jazzman 2017	1167.7 ± 38.9 defg	154.4 ± 12.8 def

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

contents could be due to storage conditions and/or duration. Hexanal content is directly related to oxidative off-flavors and is easily recognized because of its low odor threshold (5 ng/g) in rice (Buttery et al., 1988). Cultivar CLJ01 2017 had greater levels of hexanal than the other varieties (Table 3), followed by the two Thai samples, and RU1701105 had the lowest concentration of hexanal. Cultivar CLJ01 2017 had greater levels of hexanal than its respective 2018 counterpart, implying the association of high hexanal content and storage duration. The high hexanal content in the two Thai samples supports the speculation that they may have been stored for a long period of time.

Chain-Length Distribution of Amylopectin

When amylopectin chain-length distribution was characterized by HPAEC-PAD (Table 4), CLJ01 2018 had the longest average chain length, which can be ascribed to its greater proportion of B2 and B3+ chains. The 3 Ladies HOM MALI, ARoma17, RU1701105, Calaroma-201, and CLJ01 2017 had shorter average chain lengths, which can be attributed to their smaller proportion of B2 and B3+ chains. Jazzman 2018 and Jazzman 2017 were most similar to the Thai varieties in their average chain length.

Gelatinization Properties

Overall, Jazzman 2018 and Jazzman 2017 exhibited greater gelatinization temperatures; whereas Calaroma-201 displayed lower gelatinization temperatures (Table 5). It has been shown that elevated growing temperature is associated with reduced amylose content and increased amylopectin long chains, which result in greater gelatinization temperatures (Patindol et al., 2014; Asaoka et al., 1985). Jazzman had the greatest gelatinization temperatures, which could be ascribed to its greatest average amylopectin chain length. Calaroma-201

Table 4. Amylopectin chain-length distribution of jasmine rice samples from Thailand and grown in the U.S.

Sample	Percent Composition (%) A (DP6-12)	B1 (DP13-24)	B2 (DP25-36)	B3+ (DP37-65)	Average Chain Length
Golden Phoenix	26.71 ± 0.33 a†	47.98 ± 0.22 b	14.25 ± 0.15 ab	11.05 ± 0.40 abc	20.49 ± 0.17 abc
3 Ladies HOM MALI	26.87 ± 0.49 a	47.75 ± 0.37 b	14.56 ± 0.14 a	10.82 ± 0.01 abc	20.42 ± 0.05 abcde
ARoma17	26.99 ± 0.05 a	48.83 ± 0.15 a	13.69 ± 0.06 bc	10.48 ± 0.16 c	20.14 ± 0.05 e
RU1701105	27.13 ± 0.31 a	48.35 ± 0.13 ab	13.45 ± 0.49 c	11.06 ± 0.32 abc	20.29 ± 0.02 bcde
Calaroma-201	27.17 ± 0.40 a	48.32 ± 0.15 ab	13.76 ± 0.15 bc	10.74 ± 0.10 bc	20.23 ± 0.09 cde
CLJ01 2018	26.20 ± 0.16 a	47.93 ± 0.04 b	14.27 ± 0.03 ab	11.60 ± 0.09 a	20.62 ± 0.05 a
CLJ01 2017	26.77 ± 0.13 a	48.84 ± 0.22 a	13.91 ± 0.03 abc	10.50 ± 0.13 c	20.18 ± 0.03 de
Jazzman 2018	26.34 ± 0.00 a	48.39 ± 0.02 ab	13.94 ± 0.01 abc	11.33 ± 0.01 ab	20.53 ± 0.01 ab
Jazzman 2017	26.35 ± 0.07 a	48.17 ± 0.14 ab	14.24 ± 0.02 ab	11.23 ± 0.20 abc	20.45 ± 0.07 abcd

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

Table 5. Gelatinization properties of jasmine rice samples from Thailand and grown in the U.S.

Sample	Onset (°C)	Peak (°C)	End (°C)	Enthalpy (J/g)
Golden Phoenix	65.6 ± 0.7 cd†	71.7 ± 0.2 cd	79.1 ± 0.6 cd	8.28 ± 0.11 a
3 Ladies HOM MALI	65.8 ± 0.1 c	72.1 ± 0.0 c	79.1 ± 0.2 bcd	7.93 ± 0.08 a
ARoma17	66.4 ± 0.0 bc	73.0 ± 0.0 b	80.6 ± 0.0 abc	7.39 ± 0.32 a
RU1701105	64.9 ± 0.1 cde	71.6 ± 0.0 cd	79.1 ± 0.0 cd	6.11 ± 0.14 a
Calaroma-201	64.3 ± 0.1 de	70.1 ± 0.2 e	77.1 ± 0.4 d	7.62 ± 0.17 a
CLJ01 2018	67.4 ± 0.0 b	74.3 ± 0.0 a	82.8 ± 1.4 a	8.08 ± 0.34 a
CLJ01 2017	63.8 ± 0.4 e	71.1 ± 0.1 d	78.8 ± 0.3 cd	8.42 ± 0.02 a
Jazzman 2018	69.1 ± 0.1 a	74.6 ± 0.2 a	82.0 ± 0.1 a	8.00 ± 0.21 a
Jazzman 2017	67.7 ± 0.3 ab	74.0 ± 0.2 a	81.5 ± 0.2 ab	8.31 ± 0.08 a

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

and CLJ01 2017 had lower gelatinization temperatures, which could be explained by their shorter average amylopectin chain length. The high gelatinization temperatures of Jazzman suggest that a greater temperature is required to cook the rice, so cooked rice texture could be affected. Because the U.S. jasmine rice cultivars were grown in different regions, with temperatures greatest in Louisiana, followed by Arkansas and then California, their gelatinization temperatures reflect their respective growth temperatures. Crop year could also be a contributing factor affecting gelatinization temperatures as demonstrated by Jazzman 2018 and CLJ01 2018 both having greater gelatinization temperatures than the 2017 crop year.

Pasting Properties

Jazzman 2018 exhibited the greatest peak and breakdown viscosities, but the lowest setback and total setback viscosities (Table 6; Fig. 1). Cultivar CLJ01 2017 dis-

Table 6. Pasting properties of rice flour of jasmine rice samples from Thailand and grown in the U.S. by a Rapid ViscoAnalyser.

	Pasting Viscosities (cP)					
Sample	Peak	Trough	Breakdown	Final	Setback	Total Setback
Golden Phoenix	3849 ± 22 b†	1971 ± 108 ab	1878 ± 130 bc	3411 ± 42 d	-438 ± 64 e	1441 ± 66 cd
3 Ladies HOM MALI	3603 ± 13 c	2035 ± 17 a	1568 ± 30 de	3611 ± 31 c	8 ± 44 c	1576 ± 14 b
ARoma17	3301 ± 7 d	1662 ± 5 d	1640 ± 12 cd	3058 ± 7 e	-243 ± 0 d	1397 ± 12 de
RU1701105	3106 ± 47 e	1757 ± 28 cd	1349 ± 75 e	3758 ± 27 b	653 ± 74 b	2002 ± 1 a
Calaroma-201	3368 ± 4 d	1651 ± 11 d	1717 ± 7 bcd	2947 ± 15 f	-421 ± 11 de	1296 ± 4 ef
CLJ01 2018	3654 ± 12 c	1868 ± 4 abc	1786 ± 16 bcd	3393 ± 4 d	-261 ± 16 de	1524 ± 0 bc
CLJ01 2017	2776 ± 17 f	1880 ± 62 abc	897 ± 80 f	3865 ± 27 a	1089 ± 44 a	1986 ± 35 a
Jazzman 2018	4093 ± 46 a	1856 ± 0 bc	2237 ± 46 a	2944 ± 13 f	-1149 ± 59 g	1089 ± 13 g
Jazzman 2017	3691 ± 41 c	1783 ± 30 cd	1908 ± 70 b	3066 ± 2 e	-625 ± 43 f	1283 ± 28 f

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

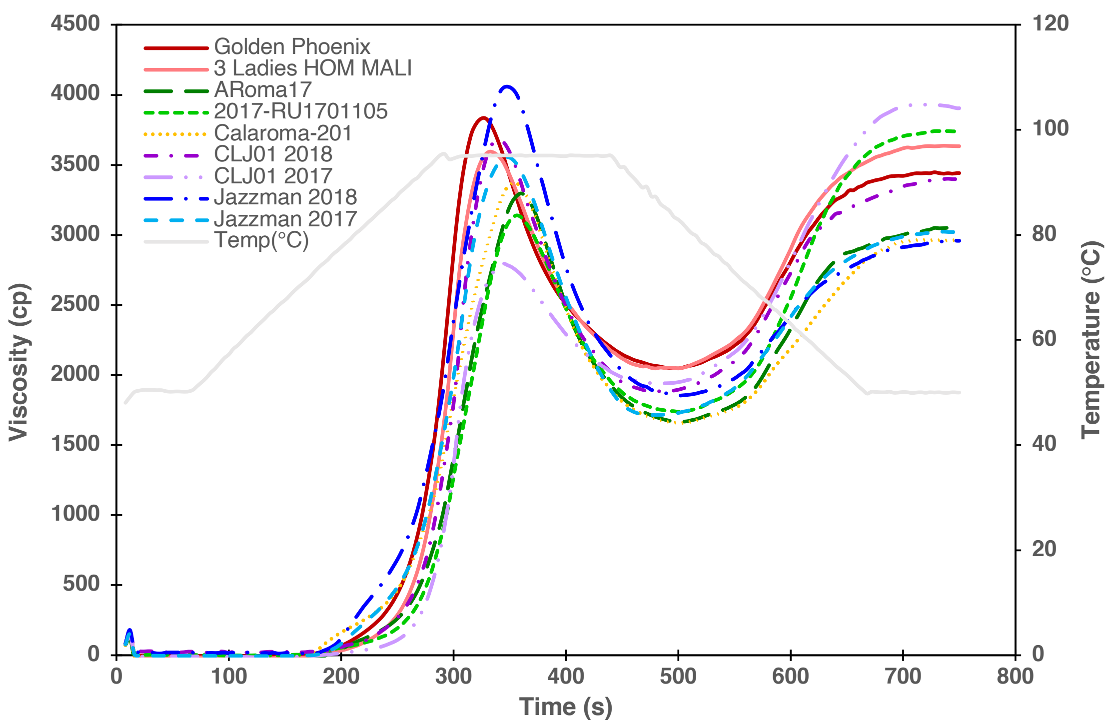

Fig. 1. Pasting profiles of jasmine rice samples from Thailand and grown in the U.S. with a Rapid ViscoAnalyzer.

played the lowest peak viscosity, the smallest breakdown, and greater final, setback, and total setback viscosities. The two Thai jasmine samples differed from each other in peak, breakdown, final, setback, and total setback viscosities. ARoma17 had greater peak and breakdown viscosities than RU1701105 but lower final, setback, and total setback viscosities. Both Arkansas cultivars had lower peak and trough viscosities than the Thai controls. Calaroma-201 was similar to ARoma17 in pasting, except for a lower final viscosity, which was similar to that of Jazzman 2018. The U.S. variety most similar to the Thai jasmine in pasting properties was CLJ01 2018.

The pasting properties of rice flour are affected by its chemical composition, including protein and lipid contents, and by starch composition and structures. Amylopectin content contributes to swelling of starch granules and pasting, whereas amylose and lipids inhibit the swelling (Tester and Morrison, 1990). Protein content may negatively impact peak viscosity (Wang et al., 2014), and protein-starch interactions may also affect viscosity (Hamaker and Griffin, 1990). Amylose content has been reported to be negatively correlated with peak, final, and breakdown viscosity, but positively correlated with setback viscosity (Patindol et al., 2014), which indicates the tendency of starch to retrograde during cooking. The lower peak and breakdown viscosities and greater final, setback, and total setback viscosities of RU1701105 and CLJ01 2017 were attributed to their greater protein and amylose contents. In contrast, the greater peak and breakdown viscosities and lower setback and total setback of Jazzman 2018 were proposed to be due to its low protein and amylose contents. The high amylose contents of RU1701105 and Calaroma-201 were correlated with lower pasting viscosities. ARoma17 and RU1701105 had high lipid contents and showed lower overall pasting viscosities.

Cooked Rice Texture

When cooked, RU1701105 had greater hardness but lower stickiness compared with most other samples (Table 7). Jazzman 2018 and Calaroma-201 were slightly stickier than the other samples. In a previous study, rice high in amylose and protein contents were found to have increased cooked rice hardness, but reduced stickiness, and gelatinization temperature was positively correlated with cooked rice hardness (Mestres et al., 2011). The cultivar RU1701105 had the greatest hardness value and was the least sticky, which is attributed to its high amylose and protein contents. Calaroma-201 and Jazzman 2018 had greater stickiness values, which can be attributed to their low protein contents. For the Louisiana samples, hardness and stickiness were not significantly different between the 2017 and 2018 crop years. Cultivar CLJ01 2018 had the hardness and stickiness, which was closest to that of the Thai varieties.

Statistical Analysis

Three clusters were found among the nine rice samples based on all data according to similarities and differences by Ward's hierarchical cluster analysis (Fig. 2). Calaroma-201 was most similar to the Thai jasmine rice among the U.S. jasmine cultivars. The Arkansas cultivars were more similar to each other and CLJ01 2017, while the Louisiana cultivars were more similar to each other as well. Cluster 3 of Louisiana cultivars were more similar to the Thai jasmine than Cluster 1 of Arkansas cultivars.

Conclusions

Based on the kernel dimension and color, Calaroma-201 was most similar to Thai jasmine. Jazzman 2018 was closer to the Thai varieties in chemical attributes,

Table 7. Cooked rice texture of jasmine rice samples from Thailand and grown in the U.S. by a texture analyzer.

