UNDERSTANDING GROWER PERCEPTIONS OF PLANT BIOSTIMULANTS IN GEORGIA BLUEBERRY PRODUCTION

by

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(Under the Direction of JENNIFER THOMPSON)

ABSTRACT

This thesis explores the use of plant biostimulants among agricultural producers in the commercial Georgia blueberry industry. To contextualize this research we surveyed Georgia blueberry farmers (N=37; 1,811 ha) about their production practices; pest, disease, and weed management; agrichemical use; and perceptions about key blueberry production concerns. Survey results indicate an increase in plantings of southern highbush cultivars, irrigation use, and yield in comparison to previous years. Interviews with Georgia Blueberry Growers (N=10) indicate that there is substantial ambiguity among growers regarding the definition and efficacy of plant biostimulants. Growers draw on a wide range of information resources but put the most trust in those that are perceived as unbiased or have established expert credentials. From university-based research and Extension, they seek clarity about what plant biostimulants are and how they work, as well as an impartial review of biostimulant products on the market and the benefits they can provide.

INDEX WORDS: Mixed methods research, agricultural technology, scientific uncertainty, survey research, semi-structured interviews, thematic analysis, qualitative research, agricultural anthropology, farmer-focused research

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DEDICATION

I wish to dedicate this thesis to my partner, Kendra and our beloved pets Tezcatli, Bandit, and Chewie.

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CHAPTER 1

PLANT BIOSTIMULANTS AND GEORGIA BLUEBERRY PRODUCTION

Introduction

Plant biostimulants can be loosely defined as non-fertilizer additives that promote plant growth and soil health. Over the last few decades, the global plant biostimulant industry has rapidly expanded—with many companies seeking to introduce plant biostimulant products as more economically and environmentally sustainable alternatives to conventional agrochemicals (Calvo et al., 2014). Many claims have been made regarding plant biostimulants: that they have the potential to increase product shelf-life, enhance plant uptake of nutrients, improve soil structure, increase the retention of soil organic matter, or protect against pathogens. Yet the effects of most plant biostimulant products are not well established. There are significant gaps between the body of scientific knowledge and the marketing claims put forth by plant biostimulant companies about their products.

There is an uncertainty around plant biostimulants—how they work, their effectiveness, and which products fall under their category—that influences the ability for government/regulatory bodies, commercial manufacturers, retailers, and end-product users to effectively incorporate plant biostimulants into the broader agricultural production system. This type of uncertainty around emerging technologies is not new; it is an issue that is prevalent in many areas within agriculture, such as with the development of new plant breeding technologies, or grower adoption of new seed varieties (Lassoued et al., 2018; Marra et al., 2003). Some researchers suggest that to allay legitimate concerns about emerging technologies it may be beneficial to develop regulatory standards that instill trust yet allow for sufficient innovation and consumers to familiarize themselves with a product over time (Bonnín Roca et al., 2017; Halaweh, 2013).

There are a number of agroecological practices that have been successfully incorporated into industrial farming systems such as cover crops, conservation-tillage, microbial inoculation, smart irrigation, and riparian buffer zones (Bengtsson et al., 2005; Poeplau & Don, 2015). However, other technologies such as plant biostimulants, which play on the hopes of individuals for a panacea to solve all the problems ailing the agriculture industry, as of now have yet to deliver. By implementing focused, case-study based research around plant biostimulants, this thesis seeks to contribute to the knowledge pool that may in greater consequence help to achieve agricultural sustainability.

Purpose Statement

Blueberry production is a quickly developing agricultural sector in Georgia and is heavily dependent on external inputs for its success. Plant biostimulants, along with other technologies, are being considered by blueberry growers as potential resources for enhancing production. This project strives to understand the perceptions and attitudes that Georgia blueberry growers have towards biostimulants, and their perceived value as a management strategy in blueberry production. Specifically, it aims to characterize producers' understandings of the concept of biostimulants, their perceptions of the effects that biostimulants have on blueberry production, and the factors that affect their decisions of how/when to use biostimulants. From an applied perspective, the knowledge gathered in this study will help guide greenhouse and field research studying the effects of biostimulants on Georgia blueberry production. In a broader sense, this project contributes to research about how people make sense of, navigate, and respond to uncertain science and technology in the context of their lives and livelihoods.

The objective of this case-study is to contribute to developing knowledge about agricultural producers' orientations towards novel or emergent biotechnology in the context of supporting the development of more sustainable agricultural practices. **This project asks: How is the concept of 'biostimulants' understood by Georgia blueberry growers, and how do growers use these products in the context of their production practices?**

Objectives

The specific objectives of this case-study were to:

1. Characterize Georgia blueberry growers understanding of the concept of biostimulants.
2. Determine how Georgia blueberry growers perceive biostimulants fitting into their production practices: (a) how growers use biostimulants, (b) how growers weigh the risks and benefits of biostimulants, and (c) how growers assess the effectiveness of biostimulants.
3. Determine what information sources, including other stakeholders, that Georgia blueberry growers rely on for trusted information regarding biostimulants.

A goal of this project was to directly inform current and future applied research on the effects of biostimulants on Georgia blueberry production. Data collection methods that could elicit the necessary information aimed to do so by focusing on a specific objective to:

4. Determine the information around biostimulants that Georgia blueberry growers want/need from researchers.

Literature Review

This review of literature focuses on topics related to plant biostimulants and their fit within the broader United States agricultural industry. Plant biostimulant definitions, history, components, products, uses, regulatory designations, and debates are described. A theoretical framework is presented that was used to guide research methods, analysis, and interpretation of data. Literature is reviewed regarding the Georgia blueberry industry and its potential for learning how plant biostimulants may be understood and utilized as a management strategy by agricultural producers.

Plant biostimulants have been put forth by retailers and chemical suppliers as a potential source for solutions to help mitigate the challenges in crop production by improving soil health and crop productivity, while simultaneously decreasing the need for synthetic agrochemicals. Across domains, the term "plant biostimulant" generally refers to products that contain either microbes or plant/animal derived constituents which are alleged to stimulate plant growth and improve crop yield and soil health (Halpern et al., 2015). There is a lack of sufficient knowledge on the effectiveness of many plant biostimulant products which has led to a great deal of uncertainty across domains. There is a potential to make sense of this issue through science and technology research that illuminates the varying underlying factors that contribute to uncertainty around plant biostimulants and places an emphasis on the end-products users, which in this case are farmers and other agricultural workers. These individuals must navigate an intricate web of information sources and rely on a variety of learning methods in order to effectively use any plant biostimulant product.

There is an inherent level of risk that accompanies farming which can be attributed to the various financial, legal, environmental, and human-related uncertainties that farmers must deal with on a daily basis that often necessitates heterogeneous decision making based on incomplete information. In the case of plant biostimulants, retailers/chemical manufacturers may benefit from the ambiguity surrounding these products (e.g., what plant biostimulants do, how they work) since this provides marketers an opportunity to make sweeping claims regarding their potential benefits. Nevertheless, the uncertainty about what plant biostimulants are and their fit within agricultural production systems may actually prevent farmers from using them since producers generally adopt new technologies to help reduce the uncertainties in their practices, rather than take on new uncertainties/risks (including cost, time, potential impact on the product). Understanding what growers know and believe about plant biostimulants, as well as how they use them, may clarify their potential for contributing to agricultural sustainability endeavors.

Biostimulants as an alternative

Recently within the United States agricultural sector, stakeholders have explored plant biostimulants for their potential to contribute towards meeting the needs of agricultural sustainability measures. Conventional agriculture is limited in its capacity to improve production yields while reducing the overall negative environmental and human health effects of current practices. Although there are a range of proven sustainable agriculture practices in use today, until these measures can fully meet the ever-increasing needs in agriculture, plant biostimulants will continue to be explored as an option. Due to the natural origin of many plant biostimulant products, they are being marketed as sustainable alternatives to synthetic agrochemicals. It is clear that there are some components found within plant biostimulant products (e.g., beneficial microorganisms, seaweed extracts) that are effectively used as agricultural management tools and have established purposes. There are also discrete plant biostimulant products that have been shown through independent research to have a positive effect on production in limited circumstances. However, there is a wide array of plant biostimulant products on the market today, and the uses of many far exceeds clear evidence of their effectiveness.

Downside of synthetics

Synthetic chemicals are widely used in the agricultural industry in the forms of fertilizers, herbicides, pesticides, and growth regulators and have varying levels of environmental consequences. The production of synthetic nitrogen fertilizers requires significant amounts of energy which contributes to global CO_2 and greenhouse gas emissions (Michalsky & Pfromm, 2012). Ammonia (NH_3), a key intermediate compound for many nitrogen based fertilizers, is primarily produced through the energy-consuming Haber-Bosch process (Baltrusaitis, 2017). In 2019 the conversion of atmospheric nitrogen and hydrogen (in the form of the natural gas Methane, CH_4) into nitrate through the Haber-Bosch process was estimated to be responsible for 1.4% of global CO_2 emissions and 1% of total energy consumption worldwide (EPA, 2020). The manufacturing and production of potassium and phosphorus, the other primary macronutrients necessary for plant health and productivity, are mainly derived from the mining of rock and are not as energy consuming as nitrogen fertilizers.

While synthetic fertilizers can effectively supply nutrients necessary to grow and produce crops, they are highly inefficient from a biochemical perspective, and a significant amount of what is applied is not fully utilized (Baligar et al., 2001). Much of what is applied instead leaches through the soil into groundwater or is lost due to drainage into waterways as runoff, affecting environmental quality and having a negative impact on human health (e.g. soil acidification, air and water pollution, harmful algal blooms) (Di & Cameron, 2002; Wolfe & Patz, 2002). This inefficiency is accounted for in farm management systems and is typically offset by the overapplication or reapplication of additional fertilizers needed to sustain full production throughout the season, further exacerbating the effects on the environment.

The use of many synthetic agricultural products relies on the depletion of mineral resources and does not adequately solve the central challenges facing agricultural production of sustaining long-term soil fertility or pest management (Cordell et al., 2009). Additionally, there are fears held by many of the risks synthetic agrochemicals may have on human and environmental health (i.e., the unintended consequences like harmful algal blooms, water pollution, or cancer).

The pitfalls of synthetic fertilizer practices have motivated the drive for alternative methods to provide nutrients needed in crop production. Commercial crop management systems are introducing more sustainable practices in order to increase the availability of soil nutrients for cultivated plants while minimizing the negative repercussions. A number of practices, including cover cropping, crop rotation, conservation tillage, and the use of slow-release organic fertilizers, have proven successful in retaining soil nutrients. Still, the use of these more sustainable methods in most cases is not sufficient to maintain an adequate supply of fertilizer needed for crop production. As a result, technologies such as biostimulants which are less well understood are also being pursued to further assist in crop production.

Evidence on plant biostimulants

Plant biostimulants are typically derived from natural products, including waste materials (e.g., fish waste, hen feathers, collagen from skins, fruit waste) conceivably avoiding many of the detrimental environmental impacts attributed to synthetic products (Drobek et al., 2019).

There is substantial evidence to support the claim that some compounds that fall under the “plant biostimulant” classification have the potential to serve as a source for mitigating challenges in crop production. For example, plant-beneficial microbes applied directly to the seedcoat have been shown to promote crop growth and control plant pathogens (Rocha et al., 2019). Microbial biological control agents (MCBAs), such as *Trichoderma spp*., are commonly found in plant biostimulant products and can utilize a variety of modes of action to suppress plant pathogen communities (Köhl et al., 2019). Seaweed extracts are well-documented for their plant-growth promoting effects and increases to crop tolerance to abiotic stress (Battacharyya et al., 2015). Further, it is industry standard to inoculate legume seeds with beneficial *Rhizobium* in order to encourage efficient root colonization and increased atmospheric nitrogen (N_2) fixation (Deaker et al., 2004). Nevertheless, although specific ingredients found in many biostimulants have recognized actions, much is still unknown regarding the effectiveness of individual products. Biostimulant products vary considerably in terms of their compositions and claims; thus, they are likely to vary widely in their effectiveness for different crops and in different conditions.

Some plant biostimulant applications have been demonstrated effective in limited-use case scenarios. A study of foliar applications of various classes of plant biostimulants on strawberry found a 20% increase in berry yield in treated fields (Soppelsa et al., 2019) A review article showed that while there is scarce research on the subject, several studies indicate that plant biostimulants may improve fruit quality (Rodrigues et al., 2020).

However, the widespread uses of plant biostimulants far exceeds the limited research available on them. The issue of variability among products further necessitates research in order to form a concrete understanding of the utility that they may provide in crop production. There are some ingredients included in plant biostimulant products that indicate they fulfill a beneficial role in crop production, but they have yet to be established as reliable, effective resources. Much attention has been brought to the application possibilities for plant-beneficial microbes and the need for further understanding the circumstances that play a role in their utilization. Due to the highly selective nature of plant-microbe symbiotic interactions, as well as the broad host of organisms and environmental factors that alter how plant-beneficial microbes affect crops, research is just beginning to illuminate their full potential (Finkel et al., 2017). Arbuscular mycorrhizal fungi provide vital services to plant health, particularly in improving crop nutrition and abiotic stress tolerance (Chen et al., 2018). Balancing the relationship between plant growth-promoting rhizobacteria and mycorrhizal fungi aides in the retention and storage of soil nutrients for sustained crop utilization (Barea et al., 2002). Plant hormones and other growth regulators can directly improve plant stress response and crop yield (Davies, 2012). Though there have been advances in using biological compounds as herbicides, they are still set back by many biological, environmental, and technological constraints (Auld et al., 2003).

Biostimulant term and history

Many of the principles through which plant biostimulants affect crop production are fundamental properties of soil fertility and plant growth that humans have explored and relied on since antiquity. The ancient Greek philosopher Theophrastus (372–287 BC) considered the mixing of different soils together as a means for ‘remedying defects and adding heart to the soil’ (Tisdale & Nelson, 1966). Pliny the Elder (23 – 79 AD) noted that the ‘peoples of Britain and Gaul’ fertilized their soils with ‘Margo’ (considered to be maerl, a type of red algae found in the English Channel) (Mac Monagail et al., 2017). As research has expanded the scientific knowledge of these historical practices, society's understanding of plant biostimulants has developed along with it.

Over the last few decades biostimulant related products have increasingly been incorporated in agricultural productions (Calvo et al., 2014). Precursors to the modern-day concept of biostimulants include terms such as "biogenic stimulants" and "biostimulators" (Yakhin et al., 2017). Early usage associates the "biostimulant" concept with "non-fertilizer products which have a beneficial effect on plant growth" (Russo & Berlyn, 1991).

Public/Market ambiguity around biostimulants

The relatively recent introduction of "plant biostimulants" as a term for agrochemical products has led to a lack of state/federal regulation of its usage, or standardization across market suppliers. As such, the definition of what constitutes a biostimulant has not yet solidified, with many competing and contradicting ideas (Yakhin et al., 2017). The confusion is furthered by the usage of similar and competing terms including biofertilizers, biopesticides, bioinsecticides, bioherbicides, biofungicides, and biorationals (Chojnacka, 2015; Matyjaszczyk, 2018). There are also homemade or marketed products such as "compost tea," "vermicompost tea," and "worm tea" that may include locally effective microorganisms similar to those that are also found within many commercial plant biostimulant products (Edwards et al., 2010).

Academic uncertainty around biostimulants

One reason for the inability to form a universal consensus for the term biostimulant centers around a lack of agreement on what sets biostimulants apart from other biologically derived beneficial crop production products. Bulgari et al. (2015) define biostimulants as "extracts obtained from organic raw materials containing bioactive compounds." The components that may be included in such a broad definition varies widely, leading to biostimulant-labeled products that can potentially consist of beneficial bacteria, fungi, humic acids, fulvic acids, protein hydrolysates, amino acid formulations, seaweed and fish extracts, biopolymers, enzymes, plant growth hormones, animal meals, simple sugars, chemical activators, chelates, antioxidants, vitamins, macro/micro-nutrients, or other beneficial elements (Du Jardin, 2015). Many of these ingredients also form the basis of other products not associated with biostimulants (e.g.. plant growth regulators, inoculants, pesticides, fungicides, bactericides, fertilizers). While similar in composition, these products serve their own function in assisting crop production, with a well-described and distinct mode-of-action (Davies, 2012).

Some definitions proposed by researchers emphasize the ultimate effect that a plant biostimulant may have on plant productivity rather than the specific compound or mechanism through which they are effective. Du Jardin (2015) describes a biostimulant as “any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content” (p.3). Similarly, the 2018 U.S. Farm Bill includes a statutory definition for “plant biostimulants,” with the sole purpose of clarification within the legal document, which it describes as “a substance or micro-organisms that, when applied to seeds, plants, or the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stressor crop quality and yield” ("Agricultural Improvement Act of 2018," 2018). This definition does not discretely exclude any compounds from eligibility, nor does it address the modes of action through which a plant biostimulant is active but rather focuses on their predominant effect.

Knowledge regarding how plant biostimulants function is still relatively sparse, and research is underway to understand their mechanisms of action (Brown & Saa, 2015). Due to this lack of information, some researchers argue that biostimulants should be defined based on the inexplicable potentially “emergent” properties they may entail rather than a specific mode-of-action or constituent composition. Yakhin et al. (2017) recently proposed to define biostimulants as “a formulated product of biological origin that improves plant productivity as a consequence of the novel or emergent properties of the complex of constituents, and not as a sole consequence of the presence of known essential plant nutrients, plant growth regulators, or plant protective compounds” (p. 1). Definitions such as this focus on the uncertain aspects of the biostimulant concept and contend the term as more of a placeholder until further discovery.

Regulatory uncertainty around biostimulants

Current federal regulations may prohibit the sale or registration of plant biostimulant products if they also include labeling of these functions (e.g., plant growth regulator or pesticide). In the United States there is currently no applicable regulatory definition listed for biostimulants under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which is administered by the Environmental Protection Agency (EPA, 2019). Currently, biostimulant companies are free to market their products without EPA registration so long as said products are not described or used in a manner that can be claimed as a plant growth regulator, pesticide, defoliant, desiccant, or nitrogen stabilizer (EPA, 2019). Under FIFRA regulation, products that serve any of these functions are federally designated as a pesticide and must be registered with the EPA in order to be legally sold or marketed.

Theoretical Framework

Science and technology studies and emerging technologies

In agriculture, where the introduction of new practices is often oriented towards increasing yields or decreasing cost, the consequences of any improvement measures have real-world effects on the sustainability of food production. A Science and Technology Studies approach allows researchers to examine the historical, cultural, and social impact that scientific and technological developments have on society with the intent of improvement. The motivations underpinning this field of research can range from seeking to understand the processes and effects connected to the development of scientific knowledge, to initiating change or activism (Sismondo, 2008). By developing an in-depth understanding of how a specific technology is framed within a specific field, it is possible to use that information to illuminate how social context (i.e., the individuals and organizations overseeing research) affects the production of scientific knowledge, as well as inform groups involved, ultimately improving the sustainability or adoption practices of that technology. This is especially the case in the context of emerging agricultural technologies (Vaughan, 1999).

Emerging technologies can be broadly defined as technologies or innovations whose practical applications and development are largely unrealized. They may be identified by their relative novelty, rapid growth, untapped market potential, and high-technology base (Cozzens et al., 2010). In addition, emerging technologies may have the potential to instill prominent impact, yet suffer from a lack of coherence and high levels of uncertainty and ambiguity (Rotolo et al., 2015). As clarity develops around a certain technology, efficient adoption or alteration of said technology is possible.