Sample	Hardness	Stickiness
	(g)	(g.sec)
Golden Phoenix	6048 ± 421 b†	-403 ± 6 cde
3 Ladies HOM MALI	6778 ± 233 ab	-333 ± 43 abc
ARoma17	5474 ± 519 b	-348 ± 35 bc
RU1701105	8464 ± 736 a	-206 ± 5 a
Calaroma-201	6377 ± 204 b	-521 ± 57 de
CLJ01 2018	6005 ± 245 b	-359 ± 17 bc
CLJ01 2017	5930 ± 711 b	-258 ± 59 ab
Jazzman 2018	5540 ± 46 b	-534 ± 26 e
Jazzman 2017	6896 ± 351 ab	-386 ± 26 bcd

† Means ± standard deviations of duplicate measurements followed by a common letter in a column are not significantly different at $P < 0.05$.

and both Jazzman 2018 and Jazzman 2017 were similar to the Thai in average amylopectin chain length. Cultivar RU1701105 and the Thai jasmine rice samples had similar gelatinization temperatures. Cultivar ClJ01 2018 was most similar to the Thai jasmine in pasting properties and cooked rice texture. Calaroma-201 was most similar to Thai jasmine rice samples when considering all properties. The Arkansas varieties were generally similar to each other, and Louisiana varieties were similar to each other, but each of these categories is different from the Thai jasmine rice samples. This study demonstrates that the properties of jasmine rice are strongly influenced by genetics, growing location, and crop year.

Acknowledgments

I thank Dr. Kent McKenzie, Dr. Karen Moldenhauer, and Dr. Adam Famoso for providing jasmine rice samples, the Student Undergraduate Research Fellowship (SURF) for funding for this project, and the University of Arkansas System Division of Agriculture's Rice Processing Program for allowing the use of their lab equipment.

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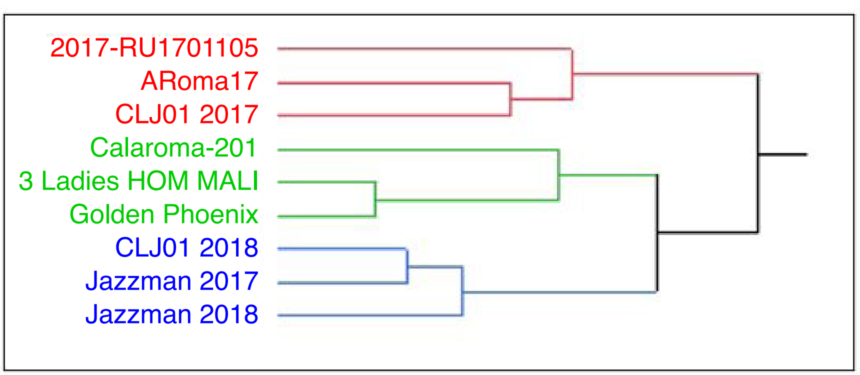

Fig. 2. A dendrogram obtained from the Ward's hierarchical cluster analysis of the kernel appearance, chemical composition, fine structure of starch, pasting characteristics, and cooked rice texture of nine jasmine cultivars.

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The economics of on-farm rice drying in Arkansas

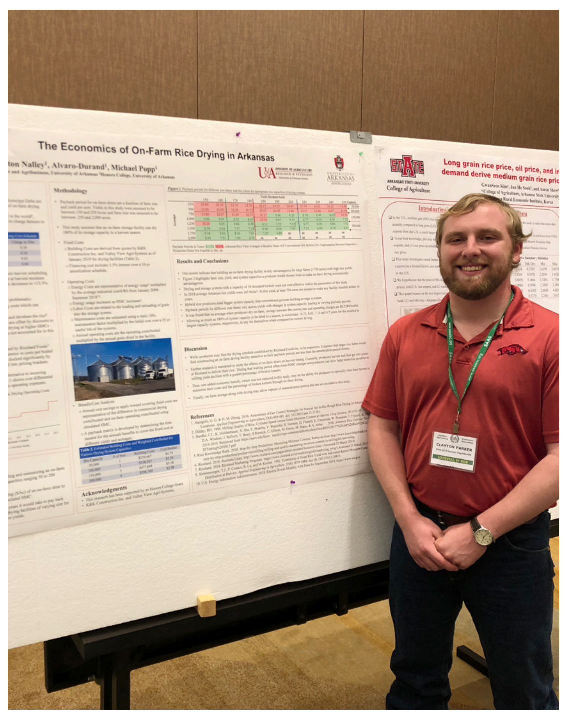
Meet the Student-Author

Clayton Parker

Living in a small town like Carlisle, Arkansas, agriculture was inescapable, even more so because I also lived on our four-generations old family farm. From riding the tractor with my father as a kid to walking the fields and working the land now myself, farming has always been a love in my life. After my high school graduation, it led me to pursue a bachelor's degree in agribusiness at the University of Arkansas. As an honors student, I have gained pertinent knowledge to succeed as a business person and leader in today's agricultural industry. The experiences in the classroom and as a researcher have helped me gain the tools to create what I hope are valuable tools for other farmers in Arkansas. Upon graduation, I plan to return home to the farm and start the fifth-generation of operation alongside my father and grandfather. My time at the University of Arkansas would not be the same without the friends and professors that have been there to support me along the way, and I am forever grateful for them. I would like to thank my mentor, Dr. Lanier Nalley, as well as my committee members Dr. Michael Popp and Dr. Alvaro Durand-Morat for their advice, expertise, and support in this process.

Research at a Glance

- Rice farmers are charged at buying points to dry their rice at rates that can represent a significant percentage of the cash price they receive for their grain.
- This research analyzes the potential benefit on-farm rice drying can provide Arkansas farmers by finding the feasibility of constructing and operating on-farm drying and storage facilities.
- The results of this research found that on-farm rice drying could be a viable long-term solution to high commercial drying rates for farmers who assume the risk of high initial investments to build the facilities.



Parker presented his research at the 2020 Southern Agricultural Economics Association annual meeting in Louisville, Kentucky.

The economics of on-farm rice drying in Arkansas

Clayton Parker and Lanier Nalley†*

Abstract

Globally, rice producers are faced with the temporal problem of deciding the optimal time to harvest rice. When harvested, paddy rice is typically at a harvest moisture content (HMC) between 15% and 22% and subsequently dried by the mill to a moisture content (MC) of 12.5%. Riceland Foods Inc., the largest miller of rice in the world, uses a stair-step pricing model to charge farmers to dry, which can complicate the timing of harvest as producers try to balance the tradeoff of minimizing drying costs by waiting to harvest at lower HMC vs. maintaining higher rice quality typically observed when harvesting at higher HMC. This study estimates the costs of on-farm drying as an alternative to commercial drying. This study estimates the total fixed and operating costs using current building, operating, insurance, and financing costs to establish and run an on-farm rice drying and storage facility with capacities between 1,750 and 7,000 m^3 for varying farm sizes (acres grown and yield observed), while drying from a simulated HMC range of 16% to 23%. A cost/benefit analysis compares on-farm operating costs to the current Riceland drying costs. This study finds an average savings of \$16.38/ton within the simulated HMC range once payback has occurred. Payback periods when drying at full capacity ranged from 7.52 to 12.26 years, where the larger capacity systems had shorter payback periods compared to the smaller systems. The results of this study can provide rice farmers with important information when considering on-farm drying and storage systems in the Mississippi Delta region.

* Clayton Parker is a May 2020 honors program graduate with a major in Agribusiness.
† Lanier Nalley, the faculty co-mentor, is a Professor in the Department of Agricultural Economics and Agribusiness.

Introduction

Globally, rice producers are faced with the temporal problem of deciding the optimal time to begin rice harvest. Rice is unique in that producers are paid both by the quantity of rice produced as well as the quality (head rice yield, HRY) of the rice, which is not determined until after the milling process. Rice requires post-harvest processing, including drying to a 12.5% moisture content (MC) for storage and milling (Rice Knowledge Bank, 2018). Because the rice must be dried, commercial mills charge rice producers. The HRY is directly affected by the moisture content of the rice at harvest (HMC; Dilday, 1989). Rice that has a greater HRY receives a premium from buyers, while lower HRY receives a discount. This puts farmers in the predicament of deciding when to harvest, based on HMC. The greater the HMC, the higher the quality, but the higher the associated drying costs; whereas the lower the HMC, the lower the drying costs, but this can result in lower HRY and reduce potential profits.

Empirical studies have found that long-grain rice varieties in Arkansas experience losses in HRY when HMC deviates from the optimal range of 15% to 22% (Siebenmorgen et al., 1992). Compounding the problem is that there is a different optimum for each rice cultivar and type (long-, medium-, and short-grain). The respective HMC that maximizes HRY is different for each rice cultivar (Siebenmorgen et al., 1992). Further, the HMC, which maximizes the HRY, may not maximize profits as it does not account for drying costs.

Riceland Foods, headquartered in Stuttgart, Arkansas, is the largest rice mill in the world (Riceland Cares, 2019a). Riceland uses a stair-step model to price drying costs within ranges of varying HMC, presented in Table 1 (Riceland, Marketing Programs, 2019b). This stair-step pricing method can either lead to large cost savings or additions if a producer harvests close to the HMC at a stair step pricing point. Hence, the subsequent drying cost compounds uncertainty for rice producers.

Rice producers can potentially mitigate the uncertainties associated with the Riceland stair-step pricing method by drying their rice on-farm. Previous studies (Young and Wailes, 2002) analyzed the cost of on-farm drying, and other studies (Nalley et al., 2016) have analyzed the impact of HMC on the net value of rice (NV) through HRY. But to date, there is a void in the literature on the impact of on-farm drying on NV at varying HMC using on-farm drying costs. As such, the objectives of this study are to:

1. Estimate the cost ($/0.035 m^3) to build and operate an on-farm drying and storage facility over an expected useful life.
2. Estimate payback periods when constructing and operating on-farm drying facilities at different capacities with varying rates of throughput.

This study is pertinent given the thin margins rice producers are currently experiencing. The results from this study should help determine the feasibility of on-farm drying, given farm size and expected yields.

Materials and Methods

This study utilized secondary data to estimate the relative profitability of on-farm drying in comparison to commercial drying. Assumptions were made for the following factors: energy usage and costs, labor costs, insurance costs, maintenance costs, building costs, lending costs, useful life, and yield. Risk was analyzed using @Risk (an Excel add-in program, Palisade, Ithaca, N.Y.) to simulate HMC (from historical HMC percentages in Arkansas), and energy costs (from U.S. Energy Information Administration industrial rates January 2008 to September 2018), as these two continuous variables are the main drivers of uncertainty for on-farm drying on an annual basis.

This study assumed storage systems with 14.63-m diameter bins and a capacity of approximately 1,750 m^3. The approximate total capacities ranged from 1,750 to 7,000 m^3, consisting of 1, 2, 3 or 4 bins, a dump, a 25.4-cm loop system, sweep augers, concrete necessary for the pad, and ramps, fan systems, and other required electrical hardware. Quoted 2019 prices from various contractors in Arkansas for these systems ranged from $239,273 to $617,570.

Lending information was provided by Farm Credit Services (G. Golleher, pers. comm., 12 August 2019). For this study, an estimated interest rate of 5.5% and an expected useful life of 35 years was assumed. Interest was equal to the sum of compounding interest payments found using the 2018 Microsoft Excel® Payment (PMT) function over a 10-year amortization period.

A static repair factor of 10% was assumed and used to determine the total value of repairs to the drying system.

Table 1. Riceland Foods 2019 rice drying fee schedule.

Harvest Moisture Content	Drying Costs
%	dollars/metric ton
Less than 13.5	13.50
13.6 thru 18.9	16.43
19 thru 21.9	19.35
Greater than 22.0	27.00

Total maintenance, in dollars, for the entire life of the drying facility was a product of building costs and the static repair factor. Annual maintenance was estimated to be total maintenance divided by the expected useful life. Annual maintenance per metric ton was estimated to be annual maintenance divided by the fixed storage capacity of a facility.

Insurance rates were assumed to be static at a rate of 0.55% of the book value of the asset. A salvage value of zero after a 35-year useful life was used to determine the average book value of the asset. Annual insurance costs were calculated by multiplying the average book value by the static insurance rate. Total insurance costs were equal to annual insurance costs multiplied by the expected useful life. Thus, the total fixed cost was estimated to be the sum of building costs, total maintenance, total interest, and total insurance.

Hypothetical HMCs were simulated 1,000 times using @Risk and a normal distribution truncated between 16% to 23%, representative of 1,000 potential loads of harvested rice brought into Riceland. The simulated HMCs were used to determine energy usage, and on-farm costs (per metric ton) and compared to the Riceland stair-step pricing in Table 1. Atungulu and Zhong (2016) provided the relevant equations to estimate the energy needed to dry each of the 1,000 simulated HMC down to 12.5% MC using the average national industrial energy cost/kWh from January 2008 to September of 2018, which ranged from $0.0667 to $0.071 per kWh (U.S. EIA, 2018).

Labor costs were subject to multiple assumptions within this study, and only additional labor to load and unload the system was accounted for. Labor varied by the capacity of the drying facility. Labor was not a function of HMC. The hourly wage was assumed to be $10/hour. The total operating cost/t for each of the 1,000 HMC simulations was estimated to be the summation of the energy cost/t of each iteration and the labor costs/t.

Paddy yield and farm size were integral factors in this study, as they determine the throughput on a drier. Farm size was analyzed at 101.23-hectare increments, ranging from 101.23 to 809.72 ha. Yield intervals ranged from 7.56 to 12.60 t/ha at 0.50 t intervals. Yield intervals were based around state averages and variety trials done by Hardke et al. (2018).

For a comparison to be made between on-farm drying costs and commercial drying costs in Table 1, total drying cost/t and total savings/t (the difference between on-farm operating costs and the Riceland drying schedule) were estimated for each of the 1,000 HMC simulations. Annual cost savings were representative of the amount of money saved by a producer at a given rate of production, where it was equal to the total farm production multiplied by the average cost savings per bushel. The total benefit over the

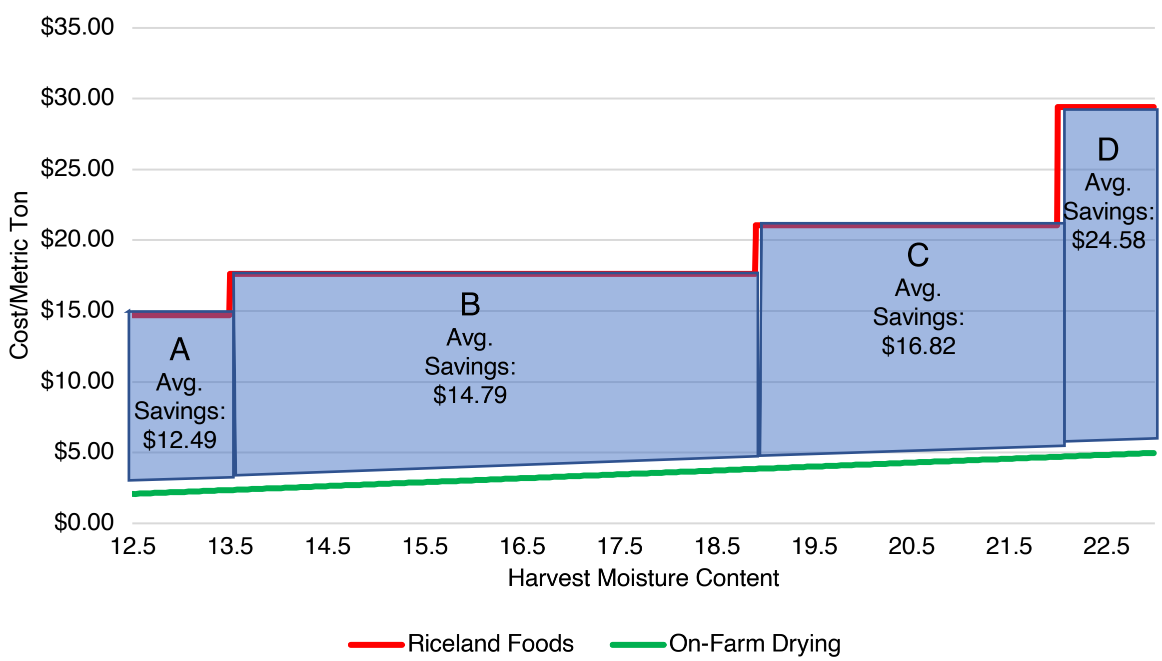


Fig. 1. The difference in on-farm drying operating costs and Riceland Foods, Inc.'s 2019 rice drying fee schedule once the on-farm drier has been paid back. Shaded portions are representative of the total savings throughout the range of harvest moisture content (HMC) between its on-farm operating costs and its respective Riceland cost once the on-farm drier has been paid back. The average savings is listed for each bracket: (A) HMC <13.5%, (B) 13.5% < HMC <18.9%, (C) 19.0% <HMC <21.9%, (D) HMC> 22%.

lifetime of the facility was estimated to be equal to the expected useful life multiplied by annual cost savings/1000 (which finds the average annual cost savings for all 1,000 HMC iterations).

The drying capacity of each drier was determined by the number of cycles each grain bin can run through in a harvest season. Drying capacities were determined by the initial HMC (more moisture results in lower capacity) for each iteration as well as the relevant drying functions provided by Atungulu and Zhong (2016). The study only analyzes the lesser of capacity or output (yield * farm size) to ensure consistency of the proportion of fixed capacity dried by each size drier.

Results and Discussion

When comparing the commercial (Riceland Foods 2019 cost schedule) and on-farm costs (Fig. 1), it was found that there were savings associated with on-farm drying across all HMCs from 12.5% to 23% after payback has occurred. The average savings associated with each bracket in the Riceland Foods 2019 cost schedule and the simulated HMC ranged from \$12.49/t to \$24.58/t, where the brackets increased in HMC (Fig. 2). In the 1,000 simulated HMC ranging from 16.0% to 23.0%, there was an average savings of \$16.38/t. These "savings" are relative comparisons to commercial driers only after the on-farm drier has been paid back. Thus, the payback period is of importance to producers.

While Fig. 1 illustrates the cost differences between on-farm and commercial drying once the on-farm drier has been fully paid back, Table 2 illustrates the payback periods of each capacity system. The payback period was equal to the number of years needed to pay back the total fixed cost of the facility using the annual savings at varying production rates. Each system was limited to drying 166.43% of its storage capacity in a 98-day harvest season, assuming 100% of the drying capacity was used to dry rice. This harvest season was taken from the 5-year average of Arkansas rice harvest progress from the National Agriculture Statistics Service (USDA-NASS, 2019). This historical harvest season length for Arkansas, may be too long for any individual farm. When drying at full capacity, the payback periods ranged from 7.52 to 12.26 years. The smallest capacity of 1,750 m^3 had a payback period of 12.26 years, while the largest capacity of 7,000 m^3 had the fastest payback period of 7.52 years. This seemed counterintuitive, but the larger throughput of the larger drier helps pay back the initial investment quicker. When considering that payback periods needed to be less than or equal to the 10-year amortization period to be advantageous to farmers, the 1,750 m^3 capacity system was not feasible. The Arkansas state average rice yield in 2018 was 8.21 tons/ha (Hardke et al., 2018); and at this yield, at least 404.9 ha of rice was needed for any facility to be feasible within 10 years. Higher yielding producers could potentially need a larger capacity and likely experience lower payback periods via higher throughput when holding acreage constant.

Conclusions

While the high initial costs of constructing a grain drying and storage system are a significant barrier to entry for many rice producers, on-farm drying could prove to be an attractive investment relative to high commercial drying costs. Larger capacity systems were found to be more cost-effective because of the lower payback periods that were estimated. Farmers with higher rates of production would see more benefit from on-farm storage, as shown by lower payback periods for larger capacities and production rates.

Table 2. Payback periods for various capacity on-farm drying systems under different farm sizes and rice yields.

	Yield (metric tons/hectare)											
Hectares	7.56	8.06[b]	8.57	9.07	9.57	10.08	10.58	11.09	11.59	12.09	12.60	Capacity
101.23	27.20[a]	25.50	24.00	22.66	21.47	20.40	19.43	18.54	17.74	17.00	16.32	1,750
202.43	13.60	12.75	17.78	16.79	15.91	15.12	14.40	13.84	13.14	12.60	12.09	3,500
303.64	13.44	12.60	11.86	11.20	10.61	10.08	9.60	9.16	11.63	11.15	10.70	5,250
404.86	10.08	9.45	11.80	11.15	10.56	10.03	9.56	9.12	8.73	8.36	8.03	
506.07	10.70	10.03	9.44	8.92	8.45	8.03	9.53	9.10	8.71	8.34	8.01	7,000
607.29	8.92	8.36[c]	9.82	9.27	8.78	8.34	7.95	7.58	na	na	na	
708.50	9.53	8.94	8.41	7.95	7.53	na	na	na	na	na	na	
809.72	8.34	7.82	na[d]	na	na	na	na	na	na	na	na	

[a] Payback periods that were greater than 10 years were highlighted in red. Payback periods that were less than or equal to 10 years were highlighted in green.

[b] Arkansas rice yield averages in tons/ha for 2018 were labeled to highlight the impact of yield and variety selection on payback periods: State 8.21 (green line), Conventional 9.12 (red line), and Hybrid 10.78 (blue line).

[c] Black lines in-between cells segment production rates within 166.43% of fixed storage capacity. All production rates above a segment were feasible but may not be optimum for that system capacity.

[d] Production rates that were outside the drying capacity of any dryer in the study were labeled as "na" for not applicable.

Other potential benefits to on-farm drying, which this study did not assess and warrant further research are: the impact on harvest timing and duration, effects on the marketing abilities of farmers, and enhanced quality preservation.

Acknowledgments

I would like to thank the University of Arkansas Honors College for providing funding for travel and presentation materials to present this project.

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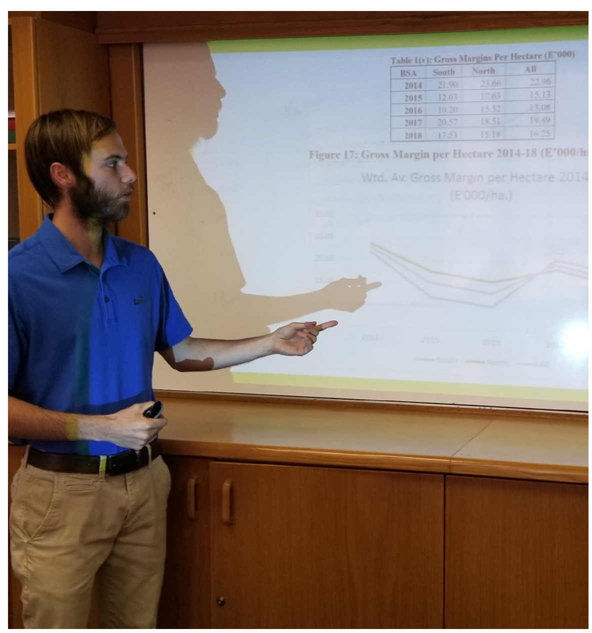
The impact of income on nutrition: A case study of Northern Mozambique

Meet the Student-Author

Hunter Swanigan

I am from Jefferson City, Missouri, and graduated from Jefferson City High School in 2016. I was not exactly sure what I wanted to do next. I decided to attend the University of Arkansas to expand my horizons. After my sophomore year, I studied abroad in Mozambique, which exposed me to international development, and influenced me to pursue a career in this direction. The next summer, I worked in Eswatini (formerly Swaziland) for the Eswatini Cane Growers Association through an internship program with the University of Arkansas. While in Fayetteville, I was a member of the Agricultural Business Club, the National Society of Leadership and Success, and the Honors College. I also took three semesters of Swahili. I graduated Summa Cum Laude in December of 2019, majoring in Agricultural Business and minoring in International Economic Development. I was also the Agricultural Business Club Outstanding Sophomore in 2017.

I would like to thank Dr. Nalley for showing me the world of international development by helping start both the Mozambique and Eswatini programs. He went above my highest expectations for an advisor for both what I could do after graduating and with working on my thesis. I thank all of my committee members, Drs. Jennie Popp, Amy Farmer, and Lanier Nalley for always answering any questions and being willing to help me throughout my time at the University of Arkansas. I also thank the Honors College, Dale Bumpers College, and the Study Abroad office for funds that allowed me to travel to Mozambique.



Hunter presenting his work during his internship in Eswatini at the Eswatini Cane Growers Association during the Summer of 2019.

Research at a Glance

- Many people in low-income countries suffer from malnutrition for a variety of reasons, with financial costs being a large barrier.
- Prices for food available in Mozambique during the dry season were collected and compared against 3 different income levels to determine what percent of the population could meet their nutritional needs with their limited income.
- Thirty-six percent of individuals in Mozambique could not meet their nutritional needs with what was available. Individuals who grew food at home could meet their needs, as their annual food budget was drastically reduced. Supplementation of calcium through the government or a non-governmental organization could decrease the annual food budget needed to meet nutritional recommendations.

The impact of income on nutrition: A case study of Northern Mozambique

Hunter Swanigan and Lawton Lanier Nalley†*

Abstract

In 2017, Mozambique ranked as one of the least developed countries in the world by measures of health, education, and income. With a minimal annual income, purchasing adequate food to meet recommended levels of nutrients for a healthy diet is difficult, leaving 40% of the country undernourished. This study analyzed what foods are available during the dry months (hungry season) of May through October in the Nampula province of Mozambique to determine if it is possible to meet recommended levels of nutrients from purchasing and growing food. Three different levels of income were used to determine what percentage of the country could purchase the recommended levels of nutrients: per capita income, government minimum wage, and the minimum wage at a private firm. Based on these income groups, 36% of the country would not be able to meet their needs from only buying food from the market at any time of the year. Those who grow their own food made meeting their nutrient needs more feasible, as they did not spend as much of their income (8% to 17%) on food. Different models were constructed to analyze the effect of the supplementation of specific vitamins and minerals that are continuously difficult to obtain. The most significant supplementation was of calcium, reducing the theoretical percentage of annual income spent on food from 325% to 65%. Based on these results, non-governmental organizations (NGO) or the Mozambican government should focus on a wide-scale supplementation program focusing on calcium to ensure proper nutrition.

* Hunter Swanigan is a 2019 honors program graduate with a major in Agricultural Business and a minor in International Economic Development.

† Lawton Lanier Nalley is a professor in the Department of Agricultural Economics and Agribusiness.

Introduction

Mozambique has been one of the most impoverished countries in the world since gaining independence from the Portuguese in 1975 (CIA, 2018). Although the government of Mozambique continues to work to improve the country's economic wellbeing, as of 2017, Mozambique ranked 222nd out of 229 countries in the world with a gross domestic product (GDP) per capita of $1,300 (CIA, 2018). The Human Development Index, which measures human development based on health, education, and standard of living, scored Mozambique a value of 0.418 in 2016, ranking the country 181st out of 188 countries in the world (UNDP, 2016). A 2015 estimate found that 46.1% of the country's population was under its own poverty line (CIA, 2018).

With Mozambique's standard of living, it can be very difficult to meet the recommended dietary allowance (RDA) for essential nutrients, which is defined as "average daily level of intake sufficient to meet the nutrient requirements of nearly all (97% to 98%) healthy people" (National Institutes of Health, 2018). The per capita consumption of fruits and vegetables has been cut in half since the 1960s and is the lowest in the region, and per capita consumption of animal protein and healthy fats from nuts and oils was also low, even relative to its region (Lourdes et al., 2011).

With the lack of a diverse diet and fruits and vegetables, undernutrition, which is defined as "deficient bodily nutrition due to inadequate food intake or faulty assimilation," is widespread across Mozambique with 43% of the children in Mozambique suffering from moderate to severe growth stunting, which is mainly caused by lack of proper nutrients at a young age (UNICEF, 2013). Micronutrient deficiencies such as vitamin A, iodine, and iron are the most widespread across the country, which again can be traced to lack of a healthy, diverse diet (FAO, 2010). In total, roughly 40% of the population of Mozambique was classified as undernourished from 2005 to 2007 (FAO, 2010). The purpose of this study was to investigate if an individual in Northern Mozambique can attain a portfolio of foods by either purchasing food at the market or growing food at home in the dry (hungry) season that will meet their nutritional needs with different income levels. Lastly, we will identify specific food items that could effectively 'fill in the gaps' of any nutrient deficiencies which are prohibitively expensive or simply not available to purchase or grow. These results will provide policymakers and non-governmental organizations (NGO) with useful data on what macro and micronutrients are limited in the dry season and the correlation with income and the ability to consume a holistically healthy diet.