The uncertainty that surrounds plant biostimulants as an emerging agricultural technology affects the decision making of producers and workers. With a multitude of unknowns surrounding biostimulants, it can be difficult for individuals to successfully use them in a manner that is effective. Further exploring the underpinnings of plant biostimulants as a concept may help towards developing understanding that can be used for informing agricultural stakeholders of more effective incorporation of plant biostimulant products.

Risk and Methods of Learning

Growers face risks when deciding which on-farm practices and technologies to adopt or discontinue, including in biostimulants. The choices that growers make and their ability to manage uncertainties will contribute to the success or failure of their farm business. Growers need to weigh how their decisions will affect various production, financial, legal, environmental, social, and human-health related risks (Huirne et al., 2000). These uncertainties influence how growers determine whether and how to include biostimulants in their agricultural practice. Prior to growers deciding to incorporate a new biostimulant product, they first must assess the potential impacts it will have on many aspects of the farm (e.g., crop yield, profit margin, legal liability, environmental effects, and the health and safety of others) (Libbin & Boehlje, 1977). If growers do not foresee, or have enough evidence, that a biostimulant product will measurably improve their farm prospects, then they may decline its use. On the other hand, growers also face the risk of lost opportunity in their decision to not adopt a specific biostimulant practice, which could potentially cause them to miss out on gaining an edge that would improve their position in the market, economic competitiveness, or overall profit. In any case, the risks that growers face are not independent but are rather linked, and how they respond to one problem will ultimately affect others (Hao, 2010).

Farmers turn to several different strategies for adopting new technologies in order to effectively manage this dilemma. Stone posits that growers rely on environmental, social, and didactic forms of experience in order to decide which action they believe will lead to success (Stone, 2016). Growers depend on environmental learning or learning-by-doing. Either through deliberate or unintended experimentation, growers can utilize past personal experiences in order to help draw conclusions in the present (Foster, 1995). Through social learning, growers can make decisions by learning from the experiences of others regarding similar technologies (Munshie, 2004). Another way of knowing that is not commonly understood that impacts growers' decision making is experience they gain through 'didactic learning'—information originating from external agricultural stakeholders with their own vested interest (e.g.. materials suppliers, agricultural consultants, Extension agents, environmental activists, governmental bureaucrats, regulatory authorities, NGOs) that can influence choices made on a farm (Stone, 2016). Regardless of the way of knowing, it takes farmers a considerable amount of time and resources in order to reduce uncertainties in agricultural decision making (Byerlee, 1982).

In order to determine the best research and management practice recommendations for biostimulants, it is necessary to understand how farmers are developing knowledge about biostimulants, what sources of information farmers turn to for information, as well as who they trust and their reasons for doing so. Biostimulants may have the potential to play a significant role in the improvement of agricultural production systems across the globe; however, without clearly identifying how the technology users (i.e., growers) learn about, communicate, and conceptualize the utility of biostimulants, it is not possible to adequately move forward in improving its sustainability.

The ill-established concept of biostimulants has also contributed to a dissonance of understanding between the different groups of stakeholders within the agricultural industry. Market suppliers, growers, researchers, and Extension agents may all operate with a unique interpretation of what a biostimulant entails. Even within these sub-categories there may be alternative conceptions around biostimulants (i.e., discrete market suppliers with similar biostimulant products may choose to label differently depending on individual motivations). Additionally, bad actors with selfish motivations can severely undermine the industry for everyone else. Until these sources of uncertainty and misunderstanding are addressed, they will continue to inhibit any endeavors to successfully implement biostimulant research or knowledge in farm production systems.

Farmer-Oriented Research

A farmer-oriented research framework ensures that researchers are investigating questions that will ultimately lead a more successful transfer of technology and scientific knowledge (Farrington, 1988). An underlying principle of a farmer-focused research model is that "successful agricultural research and development must *begin* and *end* with the *farmer*" (Rhoades & Booth, 1982, p. 132). A key component of this approach is the acknowledgement that growers serve as local experts of agricultural practices and can provide significant insight into potential problems and their solutions. Technical experts (i.e., scientific researchers) view agricultural issues from a different lens than local farmers and may not have the appropriate knowledge to adequately identify the problem that needs to be addressed. Insufficient communication between local experts and technical researchers can potentially inhibit progress in this endeavor. To help overcome this obstacle, individuals with "interactional expertise" (i.e., someone who has in-depth experience in both the localized subject at hand and the technical research side) can facilitate a two-way exchange of information and increase the opportunity for meaningful research and the coproduction of knowledge (Carolan, 2006).

A farmer-oriented approach assures that target users of scientific research are involved in multiple steps of the process to confirm, modify, and evaluate research questions and proposed recommendations. Accordingly, this may lead to research that can better guide greenhouse and field research into the effects of plant biostimulants on crop production and soil environmental health.

Case Study of Plant Biostimulants: Georgia Blueberry Industry

The Georgia blueberry industry offers a specific opportunity for research on the role of biostimulants. Blueberry production is a fast-growing agricultural sector in Georgia and is economically the number one fruit crop in the state. The USDA Agricultural Census reported that in 2017 Georgia had 1,076 blueberry farms spanning over a total of 18,361 acres (USDA-NASS, 2017). From the years 2000-2017, the statewide farm gate value of blueberry production in Georgia increased 1,125% from $18.5 million to $226.6 million (UGA, 2018). However, Georgia's blueberry yield per acre is much lower compared to other regions of the United States, and less than half the yield of states leading in production (i.e., California, Oregon, Washington) (USDA-NASS, 2019b). The Georgia blueberry industry faces many unique challenges and is highly dependent on external resources and inputs for its success. Protocols and practices for maximizing yields are still in flux, which represents a significant opportunity to improve crop efficiency and agricultural sustainability. Biostimulants, along with other resources (e.g., alternative fertilizers, pollination, and irrigation strategies), are being explored by blueberry growers as potential technological aides in enhancing production. In-depth research of the circumstances surrounding biostimulants in the Georgia blueberry industry will provide insight applicable on a wider scale.

Commercial production of blueberries primarily occurs in the southeastern part of the state, with three counties (Bacon, Clinch, and Appling) making up over 50% of revenue (UGA, 2018). The two main types of blueberry grown in the state are southern highbush (*Vaccinium corymbosum x Vaccinium darrowii*) and rabbiteye (*Vaccinium virgatum*) (Itle & NeSmith, 2016). Rabbiteye blueberries are native to the southeastern United States and perform well in the region's poor soil, climate, and environmental pressures (Scherm & Krewer, 2008). Southern highbush, while less suited to the area than rabbiteye, is grown primarily in the southern part of the state because of its preferred earlier harvest window (mid-April through May) allowing for a more favorable market price (Scherm & Krewer, 2003).

In general, the long growing season and warm, humid climate of the Southeast contribute to the significant pest, weed, and disease pressure commonly found in Georgia blueberry production (Scherm & Krewer, 2008). Pesticides are frequently used to alleviate the many issues caused by environmental factors. Further adding to these challenges, damage caused by the increasing frequency of extreme weather events related to climate change, including late spring freezes, has contributed to significantly lower yields than expected across Georgia (GDA, 2018). Revenue from blueberry production noticeably decreased over the last few years, even as the number of acres planted increased across the state (USDA-NASS, 2017). Due to the difficulty of producing blueberries in the region, most commercial farms follow conventional practices, although a small portion of blueberry farms are certified organic (Scherm & Krewer, 2008). Other areas of the United States with less humidity and precipitation are more competitive for organic production. Even with a price premium for organic blueberries, the limited inputs allowed in organic production minimizes the ability for many growers to mitigate environmental challenges in an economically sustainable manner.

Methodology

Both qualitative and quantitative research methods were selected for this case study in order to elicit information-rich data to meet the dual goals of understanding growers' perceptions and attitudes towards biostimulants as well as identifying applied knowledge to assist in the development of greenhouse and field trials. A motivating factor for combining qualitative and quantitative methods is learning about the issues at hand from multiple facets of knowledge through triangulation of data (Mathison, 1988). Qualitative research facilitates in-depth characterization of participant perspectives on complex issues (Taylor et al., 2015), while quantitative survey research allows for greater generalization of results through statistical analysis (Polit & Beck, 2010). Together, the two approaches have the potential to improve overall understanding of a topic when used strategically within a research design and when differences in epistemological assumptions are addressed (Barbour, 1998).

There are different viewpoints as to how qualitative and quantitative methods can be used within a single project – either as mutually exclusive approaches, or as combinable sources of information (Rossman & Wilson, 1985). Combining research methods affects all areas – including design, data collection, and analysis, which necessitates careful consideration of purpose and approach. In this study, quantitative methods were used to triangulate findings by providing an alternative perspective to the qualitative research approach. Different modes of data collection can provide different results and levels of understanding on a single topic – a reflection of the limitations present in any research approach. Triangulation is a strategy for improving validity of findings and removing bias in research (Mathison, 1988).

Prior to the COVID-19 pandemic many aspects of data collection for this project were intended to be in-person. Research procedures were altered in order to abide by health and safety guidelines set forth by the IRB and are reflected below.

Participant Observation

Participant observation was utilized to develop firsthand knowledge of the key issues facing blueberry producers in Georgia and the role of biostimulants among these issues. Furthermore, participant observation helped to inform the development of the grower survey and interviews and as well as contribute to overall analysis. I conducted 35-40 hours of participant observation spread throughout eight in-person and virtual blueberry networking and education events between September 2019 and March 2021. Prior to the start of the COVID-19 pandemic, four in-person participant observation events occurred primarily in southern Georgia including a Georgia Berry Exchange meeting (formerly Georgia Blueberry Growers Association), the 2020 Southeast Regional Fruit and Vegetable conference, and two University of Georgia Extension field days and research updates. My role at these events was that of an *observer as participant* in which I recorded field notes in real time about the interactions, dialogue, and questions to help identify concerns and attitudes of attendees (Kawulich, 2005). Following events, field notes were developed with further detail to reflect on observations made that day.

After the start of the pandemic in March of 2020, all blueberry networking and education meetings were cancelled or moved to virtual format. During this period, I observed four virtual events including one blueberry advisory board meeting and three research updates held by

University of Georgia Extension. The participant observation focus for these events was to make note of issues, concerns, and questions of attendees.

Survey of Georgia Blueberry Growers

A survey was developed based on a study previously conducted by University of Georgia researchers (Scherm et al., 2001). The purpose of the survey was primarily to update the knowledge available on Georgia blueberry production and gain a broad understanding of the scope of biostimulant use in the industry. Furthermore, it provided a much-needed update to the now two-decade old survey of Georgia blueberry production. The survey included multiple-choice, fill-in-the-blank, and free response questions. Most of the questions were pulled directly from the Scherm et al. (2001) survey to allow for comparison of changes to production practices and issues. Agrochemical product lists were updated with the help of Renee Holland, a University of Georgia Extension area blueberry agent involved with the research. Questions related to plant biostimulants and an opt-in for subsequent interviews were added to the survey. The survey was developed using the online survey platform Qualtrics. Paper-based versions of the survey were also printed for in-person events. A copy of the survey is included in Appendix A.

Over the course of thirteen months (January 2020 – January 2021) the survey was distributed by the researcher, cooperating university researchers, and Extension agents to approximately 500 Georgia blueberry growers. Surveys were distributed in-person at a University of Georgia Extension research update, and the 2020 Southeast Regional Fruit and Vegetable conference, as well as online through a University of Georgia Extension blueberry industry listserv. Additionally, surveys were distributed online to growers who expressed interest in completing one during in-person events. The survey was also advertised at two virtual University of Georgia Extension meetings.

Interviews

Semi-structured personal interviews allow for in-depth examination of people's lived-experiences and perspectives. Interviews can provide rich descriptive data intended to allow the researcher to explore key phenomenon surrounding the research topic (Harrell & Bradley, 2009). Due to the private nature of many interviews, it is possible to establish enough trust between the researcher and participant through open communication of the research purpose, clearly worded questions, and guarantee of anonymity of responses which can lead to great insight into a person's opinions and views (Choy, 2014). Studies have shown that interviews provide more open responses from participants during discussion compared to other forms of qualitative data collection like focus groups (Morgan, 1993). The flexibility of semi-structured interviews works well for small-scale case studies and exploring new topics and ideas as they emerge (Drever, 1995). Participant observation field notes, collected documents, and journal entries served as a validation strategy to identify convergent and divergent perspectives to research conclusions (Flick, 2004).

For this study, ten interviews were conducted with Georgia blueberry growers to investigate their perceptions of plant biostimulants in blueberry production. Initially, the research plan was to conduct walking interviews, a variation of the standard semi-structured in-depth interview, that utilizes the environment to elicit enriched participant responses during discussion. The interactions with the landscape were intended to promote deeper access to the wealth of knowledge that informants have in connection with the meanings created with their surroundings (Evans & Jones, 2011). Due to the limitations imposed by the COVID-19 pandemic in conducting in-person activities, as well as participant preferences towards speaking by phone rather than video communication platforms such as Zoom, telephone interviews were held instead.

The interview participants consisted of Georgia blueberry growers and farm managers. Recruitment began with growers identified as partners in the SARE grant that funded this research, and continued through purposive snowball sampling to identify additional participants (Noy, 2008). We purposefully recruited a sample that sought maximum variation across multiple domains, including growers' familiarity with biostimulants, their experience using biostimulants, and the characteristics of farm production (e.g., conventional/ organic, size, location, length of time in industry) (Patton, 2015). Each participant also completed a Georgia blueberry grower survey either before or after the interview. The interview guide is included in Appendix B.

Interviews lasted approximately 30-60 minutes. Open-ended questions were asked based on a semi-structured interview guide developed to allow participants to share unrestricted responses of their thoughts on plant biostimulant related topics. Interviews were audio-recorded and transcribed into a digital word document.

Data Analysis

Survey data was analyzed using the statistical program JMP 14. Descriptive analysis was used on both quantitative and categorical variables (Norušis, 2006). In addition to providing background information, the survey data provided the opportunity for triangulating analysis with other data collection methods (Flick, 2004).

Interview transcripts provided the foundation for qualitative analysis. H. Russell Bernard (2017) describes qualitative analysis as a "search for patterns in data and for ideas that help explain why those patterns are there in the first place" (p. 429). The are many approaches to qualitative data analysis, with the two primary being interpretative analysis (exemplified by discourse analysis) and content analysis (exemplified by thematic analysis) (Sgier, 2012). For this study, a thematic analysis approach was utilized due to its strength in creating condensed broad descriptions of a phenomenon upon which valid inferences can be made (Elo & Kyngäs, 2008).

Following transcription, interview data was uploaded and managed using the qualitative data analysis software ATLAS.ti 9.1 (Scientific Software Development GmbH). This study utilized a six-phase thematic analysis process as outlined by Braun and Clarke (2006). The first step of the analysis process, familiarization, occurred during both the initial transcription of data and its subsequent review. Specific attention focused on information that growers conveyed about their values, information sources, shared agreement, and sensory experiences. Second, initial codes were generated according to the research objectives used to frame the interview and then applied to the text, a process known as *structural coding* (MacQueen et al., 1998). This allowed for segments of data related to specific interview questions to be grouped together for more detailed coding and analysis. Then I conducted a subsequent round of *concept coding* in which data was assigned meso and macro levels of meaning based on ideas and processes identified during data familiarization and structural coding (Saldaña, 2016). Codes were then combined, assigned definitions, and organized to form a codebook (DeCuir-Gunby et al., 2011). Third, codes were reorganized into potential themes, which were then mapped to connect the underlying concepts. Fourth, through an iterative process, the initial themes were then reviewed, compared, recategorized until refined themes were identified. Fifth, the meanings of the final themes were then defined and aspects of the data that the themes capture were determined

(Braun & Clarke, 2006). Discussion of the analysis was then provided in the final step of the process, which was a production of a report.

Subjectivity Statement

In qualitative research, subjectivity is described as the values and beliefs that a researcher brings to a research project (Kalu, 2019). The researcher's subjectivity affects his/her research questions, theoretical framework, data collection methods, and analysis. Identifying the subjectivities that a researcher brings to a project can help to recognize their effects on the study's overall research approach and conclusions. The following is a reflection of my positionality within this research project.

Since completing my undergraduate studies, I have spent approximately five years living/working in rural Georgia and Alabama. In that time, I have trained as a horticulturist and educator and am familiar with many of the challenges around fruit and vegetable production. As part of my graduate studies and research, I have had the opportunity to develop my understanding of Georgia blueberry production through attendance at blueberry cooperative membership organization meetings, as well as Extension education and blueberry industry networking events.

As an agricultural researcher, I am skeptical of the claims that marketers make about the benefits that plant biostimulants can bring to growers. Based on my research and review of literature, I believe that more research is needed in order to determine the full potential plant biostimulants can contribute to agricultural production systems. I am supportive of many sustainable production strategies—like conservation tillage or cover cropping, and sincerely hope that over time plant biostimulants can fulfill an effective niche as an alternative resource. However, as of now I do not think there is adequate evidence to show that plant biostimulants have developed enough to sufficiently contribute as a crop management tool.

In the southeastern United States, there is a long history of contention regarding civil rights and race tied to agricultural production, slavery, and segregation. Issues which are still present today, including in the Georgia agricultural industry. Much of the area in south Georgia where a substantial portion of the state's blueberries are now grown previously produced cotton, tobacco, peanuts, and timber (Krewer & NeSmith, 2000; Nipp, 1972; Upadhaya & Dwivedi, 2019). As a person of color, who identifies as both African American and Latino, I originate from a vastly different socio-cultural background than those farmers who are the core focus of my research. The cultural differences between a researcher and study participants can potentially affect how a study is conducted and ultimately the validity of its results. Conducting transparent research that openly presents how data was collected, the data itself, and subsequent analysis can help to mitigate inevitable bias. Additionally, research memos which document thought process during different stages of the research can also assist in providing clarity.

A goal of this project was to establish a relationship with participants founded on mutual respect for individual/local expertise—to convey to participants a recognition of the value they bring to the research process through their wealth of experience in the agricultural industry and the insight they provide. As such it was important to be aware of any biases that I may hold and maintain an openness to learning from participants whose experience I recognize and value in the context of this research. It was necessary to rely on research partners and existing networks in order to broker relationships and communication. I believe I built relationships and rapport with research participants over time.

Roadmap

This thesis consists of two studies focused on blueberry production in Georgia and grower perceptions of plant biostimulants as a resource in their agricultural production system. Chapter 2 focuses on the survey data and provides an update of Georgia blueberry production practices and horticultural issues. Chapter 3 draws upon semi-structured interviews with Georgia blueberry growers to explore their perceptions of plant biostimulants on blueberry production and soil biological health. Chapter 4 summarizes the major conclusions and implications of the studies and provides recommendations for future research.

CHAPTER 2

GEORGIA BLUEBERRY GROWER SURVEY[1]

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[1]Joel Kirksey, Jennifer Thompson, Mussie Habteselassie, Renee Holland, and Rachel Itle. To be submitted to *International Journal of Fruit Science*

Abstract

It has been 20 years since university researchers conducted an extensive survey of Georgia blueberry industry agricultural practices and issues. In that time Georgia blueberry production has expanded by nearly 300%, and blueberries have become the leading fruit crop in the state. In 2020, a survey of growers was conducted to learn about the changes within the Georgia blueberry industry. The survey was based on a previous 1999 survey that covered a range of topics including general production information, pest, disease, and weed management, agrichemical use, and grower perceptions on blueberry-related issues. The purpose of the survey was primarily to develop background information on Georgia blueberry growers, and production practices. Furthermore, it provided a much-needed update to the now two-decade old survey of Georgia blueberry production. Additional questions were included in the survey pertaining to plant biostimulant usage and perceptions within the Georgia blueberry industry. The survey participants combined represent 1,643 bearing hectares of Georgia blueberry production (an estimated 16% of statewide planted area in 2019) and include both organic and conventional farms. In comparison to the previous survey, prominent differences include increases in plantings of southern highbush cultivars, irrigation use, and yield. Producers reported spotted-wing drosophila, a pest that was not present during the last survey, as a major pest concern. Furthermore, damage caused by freeze events continues to be an important issue. Overall, producers reported planning to continue increasing their production area by an average of 28.5% within the next five years.

Introduction

Over the last century blueberries have become a prominent fruit crop in the United States. More than half of all commercial blueberries in the world are produced in the United States, and the majority of blueberries are grown in western, southeastern, and northeastern regions (Evans & Ballen, 2014). Blueberry plants that are commercially grown and sold in the U.S. include lowbush (*Vaccinium angustifolium)*, northern highbush (*Vaccinium corymbosum*), southern highbush (*Vaccinium corymbosum x Vaccinium darrowii*), and rabbiteye (*Vaccinium virgatum*). In 2019 the U.S. harvested 102,700 acres of blueberries at a value of $908.7 million (Eklund, 2020).

Blueberry production is a fast-growing agricultural sector in Georgia and is economically the number one fruit crop in the state (UGA, 2018). Georgia blueberry production typically ranks high nationally, ranking first in harvested acres (21,700) and fourth in value of utilized production in 2019 (Eklund, 2020). Between the years 2000-2017, the statewide farm gate value of blueberry production in Georgia increased 1,125% from $18.5 million to $226.6 million (Scherm & Krewer, 2003; UGA, 2018). As of 2017, Georgia had 1,076 blueberry operations spanning over a total of 7,430 hectares (18,361 acres) (USDA-NASS, 2019a). Commercial production of blueberry primarily occurs in the southeastern part of the state, with three counties (Bacon, Clinch, and Appling) making up over 50% of revenue (UGA, 2018).

The Georgia blueberry industry faces many unique challenges and is highly dependent on external resources (e.g., Extension, blueberry breeding programs) and inputs (e.g., fertilizers, pesticides) for its success. Although blueberries are Georgia's top fruit crop, the state's blueberry yield per acre is lower compared to other regions of the United States, and less than half of some western states (e.g., California, Oregon, Washington) (USDA-NASS, 2019). The two main types of blueberry grown in Georgia are southern highbush (*Vaccinium corymbosum x Vaccinium darrowii*) and rabbiteye (*Vaccinium virgatum*) (Itle & NeSmith, 2016). Rabbiteye blueberries are native to the southeastern United States and perform well in the region's poor soil, climate, and environmental pressures (Scherm & Krewer, 2008). Southern highbush, while less suited to the area than rabbiteye due to being a hybrid of a northern variety, is grown because of its preferred earlier harvest window (mid-April through May) allowing for a more favorable market price (Scherm & Krewer, 2003).

In general, the long growing season and warm, humid climate of the Southeast contribute to the significant pest, weed, and disease pressure commonly found in blueberry production (Scherm & Krewer, 2008). In recent years, damage caused by the increasing frequency of extreme weather events related to climate change, including late spring freezes, has contributed to significantly lower yields than expected across Georgia (Agriculture, 2018). Revenue from blueberry production noticeably decreased from 2012 to 2017, even as the number of acres planted increased across the state (USDA-NASS, 2019a)

Despite the growth of the blueberry industry in Georgia, it has been twenty years since producers have been surveyed to gather information about their current production practices and key issues of concern within the Georgia blueberry industry (Scherm et al. 2001). As part of a larger study aimed at understanding emerging practices within the industry, we surveyed blueberry producers to assess how production practices and agricultural issues have changed in the last few decades.

Materials and Methods

The survey was developed based on a study conducted by University of Georgia researchers in 1999 (Scherm et al., 2001). Most of the questions were pulled directly from the Scherm et al. (2001) survey to allow for comparison of production practices and key issues over time. The survey included multiple-choice, fill-in-the-blank, and free response questions. Agrochemical product lists were updated by Renee Holland (RH), the University of Georgia

Cooperative Extension area blueberry agent involved with the research. Questions related to plant biostimulants and an invitation to opt-in to a subsequent interview were added to the current survey. A digital version of the survey was developed using the online survey platform Qualtrics. Paper-based versions of the survey were also made for in-person events. A copy of the survey is included in Appendix A.

Over the course of thirteen months (January 2020 – January 2021) the survey was distributed to approximately 500 Georgia blueberry growers through multiple outlets. As farmer survey response can be strikingly low (Pennings et al., 2002), we engaged in multiple and sustained efforts to collect completed responses. The COVID-19 pandemic occurred during the data collection phase of this research, disrupting operations and in-person meetings across the Georgia blueberry industry which may have further exacerbated challenges in collecting completed surveys. In January of 2020, approximately 75 paper-based surveys were distributed in-person to attendants at the annual University of Georgia Extension research winter update and the 2020 Southeast Regional Fruit and Vegetable conference. At these events survey distribution stations were established near entrances and all attending blueberry growers were invited to participate upon arrival. During the in-person events, researchers also collected contact information from growers who expressed interest in completing a survey at a later time. These growers were sent a follow-up email inviting them to complete an online version of the survey. A link to the online survey was distributed to approximately 500 growers through a University of Georgia Extension blueberry industry listserv in the months of December 2020 and January 2021. The survey was also advertised at two virtual University of Georgia Extension meetings. Finally, commercial Georgia blueberry growers identified through online web searches were also invited to complete the survey through telephone contact or email invite when available.

Growers participating in other components of the larger research study (e.g., interviews, field trials) were also invited to participate.

Survey data was analyzed using the statistical software program JMP 14. Summary statistics were collected of both quantitative and categorical variables. The study was reviewed and approved by UGA's Institutional Review Board. All participants gave consent to participate; they were compensated with $5 for their time and were entered into a drawing for two $50 gift cards.

Results and Discussion

Sample

We received a total of 68 surveys, of which 37 were usable responses (based on completion rate of at least 70% and removal of duplicate farms). Farm size of survey participants ranged from approximately 1 hectare (2 acres) to more than 256 hectares (635 acres), with an average farm size of approximately 49 hectares (~121 acres). The completed surveys represent approximately 1,661 bearing hectares (4,105 acres), and 1,811 hectares (4,475 acres) (see Table 2.1) in total planted area, an estimated 16% of blueberry production area in Georgia at the time of the survey. Average bearing blueberry production area of survey respondents was 71% larger in comparison to the previous Scherm et al. (2001) survey. Our survey respondents reported that their experience in blueberry production ranged from 3 to 50 years, with an average of 18 years.

In 2019, most commercial blueberry production in Georgia occurred in southern part of the state in Bacon, Appling, and Clinch counties (UGA, 2020). Farms in these counties accounted for 58% of the survey responses and 61% of the total planted area in the survey, with most being from Bacon county (45% and 50%, respectively) (see Figure 2.1). Farms in Brantley and Coffee counties also accounted for a significant amount of survey responses (13%) and total planted area (30%). Other counties from across the state with producers represented in this survey include Baker, Burke, Candler, Colquitt, Jeff Davis, Meriwether, Mitchell, Tift, Ware, and Wilcox counties.

General production information

According to the survey, 62% of producers reported growing a mix of both rabbiteye and southern highbush blueberries, whereas 37% only grew one type. More than half of our respondents' blueberry production area was planted with southern highbush (58%) with the remainder planted with rabbiteye (42%). This marks a significant shift from previous surveys in which producers reported planting mostly rabbiteye (Moore, 1993; Scherm et al., 2001). This difference could be related to southern highbush having an earlier harvest window than rabbiteye, which can lead to a better market price for producers. Furthermore, although early southern blueberry breeding efforts primarily focused on rabbiteye development due to their adaptation to the local environment, beginning in the late 1990s increased research efforts were made towards developing southern highbush varieties in order to take advantage of the earlier market window (NeSmith, 2008).

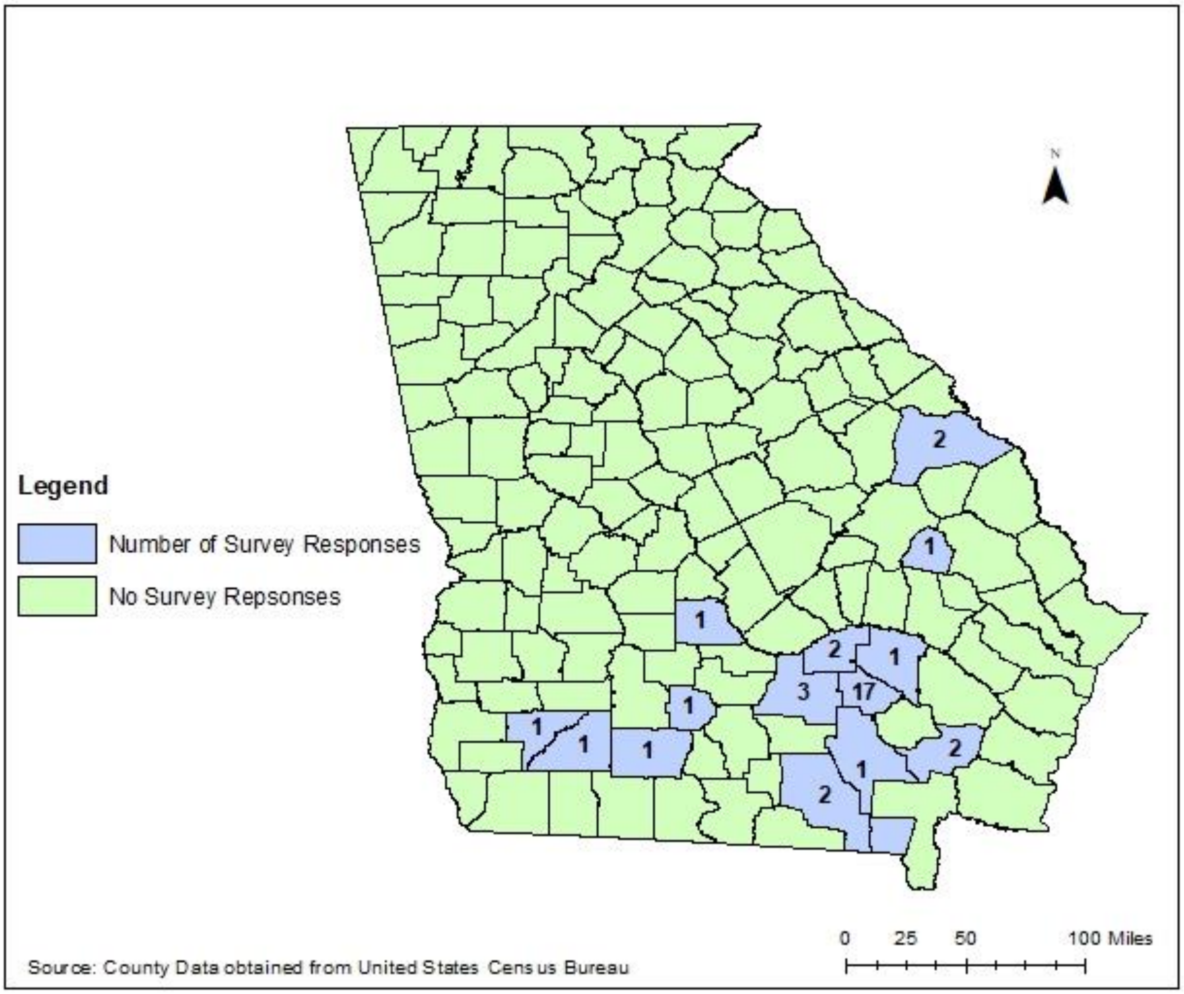
The most common rabbiteye varieties reported by producers were 'Brightwell' (n=26) and 'Premier' (n=11), both of which are unpatented and the products of early blueberry cultivar development. Previous studies also reported widespread use of the 'Brightwell' cultivar, although 'Premier' was not as commonly grown (Moore, 1993; Scherm et al., 2001). 'Brightwell' was first released for commercial use in 1981 by the University of Georgia, and 'Premier' in 1978 by the University of South Carolina. For southern highbush, previous studies reported higher planting rates of different varieties than our present survey (e.g., 'O'Neal', 'Reveille', and 'Star'). In our study, the most common southern highbush cultivars reported were

‘Farthing’ (n=25), ‘Suziblue’ (n=8), and ‘Star’ (n=8). ‘Farthing’ is a relatively newer blueberry variety developed in the early 2000s by the University of Florida blueberry breeding program and patented in 2008, when blueberry production in the Southeast was rapidly expanding. At the time of its patent, ‘Farthing’ was distinguished by its desirable traits of low chilling requirement (300 hours), vigorous growth, and earlier ripening window than other southern highbush varieties (e.g., ‘Star’) (Lyrene, 2008). ‘Suziblue’ was patented by the University of Georgia in 2010, and has similar desirable characteristics as ‘Farthing,’ including a low chilling requirement (400 hours), vigorous growth, and early ripening period (first week of May in south Georgia) (Nesmith, 2010).

Table 2.1. General Production Information

Variable	**Mean**	**Min**	**Max**	**Total**
Blueberry experience (years) (n=37)	18.0	3.0	50.0	669
Farm size (ha) (n=37)	48.9	0.8	256.9	1811.0
Rabbiteye (RE) bearing (ha) (n = 37)	21.7	0	101.1	757.5
Southern High Bush (SHB) bearing (ha) (n=37)	26.5	0	121.4	904.0
Irrigation (ha) (n = 36)	40.1	0	163.8	1445.0
	Yes	**No**	**Mean**	
Plans for expansion (n=37)	56.7%	43.2%	23.7 ha	
	RE	**SHB**	**Total**	
Yield per bearing area (n=28)	6,516 kg/ha (n=28)	6,784 kg/ha (n=27)	6.646 kg/ha (n=28)	
	Fresh	**Processed**	**Total**	
Crop able to market (n=32)	68.8%	21.7%	90.5%	

Figure 2.1. Number of Georgia Blueberry Grower Survey Responses by County



Both rabbiteye and southern highbush varieties showed higher yields in comparison to the earlier survey of growers, with southern highbush having the greatest increase (Scherm et al., 2001). Producers reported having average yields of 6,784 kg/hectare (an increase of 86.3%) for southern highbush blueberries, and 6,516 kg/hectare (25.3% increase) for rabbiteye blueberries, with an overall yield of 6,646 kg/hectare (Scherm et al. 2001). It is possible that the higher yields for southern highbush varieties over rabbiteye could be due to the introduction of newer varieties (e.g., ‘Farthing’, ‘Suziblue’) with higher yield capacities than those available during the previous survey when the Georgia blueberry industry was developing more rapidly.

Survey participants reported being able to market 90.5% of the harvested crop, selling 68.8% of their harvest as fresh blueberries, and 21.7% as processed. Previous studies have also indicated a trend towards more fresh market production. Scherm et al. (2001) reported 53.4% of producers selling their harvest as fresh, an increase from an earlier survey where 33% of growers did the same (Moore, 1993). It is possible the increase in fresh market production reflects the higher consumer demand for blueberries in general.

Consumer demand for blueberries in the U.S. has steadily increased over the years, leading to both seasonal and geographical expansion of blueberry production (Kramer et al., 2020). In our survey, a majority (58.5%) of growers indicated having plans for expanding production over the next five years, with an average expected increase of 23.7 hectares (58.5 acres). At this rate, growers expect to increase total planted area by 28.5% by 2025.

Survey results indicate that 83% of the total planted area was irrigated. In previous studies, Georgia blueberry growers reported equipping 71% and 62% of their production with irrigation in 1991 and 1999, respectively (Florkowski et al., 1992; Scherm et al., 2001). It is possible that the higher rate of irrigation could be a result of general trend of southeastern farmers' increased reliance on agricultural technology for improving yield and land use capacity. One study of farmers across Alabama, Florida, Georgia, and North Carolina showed increased irrigation use from 2012 to 2017 (Combs, 2019). Overall, water supply did not appear to be a significant issue for most, although drought was considered 'major' or 'moderate' issues by 43.2% of growers. This is a decrease from a previous survey, where a majority of Georgia blueberry growers considered drought a major concern (Scherm et al., 2001).

Horticultural problems

Producers rated damage caused by freezing weather as the most important horticultural production issue. Freeze injuries to flowers and fruit were considered 'major' or 'moderate' issues by 89.1% and 75.6% of growers, respectively (see Table 2.2). Throughout the last century winter surface temperatures have continually increased, with recent years reaching new record highs (Liberto, 2020). Warmer winter weather combined with the use of southern highbush cultivars with low chill requirements has led to earlier flowering and fruiting. Additionally, frequent occurrences of drastic temperature fluctuations have resulted in late freezes that can cause severe production damage for southeastern producers (Nickle, 2018). It is possible that while freeze injury remains a consistent constraint for many blueberry growers, some may be adjusting, as there was a small decrease compared to a previous survey where 100% of growers viewed freeze injury as a significant problem (Scherm et al., 2001). Southeastern producers have few practical options for reducing the consequences of freezes on blueberry production, with continuous overhead irrigation during freeze events as the most promising (Smith, 2019). A 2016 study of blueberry producers in Florida and Georgia showed 88% use some form of frost protection (e.g., irrigation, wind machines, covers, heat), with 98% of those using overhead irrigation (Conlan et al., 2018). Gibberellic acid has also been explored as an option for treating flower injury caused by freezing weather as it has shown in experimental settings to possibly reduce the overall negative effect during light freezes (NeSmith et al., 1999). Nevertheless, only 23.5% of producers in our survey reported treating their crops with gibberellic acid.

Around half of all producers considered poor pollination (59.4%) and fruit set (48.6%) as major or moderate challenges affecting production. Commercial blueberry production depends on insects (typically bees) to achieve enough pollen transfer for adequate fruit set (MacKenzie, 1997). The pollination needs of small blueberry fields have shown to be primarily fulfilled by wild bees, however, larger operations require managed bees brought in from external suppliers (Isaacs & Kirk, 2010). In recent years, several U. S. commercial beekeepers have reported declines in bee populations, an issue referred to as colony collapse disorder (Evans & Chen, 2021). The decline in bee populations seems not to have greatly affected producers in our survey, as concern about this issue appears to be slightly lower compared to a previous survey (Scherm et al., 2001).

Table 2.2. **Horticultural Problems (n=37).**

Problem[1]	Percent of producers considering problem		
	Major	Moderate	None
Freeze injury: flowers	43.2	45.9	10.8
Freeze injury: fruit	32.4	43.2	24.3
Pollination	16.2	43.2	40.5
Lack of vigor	18.9	37.8	43.2
Harvest damage: mechanical	18.9	37.8	43.2
Poor fruit set	18.9	29.7	51.3
Waterlogging	10.8	35.1	54.0
Drought	10.8	32.4	56.7
Poor soil fertility	5.4	35.1	59.4
Harvest damage: hand picking	5.4	32.4	62.1

[1] Table organized by aggregate of percent of producers who consider horticultural issue as a 'major' or 'moderate' problem in descending order.