Materials and Methods

Data were collected from Nampula (the city) in the summer of 2018. After data on the cost of available food was collected while in the country, previously published data by The World Bank (2018) and Hansen (2016) of Mozambique's income levels and average household size were used. Linear programming was used to build possible "meal templates" that met a households' daily dietary reference intake (DRI), derived from the National Institutes of Health, and its respective cost. The World Bank's per capita GDP estimate for Mozambique was used as an "average" income ($426.22; Income #1). The government minimum wage ($771.71 per year; Income #2), as well as the minimum wage at a private company ($895.46 per year; Income #3), were used as alternative yearly incomes. Data on household size was gathered from research in 2016 and was set at 6.6 people/household (Hansen, 2016). Since nutritional requirements vary based on age and gender, different levels were used to simulate a typical household of 6.6 people. The DRI for a male and female in the age range of 19 to 30 years, a male and female in the age range of 14 to 18 years, and a male and female in the age range 4 to 8 years were used. Lastly, DRI for a female aged 4 to 8 years multiplied by 0.6 was used to build a household total of 6.6 people. Data on food items available during the dry season were collected in various markets in Nampula during June of 2018. A local translator was used to ask vendors their prices for respective items in order to get the most accurate price for an individual living in the area (Table 1). Data were sourced from a study conducted in the same area in 2015 of food items that were commonly grown in home gardens (Hansen, 2016). Three food items were grown at home that were not available to purchase at the market (cassava leaves, bean leaves, and sweet potato leaves). Prices for these items were calculated by multiplying the price of a similar food item, cabbage, by 1/8. This was done because the food items grown at home would have a small price if available at the market. All prices were converted from Mozambique metical's to U.S. dollars at the rate of $1 = 60.84 meticals. The first goal of this study was to determine if a well-balanced meal is attainable, given each level of yearly income. The price of obtaining a DRI sufficient meal for a 6.6 person household daily was calculated and multiplied by 365 and then compared to each of the three income scenarios to see if each respective income was sufficient to at least provide healthy meals for the entire household for a year. From these results, we identified certain crops/food that could be added to the area that would remove nutrient deficiencies in hopes of improving the area's overall nutrition profile in a cost-effective manner.

Three different models were used to represent different scenarios in which individuals may find themselves in Mozambique (Table 2). Model A, representing the Urban Consumer, had no constraints on food available; all food items could be consumed that were found in markets around Nampula. In this model, it is assumed that the individual purchased all their food from the market, and none is grown at home, representing the average urban Nampula consumer. This model would represent the 36% of the Mozambican population that lives in urban areas and does not grow food at home (CIA, 2018). Model B, representing the Rural Consumer, has no food constraints, but it is assumed that supplemental food is grown at home. The different prices/serving of food items used in this model were found by subtracting the percentage of households growing the food from 100% and multiplying this value by the market price. For example, 20% of households surveyed grew bananas (Table 1), which have a market price of $0.08/serving. As such, rural consumers had a cost of $0.08*(1-0.2) = $0.06/serving. Data for the percentage of households growing certain food items came from a survey of 60 families in the Nampula region in the summer of 2015 (Hansen, 2016). Model C is similar to Urban Consumer in the fact that no food is grown at home; all nutrition is bought. That being said, model C considered seasonality by removing all fruits available on the market from the model, given their obvious seasonality, and represents the Seasonal Urban Consumer, which highlights what is more likely

Table 1. Price per serving of foods available in Nampula Mozambique, summer 2018.

Food Item	Serving	U.S.$/Serving	% of Homes Growing Food[a]
2% milk	1 liter	1.56	0.00
Apple	1 kg	2.63	0.00
Banana	1 medium	0.08	20.00
Bean	1 kg	0.41	41.70
Bean leaves	900 g	0.07	86.70
Cabbage	1 head	0.58	0.00
Cassava root	1.6 kg	0.33	66.70
Cassava leaves	900 g	0.07	93.30
Chicken	1 whole bird (1.3 kg)	3.70	31.70
Cucumber	1 kg	0.90	0.00
Eggs	1 egg	0.16	8.30
Fish	1 kg	1.89	0.00
Green bell pepper	1 small	0.08	0.00
Large roll	1 roll	0.08	0.00
Lettuce head	1 head	2.78	0.00
Limes	1 kg	0.33	50.00
Maize flour	1 kg	0.41	15.00
Milo drink	400 g	4.93	0.00
Oil (rapeseed)	1 liter	1.23	0.00
Orange	1 large orange	0.07	15.00
Peanut butter	400 g	2.78	0.00
Peanuts	200 g	2.63	66.70
Pineapple	1 small	0.14	13.30
Potatoes	1 kg	0.82	0.00
Pumpkin	1 kg	3.93	0.00
Rice	1 kg	0.66	20.00
Spaghetti	1 pack	1.07	0.00
Sweet potato	1 kg	3.60	48.30
Sweet potato leaves	900 g	0.07	76.70
Tomato	1 kg	1.31	30.00
White onion	1 kg	1.97	0.00

[a] Data retrieved from Hansen (2016).

available to purchase during the dry (hungry) season.

Three different income levels were used for each of the model scenarios (Urban Consumer, Rural Consumer, and Seasonal Urban Consumer) described above. The lowest annual income (Income #1) was attained from The World Bank (World Bank, 2018) and defined as the per capita income of the entire country. The next income level (Income #2) is the government minimum wage for the country for 2018. Lastly, the minimum wage at a private company in 2018 (Income #3) was used, which was the highest of the 3 incomes. Finally, the feasibility of each model was found by comparing the annual cost for a household given the constraints of each model to the three different income levels.

Results and Discussion

In the Urban Consumer model, the final cost per household (of 6.6 people) to obtain a diet that meets DRI of nutrients was estimated to be $2,852.09 annually. As shown in Table 3, the results from the Urban Consumer model consist of a diet that is made up of foods including milk, beans, fish, oil, and oranges.

The binding constraints in the Urban Consumer model include carbohydrates, vitamin C, vitamin D, calcium, iron, and calories. Food items high in vitamin C that are available in the area include cassava and bean leaves (which are only grown at home so are not included in the Urban Consumer or Seasonal Urban Consumer models), cabbage, cassava root, limes, potatoes, and Milo drink mix. The only foods which contain vitamin D are fish, Milo drink mix, eggs, and milk, which are all relatively expensive foods. Food items high in calcium include Milo drink mix, bean and cassava leaves, milk, beans, and cabbage. Foods high in iron include Milo drink mix, beans, and cassava leaves.

In the Rural Consumer model, the final annual cost to provide a nutritious diet for a household is $70.30 (Table 3), which is attainable for all three income groups analyzed in this study. The reduction in cost is associated with food grown at home supplementing market-bought food. This diet consists entirely of cassava leaves and fish (Table 3), as this is the least expensive way to meet DRI. This low price is because cassava leaves are grown at home and thus cost very little to attain.

Like the Urban Consumer model, the binding constraints for the Rural Consumer were vitamin D and calories. As stated earlier, foods high in vitamin D include fish, Milo drink mix, eggs, and milk. This model is affordable, requiring 8% to 17% of annual income, and covers most micronutrients.

Lastly, the Seasonal Urban Consumer model has the highest final cost at $2,913.91 annually (Table 3). This is due to the constraint of seasonality in foods, removing fruits from the market, thus removing low-cost sources of key vitamins and minerals. The Seasonal Urban Consumer model consists of milk, beans, cabbage, and fish (Table 3). The binding constraints are carbohydrates, vitamin C, and vitamin D.

The Seasonal Urban Consumer model is very similar to the Urban Consumer model; however, the Seasonal Urban Consumer does not have the binding constraints of calcium, iron, or calories that are present for the Urban Consumer. Because there are no fruits available in the Seasonal Urban Consumer model, it consists of more milk and beans than the Urban Consumer model, which addresses the constraints of calcium and iron. The Seasonal Urban Consumer model also introduces cabbage to meet micronutrients usually met by fruits.

In order to reduce the final cost of food for the year, the binding constraints were modeled as being supplemented (either through a NGO or a targeted government program), making it unnecessary to purchase these vitamins/minerals. Since vitamin D was binding in each model, it was removed from the models and reestimated to see how the optimal meal plan would change, both with regard to the food items and the associated final cost. This did not change the final price significantly, only changing the percentage of income spent on food by 1% in all three models. The most significant change came from supplementing

Table 2. Description and objectives of models (A, B, and C) used to represent different food and nutrition scenarios in which individuals may find themselves in Mozambique.

Model A Urban Consumer	Model B Rural Consumer	Model C Seasonal Urban Consumer
All food bought at the market	Food bought at the market and grown	All food bought at the market, no fruits
Minimize: total fat, saturated fat, sodium, cholesterol, carbohydrates	Minimize: total fat, saturated fat, sodium, cholesterol, carbohydrates	Minimize: total fat, saturated fat, sodium, cholesterol, carbohydrates
Maximize: fiber, protein, vitamin A, vitamin B12, vitamin C, vitamin D, iron, calcium, potassium, calories	Maximize: fiber, protein, vitamin A, vitamin B12, vitamin C, vitamin D, iron, calcium, potassium, calories	Maximize: fiber, protein, vitamin A, vitamin B12, vitamin C, vitamin D, iron, calcium, potassium, calories

calcium. This changed four scenarios (Urban Consumer, Income #2, Urban Consumer, Income #3, Seasonal Urban Consumer, Income #2, Seasonal Urban Consumer, Income #3) from not being feasible to being feasible, with the largest cost change (although still not feasible) in Seasonal Urban Consumer, Income #1, reducing the percentage of income spent on food from 682% to 140%. The differences in diet when calcium is supplemented is less milk and leafy greens are consumed, and more oil, cassava root, and maize flour are consumed. Milo, which is widely available across Africa, is a powdered drink mix that is high in protein, vitamin B12, vitamin C, vitamin D, iron, and calcium. It is shelf-stable, and dense in calories and nutrients, making it ideal for transportation. A government subsidy or cost reduction by the company that produces Milo for those at risk of undernutrition, mainly children and pregnant women, would be beneficial. Another similar option would be subsidizing fortified ready-to-eat cereals and/

Table 3. The number of servings of each food item in the Urban, Rural, and Seasonal Urban Consumer models (A, B, C, respectively) and final annual price per household (HH).

Food Item	Model A Serving	Model B Serving	Model C Serving
2% milk	0.64		1.35
Apple			
Banana			
Bean	0.34		0.94
Bean leaves			
Cabbage			0.26
Cassava root			
Cassava leaves		9.65	
Chicken			
Cucumber			
Eggs			
Fish	0.1	0.1	0.1
Green bell pepper			
Large roll			
Lettuce head			
Limes			
Maize flour			
Milo drink			
Oil (rapeseed)	0.08		
Orange	19.34		
Peanut butter			
Peanuts			
Pineapple			
Potatoes			
Pumpkin			
Rice			
Spaghetti			
Sweet potato			
Sweet potato leaves			
Tomato			
White onion			
	Model A	**Model B**	**Model C**
Final Annual Price/HH	$2,852.09	$70.30	$2,913.91

or bread, both of which are already eaten in urban areas. More relevant to rural areas would be the introduction and/or increase in production of crops that are high in calcium, such as spinach, kale, collard greens, and similar dark leafy greens.

Conclusions

Households growing their own food were able to meet their DRI in a much more cost-effective manner than those that did not. The largest reduction in the annual cost per household came from supplementation of calcium, which changed the feasibility of four scenarios from being not possible to being possible to meet their DRI with their annual income. Further research into identifying food items that are high in calcium that could be produced in the country in an economically efficient manner, especially for those living in urban areas, would have the largest impact on those living in Mozambique.

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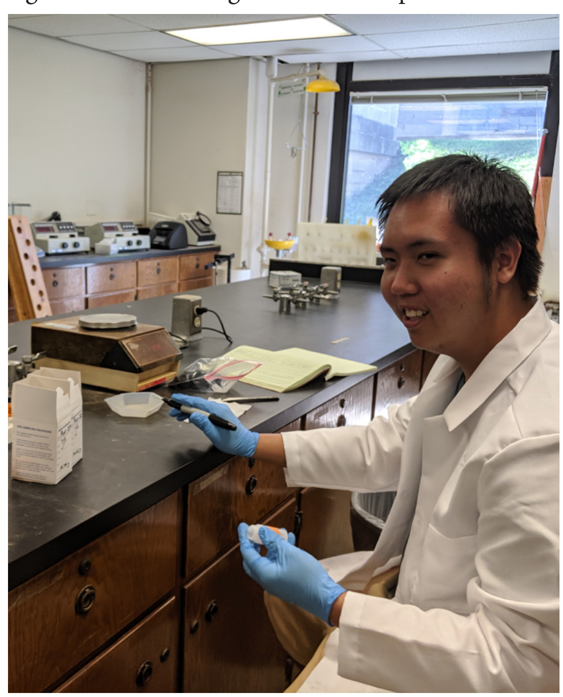
Decomposition in pasture soil receiving excreta from ruminants fed alfalfa forage diet supplemented with increasing proportions of Sericea Lespedeza legume

Meet the Student-Author

Yang Kai Tang

My country of origin, Malaysia, is situated near the equator where the Malaysian peninsular is protected from storms and tsunamis from the Indian Ocean by the Indonesian archipelago. The predictable tropical climate also allows for tropical rainforests and mangrove swamps to flourish. Malaysia's biodiversity of tropical rainforests is unparalleled, with wetlands being the only other biome that can compare in terms of biodiversity. Before attending the University of Arkansas, I had always thought of the soil as only being the ground that supports our weight and as a growth medium for plants and trees. Through specific classes that I have taken at the University of Arkansas, I learned how important soil is to sustain and support life on Earth, as food and water are essential to human survival. The professors at the University of Arkansas taught me the interconnectedness of soil with water quality, greenhouse gas emissions, and human survivability. These experiences, coupled with the opportunity to start an undergraduate research project under Dr. Mary Savin, allowed me to learn more about being an environmental and soil scientist and gain hands-on research experience. I would like to thank Dr. Mary Savin, my mentor, for guiding me throughout this research project, and Dr. Dirk Philipp for his help and support. I would also like to thank Samuel Park and Mason Downing for assisting me with collecting data for the experiment.