Diseases

There are a wide array of diseases that can potentially effect blueberry production, with a number of new diseases emerging as issues in recent years (Cline, 2012). In our study, leaf spots were indicated by the highest number of growers as a concern with 72.9% identifying them as a 'major' or 'moderate' issue (see Table 2.3). There are a few different pathogens which can cause leaf spots (e.g., *Gloeosporium minus*, anthracnose, or rust fungi) with *Septoria albopunctata* being the major concern for Georgia blueberry production. Most produce (67.5%) reported leaf spots as a moderate concern, and it is possible that this change may not reflect growers most pressing disease concern. In southeastern blueberry production, Septoria leaf spot tends to first appear between April to mid-June, with disease severity rapidly increasing into the fall (Ojiambo & Scherm, 2005). Effects of the disease may include premature defoliation, reduced photosynthesis on affected leaves, and reduced fruit yield (Ojiambo et al., 2006). In blueberries, the fungicide Indar (fenbucazole) has been shown to significantly reduce defoliation and increase yields (Cline, 2000). In our survey, 32.3% of producers (28.7% of total planted area) reported using fenbucazole with an average of 1.7 sprays per treated area (see Table 2.4).

According to our survey, there were a variety of diseases that growers similarly considered as significant constraints. Phytophthora root rot (*Phytophthora cinnamomi*) was considered as ‘major’ or ‘moderate’ issue by over two-thirds (67.5%) of producers. Phytophthora disease presence may cause chlorosis, defoliation, and root necrosis, and has been shown to increase with the frequency of flooding (Silva et al., 1999). A study of precipitation extremes in Georgia showed an increase in the number of very heavy precipitation days from 1971 to 2010 (Keggenhoff et al., 2014). In our study, waterlogging was reported as a ‘major’ or ‘moderate’ issue by 45.9% of growers.

Botrytis flower blight (*Botrytis cinerea*) and blueberry rust (*Pucciniastrum vaccinii*) were each considered a ‘major’ or ‘moderate’ threat by 56.7% of producers. Botrytis disease susceptibility increases as blueberry flower develops, with research showing southern highbush appearing to be more greatly affected in comparison to rabbiteye (Smith, 1998). There is evidence to support that some biofungicides, such as a combination of cyprodinil and fludioxonil, may prove effective in treating botrytis flower blight (Abbey et al., 2021). In our survey, 47.0% of producers (59.7% of total planted area) reported using cyprodinil and fludioxonil with an average of 1.7 sprays per treated area. Research suggests that certain cultivars such as 'Climax' (rabbiteye) and 'Bluescrisp' (southern highbush) are more likely to experience severe rust disease incidence (Scherm et al., 2008). Azoxystrobin is a recommended treatment for blueberry rust, which 58.8% of producers (63.6% of total planted area) reporting using at an average rate of 2.1 sprays per treated area.

Mummy berry (*Monilinia vaccinii-corymbosi*) was considered as 'major' or 'moderate' disease by 54% of producers, a decrease from a previous survey, in which 79.3% of growers considered it as a problem (Scherm et al., 2001). Overall marketable yield can be greatly impacted by the presence of mummy berry which can remain symptomless during early development, but cause greyish hardened berries downgrading fruit quality (Scherm & Copes, 1999). Mummy berry can remain in the field over winter, persisting in fallen fruit on the soil surface. Reducing disease presence by burying affected fruit in the soil through mechanical cultivation has been recommended by some agricultural advisors (Schilder et al., 2008). Approximately a quarter (25.7%) of producers in our survey identified as "always" or "often" using mechanical cultivation (see Table 2.5).

Table 2.3. Disease Problems (n=37).

Disease[1]	**Percent of producers considering problem**		
	Major	**Moderate**	**None**
Leaf spots	5.4	67.5	27.0
Phytophthora root rot	13.5	54.0	32.4
Blueberry rust	10.8	45.9	43.2
Botrytis flower blight	8.1	48.6	43.2
Mummy berry	8.1	45.9	45.9
Exobasidium (leaf and fruit spot)	13.5	37.8	48.6
Stem blight	0	51.3	48.6
Twig blight	0	48.6	51.3

Stem canker	0	43.2	56.7
Post-harvest fruit rots	21.6	18.9	59.4
Pre-harvest fruit rots	10.8	24.3	64.8
Ring nematode	8.1	18.9	72.9
Blueberry stunt	0	10.8	89.1

[1] Table organized by aggregate of percent of producers who consider disease as a 'major' or 'moderate' problem in descending order.

Table 2.4. Agrichemical Use (n = 34).

Active Ingredient	Usage pattern		
	Percent of producers	**Percent of total area**	**Sprays per treated area**
Growth regulator			
Gibberellic acid	23.5	1.9	1.6
Fungicides			
Lime sulfur/calcium polysulfide	70.5	67.7	1.0
Captan	67.6	72.2	3.7
Azoxystrobin	58.8	63.6	2.1
K-phite	50.0	42.2	1.9
Propiconazole	47.0	48.8	1.8
Cyprodinil + Fludioxonil	47.0	59.7	1.7
Fenbuconazole	32.3	28.7	1.8
Herbicides			
Glyphosate	50.0	54.3	2.4
Oryzalin	47.0	54.4	2.5
Paraquat	38.2	38.4	2.5
Simazine	35.2	37.3	1.7
Sethoxydim	20.5	24.9	1.6
Diuron	14.7	17.0	1.3
Hexazinone	2.9	2.6	1.0
Fluazifop	2.9	2.5	-
Norflurazon	2.9	1.7	-
Insecticides			
Zeta-cypermethrin	58.8	61.7	2.0
Malathion	52.9	66.1	2.1
Diazinon	52.9	58.7	1.1
Superior (Horticultural) Oil	38.2	35.1	1.0
Phosmet	35.2	47.2	1.0

Acetamiprid	32.3	47.9	1.4
Pyrethrins	8.8	3.3	4.0
Spinosad	17.6	26.2	2.4

Table 2.5. Horticultural Practices (n=31).

Practice	Percent of producers using practice			
	Always	Often	Sometimes	Never
Scout fields once a week or more during main growing season	67.7	22.5	6.4	3.2
Select cultivars with improved yields	58.0	25.8	12.9	3.2
Maintain record of field history and pest problems	48.3	22.5	19.3	9.6
Mulching	46.6	16.6	26.6	10.0
Nutrient analysis (soil test)	45.1	25.8	22.5	6.4
Mechanical cultivation (e.g., rotary hoe, disk)	9.6	16.1	22.5	51.6

Pests

Scale insects (superfamily Coccoidea) were reported as the most important pest concern among growers in our study, with 75.6% considering them a "major" or "moderate" concern (see Table 2.6). This is a notable increase compared to the 1999 survey, in which less than half (42.8%) of producers indicated scale insects as a substantial concern (Scherm et al., 2001). When present in high concentrations, scale insects may cause major damage and possibly kill blueberry plants. Managing scale insects in blueberries can be difficult due to their hard outer shell; however, horticultural oil has been recommended as a treatment option (Hahn, 2011). In the present survey, 38.2% of producers (35.1% of total planted area) reported using horticultural oil, with an average of 1.0 sprays per treated area.

Spotted-wing drosophila (*Drosophila suzukii)* was reported as a "major" or "moderate" pest by 70.2% of producers. Spotted-wing drosophila is an invasive pest first detected in the U.S. in 2008 and has since become a severe nuisance to many berry production systems (Drummond et al., 2019). A number of conventional insecticides have proven to be effective treatments for Spotted-wing drosophila including malathion and spinosad (Sial et al., 2019; Van Timmeren & Isaacs, 2013). However, experimental studies have shown that rainfall following application of insecticides may lead to reduced effectiveness (Gautam et al., 2016). In our survey, 52.9% of growers (66.1% of total planted area) reported using malathion in their production system with an average of 2.1 sprays per treated acre. A smaller number of producers (17.6% [26% of total planted area]) reported using spinosad to treat insect pressure, with an average of 2.4 sprays per treated area.

Other arthropod species of concern include gall midge (*Dasineura oxycoccana*) and flower thrips (*Frankliniella spp.*), which were considered as "major" or "moderate" pests by 59.4% and 56.7% of growers, respectively. Both species were reported as a higher concern in the current survey compared to the previous survey (Scherm et al., 2001). Gall midge may greatly affect floral buds reducing fruit set and yield (Liburd & Finn, 2002). Effective treatment options for gall midge include acetamiprid and zeta-cypermethrin (Collins & Drummond, 2018). In the present survey, 32.3% of growers (47.9% of total planted area) reported treating their blueberry crops with acetamiprid, with an average of 1.4 sprays per treated area. Furthermore, 58.8% of growers (61.7% of total planted area) indicated using zeta-cypermethrin in their production, with an average of 2.0 sprays per treated area.

Table 2.6. Pest Problems (n=37).

Arthropod[1]	**Percent of producers considering problem**		
	Major	**Moderate**	**None**
Scale	10.8	64.8	24.3
Spotted wing drosophila	40.5	29.7	29.7
Gall midge	27.0	32.4	40.5
Flower thrips	21.6	35.1	43.2
Flea beetle	5.4	43.2	51.3
Fire ant	8.1	37.8	54.0

Whiteflies	8.1	37.8	54.0
Bud mite	8.1	29.7	62.1
Sharpnosed leafhopper	2.7	35.1	62.1
Webworm	2.7	35.1	62.1
Blueberry maggot	2.7	27.0	70.2
Azalea caterpillar	2.7	21.6	75.6
Chilli thrips	2.7	16.2	81.0
Plum curculio	0	18.9	81.0
Stemborer	0	16.2	83.7
Cherry fruitworm	0	13.5	86.4
Cranberry fruitworm	0	13.5	86.4
Spanworm	0	10.8	89.1

[1] Table organized by aggregate of percent of producers who consider pest as 'major' or 'moderate' problem in descending order.

Weeds

Weed pressure has the potential to be a sizable issue in blueberry production, especially among organic systems where treatment options are limited (Krewer & Walker, 2006). Maintaining vegetation-free areas is critical for the establishment and growth of thriving blueberry plants (NeSmith & Krewer, 1995). In the present study, growers considered perennial and annual grasses as the most noxious weeds in their production system with an overwhelming majority, 91.8% and 89.1% respectively, indicating them as a "major" or "moderate" problem (see Table 2.7). Vines were also reported as major weeds with 86.4% of growers reporting them as a "major" or "moderate" issue. More than half of survey respondents ranked annual and perennial broadleaves as problematic weeds. Woody species (e.g., oaks, pine) were the only weed type not considered a problem by a majority of growers.

Among chemical herbicides commercially available, glyphosate was the most common treatment option used by 50% of growers (53.4% of total planted area), with an average of 2.4 sprays per treated area. Oryzalin was similarly identified as a common treatment option used by

47% of growers (54.4% of total planted area) at an average of 2.5 per treated area. Other herbicides utilized by growers in substantial amounts include paraquat and simazine.

Along with mechanical cultivation, mulching has been used as an effective tool for managing weed populations. Mulch types used by blueberry producers include black plastic, sawdust, landscape fabric, compost pine leaves, and pine bark (Forge et al., 2012; Krewer & Walker, 2006). In the present study, 63.2% of producers identified as "always" or "often" using mulch in their production system. This is a notable increase compared to a past survey of Georgia blueberry growers where only 13.7% reported using mulch (Scherm et al., 2001).

Table 2.7. Weed Problems (n=37).

Weed Group	Percent of producers considering problem		
	Major	**Moderate**	**None**
Perennial grasses	40.5	51.3	8.1
Annual grasses	37.8	51.3	10.8
Vines	29.7	56.7	13.5
Annual broadleaves	10.8	56.7	32.4
Perennial broadleaves	16.2	43.2	40.5
Woody species	8.1	40.5	51.3

[1] Table organized by aggregate of percent of producers who consider weed issue as a 'major' or 'moderate' problem in descending order.

Plant Biostimulants

The agricultural industry in recent years has begun to explore plant biostimulants for their potential use as a crop management resource (Calvo et al., 2014). Across domains, the term "plant biostimulant" generally refers to products that contain either microbes or plant/animal derived constituents which are alleged to stimulate plant growth and improve crop yield and soil health (Halpern et al., 2015). Among survey participants in the present study, 27% percent reported currently using plant biostimulants in their production (see Table 2.8).

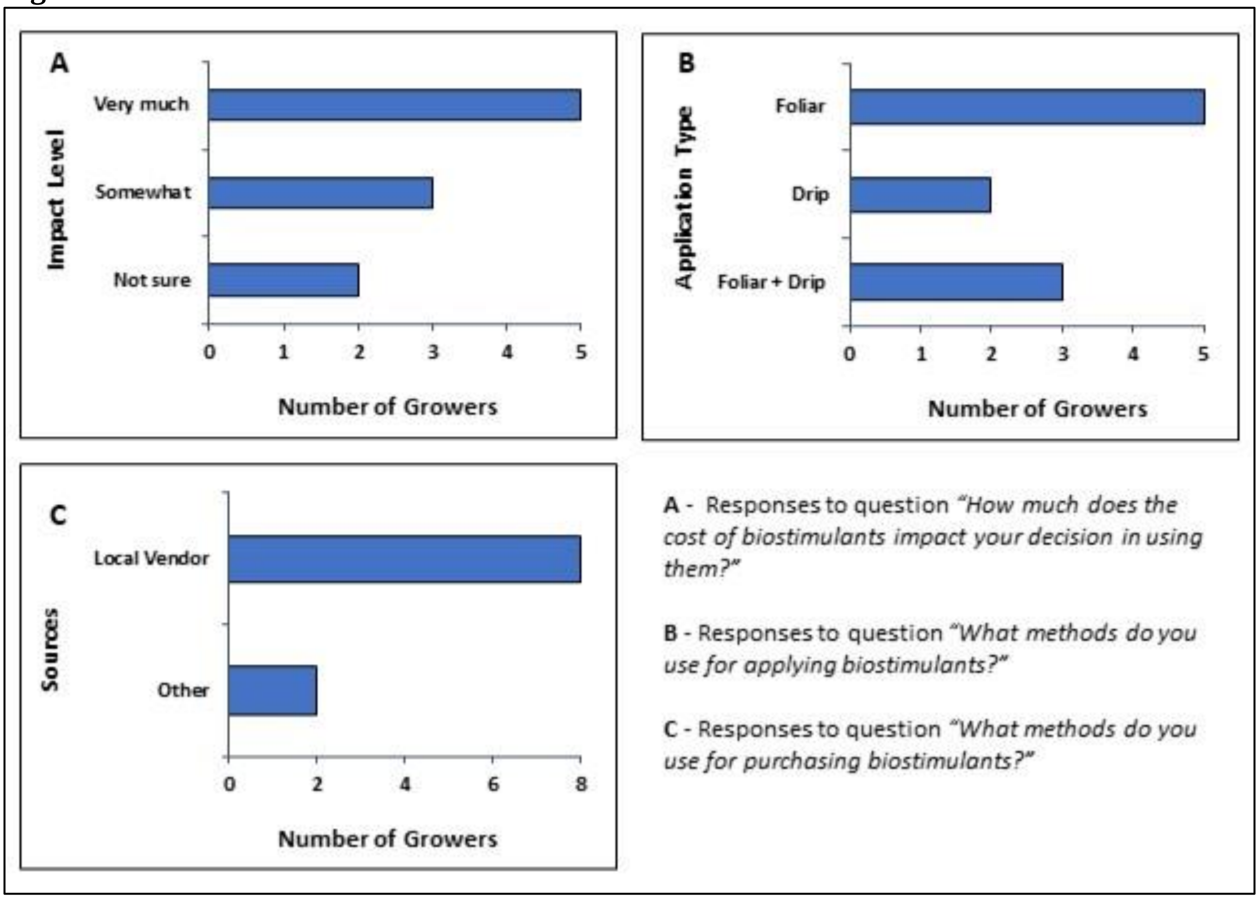
When asked if their knowledge of plant biostimulants has changed at all within the last year, the majority (67%) reported no change in their level of understanding. Most participants (80%) reported the cost of plant biostimulants as “very much” or “somewhat” impacting their decision to use them (Figure 2.2A). It has been noted elsewhere that growers weigh how their on-farm decisions, such as the purchasing of agricultural products, will affect various production, financial, legal, environmental, social, and human-health related risks (Huirne et al., 2000).

Table 2.8 Plant Biostimulants

Variable	Yes	No
Currently using plant biostimulants (n = 33)	10	23
Knowledge of biostimulants has changed at all over the last year (n = 31)	10	21

Among growers who are currently using plant biostimulants, 50% identified applying plant biostimulants using foliar methods (Figure 2.2B), and 80% identified purchasing plant biostimulants from a local vendor (Figure 2.2C). The remainder of the participants identified other sources for obtaining plant biostimulants including a “biostimulant consultant” and directly from the chemical manufacturer. Currently, biostimulant companies are free to market their products without EPA registration so long as the products do not claim to be a plant growth regulator, pesticide, defoliant, desiccant, or nitrogen stabilizer (EPA, 2019).

Figure 2.2. Plant Biostimulants



Conclusions

The Georgia blueberry industry has expanded considerably over the last few decades, and the results of this survey indicate that production has changed as well. The land area allocated for blueberry production in Georgia has expanded from approximately 1,800 hectares in 1999 to more than 10,800 hectares in 2019 (Scherm et al., 2001; UGA, 2020). According to the current survey, growers expect to increase their planted area by approximately 28.5% within the next five years. Compared to a similar survey conducted in 1999, growers have increasingly adopted new southern highbush varieties developed through university research and breeding efforts likely to broaden their market window. Plant injury caused by freezing weather remains a problematic issue for many. Disease pathogens such as mummy berry and leaf spot also persist as challenges that producers face. Spotted-wing drosophila, not present during earlier phases of blueberry industry development in North America, has become a critical pest affecting a majority of growers. Gowers continue to employ a wide range of chemical options for pest, disease, and weed management. Currently the use of biostimulants within the Georgia blueberry industry is low, with growers who do use them primarily receiving products from local chemical providers. Overall, responses from this survey indicate that issues that posed challenges to growers during earlier periods of Georgia blueberry industry development continue to remain, with new problems arising necessitating growers to adapt by utilizing the tools and resources available.

CHAPTER 3

UNDERSTANDING GROWERS' PERCEPTIONS OF PLANT BIOSTIMULANTS IN BLUEBERRY PRODUCTION AND SOIL BIOLOGICAL HEALTH[1]

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[1]Kirksey, Joel and Thompson, Jennifer. To be submitted to *Culture, Agriculture, Food, and Environment*

Abstract

Farmers are exploring plant biostimulants as a potential solution for decreasing the use of synthetic fertilizers and their negative consequences, while simultaneously improving soil health and crop productivity. In the United States, the relative novelty around the concept of plant biostimulants has resulted in a lack of consistency in the use of the term in state/federal regulation and across market suppliers. Among agricultural stakeholders, there are many competing ideas regarding which products constitute a plant biostimulant. This paper examines the use of plant biostimulants through semi-structured interviews with 10 Georgia blueberry growers. The interview participants collectively represent 1,744 bearing acres of Georgia blueberry production, over 230 years of blueberry farming experience, and both organic and conventional farming methods. Results suggest there is great variability among growers' familiarity with plant biostimulants and questions they want answered by researchers. Additionally, our results indicate that there is substantial uncertainty among growers regarding plant biostimulants. Specifically, growers seek clarity about what plant biostimulants are and how they work, as well as an impartial review of biostimulant products on the market and the benefits they can provide to growers' production systems. Finally, growers prefer university Extension over other sources of information on plant biostimulants.

Introduction

The continual depletion and degradation of natural resources, rising atmospheric greenhouse gases, and a growing global population expected to reach 10 billion by 2050 indicates that changes to conventional agriculture are needed to avoid potentially catastrophic results for human society (IPCC, 2014; Matson et al., 1997; UN, 2015). In order to achieve agricultural sustainability, various strategies have developed to sustain economic profitability while reducing social and environmental consequences. There are a number of agroecological practices that have been successfully incorporated into industrial farming systems including cover crops, conservation-tillage, microbial inoculation, smart irrigation, and riparian buffer zones (Bengtsson et al., 2005; Poeplau & Don, 2015).

Plant biostimulants, which are loosely defined as non-fertilizer additives that promote plant growth and soil health, are a recent addition to the list of products being marketed to solve the challenges of 21st century agriculture. Over the last few decades, the global plant biostimulant industry has rapidly expanded with many companies seeking to introduce plant biostimulant products as more economically and environmentally sustainable alternatives to conventional agrochemicals (Calvo et al., 2014). Many claims have been made regarding plant biostimulants—that they have the potential to increase product shelf-life, enhance plant uptake of nutrients, improve soil structure, increase the retention of soil organic matter, or protect against pathogens. However, the effects of most plant biostimulant products are not well established. There are significant gaps between the body of scientific knowledge and the marketing claims put forth by plant biostimulant companies about their products.

There is an uncertainty around plant biostimulants—how they work, their effectiveness, and which products to include—that influences the ability for government/regulatory bodies, commercial manufacturers, retailers, and end-product users to effectively incorporate plant biostimulants into the broader agricultural production system. This type of uncertainty around emerging technologies is not new, it is an issue that is prevalent in many areas within agriculture, such as with the development of new plant breeding technologies, or grower adoption of new seed varieties (Lassoued et al., 2018; Marra et al., 2003). Grower skepticism for new agricultural technologies is not unfounded, as other promising solutions for addressing production needs have proven less than satisfactory. For example, many agricultural products, initially potent treatments in crop management programs, are now ineffective due to chemical resistance which has led to an “arms race” as stakeholders determine the best countermeasures for dealing with pesticide and herbicide resistant organisms (Jasieniuk et al., 1996; Kilman, 2010). Some researchers suggest that to allay legitimate concerns about emerging technologies it may be beneficial to develop regulatory standards that instill trust yet allow for sufficient innovation and consumers to familiarize themselves with a product over time (Bonnín Roca et al., 2017; Halaweh, 2013).

Although plant biostimulants are a fairly new commercial market, many of the principles through which plant biostimulants affect crop production are fundamental properties of soil fertility and plant growth that humans have explored and relied on since antiquity. The ancient Greek philosopher Theophrastus (372–287 BC) considered the mixing of different soils together as a means for ‘remedying defects and adding heart to the soil’ (Tisdale & Nelson, 1966). Pliny the Elder (23 – 79 AD) noted that the ‘peoples of Britain and Gaul’ fertilized their soils with ‘Margo’ (considered to be maerl, a type of red algae found in the English Channel) (Mac Monagail et al., 2017).

There is substantial evidence to support the claim that some compounds generally categorized as “plant biostimulants” have the potential to serve as a source for mitigating challenges in crop production. Plant beneficial microbes applied directly to the seedcoat have been shown to promote crop growth and control plant pathogens (Rocha et al., 2019). Microbial biological control agents (MCBAs), such as *Trichoderma spp*., commonly found in plant biostimulant products, can utilize a variety of modes of action to suppress plant pathogen communities (Köhl et al., 2019). Seaweed extracts are well-documented for their plant-growth promoting effects and ability to increase crop tolerance to abiotic stress (Battacharyya et al., 2015). It is industry standard to inoculate legume seeds with beneficial *Rhizobium* to encourage efficient root colonization and increased atmospheric nitrogen (N_2) fixation (Deaker et al., 2004). Nevertheless, although specific components found in many biostimulants have recognized mechanisms of action, little is known about the effectiveness of individual products. Biostimulant products vary considerably in terms of their compositions and claims; thus, they are likely to vary widely in their effectiveness for different crops and in different conditions.

Some plant biostimulant applications have been demonstrated effective in limited-use case scenarios. A study of foliar applications of various classes of plant biostimulants on strawberry found a 20% increase in berry yield in treated fields (Soppelsa et al., 2019) A review of studies showed that while there is scarce research on the subject, several results indicate that plant biostimulants may improve fruit quality (Rodrigues et al., 2020). However, the widespread uses of plant biostimulants far exceeds the limited research available on them.

Further, the variability among products necessitates further research to determine their impact in crop production. Some ingredients in plant biostimulant products suggest a beneficial role in crop production, but they have yet to be established as effective and reliable. For example, much attention has been brought to the application possibilities for plant-beneficial microbes and the need for further understanding the circumstances that play a role in their utilization. Due to the highly selective nature of plant-microbe symbiotic interactions, as well as the broad host of organisms and environmental factors that alter how plant beneficial microbes affect crops, research is still beginning to illuminate their full potential (Finkel et al., 2017). Arbuscular mycorrhizal fungi provide vital services to plant health, particularly in improving crop nutrition and abiotic stress tolerance (Chen et al., 2018). Balancing the relationship between plant growth-promoting rhizobacteria and mycorrhizal fungi aides in the retention and storage of soil nutrients for sustained crop utilization (Barea et al., 2002). Plant hormones and other growth regulators can directly improve plant stress response and crop yield (Davies, 2012). Though there have been advances in using biological compounds as herbicides, they are still set back by many biological, environmental, and technological constraints (Auld et al., 2003).

Plant biostimulant policy and regulations

Precursors to the modern-day concept of biostimulants include terms such as “biogenic stimulants” and “biostimulators” (Yakhin et al., 2017). Early usage associates the “biostimulant” concept with “non-fertilizer products which have a beneficial effect on plant growth” (Russo & Berlyn, 1991). The relative novelty around the concept of biostimulants has resulted in a lack of state/federal regulation on usage of the term, and little standardization across market suppliers. As such, the definition of what constitutes a biostimulant is not yet solidified, with many competing and contradicting ideas (Yakhin et al., 2017). The confusion is furthered by the use of similar and competing terms including biofertilizers, biopesticides, bioinsecticides, bioherbicides, biofungicides, and biorationals (Chojnacka, 2015; Matyjaszczyk, 2018). There are also homemade or marketed products such as “compost tea,” “vermicompost tea,” and “worm tea” that may include locally effective microorganisms similar to those that are also found within many commercial plant biostimulant products (Edwards et al., 2010).

In the United States there is currently no applicable regulatory definition listed for biostimulants under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which is administered by the Environmental Protection Agency (EPA) (EPA, 2019). Part of this reason is due to the novelty of plant biostimulants compared to other longer established crop fertilizer technologies. Although federal regulations prohibit the sale or registration of plant biostimulant products if they also include labeling of these functions (e.g., plant growth regulator or pesticide), biostimulant companies are free to market their products without EPA registration so long as the products are not described for use as a plant growth regulator, pesticide, defoliant, desiccant, or nitrogen stabilizer (EPA, 2019).

The Agriculture Improvement Act of 2018 (AIA) marked the first significant mandate by the United States Congress regarding legal oversight of plant biostimulants. The AIA mandated that the U.S. Department of Agriculture (USDA), “submit a report to the President and Congress that identifies any potential regulatory, non-regulatory, and legislative recommendations, including the appropriateness of definitions for plant biostimulant, to ensure the efficient and appropriate review, approval, uniform national labeling, and availability of plant biostimulant products to agricultural producers” ("Agriculture Improvement Act of 2018," 2018). As part of this endeavor, in 2019 the EPA released a draft guidance titled *EPA Draft Guidance for Plant Regulator Label Claims, Including Biostimulants* that sought public comment on potential regulatory distinctions for plant biostimulants (2019). As indicated by the proposed guidance, substances such as plant biostimulants may be considered and regulated as a “plant regulator” if they accelerate or retard the rate of plant growth or maturation through physiological action, otherwise alter plant behavior, or fail to fall under an exclusion category. Under FIFRA regulation, products that serve any of these functions are federally designated as a pesticide and must be registered with the EPA in order to be legally sold or marketed ("Federal Insecticide, Fungicide, and Rodenticide Act ", 2019). In other words, the current draft definition would allow commercial marketers to label products as plant biostimulants without being regulated as a pesticide so long as the previously mentioned claims specific to plant regulators are not used. As of July 2021, this guidance has yet to be finalized.

The current study

The objective of this case-study was to contribute to developing knowledge about agricultural producers' orientations towards novel or emergent biotechnology in the context of supporting the development of more sustainable agricultural practices. Our primary focus was understanding how the concept of "plant biostimulants" is understood by Georgia blueberry stakeholders and how Georgia blueberry growers use biostimulants in the context of their broader production practices.

The Georgia blueberry industry was selected for our study as it offers a unique opportunity for research on the role of plant biostimulants in agricultural systems. Blueberry production is a fast-growing agricultural sector in Georgia and is economically the number one fruit crop in the state (UGA, 2018). Georgia consistently leads as one of the top blueberry producing states in the United States, however blueberry yield per acre is much lower compared to other regions, and less than half the yield of states leading in production (e.g., California, Oregon, Washington) (USDA-NASS, 2019b). The Georgia blueberry industry faces many unique challenges and is highly dependent on external resources and inputs for its success. Protocols and practices for maximizing yields are in still in flux, which represents a significant opportunity to improve crop efficiency and agricultural sustainability. Plant biostimulants, along with other resources (e.g., alternative fertilizers, pollination, and irrigation strategies), are being explored by blueberry growers as potential technological aides in enhancing production.

Drawing on semi-structured interviews with Georgia blueberry growers, this paper examines grower perceptions of plant biostimulants, motivations for incorporating plant biostimulants into their production systems, the perceived benefits and risks, and how various stakeholders are viewed as resources.

Theoretical Framework

The uncertainty that surrounds plant biostimulants as an emerging agricultural technology affects the decision making of producers and workers. In general, farming is a risky endeavor with agricultural producers bearing many of the upfront costs and relying on favorable circumstances (e.g., weather, labor, market) for overall success. With a multitude of unknowns surrounding biostimulants, it can be difficult for individuals to successfully use them in a manner that is effective. There are great risks involved for growers when deciding which on-farm practices and technologies to adopt or discontinue, including in plant biostimulants. The choices that growers make and their ability to manage uncertainties will contribute to the success or failure of their farm business.

Farmers turn to several different strategies for adopting new technologies in order to effectively manage this dilemma. Stone (2016) argues that growers rely on environmental, social, and didactic forms of experience in order to decide which action they believe will lead to success. Growers depend on environmental learning or learning-by-doing. Either through deliberate or unintended experimentation, growers utilize past personal experiences in order to help draw conclusions in the present (Foster, 1995). Through social learning, growers learn from the experiences of others regarding similar technologies (Munshie, 2004). Another way of knowing that impacts growers’ decision making is the experience they gain through ‘didactic learning’— meaning their learning from external agricultural stakeholders with their own vested interest (e.g., materials suppliers, agricultural consultants, Extension agents, environmental activists, governmental bureaucrats, regulatory authorities, NGOs) can influence choices made on a farm (Stone, 2016).

Research Methods

Qualitative interviews were chosen as a research method for this case study in order to elicit information-rich data to meet our dual goals of understanding growers' perceptions and attitudes towards biostimulants, as well as identifying applied knowledge to assist in the development of greenhouse and field trials. A thematic analysis approach was utilized due to its strength in creating succinct descriptions of qualitative data upon which valid inferences can be made (Elo & Kyngäs, 2008). All study materials and procedures were approved by the Internal Review Board (IRB) at the University of Georgia.

Selection of interview participants

Georgia blueberry growers were included as study participants based on their specific insight into the issues and challenges of integrating plant biostimulants as a farm management strategy. A purposive sampling method was used to invite key informants with a broad range of plant biostimulant familiarity and blueberry production experience that could shed light on the diverse perspectives surrounding the research subject matter (Patton, 2015). Eligible participants were initially identified through a survey distributed by the researchers to approximately 500 Georgia blueberry growers. Surveys were distributed in-person at Georgia blueberry education and networking events, as well as online through a University of Georgia Extension blueberry industry listserv. (Survey results are being reported elsewhere.) Renee Holland, the Georgia Commercial Blueberry Extension Specialist, also identified growers who could speak to strategies for using plant biostimulants in commercial blueberry operations. We purposefully recruited a sample that sought maximum variation across multiple domains, including growers' familiarity with biostimulants, their experience using biostimulants, and the characteristics of farm production (e.g., conventional/ organic, size, location, length of time in industry) (Patton, 2015). Growers initially identified as partners in the Southern Sustainable Agriculture Research and Education grant that funded the research project of which this is a part were also invited to participate. Finally, we used snowball sampling to identify further key informants through recommendations by interview participants (Etikan et al., 2016). Eligible growers were invited to participate until saturation was met and no other recommended informants were identified.

Semi-structured interviews

Project investigator Joel Kirksey (JK) conducted ten semi-structured telephone interviews with Georgia blueberry growers between September 2020 and February 2021. Initially, the research plan was to conduct walking interviews, a variation of the standard semi-structured in-depth interview, that utilizes the environment to elicit enriched participant responses during discussion . Due to the limitations imposed by the COVID-19 pandemic in conducting in-person activities, as well as participant preferences towards speaking by phone rather than video communication platforms such as Zoom, telephone interviews were held instead. JK or RH contacted eligible growers by telephone or email to schedule interviews. At the beginning of the interview, JK reviewed general information regarding the study, answered any questions, and obtained verbal informed consent. The interview structure consisted of a series of open-ended questions based on an interview guide developed to allow participants to share unrestricted responses of their thoughts on topics related to the research objectives. Each interview lasted approximately 30-60 minutes. Each participant also completed a blueberry production survey either before or after the interview. The interview guide is included in Appendix B.

Interviews were audio-recorded and transcribed. Data was stored and secured on a password protected computer and digital cloud. Any direct/indirect identifiable information was removed and stored on separate password protected files. All data was only accessible by researchers authorized by the IRB.

Coding and data analysis

Following transcription, interview data was uploaded and managed using the qualitative analysis software program ATLAS.ti 9.1 (Scientific Software Development GmbH). This study utilized a six-phase thematic analysis process as outlined by Braun and Clarke (2006). The first step of the analysis process, familiarization, occurred during both the initial transcription of data and its subsequent review. Specific attention focused on information that growers conveyed about their values, information sources, shared agreement, and sensory experiences. Second, initial codes were generated according to the research objectives used to frame the interview and then applied to the text, a process known as *structural coding* (MacQueen et al., 1998). This allowed for segments of data related to specific interview questions to be grouped together for more detailed coding and analysis. Researchers then conducted a subsequent round of *concept coding* in which data was assigned meso and macro levels of meaning based on ideas and processes identified during data familiarization and structural coding (Saldaña, 2016). Codes were then combined, assigned definitions, and organized to form a codebook (DeCuir-Gunby et al., 2011). Third, codes were reorganized into potential themes, which were then mapped to connect the underlying concepts. Fourth, through an iterative process, the initial themes were then reviewed, compared, and recategorized until refined themes were identified. Fifth, the meanings of the final themes were then defined and aspects of the data that the themes capture were determined (Braun & Clarke, 2006). Discussion of the analysis was then provided in the final step of the process, production of a report.

Results

Sample Description

Background information gathered from survey responses indicated that the production acreage of the 10 interview participants totaled 706 bearing hectares, representing 8% of the statewide total in 2019. Participant farm size ranged from 4.0 – 256.9 hectares (ha) with an average farm size of 82.1 ha. Most participant blueberry farm locations (70%) were in Bacon county, the top blueberry producing county in the state in terms of both planted area and production value (UGA, 2020). Other participants were located in either Coffee (20%) and Candler (10%) counties, with the former being another leading blueberry producing area. The vast majority (90%) of participants claimed full or partial ownership of their blueberry farm, four of whom also filled the role of farm manager. One grower solely identified as a farm manager with no ownership stake. The level of blueberry growing experience among participants ranged from 5 – 39 years with an average of 23.3 years. All participants responded that either they or a family member are involved in the day-to-day decisions of what products to purchase, apply, and application schedule.

In terms of farming system, half of our interviewees exclusively followed conventional practices, three were exclusively certified organic, and two produced blueberries under both systems. Eighty percent of participants produced both rabbiteye (RE) and southern highbush (SHB) blueberries, the top varieties grown in the state. Of those, five grew mostly SHB, one grew mostly RE, and two were evenly split between the two types. One participant exclusively grew SHB, and one exclusively grew RE. When asked how their production has changed over the last five years, eight had introduced new cultivars, seven had expanded acreage, and four had added an organic label. The majority (70%) of participants indicated plans for expansion in the next five years, mostly in SHB.

Further background details were provided through discussion with growers through interviews. Most participants had worked in the blueberry industry for a significant amount of time and were concurrently involved in other businesses outside of blueberry production, with farming other agricultural crops as the most common economic venture. Four participants reported blueberry farming as their sole business.

Table 3.1. Participant Characteristics (n=10)

Variable		
Farm Characteristics		**(n/10)**
Farm Type	Conventional	5
	Organic	3
	Conventional + Organic	2
Farm Size (hectares of production)	<20	1
	20-80	5
	>80	4
Blueberry Type	RE	1
	SHB	1
	RE + SHB	8
Participant Characteristics		
On-Farm Role	Owner	5
	Manager	1
	Owner + Manager	4
Currently using plant biostimulants	Yes	7
	No	3

Framing blueberry production

Growers' motivations for farming blueberries included it being a family business, economic incentives, health reasons, and personal interest in working outdoors. In addition to growing blueberries, one participant worked as an independent blueberry consultant, one owned and operated a blueberry nursery, and another sold agricultural equipment.

Some participants viewed their farm as a family operation, having worked on their parents' or grandparents' blueberry farm before taking over or establishing their own farm. Prior to transitioning to blueberries, many of the participants or their families were involved in other areas of agriculture like row crop farming (e.g., tobacco, corn, soybeans, and cotton), animal raising (e.g., cattle, hogs), and timber harvesting. A few participants indicated their transition to blueberries as one of economic necessity in response to the declining tobacco industry, as the following quote illustrates:

> "I was looking for another crop to replace tobacco. This was down in South Georgia, was the heart of the tobacco field. And it looked like tobacco was going out, so we were just looking for another crop to try to replace it and I decided to plant a few [blueberries] back then." (Participant 1)

There were a variety of issues that participants indicated as challenging to their farm, with competition from other blueberry markets as the most common. Both conventional and organic growers described the increased output of blueberries from states like California and Florida as leading to lower economic profitability. Imports from foreign markets, Mexico in particular, were seen as a major cause for concern due to having a similar harvest window as Georgia, lower costs of labor, and less regulatory requirements.

> "Mexico comes in the same window that Georgia's product comes in, and there's some unfair trade advantages they have, and labor advantages that we can't really compete with. We've seen a substantial price decrease the last 10 years." (Participant 2)

Proposed solutions to this problem included government intervention to reduce the flow of blueberry imports and developing blueberry varieties with different harvest windows. Labor and the need for mechanized harvesting options were also deemed as major issues by interview participants. Other on-farm challenges indicated by growers included production related issues like pest, disease, and weed management, as well as maintaining high fruit quality and yield. One participant cited poor pollination as an obstacle to achieving desired yields. Some mentioned "drastic changes" over the last few years, with volatile weather being an issue that concerned their operation. A specific problem cited was extensive rain during the harvest season, which caused fruit splitting.