Yang in the soil lab of the Crop, Soil, and Environmental Sciences department preparing soil samples for pH and electrical conductivity analysis.

Research at a Glance

- Stabilization of organic matter helps build organic matter and contributes to healthy soil.
- The Tea Bag Index provides an easy and cost-effective method for evaluating the rate of decomposition and stabilization to compare treatments.
- Addition of a legume-containing polyphenolic compound into ruminant diets did not appear to have an impact on the decomposition or stabilization of organic matter in soil.

Decomposition in pasture soil receiving excreta from ruminants fed alfalfa forage diet supplemented with increasing proportions of Sericea Lespedeza legume

Yang Kai Tang, Mary C. Savin,† Dirk Philipp,§ Ken Coffey,‡ and Jiangchao Zhao¶*

Abstract

Healthy soil is fundamental to a productive pasture system as it will decompose labile organic matter and promote retention of carbon to build a stable, resistant pool of organic matter. An easy, standardized approach to measure decomposition and litter stabilization that is gaining popularity in both citizen science and research studies is the use of the Tea Bag Index. The Tea Bag Index is a relatively new method evaluating the loss of organic material in two different kinds of commercial tea bags (green tea and Rooibos tea) after burial in the soil for 90 days. The objective of this experiment was to use the Tea Bag Index to determine if decomposition rate and litter stabilization were affected by inputs of excreta from ruminants fed alfalfa forage diets modified with 0%, 9%, 18%, or 27% of the tannin-containing legume sericea lespedeza, urea, or an untreated negative control in soil plots (n = 4). There was no difference in decomposition rate or litter stabilization among any treatments measured in the 8 cm of surface soil during the first spring growing season after treatment application of excreta or urea to the soil. Results of this experiment indicated that animal amendments simulating urine and manure patches did not result in detectable changes in organic matter decomposition during the first spring season after application to silt loam pasture soil growing tall fescue grass in the mid-South.

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Introduction

Organic matter comprises a variety of compounds of unspecific chemical composition that are made up of the partial breakdown products of plant and animal materials that are re-synthesized into new compounds of varying stability (Brady and Weil, 2017). Decomposition is carried out primarily by the biological community. Partial decomposition can be followed by humus synthesis to stabilize and accumulate organic matter contributing to soil's ability to sequester carbon. Carbon sequestration is a viable and cost-effective option to reduce the impacts of rising levels of greenhouse gas emissions on the global climate (Minasny et al., 2017). Organic matter is essential for healthy soil as organic matter provides many benefits to the soil. Organic matter reduces bulk density by providing increased porosity, stores water, increases the cation exchange capacity, serves as a nutrient reservoir, improves soil structure, and acts as a carbon sink.

Decomposition is an integral part of the carbon cycle. The Tea Bag Index was developed as a cost-effective, simple-to-execute, practical, and standardized method of measuring decomposition rate and litter stabilization in soil (Keuskamp et al., 2013). The Tea Bag Index uses green (*Camellia sinensis* [Sweet.] Robert) and Rooibos (*Aspalathus linearis* [Burm.f.] R. Dahlgren) teas that differ in composition and thus decomposition rate in order to measure decomposition rate and a stabilization factor and to function as an indicator for litter decomposition in soil. Green tea decomposes rapidly and can be used to calculate stabilization as it represents the simpler organic compounds of the two teas (Keuskamp et al., 2013). Rooibos tea has a slower decomposition rate and will continue decomposing over the length of the proposed study and can be used to determine the decomposition rate of organic matter due to the increased complex organic compound content that will be humified (90 days, Keuskamp et al., 2013). The Tea Bag Index method is used as a substitute for litterbag studies. The commercially sold products consist of tea leaves wrapped in a porous bag with a mesh size of 0.25 mm that is made out of non-degradable material (Keuskamp et al., 2013). The mesh size allows microorganisms, microfauna, and small mesofauna but prevents macrofauna from entering the teabag (Setälä et al., 1996). Tea leaves are a good substitute for plant litter because the sources for much of the organic inputs into the soil are from plants.

The objective of this research project was to determine if inputs of urine or manure from sheep fed diets of alfalfa forage containing 0%, 9%, 18%, or 27% polyphenolic compound containing legume sericea lespedeza [*Lespedeza cuneata* (Dum. Cours.) G.] changed decomposition rate and organic matter stabilization in pasture soil growing tall fescue (*Lolium arundinaceum* [Schreb.] Darbysh). The decomposition rate was hypoth-esized to increase in the treatments receiving sheep urine and manure compared to the negative control. The treatments receiving manure from sheep fed with a diet containing increasing concentration of the tannin-containing legume were expected to decompose at a slower rate with greater litter stabilization compared to soil with manure input from sheep fed with alfalfa or compared to the urea positive control. The tannin and other polyphenolic compounds in the alternative legume diet were anticipated to result in greater retention of nitrogen in the animal and in organic compounds in manure rather than being in urine, thus slowing decomposition rates and facilitating retention (i.e., stabilization) into soil organic matter.

Materials and Methods

Treatments were applied to the soil surface of 40 1-m^2 pasture plots growing tall fescue on 6 November 2018. The 10 treatments were applied in a randomized block design with each treatment replicated 4 times. Treatments consisted of either urine or manure from sheep fed one of four diets: 100% alfalfa silage, or alfalfa with 9%, 18%, or 27% sericea lespedeza on a dry matter basis. Urea fertilizer was the positive control, and the negative control was untreated. Amendments applied were equivalent to 60 g N/m^2 for urea and urine treatments. The soil application rates for the respective 0%, 9%, 18%, and 27% sericea lespedeza percentages in the diet were equivalent to 50.7, 40.8, 44.7 g, or 45.4 g N/m^2, respectively, for the four manure treatments.

Litter decomposition rate and stabilization factor were calculated based on loss of mass in green and Roobios tea bags over 90 days following the protocol for the Tea Bag Index from Keuskamp et al. (2013). Four pairs of tea bags per plot were buried on 12 April 2019 to decompose for 90 days. In this experiment, decomposition was measured from April to July 2019, 5 to 8 months following the application of animal excreta or urea to the soil surface.

A soil sample was collected at the end of the study from the top 5 cm of each plot using a 6-cm diameter bulk density core, dried at 55 °C for 7 days, and used to determine bulk density. A pH and electrical conductivity (EC) probe and calibrated meters were used to measure pH and EC on 1:2 soil water (wt:vol) ratio subsamples from the bulk density soils. Soil organic matter (OM) was determined by loss-on- loss-on-ignition after grinding a subsample with a pestle and mortar, sieving through a mesh with a pore size of 2 mm, and further drying at 105 °C for 24 hours before combusting in a furnace at 450 °C for 4 hours.

Averages and standard errors for pH, EC, OM content, stabilization factor, and decomposition rate were calculated per treatment. Treatment effects were analyzed by analysis of variance (ANOVA) or Kruskal-Walis ANOVA on Ranks if data were not normally distributed. Significance was evaluated at an alpha value of 0.05.

Results and Discussion

Decomposition rate (k d^{-1}) was not different among treatments (*P* = 0.23, Fig. 1). The average decomposition rate at the study site was 0.018 d^{-1}, which was the same decomposition rate measured from 5 February to 18 April 2019 in a green roof in Fayetteville, Arkansas using the same method (LaSalle, 2019). Another tea bag index study conducted on cattle grazed grasslands in the Netherlands measured decomposition rates of 0.0158 and 0.0165 d^{-1}, which were similar to the average rate of this study (Iepema et al., 2015). The stabilization fractions of the 10 treatments were also not statistically different (*P* = 0.32, Fig. 2).

Although the ANOVA results indicated that there was a significant difference, soil pH was not different between any treatments after a Tukey's honestly significant difference test (Table 1). Microbial decomposers break down organic material and produce enzymes important in nutrient cycle processes. Soil pH is an important factor in microbial activity as all microbes have an optimum pH range at which they are most active. The ratio of bacteria-to-fungi may become unbalanced if soil pH either decreases or increases outside of optimal ranges. Bacteria tend to favor neutral soil environments, while fungi prefer more acidic soil environments. However, the treatments did not have an impact on decomposition as rate and stabilization factors were not different between treatments.

Organic matter (*P* = 0.38; Table 1), total nitrogen (*P* = 0.41; data not shown) and total carbon (*P* = 0.2; data not shown), EC (*P* = 0.56; Table 1), and bulk density (*P* = 0.46; Table 1) also were not significantly different between treatments. Inputs of OM will provide soil microbes with a fresh supply of organic carbon. Greater amounts of simple organic compounds will decompose rapidly as microbial enzymes act quickly and contribute to increased decomposition rates of OM. However, decomposition and stabilization were not affected by total OM. In future studies, particulate OM should be measured as it represents the labile fraction of total OM and may assist in determining a relationship with decomposition and stabilization rate. The carbon-to-nitrogen (C:N) ratio is another important factor in the decomposition rate because nitrogen is required by microbes to synthesize proteins and grow, and carbon serves as a food source. Although the sheep excreta and urea amendments served as a source

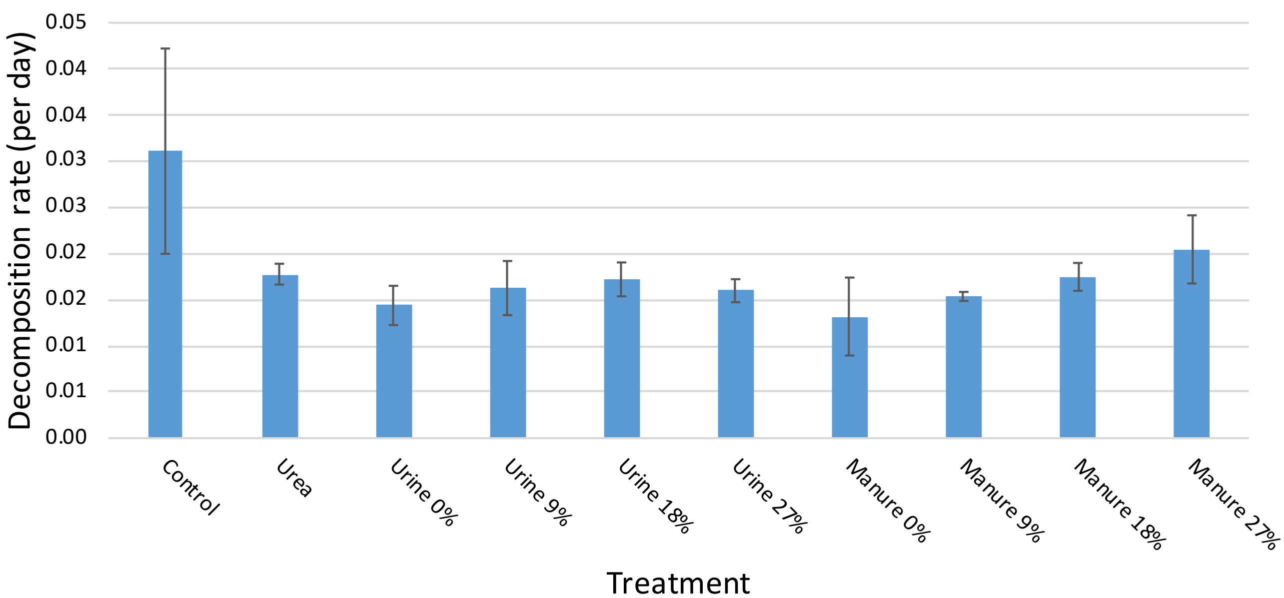

Fig. 1. Decomposition rate in soil pasture plots growing tall fescue five to eight months following application of urine or manure treatments from sheep fed a modified alfalfa-based diet or following application of a control (n = 4). The negative control was unamended, and urea was the positive control. Urine was from sheep fed alfalfa supplemented with 0%, 9%, 18%, and 27% sericea lespedeza, and manure was from sheep fed alfalfa supplemented with 0%, 9%, 18%, and 27% sericea lespedeza. The % behind the treatments represents the content of polyphenolic compounds in sheep diet.

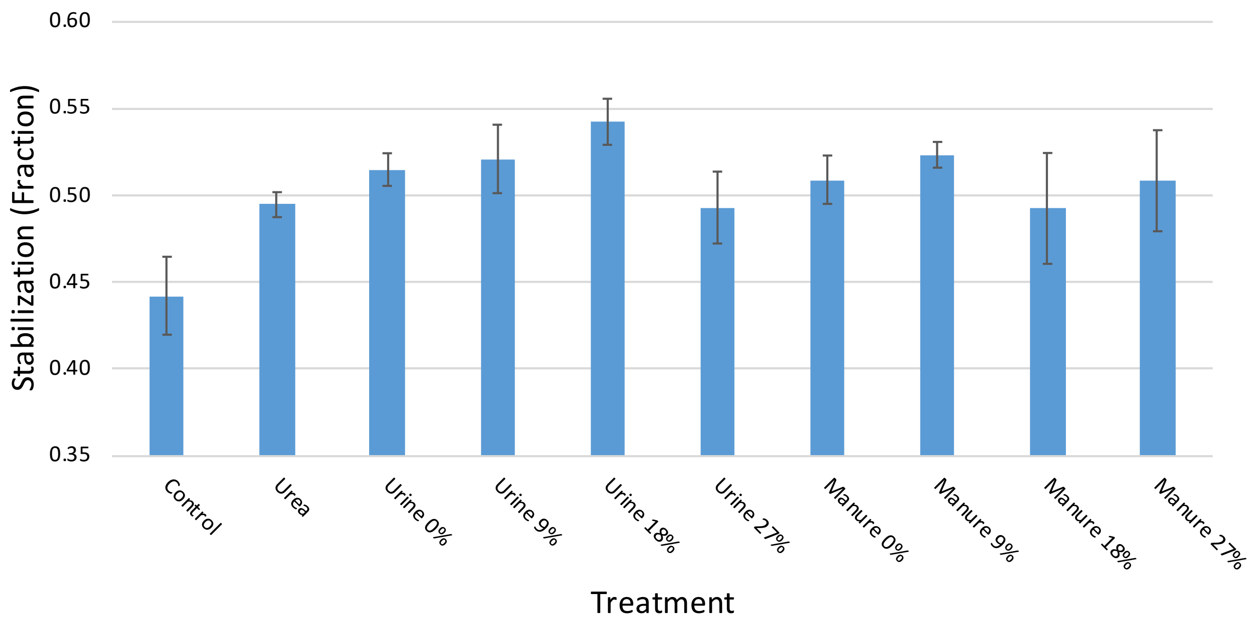

Fig. 2. Stabilization fraction in soil pasture plots growing tall fescue five to eight months following application of urine or manure treatments from sheep fed a modified alfalfa-based diet or following application of a control (n = 4). The negative control was unamended, and urea was the positive control. Urine was from sheep fed alfalfa supplemented with 0%, 9%, 18%, and 27% sericea lespedeza, and manure was from sheep fed alfalfa supplemented with 0%, 9%, 18%, and 27% sericea lespedeza. The % behind the treatments represents the content of polyphenolic compounds in sheep diet.