When asked about changes they implemented on their farms over the last few years, participants gave a range of answers. Two farmers mentioned utilizing more mechanical harvesting in their operation, but this can have downsides to fruit quality.

> "We're going more and more to mechanical harvest rather than hand harvest. Of course we always got quality issue of machine harvest, but we do the best we can with it." (Participant 2)

Irrigation is another change that some farmers implemented, whether it was adding more drip irrigation or setting a frost protection system for their overhead irrigation. Two farmers also discussed switching to new blueberry varieties. Farmers took out old varieties and added new ones that are easier to maintain or are more suitable to machine harvest to stay competitive with the influx of blueberries from Mexico.

> "There's several different varieties [I've implemented]. You got Meadowlark, you got Optimus, you got Key Crisp, you got Susie Blue, Georgia Dawn, got some [cooperative grower organization] patented varieties, Stellars, Prestow." (Participant 9)

One participant explained that their most signficant change was implementing more stringent food safety regulations. To them this meant more diligent record keeping of fertilzation and pest management schedules as well as consistent water sampling. Another participant described that when they first began blueberry farming it was not required to have irrigation or use herbicides. They did not implement a spray program since they did not have the disease, insects, or fungal pressure that they have now.

Biostimulant familiarity

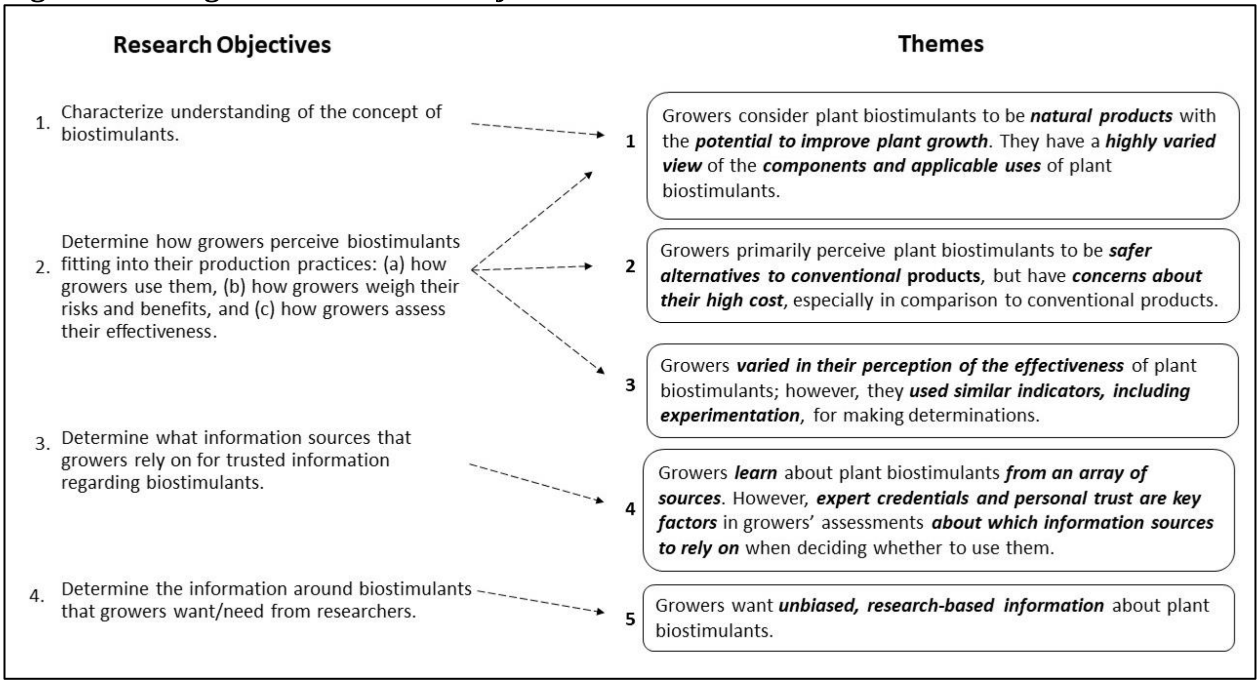
Experience with plant biostimulants varied across participants, with some growers having more knowledge and experience than others. During interviews, nearly all participants (90%) said they had previously heard of plant biostimulants, with the majority (70%) of participants currently using them in their production system. Most participants currently using biostimulants indicated using multiple plant biostimulant products. A single participant reported using only one plant biostimulant product before. An organic producer, this person was recommended a plant biostimulant product by a vendor who specializes in organics and is considered a friend.

> "He's a specialist in organic products. That's all he does, organic natural products. I figured he was ahead of the curve. He'd been doing it for years, and really believes in it." (Participant 2)

Despite using them, many of the growers indicated little familiarity with plant biostimulants. Some participants currently using a plant biostimulant product were unable to recall the name of product from memory. Three reported neither using plant biostimulants currently or in the past. When asked to characterize plant biostimulants, a few felt that they did not have enough prior knowledge to accurately describe them. The following participant gave a typical answer:

> "I'm also not sure. I think I'm just kind of too ignorant to answer that question." (Participant 3)

Figure 3.1. Diagram of Research Objectives and Interview Themes



Interview Themes

Analysis of interviews with Georgia blueberry producers resulted in five overarching themes that align with our research questions (see Figure 3.1). (1) Growers consider plant biostimulants to be natural products with the potential to improve plant growth. They have a highly varied view of the components and applicable uses of plant biostimulants. (2) Growers primarily perceive plant biostimulants to be safer alternatives to conventional products, but have concerns about their high cost, especially in comparison to conventional products. (3) Growers varied in their perception of the effectiveness of plant biostimulants; however, they used similar indicators, including experimentation, for making determinations. (4) Growers learn about plant biostimulants from an array of sources. However, expert credentials and personal trust are key factors in growers' assessments about which information sources to rely on when deciding whether to use them. (5) Growers want unbiased, research-based information about plant biostimulants. This presents an opportunity for university-based researchers and regulatory institutions to provide clarifying guidance that can help shape more effective use of plant biostimulants.

Theme 1: Growers consider plant biostimulants to be natural products with the potential to improve plant growth. They have a highly varied view of the components and applicable uses of plant biostimulants.

How growers defined biostimulants

Participants generally described plant biostimulants as "natural" products. Growers most frequently attributed plant biostimulants as existing in or originating from nature, characterizing them as being constructed through "organic processes" rather than "made in a laboratory." Some growers characterized plant biostimulants as "naturally occurring," and being "organic" or "carbon" based in structure. Plant biostimulants were characterized as a naturally-derived "phytochemical" or other "natural element" that is then added to crops. Some growers described plant biostimulants as adding "an extra dose" of something (e.g., nutrients) already present within the plant or soil. Many growers also indicated their view of plant biostimulants as natural alternatives to synthetic or conventional agrochemicals.

> "Well, I guess, it's you know a natural way to attempt to get to the same place we want to get with commercial pesticides." (Participant 6)

Half of the participants described plant biostimulants as either "living" or originating from something that was once living. Multiple participants associated plant biostimulants with a microbial component like a bacteria or fungi. One grower detailed a biostimulant product that contained an "agrobacterium." One participant described needing special knowledge to have the best chance of success with utilizing biostimulant products because "you're dealing with live organisms." Another participant described the need to aerate their biostimulant product because it was living. Another participant used a clear comparison of biostimulants as the opposite of "dead" products that are applied to the field.

> "I'd say they're different mainly in the fact that by my understanding you're taking living organisms and not some dead organic compound or something to spray out there." (Participant 3)

Another characteristic commonly attributed to plant biostimulants was the potential to improve crop production. Many growers using plant biostimulants said they did so to ultimately improve production through increased yields, bigger berries, and improved fruit quality. Growers described plant biostimulants with terms like "enhancers" and "stimulants" meant to augment plant growth. Some participants described plant biostimulants as allowing crops to make better use of resources by engaging internal growth mechanisms.

> "I would define that as a natural plant-enhancing stimulant that enables the plant to make better use of the resources it has, to make better use of things that enable plants to make better use of the water or the fertilizer, or different additives or whatever you place there, it makes better use of." (Participant 8)

However, a few participants when describing plant biostimulants' capability for improving plant growth were unable to directly identify the specific bioactive compounds contained within them or the modes of action they engage.

> "I guess they just speed up the growth of the plant is all I can tell you. I don't know what chemically or within the plant structure itself causes it to speed up, but I guess stimulates growth in the plant." (Participant 4)

> "Typically, biostimulant to me sounds like something that is naturally occurring, you know by natural organic processes, whether that be bacteria, extraction from a natural

element, or whatever, concocted in a usable form to be put out on a crop to stimulate in the purpose of fertilizer or even as a plant growth regulator, or in some cases you know there's even the thought of bacteria, of growing this protection of bacteria and fungi around the plant through the application of a biostimulant. That's what comes to mind for me." (Participant 5)

Another characteristic attributed to plant biostimulants is only needing to add "a small amount" to be effective similar to how people take supplements. One participant, when asked if they had previously heard of plant biostimulants, explained that they thought they were like probiotics that are added to the plant or soil. Another more concretely compared the function of plant biostimulants to the way probiotics work in humans.

"It's kind of like a probiotic to an individual would be I guess is we're trying to head off some problems using them rather than fix the problem on the back end. […] That's how I take they're supposed to work is building a healthier plant up front basically." (Participant 2)

How growers perceive plant biostimulants fitting into management strategy

In addition to perceiving plant biostimulants as having natural qualities and a potential to affect plant growth, there were a wide variety of other characteristics that growers attributed to them. Growers viewed plant biostimulants as products that could be applied either on their own or in conjunction with other products directly to plants or soil as a foliar spray, through drip irrigation, or indirectly by bee vector. Although most growers perceived plant biostimulants as fitting into both conventional and organic production systems, some viewed plant biostimulants as the opposite of conventional production, with one organic grower associating them exclusively with organic production. Still, others perceived plant biostimulants as not as necessary in conventional systems but having use as a replacement method.

> "You got to spray five times, it's hard to rely on it for the whole five sprays, but you can do three of them with that and then two perhaps with synthetic pesticide." (Participant 1)

Growers had a range of perspectives on the product types and applicable uses for plant biostimulants. Participants categorized plant biostimulants as nutrient/non-nutrient fertilizers, insecticides, fungicides, herbicides, nematicides, and plant growth regulators. Many growers perceived plant biostimulants as fulfilling the role of typical fertilizers that add macronutrients or micronutrients to the soil that are missing, difficult to access, or present in small amounts. Others described plant biostimulants as introducing or supporting microbes to convert inaccessible nutrients into more available forms thereby increasing crop uptake of nutrients.

Plant biostimulants were also perceived as a tool for preventing or eliminating pests, either by acting directly as a pesticide or indirectly by increasing overall plant health and resilience to environmental stresses. Plant biostimulants were similarly described as being added to plants for their protective properties, by promoting a plant's natural defenses or creating a defensive barrier to repel pests.

> "Basically, instead of using fungicides to take away […] whatever you're trying to go after, you build a layer of beneficial fungi and bacteria […] on the outside of the plant that acts like a protective barrier to the plant." (Participant 6)

Growers identified a wide variety of components as fitting into the plant biostimulant category including macro/micronutrients, seaweed extracts, humic acids, fish products, vitamins, inorganic elements, compost tea, and beneficial fungi/bacteria. Products identified by growers as plant biostimulants can be seen in Figure 3.2.

At the same time, there remained quite a bit of uncertainty among growers about which products are considered biostimulants. More than one grower openly speculated during their interview whether certain products were considered plant biostimulants in the first place. Two interview participants when asked if they had used biostimulants initially said no, but on further consideration determined that they had. There were also differences between the ingredients some growers perceived as plant biostimulants and those that typically fall within that category, with one grower citing pine mulch, a type of ground cover, as an example of a product they consider a plant biostimulant.

Figure 3.2. Plant Biostimulant Products Identified by Interview Participants

Product	**Company**	**Active Ingredients**	**Use**
BioRepel	SaferGro	Garlic Oil	Insect Repellent / OMRI Listed
Entrust	Corteva	Spinosad (a mixture of spinosyn A and spinosyn D)	Insecticide / OMRI Listed
Evergreen	MGK	Pyrethrins	Broad Spectrum Insecticide / OMRI Listed
Spintor	Dow AgroSciences	Spinosad (a mixture of spinosyn A and spinosyn D)	Insecticide
Venerate	Marrone	*Burkholderia* spp. strain A396	Insecticide
(A) Weed Slayer + (B) AgroGold	Agro Research International	A - Eugenol (clove oil) B - *Streptomyces rimosus* & *Bacillus megaterium*	Herbicide
Vectorite with CR-7	Bee Vectoring Technology	*Clonostachys rosea* strain CR-7	Microbial fungicide / OMRI Listed
Fertilex	Excel Ag	Zn, Fe, Mn, B, Mo, Mg, S	Micronutrient mixture / OMRI listed
Nutri-Max	Meherrin Ag	multiple products	Nutrient fertilizer
Soil-Set	Alltech	"Bacterial Fermentation Media" Cu, Fe, Mn, Zn	Fertilizer, blended with micronutrients / OMRI Listed

Bio-Activate	JH Biotech	*Ascophyllum nodosum* (seaweed) extract	Improve soil structure and nutrient uptake
Inocucor Garden Solution	Concentric Agriculture	20% microbial inoculum (10% each of two species) - *Bacillus subtilis* - *Saccharomyces cerevisiae*	Stimulate root growth and boost yields / OMRI Listed
Fortex	Excel Ag	--	Biostimulant and nutritional complex
Reliant Copper	Quest Products	Mono- and di-potassium salts of Phosphorus Acid	Systemic fungicide
--	Core Biologic	--	--

Theme 2: Growers primarily perceive plant biostimulants to be safer alternatives to conventional products, but have concerns about their high cost, especially in comparison to conventional products.

Participants perceived an array of benefits stemming from plant biostimulant use with the most prominent being a reduced human and environmental health risk compared to conventional products. Growers described plant biostimulants as safer for the environment and less harmful for beneficial organisms (e.g., bees, microbes) and soil health. Participants also had less concern about the risk of toxic residues that may affect consumers or workers when using biostimulants. One grower described a benefit of plant biostimulants being that workers can spray and enter the field to harvest on the same day. Another participant associated plant biostimulant use with leaving a better future for their grandchildren.

> "I feel like you have less detrimental effects on the environment with biostimulants. […] So, I guess for future, my kids, and grandkids. I would say yes, there is less risk with biostimulants." (Participant 8)

In addition to the health benefit, a few growers emphasized finding plant biostimulants to be relatively easy to use as well.

> "It appears to be it's more user-friendly, it's more soil-friendly. It appears to be that the movement's going that way, food safety's going that way, but we don't know long-term." (Particpant 9)

The biggest drawback that growers perceive of plant biostimulants is the high cost associated with them. Plant biostimulants were described as being more expensive to use per acre than other products due to higher price per unit and requiring multiple applications to achieve desired effects. Plant biostimulants were also associated with higher labor costs. One grower shared that they only use products like plant biostimulants when necessary. Most growers issued concern with how these additional costs affected their economic bottom line.

> "Well, they're expensive on the face, you know right when you first invest it. From the stuff I've researched and looked at, it is very pricey to get into biostimulant use and the efficacy of it is sometimes questionable. So, know with organic farms you have to use them, but with conventional farming it's kind of a decision you have to make whether you want to use it, because you don't have to. You know what I mean?" (Participant 6)

Theme 3: Growers varied in their perception of the effectiveness of plant biostimulants; however, they used similar indicators, including experimentation, for making determinations.

Perception of effectiveness

Participants varied on their overall impression of the effectiveness of plant biostimulant products from some reporting a definitive positive experience to others deciding to stop using a product after not seeing "any benefit." How growers perceived the effectiveness of plant biostimulants appears to have been related to their level of adoption and familiarity with plant biostimulants. Nevertheless, whatever their determination, growers expressed utilizing similar indicators including yield, fruit quality, and visual appearance. Additionally, participants described utilizing experimentation for measuring the effectiveness of plant biostimulant products.

Indicators

Participants communicated relying on blueberry yield and general plant appearance as the two most prominent indicators for determining the effectiveness of the plant biostimulant products they have used. Some growers utilized quantitative yield data (e.g., harvest rate) for determining plant biostimulants effectiveness. Others described observing the effects that plant biostimulants had on fruit quality (e.g., size, post-harvest quality grading) and overall marketable yield. A few growers detailed using visual indicators such as pest and disease presence, vegetative growth, and visual color, for determining a product's effect on a field's overall health. Multiple growers acknowledged that while visual cues can serve to indicate a plant biostimulant product to have some positive effect, it may not result in higher yields. Consistent, multi-year increased rate of fruit production seemed to provide growers with the most concrete evidence of a product's effectiveness.

Multiple participants detailed experimenting with plant biostimulants by examining year-to-year differences or only applying them to certain areas and comparing between fields, as in the following example:

> "The plant health. Sometimes you can see the plant health. But plant health don't always mean more production. What I've always told my people, you put it out, you don't tell me where you put it, if I drive by the farm, I see it, then it's working. Especially production. It's hard to see below 5 and probably below 15% production increase. If it's

5, 10% production increase, that's real subjective. But when you can drive by and tell it's a row you done something, then you know it's working." (Participant 9)

Growers described experimenting with plant biostimulants in various fashions, including trying a new commercial product or products made by acquaintances. Others indicated they used trial plots (sometimes imperfectly) to test the effectiveness of plant biostimulants.

> "We had a consultant approach us who was selling some other products, but he was a licensed dealer. […] We decided to set up a little program, a three-year program, that we succeeded in the application but not in the record keeping for the purpose of the program. So not totally a success, but anyway, carried out this program. I sprayed 16 acres in four fields, two different two acres of a kind of a control and a test in these four different fields. That ended up being the problem was we didn't have the manpower to collect the data and keep all the fruit separate. […] Did that for three years. It does seem like it had an effect. But now that the plants are a little older […] they do look healthier. I just don't have a metric to support that. They do look slightly healthier." (Participant 5)

Some participants voiced concern over the reliability of plant biostimulants and disclosed their uncertainty about the effectiveness of these products. These growers shared their belief that plant biostimulants are not as effective as synthetic or conventional products. Some growers reported their difficulty discerning the effectiveness of plant biostimulant products they had tried and were unsure if the product they used had any positive effect. Multiple participants explained that the plant biostimulant product they tried *appeared* to be effective in producing higher yields or healthier looking plants, but the results were inconclusive, and they lacked any concrete evidence that some other aspect was not a contributing factor. Nevertheless, some who were unsure of the effectiveness of their plant biostimulant products exhibited a willingness to try them again in the future.

Theme 4: Growers learn about plant biostimulants from an array of sources. However, expert credentials and personal trust are key factors in growers' assessments about which information sources to rely on when deciding whether to use them.

Growers described learning about plant biostimulants from a variety of people including other growers, chemical suppliers, and outside advisors. They described synthesizing information from a variety of information sources when deciding which agricultural practices and products to follow. Participants expressed a high level of discernment in terms of critically evaluating the veracity of information sources. Often growers express not taking information that they receive at face value, but rather corroborating resources to build a sense of certainty. Growers described cross-checking the internet with other sources like universities, cooperative organizations, Extension, and other growers.

Growers

Multiple participants described being first introduced to a plant biostimulant product through testimonial from another producer. A conventional grower mentioned being made aware of a plant biostimulant product while visiting an organic grower's farm and seeing the results for themselves. Another grower learned of a product during a conversation with group of other farmers.

> "Well, there was a couple of fellow farmers and you know we all kind of share information with one another and some farmers really believed in it, so we thought we'd give it a try." (Participant 7)

Other growers were typically perceived as a trusted information source, with some participants ranking information from other growers highly.

> “It’s always good to talk to another farmer that had success with it and word of mouth. That’s probably the most important thing. (Participant 6)

Establishing a certain level of trust either through expert credentials or personal relationship largely influenced which sources growers relied on for information about plant biostimulants. For instance, an organic grower decided to use a plant biostimulant product after being introduced to it by another organic producer who they felt could speak to its effectiveness in their specific circumstance.

Many growers expressed feeling unsure as to where reliable sources of information can be found about plant biostimulants, noting that some sources, like chemical suppliers, may not be trustworthy. Growers described feeling more comfortable receiving information about an agrochemical product from another grower compared to a sales representative. Some growers expressed hesitance at trying new plant biostimulants and preferred to wait for other producers to try a product before deciding to use it themselves.

> “I’ve got a [family member] that’s into it. I’ve got a friend that’s into it. So, I’ve told them to ‘keep on doing what you’re doing, I’m going to keep on focused with what I’m doing, and if you get something to work, let me know.’” (Participant 9)

Vendors

Participants described utilizing vendors as a source for product information but were divided on their trustworthiness. Two participants described having a personal relationship with vendors, describing them as friends who keep them up to date on new products and research trials. One participant, who is an organic grower, described having a friend who is a vendor that specializes in organic products. For some participants, advertisements by chemical suppliers are often their first introduction to a product. Many participants described communicating directly with chemical manufacturers or sales representatives for information on using plant biostimulant products. Some growers described speaking with sales representatives for further information following speaking with Extension. A few participants described finding sales representatives as generally straight-forward and study data provided by chemical manufacturers as helpful. One grower described appreciating when chemical suppliers let them try a product on part of their farm before making a big financial commitment.

There were also a significant number of participants who were skeptical of the information provided by chemical suppliers. One grower described not trusting company-funded research trials since it is possible that these companies only include data that supports their claims. A few growers described not trusting information provided by vendors since there may be a tendency to exaggerate the effectiveness of a product. From their view, it is possible that a product works but not to the extent the vendor describes.

> "If you know them good, and I mean you can trust some of them [sales representatives], and some of them you can't, because some of them ain't going to tell you what they're doing. They'll tell you part of it." (Participant 10)

Another participant shared feeling overwhelmed by the technical jargon used by sales representatives and unsure if the information being shared with them is truthful.

> "There's always a salesman that got this stuff that's "'gon do this or 'gon do that" you know? And it all sounds real good, and he will really get over my head with all these chemical breakdowns of what it is going to do to the soil or whatever. And you know, is he just talking trash or is it really worthwhile?" (Participant 1)

Some participants indicated that the most trustworthy types of information a vendor can provide are those that can be confirmed by an independent source. For example, a few growers described a vendor sharing the contact information of another grower who has tried the product in question. One participant said that the price of the product is the most reliable information a vendor can provide, since that at least can be fact checked. Another participant, when introduced to a product, refers the vendor to the local Extension specialist to conduct a research trial. Those who follow through are deemed as having confidence in the effectiveness of their product, however, most do not.

Cooperative grower organizations

Some of the participants described being members of a nationwide blueberry cooperative, which they view as a trusted information resource. According to these participants, a key benefit of the cooperative is that it is made up of blueberry growers across the country and is thus grower-oriented.

> "It's a little more clear cut from a business standpoint than a regular marketer is because of the way it's structured. It's grower owned and grower run, so therefore it's very transparent in the way they do business." (Particpant 4)

According to two growers, a horticulturist from the organization is available to visit farms, analyze samples, and advise members on treating issues. The organization was described as staying current on research and practices occurring in blueberry regions across the country. The organization also conducts internal research on agricultural products. One participant described the cooperative publishing "positive enough" results of a plant biostimulant study conducted in another state to convince them to give the product a try.

Extension

Overall, growers most frequently indicated Cooperative Extension as their preferred information source. Growers described research findings from Extension as unbiased, replicated, and reliable. Participants described utilizing Extension by attending meetings, accessing information published online, and directly reaching out to specialists and county agents. Multiple growers described speaking with Extension as their first resource to answer questions before addressing an issue or making decisions on any new or unfamiliar products. According to one grower, the strengths of Extension are their ability to identify problems and share effective treatment approaches based on what is occurring on other farms. Nevertheless, another participant voiced a challenge they experienced with Extension having a high turnover rate of agents and not consistently feeling there was a reliable person available.

Participants contrasted the reliability of Extension research with products tested by other growers, noting that other growers' results may be invalid due to unscientific methods, or due to their production size, years of experience, and openness to share. One participant described reaching out directly to an Extension specialist or county agent with questions followed by asking a chemical supplier, then other growers, then directly with the Land-Grant university.

> "I mean, we use our knowledge from the past and we look at soil samples to tell us what we need to put, and then we turn around and we've talked with our fertilizer company and our chemical companies and we look at what the University of Georgia is recommending and take that in. Take all of it in and then we decide what we want to do." (Participant 10)

Other sources

Growers expressed utilizing universities, including their state's flagship land grant institute as well as others in the region, for answers about plant biostimulants. Growers also described accessing online resources like academic journals, university websites, and social media to learn about products, and stay up to date with blueberry developments and other industries. One grower utilizes an independent former university researcher who has an online accreditation program on soil health.

Theme 5: Growers want unbiased, research-based information about plant biostimulants.

When asked about their research priorities, the growers we interviewed explained that they wanted unbiased information on the effectiveness of plant biostimulants or asked what independent research is available on plant biostimulants. Other growers wanted specific information on plant biostimulant products for their region, to know how effective plant biostimulants are, or to know if their understanding of plant biostimulants is the same as other people's.

Importantly, the uncertainties that participants had about plant biostimulants translated into the questions they wanted answered. Growers were interested in researchers providing clarity regarding plant biostimulants. They wanted an unequivocal definition of what biostimulants are, how they work, and their effectiveness or lack thereof. Growers expressed a desire for an impartial review of biostimulant products on the market and which benefits they can provide to the growers' production systems. They wanted to see definitive results of products to differentiate them from "snake oil" or other products that may be marketed to them with promises of a result that hasn't been proven in the field. Many growers looked to the university to provide this type of research.

> "Everybody that's out there promoting these private biostimulants for somebody that's selling it, so I wonder how truthful they are about the effectiveness of it, because they're trying to sell it. I think that'd be one thing that the university could help with is – and there may be more research out there that I'm not aware of about the effectiveness of different products in the market." (Participant 4)

Finally, during interviews, participants emphasized having more pressing concerns in areas of blueberry research apart from plant biostimulants. Growers expressed wishing for research on general blueberry topics such as yield, fruit quality, pruning, weed management, disease, and machine harvesting. Furthermore, growers requested university researchers focus on areas such as pollination, regenerative agriculture, organic blueberry varieties, and which varieties will yield fruit during opportune marketing windows. One grower noted how many of these aspects may be intertwined with each other.

> "I think from an economics type standpoint on the farm, it's kind of a multi-piece question, but you know improving the number of pounds that make it from the field into the fresh market. That means quality. That means yield. It means disease resistance. I know that's like a huge ask, but as we've gotten some of these newer varieties, some of them have come with their own drawbacks and so I don't know if there's one single thing that's the most important to us, it's just trying to doing what you're doing, trying to tackle all the angles one piece at a time and this biostimulant piece may be what helps us push further." (Participant 5)

Discussion

To our knowledge, this is the first study of farmers' perceptions of plant biostimulants. The goal of this study was to understand Georgia blueberry growers' understanding of plant biostimulants, and their use in the context of growers' broader production practices. Interviews indicate that growers view plant biostimulants as alternatives to conventional agrochemicals that are derived from nature or natural processes and serve as potential resources for increasing crop production. Growers described implementing plant biostimulants into their production systems as fertilizers, pesticides, fungicides, herbicides, and growth regulators.

Our findings indicate that growers' definitions of plant biostimulants are similar to those put forth by researchers, which designate a broad range of components as fitting into the plant biostimulants category. Bulgari et al. (2015) defines plant biostimulants as "extracts obtained from organic raw materials containing bioactive compounds" (p. 2). Du Jardin (2015) describes a biostimulant as "any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content" (p.3). Based on these classifications, plant biostimulant labeled products can potentially consist of beneficial bacteria, fungi, humic acids, fulvic acids, protein hydrolysates, amino acid formulations, seaweed and fish extracts, biopolymers, enzymes, plant growth hormones, animal meals, simple sugars, chemical activators, chelates, antioxidants, vitamins, macro/micro-nutrients, or other beneficial elements (Du Jardin, 2015)

It has been noted elsewhere that growers weigh how their decisions will affect various production, financial, legal, environmental, social, and human-health related risks (Huirne, 2000). Growers in our study weighed similar factors, and ultimately differed in their belief of whether plant biostimulants can meaningfully contribute to improving crop production systems. Some participants perceived plant biostimulants as having a valuable place as a management tool in their production systems, whereas others were more uncertain. Growers perceived the high cost and unestablished reliability of plant biostimulants as a drawback leading to increased economic risk of not achieving desired results with their use. For some, the economic uncertainty outweighed the potential benefit of increased human and environmental health and improved production through means that utilize the natural qualities that plant biostimulants may entail. Fundamentally, these uncertainties influence how growers determine whether and how to include plant biostimulants in their agricultural practice.

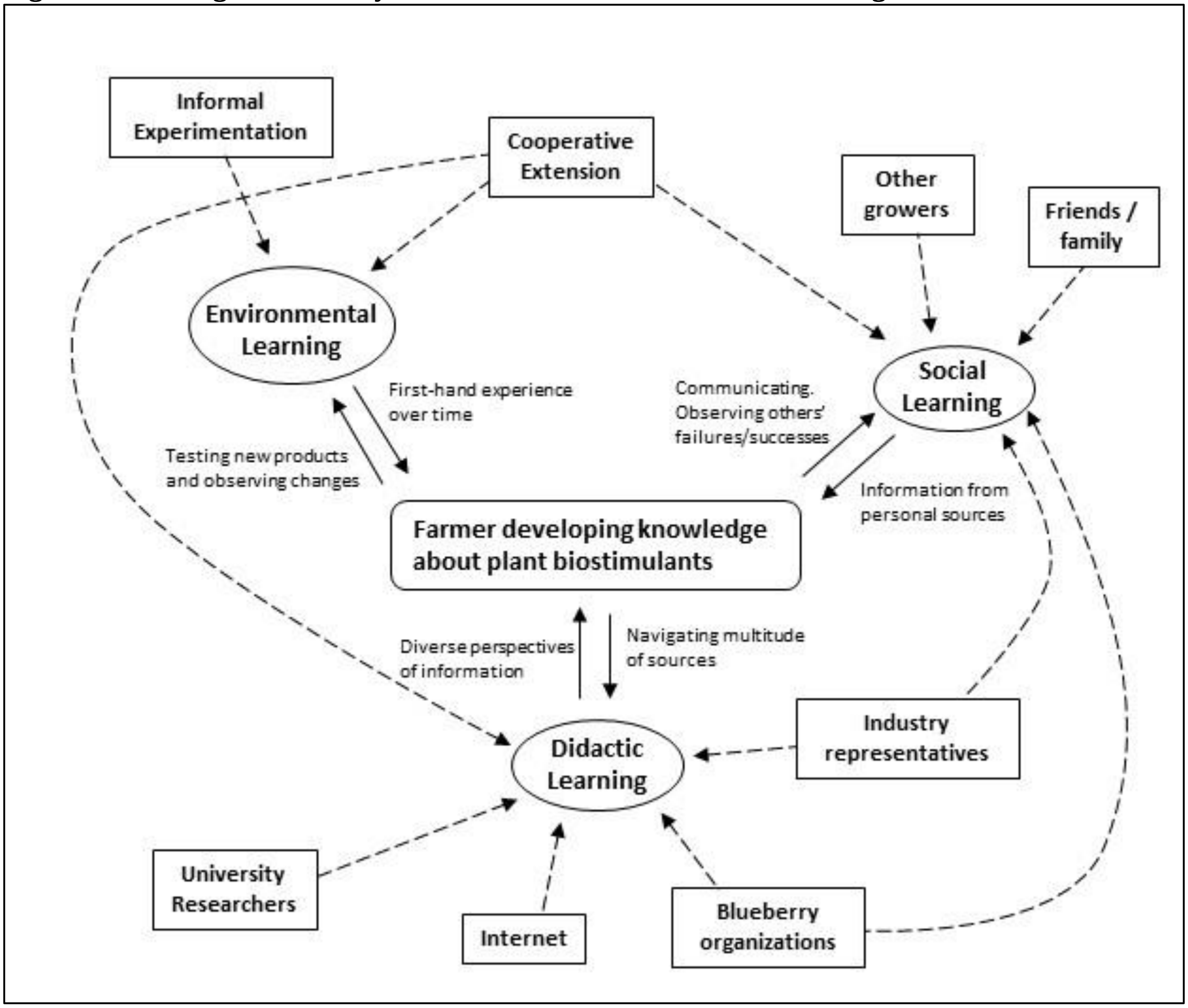
It is critical that policy makers understand the varied views of stakeholders around plant biostimulants to ensure that any regulatory decisions adequately protect the physical, social, and financial health of those likely to be affected as a result. Agricultural producers particularly are at great risk due the pronounced financial instability they have faced in recent years leading to increased farm bankruptcy filings (Dinterman & Katchova, 2018). Furthermore, as end-product users, any decisions regarding the purchasing or application of plant biostimulants will directly affect farmers' ability to effectively incorporate them into the management systems. Our study indicates that agricultural producers may perceive plant biostimulants quite differently than how plant biostimulant industry lobbying groups propose to categorize them. Policy recommendations proposed by biostimulant industry representatives center on including synthetic products for labelling as plant biostimulants and easing the ability for companies to market and sell plant biostimulant products nationwide without EPA regulation under the 'plant regulator' category (BPIA, 2019). Any regulatory definition for plant biostimulants needs to instill trust in its users and align (rather than undermine) users' understanding of the products, so that these products can be sustainably used for generations to come.

Plant Biostimulant Knowledge Production

Drawing upon Stone's (2005) General Theory of Agricultural Knowledge Production as a framework, we constructed the model presented in Figure 3.3, which illustrates how participants navigate information resources when learning about new agricultural products like plant biostimulants. Through interview discussion, multiple participants indicated a strong reliance on informal experimentation, a type of environmental learning, for informing their understanding of plant biostimulants. On-farm experimentation in various fashions (e.g., crops, crop varieties, agrochemical treatments, and cultural practices) has been well-documented as a commonly used means for learning and innovation (Saad, 2001). In the present study, participants acknowledged trying out plant biostimulant products and observing differences between previous years or untreated fields. While informal experimentation may not be the most effective or reliable form of learning, it is still a method that agricultural producers use to develop understanding of a topic through first-hand experience. Other research has shown a connection between farmer preference for first-hand learning and wanting to save time and financial resources (Franz et al., 2010).

Participants in our study used social learning, through communication and observation of friends, family, and other farmers, as a medium for developing knowledge on plant biostimulants. Social learning has been argued as a foundational tool of cultural development that allows individuals to gain understanding while avoiding some of the associated costs of individual learning (Boyd & Richerson, 1995). While its full impact in agriculture is yet to be made clear, there is evidence that producers utilize personal information networks to some extent when adopting new agricultural technologies (Conley & Christopher, 2001). Participants described deciding to use plant biostimulant products after receiving testimonials, recommendations, or observing affects from other farmers or farm operations they perceive to be similar to their own. Growers indicated that they liked to see what other growers are doing and then decide what works for themselves. Researchers have identified *prestige bias* (in which farmers adopt a practice based on another's social standing) and *conformist bias* (in which farmers adopt a practice due to it being widely adopted) as factors that may influence social learning behavior (Stone et al., 2014).

Figure 3.3. Georgia Blueberry Grower Plant Biostimulant Knowledge Production Model



Didactic learning in the context of agricultural knowledge production can be summarized as "off-farm sources of information, advice, and exhortation," with examples including state agencies, input developers and retailers, as well as non-governmental organizations (Stone, 2016, p. 6). Study participants expressed relying on resources such as cooperative grower organizations, Extension, university researchers, industry representatives, and the internet for gathering information on plant biostimulants. Through these sources, farmers can acquire a diverse array of information to guide their understanding. Participants articulated perceiving some of these sources as experts with useful information. However, growers also expressed a wide range of skepticism across these didactic agents with Extension and university researchers being most highly trusted. Chemical suppliers in general were not viewed very highly as a trusted information source; however, a personal relationship can lead to growers viewing individual suppliers as trusted resources.

These forms of learning are not independent of each other, with learning resources having the potential to fit into multiple categories. Industry representatives and members of cooperative blueberry organizations, both categorized as didactic agents, may also incorporate aspects of social learning as personal relationships and amical bonds develop. Extension, depending on the personal relationship with individual producers, has the potential to contribute to either environmental, social, and didactic learning. Many of the growers in our study described having a close, trusting relationship with Extension, whereas others viewed them as a simple resource with established credentials. Some participants had previously been involved in Extension research (e.g., field trials) which can contribute to environmental learning through personal observation of formal experimentation.

Notably, none of these forms of learning are free from uncertainty. Participants were not always confident in their own experimentation and observation; they did not always assume that information from other growers was relevant to their practice; and not all industry representatives were perceived as equally trustworthy. Growers indicated that they prefer to base their decision making on trusted input from those they perceive to have unbiased expert insight enhanced by a mutual bond developed from personal connection.

Limitations

The small sample of blueberry growers used for this study was not intended to represent all blueberry growers in Georgia or the United States. Study participants were selected based on farm characteristics and familiarity level of plant biostimulants and identified through participation in previous blueberry networking/education events and research. There is a potential this may have disproportionately represented participants who are more likely to have stronger opinions of plant biostimulants and the role of university Extension. Data analysis did not compare participant sub-groups based on technology adoption preferences. Interviews were originally intended to be conducted in person, but due to safety restrictions imposed by the COVID-19 pandemic, telephone interviews were conducted instead. While we do not believe this affected data richness, it is possible that in-person interviews may have provided different insight into growers' perceptions. The research findings are generalizable to commercial blueberry growers located in southern Georgia, however the majority of blueberry production in the state is located in this region.

Going forward, research that seeks to quantify the effect of specific plant biostimulant products on yield, fruit quality, and disease prevalence will help growers to understand the potential uses of plant biostimulants in their production system. Extension outreach that clarifies the differentiation between plant biostimulants and other agricultural products would provide helpful clarification for growers.

Conclusions

Our case study highlights the perceptions Georgia blueberry growers have about the concept of plant biostimulants as a management tool and the information sources relied on during decision making. To our knowledge this is the first study of growers' perceptions and use of plant biostimulants. Our results suggest blueberry growers' understanding of plant biostimulants are still in flux but may correspond with definitions that center on plant biostimulants developing from natural, non-synthetic processes. Growers navigate a network of information when learning about plant biostimulants and depend on trusted resources for success. Providing clarification about plant biostimulants from university Extension and researchers may ensure growers make better informed decisions on plant biostimulant use and adoption.