Table 1. Average (standard error) electrical conductivity, soil pH, total organic matter, and bulk density from soil in tall fescue pasture plots following application of urine or manure from sheep fed a modified alfalfa-based diet or in a control (n = 4).

Treatment	Electrical conductivity (μS cm^{-1})	Soil pH	Organic matter (%)	Bulk density (g/cm^3)
Negative Control[a]	233.0 (69.5)	5.5 (0.2)	3.73 (0.15)	1.62 (0.04)
Urea	218.1 (33.7)	6.1 (0.2)	4.00 (0.31)	1.54 (0.04)
Urine, 0%[b]	192.2 (19.6)	6.1 (0.0)	4.23 (0.19)	1.51 (0.06)
Urine, 9%	186.7 (26.7)	5.9 (0.1)	3.95 (0.39)	1.53 (0.04)
Urine, 18%	279.5 (44.8)	6.3 (0.2)	3.68 (0.14)	1.61 (0.07)
Urine, 27%	157.9 (30.6)	5.3 (0.1)	3.75 (0.34)	1.61 (0.08)
Manure, 0%	228.7 (26.4)	6.3 (0.2)	4.00 (0.29)	1.52 (0.04)
Manure, 9%	223.9 (47.8)	6.3 (0.2)	4.00 (0.33)	1.63 (0.09)
Manure, 18%	191.2 (11.5)	6.3 (0.3)	4.03 (0.40)	1.48 (0.04)
Manure, 27%	182.4 (22.2)	6.0 (0.3)	4.75 (0.24)	1.47 (0.09)

[a] The negative control was unamended, urea was the positive control, urine was from sheep fed alfalfa supplemented with 0%, 9%, 18%, and 27% *sericea lespedeza*, and manure was from sheep fed alfalfa supplemented with 0%, 9%, 18%, and 27% *sericea lespedeza*.

[b] The % behind the treatments represents the content of polyphenolic compounds in sheep diet.

of nitrogen, decomposition rate, and stabilization of the teas were not affected. This could be due to the rapid usage of nitrogen immediately after the amendments were added to the soil, whereas this study was conducted five to eight months after the addition of excreta and urea. Thus, it is possible that the timing of measurements did not capture alterations in the decomposition and changes in the soil properties. Alternatively, the use of tea bags may not have captured the impact inputs had on soil properties and processes.

Electrical conductivity provides a general measurement of salinity that relates to nutrient availability in soil. Salts are important for biochemicals and processes; however, salinity that is too high can hinder activity, which then affects OM decomposition rate and stabilization (NRCS, 2014). Although EC did not affect OM decomposition rate and stabilization, in future studies, further analysis of specific ion contents in the soil may reveal more definitive relationships with OM decomposition rate and stabilization, since EC provides only a general overview of salinity in soil. Soil bulk density in the surface 5 cm of the study site was slightly greater than that of a "typical" bulk density of 1.33 g/cm^3 in a medium-textured soil with 50% pore space, but this was not unexpected given that the plots were in a pasture impacted previously by cattle grazing and machinery (NRCS, 2008).

Conclusions

There were no significant differences in decomposition rate and stabilization of teabag litter buried in the soil of pasture plots receiving excreta of sheep fed diets modified to increase N retention in the animal and alter N decomposition and forms present in the urine and manure. If the diets had an effect on ruminant digestion and excretion of compounds, this did not impact decomposition rate or litter stabilization in the soil five to eight months after receiving input of excreta. These results indicate that diet modification incorporating sericea lespedeza may not alter soil carbon cycling in the first spring season after application to the silt loam soil surface growing tall fescue. Other soil processes and properties related to soil quality, such as N retention within the soil profile, may deserve further investigation to determine the impacts of excreta inputs from the animals fed diets modified with tannin-containing compounds.

Acknowledgments

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Corn response to wastewater-recycled phosphorus fertilizers

Meet the Student-Author

Shane Ylagan

I am from The Woodlands, Texas, and I graduated from The Woodlands High School in 2017. I will graduate from the Dale Bumpers College of Agriculture, Food, and Life Science with honors and a B.S. in Environmental, Soil, and Water Science with a minor in Sustainability. This project was funded by the University of Arkansas Honors College with an Honors College research grant not only in order to conduct this study but also to present the results at the 2019 Arkansas Water Resources Center Annual Water Conference.

It was not until my sophomore year when I took Introduction to Soil Science and Soil Profile Description with Dr. David Miller and Dr. Kristofor Brye, where I found my passion for Soil Science. I have been a part of the University of Arkansas soil profile description team ever since my sophomore year, where the team placed first in the 2018 Region IV Collegiate Soils Contest. Additionally, I have held two hourly research positions in the Crop, Soil, and Environmental Sciences Department dealing with soil incubation and phytoremediation studies.

I would like to thank my mentor and professor, Dr. Kristofor Brye, whose help and teachings have been not only been essential in the success of this research, but also in my success as an individual. I would also like to state my appreciation to Dr. David Miller, Dr. Lisa Wood, and Ryder Anderson for their continuous help and judgment.

Research at a Glance

- How soil or plants respond to electrochemically precipitated struvite (ECST) has not been evaluated.
- Data are needed to determine how ECST compares to common phosphorus (P) and other struvite fertilizers.
- ECST had at least similar, if not larger, plant and soil responses in corn to other common P and struvite fertilizers.

Shane overturning and mixing the field soil to air-dry at the University of Arkansas System Division of Agriculture's Rosen Alternative Pest Control Center.

Corn response to wastewater-recycled phosphorus fertilizers

Shane R. Ylagan and Kristofor R. Brye†*

Abstract

The ability to recycle phosphorus (P) from wastewaters could provide a sustainable, continuous source of P that might also help protect surface water quality from P enrichment. The mineral struvite ($MgNH_4PO_4 \cdot 6H_2O$) is an understudied material that can be created from P- and nitrogen (N)-containing wastewater and has been shown to have agricultural fertilizer value. The objective of this study was to evaluate the effects of electrochemically precipitated struvite (ECST), chemically precipitated struvite (Crystal Green; CG), diammonium phosphate (DAP), monoammonium phosphate (MAP), rock phosphate (RP), and triple superphosphate (TSP) on corn (*Zea mays*) response in a greenhouse pot study. The effects of fertilizer treatment on select plant properties were evaluated. Corn plant properties and elemental tissue concentrations differed ($P < 0.05$) among fertilizer amendments. Belowground dry matter from ECST was 1.9 times greater than that from CG, TSP, DAP, and the No P/+N, and No P/-N control treatments. Corn cob-plus-husk tissue P concentration from ECST was similar to that from MAP and DAP and was 1.2 times larger than that from CG. Corn stem-plus-leaves tissue P concentration from ECST differed from that from all other treatments and was 1.8 times greater than that from the No P/+N control. Results generated from this study not only provide information on the new, thus understudied, electrochemically precipitated struvite material, but also further demonstrate why more research should be conducted on the implementation of struvite as an alternative fertilizer-P source and struvite's potential impact on sustainable food production and the preservation of water resources.

* Shane R. Ylagan is a December 2020 honors program graduate with a major in Environmental, Soil, and Water Science and a minor in Sustainability.
† Kristofor R. Brye, the faculty co-mentor, is a Professor in the Department of Crop, Soil, and Environmental Sciences.

Introduction

Phosphorus (P) has been historically considered a nonrenewable resource that is a crucial nutrient for all life and sustains worldwide food production (Ashley et al., 2011). Phosphorus is obtained by mining phosphate-containing rock, also called rock phosphate (RP), where peak production has the potential to be reached in the next 50 years (Cordell et al., 2009; Filippelli, 2011). The combination of increasing preference for meat diets, global population growth, P demand, and P-fertilizer price with diminished quantity and quality of RP sources has the potential to severely affect the world's food supply and the world's economic, political, and social relations (Jarvie et al., 2015; Talboys et al., 2015).

Another complicating factor is that P has become a contaminant in many natural surface water sources from excessive fertilizer application, agricultural runoff containing excessive amounts of soluble and sediment-bound P from agriculturally dominated watersheds, and also from wastewater treatment plant (WWTP) effluent that contains excessive quantities of nutrients, namely P. Excess P in surface waters has been linked to eutrophication and the creation of hypoxic zones in freshwater and coastal marine environments (Hallas et al., 2019; Liu et al., 2012). The accelerating decline of RP reserves and the degradation of aquatic ecosystem health are both daunting issues that are only going to continue to grow, but there could be a solution.

The mineral struvite ($MgNH_4PO_4 \cdot 6H_2O$) is currently being studied as a potential P fertilizer. Struvite is an efficient, slow-release P source that can be recovered as a crystalline precipitate through recycling P from a variety of wastewater sources (Rahman et al., 2014). Consequently, struvite is an example of a wastewater-recycled P fertilizer that has the potential to be multi-beneficial. Crop producers who apply struvite as a fertilizer P source have the potential to not only maintain, or even increase, optimal crop yields while reducing fertilizer application rates, but also decrease the quantity of P that is lost in runoff due to struvite's slow-release characteristic (Massey et al., 2009; Talboys et al., 2015).

In order to provide more information on the possible benefits of struvite as a fertilizer-P source, a greenhouse potted-plant experiment was conducted. The objective of the study was to assess corn response to P fertilization with two wastewater-recovered struvite sources (i.e., chemically precipitated and electrochemically precipitated) and to compare corn response to that produced by other commonly used P fertilizers in an agriculturally managed silt-loam soil. It was hypothesized that corn plants amended with either struvite source would have an equal or even greater response to P fertilization than the plants that were treated with the conventional P fertilizers.

Materials and Methods

Soil Collection, Processing, and Initial Characterization

The soil used in this greenhouse study was a Captina silt-loam (Typic Fragiudults; Soil Survey Staff, 2017) that was collected from a field (36°05'47"N 94°09'58"W) at the Milo J. Shult Agricultural Research and Extension Center in Fayetteville, Arkansas, that had been under cultivated soybean production for at least several years prior. Ten, 18.9-L buckets of soil were manually collected on 18 February 2019 from the top 10 to 15 cm, transported to a greenhouse, and air-dried.

Five random subsamples of soil were collected while air-drying, oven-dried at 70 °C for 48 hours, mechanically ground, and sieved through a 2-mm mesh screen prior to soil physical and chemical property determinations, including percent sand, silt, and clay; soil pH; electrical conductivity (EC); soil organic matter (SOM); total soil N and C; and water-soluble and Mehlich-3 extractable (i.e., P, K, Ca, Mg, S, Na, Fe, Mn, Zn, Cu, and B) concentrations.

Fertilizer Treatments

Eight treatments were evaluated in this study, which included: 1) an electrochemically precipitated struvite (ECST), 2) Crystal Green (CG), a chemically precipitated struvite, 3) triple superphosphate (TSP), 4) monoammonium phosphate (MAP), 5) diammonium phosphate (DAP), 6) rock phosphate (RP; Fig. 1), 7) an unamended control that did not have added P, but had added N (No P/+N), and 8) an unamended control without added P or N (No P/-N).

This study included two different types of struvite material. Crystal Green is a chemically precipitated struvite material that was produced from a large municipal wastewater treatment plant near Atlanta, Georgia, and is commercially produced and sold by Ostara Nutrient Recovery Technologies Inc. (Fig. 1). The second struvite source was produced by researchers in the Department of Chemical Engineering at the University of Arkansas, Fayetteville, via electrochemical precipitation from synthetically made wastewater (Fig. 1).

The initial Mehlich-3 soil-test-P concentration corresponded to a P_2O5 recommendation for corn of 84.1 kg P_2O_5/ha, which equated to 36.6 kg P/ha for a yield goal of 11 Mg/ha (Espinoza and Ross, 2008). Since each P fertilizer also had a different N concentration, the corresponding amount of N was added to all treatments (except the No P/-N control) in the form of urea (46% N) in order to match the N concentration of DAP (Table 1).

Pot Preparation

Plastic, 6,435 cm^3, injection-molded nursery containers (Item # CN-NCIM/600 series, Pro Cal, South Gate, Cali-

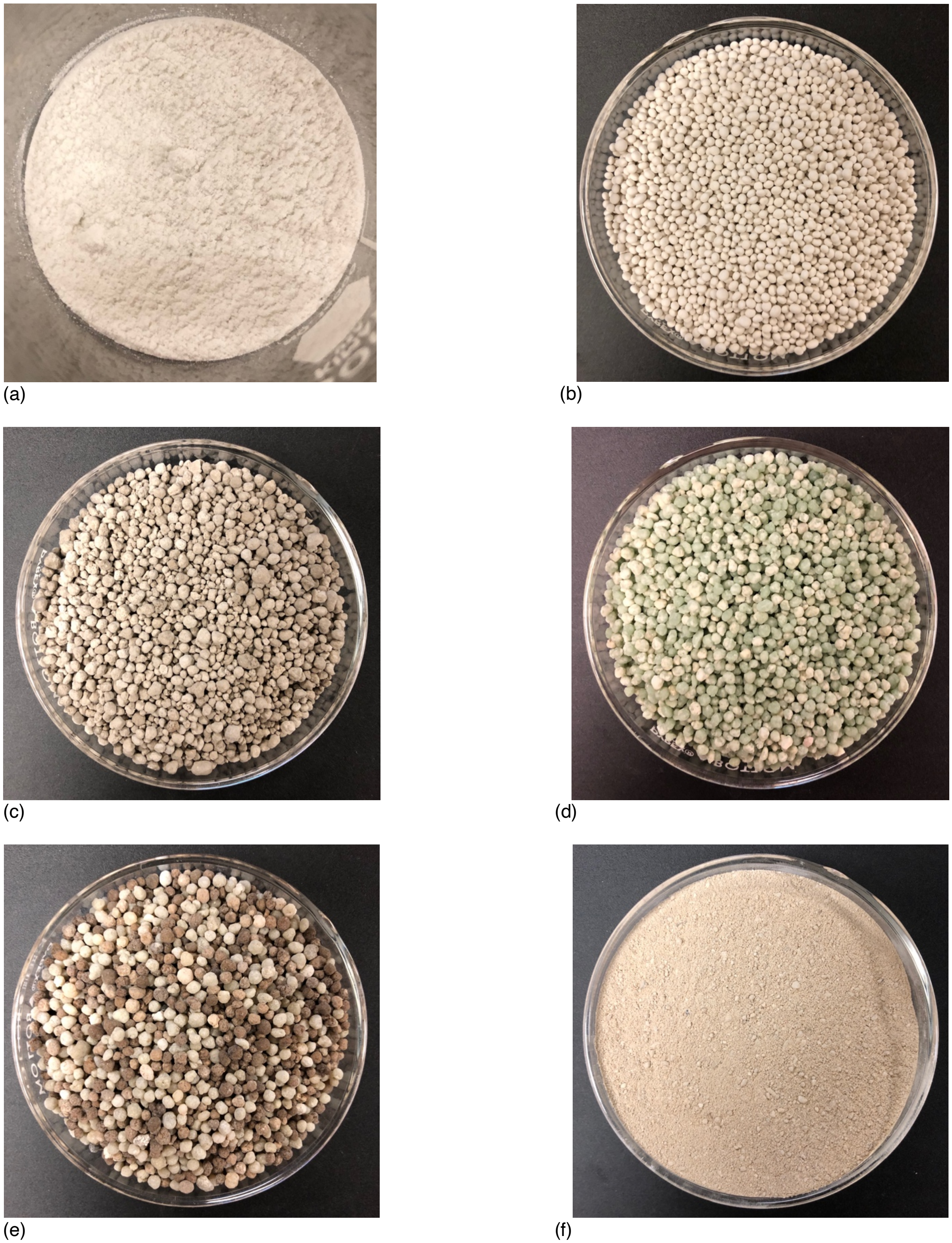

Fig. 1. The physical appearance of electrochemically precipitated struvite (a), Crystal Green struvite (b), triple superphosphate (c), monoammonium phosphate (d), diammonium phosphate (e), and rock phosphate (f).

fornia) that were 21.3 cm tall and 22.9 cm in diameter were used for this study. The pots were prepared by premixing air-dried soil and the fertilizers before the soil was added to the pots to simulate the common field practice of fertilizer incorporation by tillage.

In order to bring the air-dried soil in each pot to field moisture capacity (~26.1% v/v) initially, 684 mL of water was required. However, the target volumetric water content (VWC) range was chosen between 24% and 26% (v/v). The following day, three seeds were planted in all 24 corn pots, and the pots were randomized on a greenhouse bench. After about 10 days, the number of plants in each pot was cut back to one.

Pot Management

Three times a week, the VWC in the top 6 cm of soil in three randomly selected pots was measured using a soil moisture meter to assess the volume of water needed to be added to return the soil in the pot to the target VWC range. Furthermore, additional N in the form of urea (46% N) was applied to all of the corn P-fertilizer treatments (excluding the No P/-N control) on 5 June 2019, 40 days after planting, as the recommended mid-season N application at a field-equivalent rate of 266 kg N/ha for corn (Table 1; Espinoza and Ross, 2008).

Pot Deconstruction

The experiment was terminated on the 79th day, 15 July 2019 (Fig. 2). Each corn pot was manually deconstructivity sampled, separating the plant into belowground, cob-plus-husk, and stem-plus-leaves portions for dry matter and elemental tissue P concentration determinations. The separated plant portions from each pot were oven-dried at 66.6 °C for five days and then weighed for dry matter determinations. Subsamples were then taken from each plant tissue portion and were mechanically ground to 2 mm to determine tissue P concentrations by acid digestion (USEPA, 1996) followed by inductively coupled plasma optical emission spectrometry (ICAP-OES) (Soltanpour et al., 1996).

Statistical Analyses

Based on a completely randomized experimental design, a one-factor analysis of variance (ANOVA) was conducted with SAS 9.4 (SAS Institute, Inc., Cary, N.C.) using the PROC GLIMMIX procedure to evaluate the effect of the fertilizer treatment on plant response. Treatment means were separated by a least significant difference test at the alpha level of 0.05. Significance was judged at $P < 0.05$.

Results and Discussion

Plant Properties

All measured corn plant properties differed ($P < 0.05$) among P-fertilizer treatments (Table 2). Corn stem-plus-leaves dry matter was numerically largest from TSP, which did not differ from that in the DAP, ECST, RP, MAP, and No P/+N control treatments. Stem-plus-leaves dry matter from the No P/-N control treatment was numerically smallest among all treatments. Stem-plus-leaves dry matter from the two struvite treatments (ECST and CG) did not differ from each other, and both were similar to that from the RP, MAP, and No P/+N control treatments. The mean stem-plus-leaves dry matter from TSP and DAP, which did not differ, was 1.3 times larger than that from the No P/-N control treatment.

Corn cob-plus-husk dry matter was numerically largest from CG, which was similar to that in the ECST treatment, and both did not differ from that in the TSP, MAP, RP, DAP, and No P/+N control treatments (Table 2). Cob-plus-husk dry matter from the No P/-N control treatment was numerically smallest among all treatments. The cob-

Table 1. Summary of the fertilizer grade and nitrogen (N), phosphorus (P), and magnesium (Mg) concentrations of each fertilizer-nutrient source used in the greenhouse pot experiment (i.e., ECST, CG, TSP, MAP, DAP, RP, and urea).

		Nutrient Concentration (%)		
Fertilizer	Fertilizer Grade	N	P	Mg
ECST†	9-52-0	9.3	22.8	5.7
CG	6-27-0	5.7	11.7	8.3
TSP	0-41-0	0.0	18.2	0.6
MAP	11-48-0	11.0	20.9	1.5
DAP	18-42-0	18.1	18.3	0.7
RP	0-17-0	0.0	7.6	0.3
Urea	46-0-0	46.0	0.0	0.0

† Electrochemically precipitated struvite (ECST), Crystal Green (CG), triple superphosphate (TSP), monoammonium phosphate (MAP), diammonium phosphate (DAP), and rock phosphate (RP).

Fig. 2. The first repetition of corn fertilizer treatments at 2 (top), 6 (middle), and 11 (bottom) weeks after planting. Treatment order (left to right): 1) unamended control without added P or N (No P/-N), 2) unamended control that did not have added P, but had added N (No P/+N), 3) triple superphosphate (TSP), 4) monoammonium phosphate (MAP), 5) diammonium phosphate (DAP), 6) rock phosphate (RP), 7) Crystal Green (CG), and 8) electrochemically precipitated struvite (ECST).

plus-husk dry matter from the ECST, CG, TSP, MAP, DAP, RP, and the No P/+N control treatments, which did not differ, was 3.9 times larger than that from the No P/-N control treatment.

Belowground corn dry matter was numerically largest from ECST, which did not differ from that in the RP treatment (Table 2). Both ECST and RP were applied as powder forms, thus having larger surface areas to react with the soil and water compared to fertilizers in pellet forms, and root-excreted organic acids could have helped solubilize RP, which in turn, could have increased concentrations of plant-available P to increase dry matter production in the various plant parts (Oburger et al., 2011). Belowground corn dry matter was numerically smallest from the No P/-N control, which did not differ from that in the MAP, TSP, DAP, CG, and No P/+N control treatments. Belowground corn dry matter from both struvite treatments (ECST and CG) differed from each other, and CG did not differ from TSP, MAP, DAP, and both control treatments (No P/+N and No P/-N). Additionally, belowground corn dry matter from the ECST treatment was 2.0 times greater than that from CG, and ECST was also 1.9 times greater than that from the CG, TSP, DAP, and both control (No P/+N and No P/-N) treatments, which did not differ.

Tissue Properties

Corn tissue P concentrations (Table 3) differed ($P < 0.05$) among P-fertilizer treatments. Corn belowground tissue P concentration was numerically largest from CG and DAP, which did not differ from that in the TSP and MAP treatments. Belowground tissue P concentration was numerically smallest from the No P/-N control treatment, which was similar to that in the ECST, RP, and the No P/+N control treatments. Furthermore, corn belowground tissue P concentrations from CG was 1.4 times larger than that from the ECST treatment. Slower dissolution of the CG pellet material may have kept the P in the active root zone, whereas more rapid dissolution of the crystalline ECST material may have allowed P to move away from the active root zone in the pot and become somewhat less available to active roots. The mean belowground tissue P concentration from CG, TSP, MAP, and DAP, which did not differ, was 1.4 times greater than that from ECST, RP, and both control (No P/+N and No P/-N) treatments, which did not differ.

Corn cob-plus-husk tissue P concentration (Table 3) was numerically largest from ECST, which did not differ from that in the MAP, DAP, and the No P/-N control treatments. Cob-plus-husk tissue P concentration was numerically smallest from the No P/+N control, which was similar to the CG, TSP, and RP treatments. Cob-plus-husk tissue P concentrations from ECST was 1.2 times larger than that from CG. The ECST-P was derived from a synthetic rather than an actual wastewater, as was the CG-P. It is possible that the CG-P had additional associated compounds or complexes that rendered the P somewhat less mobile once in the plant than the relatively cleaner ECST-P. Cob-plus-husk tissue P concentration from CG did not differ from that in the TSP, MAP, DAP, RP, and the No P/+N and No P/-N control treatments. The cob-plus-husk tissue P concentration from ECST was 1.4 times larger than that from the No P/+N control treatment.

Table 2. Summary of the effects of fertilizer amendment on corn belowground, cob-plus-husk, and stem-plus-leaves tissue dry matter.

Treatment	Corn Tissue P Elemental Concentrations: Belowground Dry Matter	Cob-plus-Husk Dry Matter	Stem-Plus-Leaves Dry Matter
	----------g----------		
ECST†	28.7 a‡	11.1 a	35.8 ab
CG	14.1 c	13.4 a	33.8 b
TSP	15.4 c	13.2 a	37.7 a
MAP	16.6 bc	12.4 a	35.5 ab
DAP	15.1 c	11.6 a	36.7 a
RP	24.9 ab	12.3 a	35.8 ab
No P/+N	15.3 c	11.9 a	35.4 ab
No P/-N	13.9 c	3.14 b	27.7 c
P-value	**0.03**§	**< 0.01**	**< 0.01**

† Electrochemically precipitated struvite (ECST), Crystal Green (CG), triple superphosphate (TSP), monoammonium phosphate (MAP), diammonium phosphate (DAP), rock phosphate (RP), unamended control that did not have added P, but had added N (No P/+N), and unamended control without added P or N (No P/-N).

‡ Means in a column with different letters are different at $P < 0.05$.

§ Bolded values are significant at $P < 0.05$.

Corn stem-plus-leaves tissue P concentration (Table 3) was numerically largest from ECST, which differed from all other treatments. Stem-plus-leaves tissue P concentration was numerically smallest from the No P/+N control, which differed from all other treatments. Stem-plus-leaves tissue P concentration from both struvite treatments (ECST and CG) differed from one another, and the stem-plus-leaves tissue P concentration from CG was similar to that from the TSP, MAP, DAP, and the No P/-N control treatments. The mean stem-plus-leaves tissue P concentration from ECST was 1.2 times greater than that from the CG treatment and also 1.8 times greater than that from the No P/+N control treatment. The stem-plus-leaves tissue P concentration mean from CG, TSP, MAP, DAP, and the No P/-N control, which did not differ, was 1.5 times larger than that from the No P/+N control treatment.

Although yield was not measured in this study due to terminating the study before the corn plants reached full maturity, cob-plus-husk and stem-plus-leaves tissue P concentrations (Table 3) from ECST were greater than that from CG and TSP, which suggests that corn yields would have been at least similar, and perhaps greater, from ECST than yields from CG and TSP. Additionally, the larger cob-plus-husk and stem-plus-leaves tissue P concentrations for ECST than from CG or TSP, coupled with the lower belowground tissue P concentration from ECST than from CG or TSP, suggests that the P from ECST was more mobile in the plant than the P from CG or TSP. The relatively greater purity of the ECST material than that of the CG or TSP material may have contributed to mobility differences, as well as could have led to slightly different forms of P that were taken up by the plant roots from the various fertilizer-P sources.

Conclusions

There were differences in the degree of plant response depending on the fertilizer-P source. Both struvite treatments had at least similar, and in some cases even greater, plant responses in corn to several other commonly used fertilizer-P sources. These results provide not only more useful information on how wastewater-recycled nutrients such as struvite, in crystalline (ECST) or pelletized (CG) form, perform as compared to other commercially available P fertilizers, but also further reasons why more research should be conducted on not only the implementation of struvite as a fertilizer-P source but also struvite's potential impact on sustainable food production and the preservation of water resources. However, more research is still required in order to verify the large potential benefits of not only using struvite as a recycled-P fertilizer, but P recovery from wastewater as an alternative approach to improve wastewater quality and provide a sustainable source of fertilizer-P for further agricultural production.

Acknowledgments

This study was funded by the University of Arkansas Honors College in the form of an Honors College research grant. Thank you to Dr. Trent Roberts for providing the corn seeds used in this study.

Table 3. Summary of the effects of fertilizer amendment on corn belowground, cob-plus-husk, and stem-plus-leaves tissue P elemental concentrations.

	Corn Tissue P Elemental Concentrations		
Treatment	Belowground Tissue P	Cob-plus-Husk Tissue P	Stem-Plus-Leaves Tissue P
		g/kg	
ECST†	0.9 b‡	2.7 a	1.6 a
CG	1.3 a	2.3 bcd	1.4 b
TSP	1.2 a	2.3 bcd	1.3 bc
MAP	1.1 a	2.5 ab	1.3 b
DAP	1.3 a	2.5 ab	1.4 b
RP	0.8 b	2.1 cd	1.2 c
No P/+N	0.9 b	2.0 d	0.9 d
No P/-N	0.8 b	2.4 abc	1.4 b
P-value	**< 0.01**§	**0.01**	**< 0.01**

† Electrochemically precipitated struvite (ECST), Crystal Green (CG), triple superphosphate (TSP), monoammonium phosphate (MAP), diammonium phosphate (DAP), rock phosphate (RP), unamended control that did not have added P, but had added N (No P/+N), and unamended control without added P or N (No P/-N).

‡ Means in a column with different letters are different at $P < 0.05$.

§ Bolded values are significant at $P < 0.05$.

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DISCOVERY

The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Call for Papers

Deadline: May 4, 2021

- Share your research results in a citable publication.
- Learn how to write up and publish results of a research project.
- Enhance the value of your bachelor's degree.
- Develop skills needed to succeed in graduate school.

Submissions invited from:

- Degree-seeking undergraduate students with a major or minor within Bumpers College who are conducting research in cooperation with a faculty mentor at the University of Arkansas. Students who have received a Bumpers College Undergraduate Research Grant are expected to submit a paper based on their project.

To submit:

- Refer to the Instructions for Authors printed in this issue and posted on the website (see web address below).
- Submit via Scholarworks@UARK *Discovery* website.

For more information:

- Contact Gail Halleck, *Discovery* Managing Editor, Division of Agriculture Communications, Division of Agriculture Communications, Don Tyson Annex (DTAN), 2549 N. Hatch Ave., Fayetteville, AR 72704, 479-575-5670 or ghalleck@uark.edu

Discovery is available online at https://scholarworks.uark.edu/discoverymag/

Instructions for Authors

Authors, read closely and follow precisely:

Aim and Scope

Discovery is an avenue for Bumpers College to highlight and publish original research and independent creative projects conducted by Bumpers students in cooperation with a faculty mentor, or in other words *Discovery* is mainly an avenue to publish the Honors and research projects of students (or student teams) who undertake original, creative, and innovative independent research. Expectations are that the student(s) has gone above and beyond the requirements of literature reviews and is generating a new contribution to the field/discipline.

Eligibility

Submissions are invited from degree-seeking undergraduate students (or within one year post graduation) with a major or minor within Bumpers College who are conducting research in cooperation with a faculty mentor at the University of Arkansas. You DO NOT have to be an honors student to submit. However, **students who have received a Bumpers College Undergraduate Research and Creative Project Grant are expected to submit a paper based on their project**. This must NOT be your unedited honors thesis. The paper must be revised according to *Discovery* guidelines.

Articles submitted for publication in *Discovery* may not be submitted for publication in other university or college publications (with the exception of some departmental publications). Authors should decide on their preferred university/college publication and then submit to that publication only. If a manuscript is turned down from another university/college publication, then it can be considered for *Discovery*, but it may have to roll into the next year's issue.

Style Guidelines

Discovery uses *Scientific Style and Format: The Council of Science Editors Manual for Authors, Editors, and Publishers* as its style manual. Refer to the latest available edition of the CSE manual for any questions not covered in these guidelines. For research in disciplines where professional journals use style guides that differ significantly from the CSE, please consult the *Discovery* managing editor for guidance. It is also very helpful to look at previously published articles for guidelines when preparing your papers for *Discovery*.

View archived issues at
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Writing style should be consistent with professional journals in the student's discipline. However, articles will be reviewed and read by people with varied backgrounds. Therefore, authors should avoid scientific jargon and should use a style and vocabulary that can be understood by any educated reader. Define all abbreviations upon first use.

Format

- For honors students, please do not turn in an unedited honors thesis. Work with your advisor to meet *Discovery* requirements, which likely includes shortening total length, revising materials and methods, reducing the number of figures and tables, etc.
- Articles should be formatted in Word, 12-point text, double-spaced, in a single

column, with pages numbered, and continuous line numbering turned on so that reviewers can easily refer to comments. Length should be limited to about 2000 words, but no minimum or maximum length is required.

- PLEASE put TABLES and FIGURES one to a page at the end of the document. DO NOT embed them in the text. They will also need to be loaded separately as supplemental files when you submit through ScholarWorks.
- There is no need to mimic the format of the finished journal. The Managing Editor will import your document into InDesign and format in two columns and place tables and figures, etc.
- Report measurements in metric and other standard scientific units. Units or symbols that are likely to be unfamiliar to a general readership should be defined.
- The journal is web-only so COLOR figures and tables are encouraged. Each figure must be submitted as a color 300 DPI resolution JPG or PNG file at a standard figure width of at least 5 inches (select "constrain proportions" and height will default proportionally). The final size of figures will be adjusted by the editor to fit the page layout. Make sure that all text labels within the figure and *x*- and *y*-axis labels will be readable at the final publication size. A minimum type size of 8 points (after reduction) should be used. Make sure all text used in figures and tables is in black not gray (which is the new Microsoft default).
- Create tables using the Table function in Microsoft Word. Do not use tabs, spaces, and hard returns. This will result in the tables needing to be reformatted which allows the introduction of errors and could delay publication of your manuscript. Use a sans-serif 9 pt. font (e.g., Helvetica, Calibri) with title only in bold and centered above table (superscripts/subscripts in footnotes and table text in Helvetica 8 pt); look at prior *Discovery* journals for capitalization style, table width, and horizontal (0.05 width) rule styles. Please do not put vertical ruling lines in the tables.

  View helpful tips for creating tables at:

  https://aaes.uark.edu/files/2019/09/Table-guidelines.pdf
- Center figure captions below the figure in a 9 pt. sans-serif font such as Helvetica.
- *Indicate footnotes for tables using sequential superscript lowercase letters (a, b, c, etc.).* Place table footnotes below the last horizontal rule of the table. Footnotes used to clarify or annotate text should be placed at the bottom of the page in which the reference appears and indicated with sequential superscript numbers (1, 2, 3, etc.)
- Use a comma before the word *and* in a series: *The U.S. flag is red, white, and blue*.

Parts of the Manuscript

The title page should include the following:

- a concise, descriptive title
- authors' first names, middle initials (if any), and last names (faculty sponsor should be listed as a coauthor)
- an abstract
- a footnote identifying each author by classification and major for students; rank and department for faculty and staff; and identify faculty sponsor or mentor.

Meet the Student-Author(s) and Research at a Glance:

The **Meet the Student-Author(s)** section consists of a professional headshot (taken by Fred Miller) of student author(s) as well as a short biography (240 words; 1400 characters with spaces) that tells readers about student author(s): (high school attended, activities and awards while at the university, etc.). Please see past issues for examples. This is the place to thank professors and advisors. For **Research at a Glance**, we will need 3 brief bullet points (100 character maximum, not including spaces) that clearly and succinctly explain the main takeaways of the research (i.e., overall what was done, significance and implications of findings) for a broad-based, non-technical audience. Please avoid using jargon and technical terms. We will need a photo of the student alongside these bullet points showing student-author(s) at work in the lab, field, traveling abroad, presenting a poster, receiving an award, etc. These photos will be loaded as supplemental files when submitting through the *Discovery* Journal location on ScholarWorks@UARK.

Abstract

The *Abstract* summarizes the purpose, procedures, and main findings in 250 words or less.

Introduction

The *Introduction* states the purpose of the study, the hypothesis, and pertinent background information in 500 words or less.

Materials and Methods

The *Materials and Methods* section describes the experimental design, materials used, statistical analysis **(required)**, and any other details needed for another researcher to reproduce the study and to confirm the validity of findings and conclusions.

Results and Discussion

The *Results and Discussion* section presents appropriate data, but not all data, in text, tables, and figures and places the findings in context with other research in the field. The discussion emphasizes new and important aspects of the research and conclusions that follow from them. Include the implications and impact of the findings. Relate your findings to observations of other studies. State new hypotheses when warranted, but avoid unqualified statements not supported by your data.

Conclusions

The *Conclusions* section presents a brief (one paragraph) summation of the research project presented in the paper and the significance of the findings and practical applications. No references are necessary and please do not introduce new material not discussed previously in the paper.

Acknowledgments

The *Acknowledgment* section recognizes financial support (undergraduate research grants, etc.) and other assistance. Note support by any companies or parties with a vested interest in the research results. Please thank your advisor, other professors, co-authors, and other individuals who helped with your research in the *Meet the Student-Author* section *NOT* in Acknowledgments.

Literature Cited

The *Literature Cited* section lists the complete references corresponding to those cited in the text. Within the text, references are indicated by (Last Name, Year); e.g., (Jones, 2000) (Smith and Jones, 2000) (Brown et al., 2000; Finn, 1998). List the complete citation alphabetically (by the first author's last name). Multiple citations of the same author are listed chronologically or by order of reference in the text if dated the same year.

It is required that references be written as follows: *Author(s). Year. Title. Journal title. (month and date if appropriate); volume:pages.* As below, no italics, (unless Latin phrase or word, which requires italics):

Jones, G.R., W.F. Smith, and T.Q. Brown. 1999. Seasonal nitrate content of tall fescue. Agron. J. 55(3):49-53.

Please note: for the first author, the initials come after the surname. For subsequent authors, the initials come before the surname.

Book references are written as follows:

Authors or editors. Year. Title. Publisher, Place of publication. As below, no italics, (unless Latin phrase or word, which requires italics):

Ryugo, K. 1998. Fruit Culture: Its Science and Art.
John Wiley and Sons, London.

Internet URL citations are written as follows:

Limon, T.A., R.S. Benz. 2000. Grains of the world. Science on the Web. Prentice Hall. Accessed 17 April 2000. Available at: http:www.sciweb.com

NOTE: Please be very meticulous about the proper use of citations. All *Discovery* papers will be run through a check for plagiarism.

Manuscript Submission

Submit your Word manuscript (with page numbers and continuous line numbering) as an 8.5 × 11-in. document, with double-spaced, 12-pt. text, in a single column, to the *Discovery* journal on ScholarWorks@UARK by choosing the Submit Article option on the left side of the screen at:

https://scholarworks.uark.edu/discoverymag/

DO NOT submit through the thesis part of ScholarWorks@UARK. You must submit from within the *Discovery* site.

You will be prompted through instructions on what to upload. Please direct any questions to the Managing Editor, Gail Halleck: 575-5670 or ghalleck@uark.edu, Division of Agriculture Communications, 110 AGRI, University of Arkansas, Fayetteville, AR 72701.

Also, phone the Division of Agriculture's Communications office at (479) 575-5647 to arrange an appointment to have your photo taken for the journal by Fred Miller. Unless otherwise indicated, the editor will correspond with the first author for revisions, approval of proofs, etc.

NOTE: The first author (student) must include a current and a forwarding e-mail address (or phone number) for contact outside the school year. Please complete the Student Contact Information that you will be prompted for when you submit through ScholarWorks@UARK. It will be loaded as a supplemental file.

https://aaes.uark.edu/files/2019/09/Student-Summer-Contact-Form.pdf

Supplemental Information Checklist

- **An abstract (you will copy and paste into a separate window but abstract must remain in your Word document as well).**
- **Cover letter** stating your intent to submit (title of paper) to the *Discovery* journal with signatures of ALL co-authors included.
- **Summer contact form** (see above for website link).
- **Biographies** for each student author (see past issues for example of what to include) and Research At a Glance bullet points.

- **Photos** (at least 300 DPI, if possible) of you performing your research in the field or lab; participating in internships; studying abroad; presenting at conferences, etc. for inclusion in our Meet the Student Author portion of each paper.

Review Procedures

Papers will be reviewed by a reviewer, and decisions registered as follows:

- Publish with minor revision
- Publish with acceptable major revision
- Reject

Written comments of reviewers will be provided to the author usually via track changes through Word. Student authors are expected to make revisions as part of the publication process. Students will be required to submit a separate file stating how each comment was addressed in the revision. If the student author disagrees with a suggestion, the rationale for not making a suggested change should be provided.

View an example of a response to reviewer document at:

http://agcomm.uark.edu/agnews/pdf/example_of_response_to_reviewer_comments.pdf

When a paper is accepted "with revisions," a revised manuscript will need to be submitted through ScholarWorks@UARK and the managing editor will approve a final draft for publication.

A special thank you to the faculty mentors, editorial board members, and graduate students that participated in this publication. Through teaching appointments in the Bumpers College of Agricultural, Food and Life Sciences, research appointments in the Arkansas Agricultural Experiment Station, extension appointments through the Cooperative Extension Service, and in collaboration with other University of Arkansas Fayetteville faculty, these individuals make *Discovery* a reality every year.

About the Dale Bumpers College of Agricultural, Food and Life Sciences

Bumpers College provides life-changing opportunities to position and prepare graduates who will be leaders in the businesses associated with foods, family, the environment, agriculture, sustainability and human quality of life; and who will be first-choice candidates of employers looking for leaders, innovators, policy-makers and entrepreneurs. The college is named for Dale Bumpers, former Arkansas governor and longtime U.S. senator who made the state prominent in national and international agriculture.

About the University of Arkansas System Division of Agriculture

The University of Arkansas System Division of Agriculture's mission is to strengthen agriculture, communities, and families by connecting trusted research to the adoption of best practices. Through the Agricultural Experiment Station and the Cooperative Extension Service, the Division of Agriculture conducts research and extension work within the nation's historic land grant education system. The Division of Agriculture is one of 20 entities within the University of Arkansas System. It has offices in all 75 counties in Arkansas and faculty on five system campuses.

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