CHAPTER 4

CONCLUSIONS

The primary purpose of this study was to understand the perceptions and attitudes that Georgia blueberry growers have towards plant biostimulants and their perceived value as a management strategy in blueberry production. More broadly, we strived to contribute to developing knowledge about agricultural producers' orientations towards novel or emergent biotechnology in the context of supporting the development of more sustainable agricultural practices. To meet these objectives, a mixed-methods research approach was implemented including participant observation, a survey of Georgia blueberry industry commercial growers, and qualitative interviews with Georgia blueberry producers. Through participant observation and the survey, researchers developed background understanding of the blueberry industry, production practices/issues, and sentiment towards plant biostimulants. Qualitative interviews further illuminated grower concerns and perceptions of plant biostimulants and the blueberry industry as a whole, as well as learning strategies for knowledge production of plant biostimulants and other agricultural technologies.

Survey findings suggest the Georgia blueberry industry has changed considerably over the last few decades in terms of certain practices, however a few issues continue to remain. In addition to more statewide allocation to blueberry production, average farm size and yield appears to have increased as well. The majority of blueberry growers reported expecting to continue expanding their planted area by an average of 23.7 hectares over the next five years, indicating the industry may continue to grow as time passes. Most survey respondents reported spotted-wing drosophila, an invasive pest introduced to the United States within the last 15 years, as a concern affecting production. Disease presence continues to be a major issue for growers, with a variety of agrochemical treatments utilized for managing incidence. The majority of survey participants reported not currently using plant biostimulants in their production, as well indicating a high level of concern regarding their cost.

Farmer-oriented research can serve to improve understanding of the role that agricultural technologies such as plant biostimulants have in crop production systems as well as guide research and outreach that may lead to more sustainable adoption. Interview data indicate that Georgia blueberry growers' understanding of plant biostimulants is still developing and is influenced by their information resources and level of familiarity with plant biostimulants. Participants conveyed perceiving plant biostimulants as natural products, often contrasting them against synthetic agrochemicals. Furthermore, growers described plant biostimulants as having the potential to improve crop production; however, there was often a heightened sense of uncertainty surrounding their high cost, reliability, and effectiveness. Growers viewed plant biostimulants to be safer alternatives to conventional practices with reduced human and environmental health risk. Growers rely on social, environmental, and didactic learning in order to develop knowledge about plant biostimulants and other agricultural technologies, with expert credentials and personal trust playing key factors in determining which sources to utilize during decision making.

Implications for Future Research

There is room for improvement in how plant biostimulants are incorporated into blueberry production systems in Georgia, with Extension and university researchers having the potential to play critical roles in providing clarifying information for growers. Growers often expressed a limited level of understanding of the plant biostimulant products they use and the effects they may have on their operation. Continued research that reviews plant biostimulant products on the market and the benefits they can provide in consideration of the different circumstances that shape blueberry growers' production systems may help to make clear which products may be of use. Specifically, research that investigates the effectiveness of plant biostimulants on both organic and conventional systems, different blueberry cultivars, and on improving yield. Education outreach that explains in clear terms what plant biostimulants are, how they work, their uses, and what the research process looks like may also provide benefit for many growers. As the Georgia blueberry industry has expanded so have the accompanying issues. Producers in our study expressed a desire for general blueberry research in areas such as pruning, machine harvesting, and pollination. Additionally, participants wished for continued research on cultivar development with a focus on yield, fruit quality, and organic production.

Other potential areas of plant biostimulant research should focus on how plant biostimulants are understood by other agricultural stakeholders within the blueberry industry such as Extension and chemical suppliers. Additionally, there is room for analysis of the effect of commercial advertising and web resources on plant biostimulant awareness, which was left unexplored in this research project. As policy and legislative decisions on plant biostimulants occur, research that measures any possible shifts in grower understanding could also be useful.

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APPPENDIX A

Completion Code ______________

Georgia Blueberry Survey

The information developed from this survey will be used by scientists and extension specialists at the University of Georgia in efforts to learn more about the effects of biostimulants on blueberry production in the Southeast and provide growers with the best information possible regarding their use in production. We appreciate your time in filling out this questionnaire. All information is **strictly confidential** and will not be identified with any grower. *Completion of the survey will only take 15 to 20 minutes of your time.*

Farm Name*:
____

**This information will only be used for tracking purposes. It will be removed prior to analysis.*

I. General information about your operation:

1. On-Farm Role: [ ] Owner [ ] Farm Manager [ ] Farm Employee
   [ ] Other: (please specify)
   ____

2. State where most of your acreage is located: [ ] Georgia [ ] Florida [ ] North Carolina
   [ ] Other: ____

3. County where most of your acreage is located:
   ____

4. For how many years have you been growing blueberries: ______ years

5. Approximate acreage:

   Rabbiteye cultivars

   5.1 ______ bearing acres

   5.2 ______ non-bearing acres

   5.3 Circle your two most common rabbiteye cultivars:
   Brightwell, Climax, Tifblue, Powderblue, Premier, Alapaha, Austin, Vernon, Ochlockonee

   Other: ____

   Southern highbush cultivars

5.4 ______ bearing acres

5.5 ______ non-bearing acres

5.5 Circle your two most common southern highbush cultivars:
Camellia, Farthing, Legacy, Star, Suziblue, Emerald, Jewel, Meadowlark, Sweetcrisp, Indigocrisp,
Keecrisp, Patrecia, Georgia Dawn, Rebel,
Other: ____

6. Do you have plans for **expansion** of your blueberry acreage **over the next five years**? [ ] Yes [ ] No

6.1 If so, by how many acres? ______ acres

Which varieties are you considering planting?

6.2 Rabbiteye: ____

6.3 Southern highbush: ____

7. How has your production changed **over the last five years**?

[ ] Expanded acreage [ ] Added organic label [ ] New cultivars

[ ] Irrigating new areas [ ]Other: ____

8. How much of your blueberry acreage is set up for irrigation? ________ acres

9. Approximate yield per bearing acre in a **normal year**: ________ acres

9.1 Rabbiteye cultivars: ______ pounds per acre
9.2 Southern highbush cultivars: ______ pounds per acre

10. What percentage of your harvested crop are you able to market? _____________ %

Of the harvest that you market, what percentage is sold as fresh or processed?

10.1 fresh: ______ %
10.2 processed: ______ %

11. Do you produce blueberries under any of the following labels?

Certified Organic _____ Georgia Grown _____ Other ____

(If other, please specify) ____

12. How many meetings or conferences with focus on blueberry culture, production, and pest management have
you attended within the **past three years** (approximately):

Conferences: _____________ Field Days/Extension Events: _____________

GA Blueberry Grower Association Meetings: _______________
Other:_________________________________

13. How many times **per year** do you contact your county agent/ extension specialist with a blueberry-related
problem or question (on average)?

13.1 County Agent: _______ times per year

13.2 Extension specialist: _______ times per year

II. Blueberry pesticide use in your operation:

Indicate the relative importance of the following constraints to blueberry production on your farm (**average
over past three years**); please check only one box per row:

1. <u>Diseases</u>:

		Major problem	Moderate problem	No problem
1.1	Phytophthora root rot	[ ]	[ ]	[ ]
1.2	Blueberry stunt virus	[ ]	[ ]	[ ]
1.3	Flower blight *(botrytis blight)*	[ ]	[ ]	[ ]
1.4	Twig blight	[ ]	[ ]	[ ]
1.5	Mummy berry	[ ]	[ ]	[ ]
1.6	Preharvest fruit rots	[ ]	[ ]	[ ]
1.7	Postharvest fruit rots	[ ]	[ ]	[ ]
1.8	Leaf spots	[ ]	[ ]	[ ]
1.9	Stem blight	[ ]	[ ]	[ ]
1.10	Stem canker	[ ]	[ ]	[ ]
1.11	Ring nematode	[ ]	[ ]	[ ]
1.12	Exobasidium *(leaf and fruit spot)*	[ ]	[ ]	[ ]
1.13	Blueberry rust	[ ]	[ ]	[ ]
1.14	Other: _____________	[ ]	[ ]	[ ]

2. <u>Insects</u>:

		Major problem	Moderate problem	No problem
2.1	Fire ants	[ ]	[ ]	[ ]
2.2	Scale	[ ]	[ ]	[ ]

2.3	Blueberry maggot	[ ]	[ ]	[ ]
2.4	Flower thrips	[ ]	[ ]	[ ]
2.5	Gall midge	[ ]	[ ]	[ ]
2.6	Sharpnosed leafhopper *(sharpshooter/leafhopper)*	[ ]	[ ]	[ ]
2.7	Plum curculio	[ ]	[ ]	[ ]
2.8	Cranberry fruitworm	[ ]	[ ]	[ ]
2.9	Cherry fruitworm	[ ]	[ ]	[ ]
2.10	Stem borers	[ ]	[ ]	[ ]
2.11	Span worms	[ ]	[ ]	[ ]
2.12	Azalea caterpillar	[ ]	[ ]	[ ]
2.13	Flea beetle	[ ]	[ ]	[ ]
2.14	Whiteflies	[ ]	[ ]	[ ]
2.15	Spotted wing drosophila	[ ]	[ ]	[ ]
2.16	Webworm	[ ]	[ ]	[ ]
2.17	Chilli thrips	[ ]	[ ]	[ ]
2.18	Bud mite	[ ]	[ ]	[ ]
219	Other: ________________	[ ]	[ ]	[ ]

3. <u>Weeds</u>:

		Major problem	Moderate problem	No problem
3.1	Annual grasses *(e.g., crabgrass)*	[ ]	[ ]	[ ]
3.2	Annual broadleaves *(e.g., pigweed, cocklebur)*	[ ]	[ ]	[ ]
3.3	Perennial grasses and sedges *(e.g., nutsedge, broomsedge)*	[ ]	[ ]	[ ]
3.4	Perennial broadleaves *(e.g., goldenrod, chrysanthemum)*	[ ]	[ ]	[ ]
3.5	Vines	[ ]	[ ]	[ ]
3.6	Woody species *(e.g., oaks)*	[ ]	[ ]	[ ]
3.7	Other: ____________________________	[ ]	[ ]	[ ]

4. <u>Horticultural problems</u>:

	Major problem	Moderate problem	No problem
Freeze injury			

4.1	Flowers	[ ]	[ ]	[ ]
4.2	Fruit	[ ]	[ ]	[ ]
4.3	Poor fruit set	[ ]	[ ]	[ ]
4.4	Lack of vigor	[ ]	[ ]	[ ]
4.5	Fertility	[ ]	[ ]	[ ]
4.6	Drought	[ ]	[ ]	[ ]
4.7	Waterlogging (“wet feet”)	[ ]	[ ]	[ ]
4.8	Pollination	[ ]	[ ]	[ ]
	Harvest damage			
4.9	Hand picking	[ ]	[ ]	[ ]
4.10	Mechanical	[ ]	[ ]	[ ]
4.11	Others: ______________________	[ ]	[ ]	[ ]
	______________________	[ ]	[ ]	[ ]

5. What **percentage** of your bearing blueberry acreage received applications of the following types of agrichemicals **in**
2019?

5.1 Fungicides: ______%
5.2 Herbicides: ______%
5.3 Insecticides: ______%
5.3 Gibberellic acid (ProGibb or GibGro): ______%

6. What **percentage** of your bearing blueberry acreage received no applications of agrichemicals at all **in 2019**?

______%

Indicate which of the following agrichemicals* were used for blueberry production **in 2019**:
**If generic product was used instead of name brand, mark product that is most similar.*

7. Fungicides:

		Average number of sprays per year on treated acreage
7.1	[ ] Lime Sulfur Ultra/Sulforix *(lime sulfur/calcium polysulfide products)*	______
7.2	[ ] Ridomil Gold *(mefenoxam)*	______
7.3	[ ] Pristine *(pyraclostrobin + boscalid)*	______
7.4	[ ] Abound *(azoxystrobin)*	______
7.5	[ ] Indar 2F *(fenbuconazole)*	______
7.6	[ ] Tilt, Bumper, Propimax *(propiconazole)*	______
7.7	[ ] Quash *(metconazole)*	______

7.8 [ ] Quilt Xcel *(azoxystrobin + propiconazole)* ______

7.9 [ ] Proline *(prothioconazole)* ______

7.10 [ ] Captan *(captan)* ______

7.11 [ ] Captec *(captan)* ______

7.12 [ ] Switch *(cyprodinil + fludioxonil)* ______

7.13 [ ] Elevate *(fenhexamid)* ______

7.14 [ ] CaptEvate *(captan + fenhexamid)* ______

7.15 [ ] Ziram *(ziram)* ______

7.16 [ ] Omega *(fluazinam)* ______

7.17 [ ] Aliette *(fosetyl-Al)* ______

7.19 [ ] ProPhyt *(potassium phosphite)* ______

7.20 [ ] K-phite ______
(mono- and di- potassium salts of phosphorous acid)

7.21 [ ] Bravo Weather Stik *(chlorothalonil)* ______

7.22 [ ] Serenade Max (*Bacillus subtilis*) ______

7.23 [ ] Serenade ASO (*Bacillus subtilis*) ______

7.24 [ ] Organic Gem, Neptune's Harvest *(fish oil)* ______

7.25 [ ] Copper ______

7.26 [ ] Actinovate (*Streptomyces lydicus*) ______

7.27 [ ] DoubleNickel (*Bacillus amyloliquefaciens)* ______

7.28 [ ] Others: ________________________________ ______

________________________________ ______

8. <u>Insecticides</u>:

Average number of sprays per year on treated acreage

8.1 [ ] Horticultural oil *(Superior/ JMS stylet/ Verdant)* ______

8.2 [ ] Esteem Ant Bait *(pyriproxyfen)* ______

8.3 [ ] Professional Fire Ant Bait *(methoprene)* ______

8.4 [ ] Delegate *(spinetoram)* ______

8.5 [ ] Entrust *(spinosad)* ______

8.6 [ ] Diazinon *(diazinon)* ______

8.7 [ ] Assail *(acetamiprid)* ______

8.8 [ ] Sivanto Prime *(flupyradifurone)* ______

8.9 [ ] Altacor *(chlorantraniliprole)* ______

8.10 [ ] Avaunt *(indoxacarb)* ______

8.11 [ ] Intrepid *(methoxyfenozide)* ______

8.12 [ ] Rimon *(novaluron)* ______

8.13 [ ] Confirm *(tebufenozide)* ______

8.14 [ ] Movento *(spirotetramat)* ______

8.15 [ ] Asana or Adjourn *(esfenvalerate)* ______

8.16 [ ] Admire Pro *(imidacloprid)* ______

8.17 [ ] Actara *(thiamethoxam)* ______

8.18 [ ] Brigade *(bifenthrin)* ______

8.19 [ ] Danitol *(fenpropathrin)* ______

8.20 [ ] Surround *(kaolin clay)* ______

8.21 [ ] Sevin *(carbaryl)* ______

8.22 [ ] Imidan *(phosmet)* ______

8.23 [ ] Neemix + Trilogy *(azadiractin + clarified neem extract)*______

8.24 [ ] Malathion *(malathion)* ______

8.25 [ ] GF-120 NF Naturalyte Fruit Fly Bait *(spinosad)* ______

8.26 [ ] Mustang Max *(zeta-cypermethrin)* ______

8.27 [ ] Exirel *(cyantraniliprole)* ______

8.28 [ ] Lannate *(methomyl)* ______

8.29 [ ] Dipel (*Bacillus thuringiensis*) ______

8.30 [ ] Seduce Fire Ant Bait *(spinosad)* ______

8.31 [ ] PyGanic *(pyrethrins)* ______

8.32 [ ] Neemix, Trilogy, AzaDirect *(azadirachtin)* ______

8.34 [ ] Others: ________________________________ ______

________________________________ ______

9. <u>Herbicides</u>:

Average number of sprays per year on treated acreage

9.1 [ ] Roundup (glyphosate) ______

9.2 [ ] Broadstar (flumioxazin) ______

9.3 [ ] Gallery (isoxben) ______

9.4 [ ] Showcase (isoxaben + trifluralin + oxyfluorfen) ______

9.5 [ ] Snapshot (trifluralin/isoxaben) ______

9.6 [ ] Basagran (bentazon) ______

9.7 [ ] Devrinol (napropamide) ______

9.8 [ ] Surflan or Oryzalin (oryzalin) ______

9.9 [ ] Solicam (norflurazon) ______

9.10	[ ] Callisto (mestrione)	_______
9.11	[ ] Chateau (flumioxazin)	_______
9.12	[ ] Casoron (dichlobenil)	_______
9.13	[ ] Velpar (hexazinone)	_______
9.14	[ ] Kerb (pronamide)	_______
9.15	[ ] Karmex (diuron)	_______
9.16	[ ] Princep (simazine)	_______
9.17	[ ] Sinbar (terbacil)	_______
9.18	[ ] Reckon, Rely, Cheetah (glufosinate)	_______
9.19	[ ] Gramoxone, Firestorm, Paraquat, Parazone (paraquat)	_______
9.20	[ ] Sandea (halosulfuron-methyl)	_______
9.21	[ ] Aim (carfentrazone-ethyl)	_______
9.22	[ ] Select, Intensity, Select Max (clethodim)	_______
9.23	[ ] Fusilade (fluazifop)	_______
9.24	[ ] Poast (sethoxydim)	_______
9.25	[ ] Corn gluten meal (corn gluten)	_______
9.26	[ ] Alldown (acetic and citric acids)	_______
9.27	[ ] Herbor-G Herbicide (plant essential oils, soaps)	_______
9.28	[ ] Scythe (pelargonic and other fatty acids)	_______
9.29	[ ] Weed Zap (clove and cinnamon oils)	_______
9.30	[ ] Worry Free (citrus oil)	_______
9.31	[ ] Others: ___________________________________	_______
	___________________________________	_______

10. Growth Regulators:

	Percent of acreage	Average number of sprays per year on treated acreage
10. 1 [ ] ProGibb or GibGro:	______%	______
10.2 [ ] Others: _____________	______%	______

III. Blueberry Production Management:

1. Estimate how much money (on a per acre basis) you spent for blueberry soil fertility management **in 2019** (include costs of agrichemicals manures, mulches, and other fertilizers; application costs; costs of scouting if applicable; etc.): $____________ per acre

   1.1 When compared to previous years, have your expenditures for soil fertility management increased or decreased

In 2019 (please check):

[ ] increased [ ] decreased [ ] remained unchanged

   1.2 If applicable, give main reason(s) for increase or decrease in expenditures for soil fertility management:

   ____

   ____

2. Where do you go for information on **blueberry production** in your operation? (check all that apply):

   [ ] Previous year's pest problems
   [ ] General appearance of planting
   [ ] County extension agent
   [ ] University extension specialist
   [ ] Extension publications (e.g., spray guide, newsletters, handbooks)
   [ ] Pesticide / fertilizer dealer
   [ ] Commercial consultant
   [ ] Magazines
   [ ] Other growers
   [ ] Others (please specify):

   ____

3. Who makes day-to-day decisions about what products to purchase, apply, and the application schedule (please check all that apply):

   [ ] Yourself or family member
   [ ] Employee
   [ ] Custom applicator

4. Are you using **biostimulants** in blueberry production? ____ Yes ______ No
***If yes**, please answer the following questions:*

4.1 Which biostimulant products are you using? (Please list)

____

____

4.2 What methods do you use for applying **biostimulants**? (Check all that apply)

[ ] Drip irrigation

[ ] Foliar application

[ ] Other (Please specify): ____

4.3 How frequently do you use biostimulants?

[ ] Very Much [ ] Somewhat [ ] Not sure [ ] Not Really[ ] Not At All

4.4 At what times during the season do you apply **biostimulants**? (Check all that apply)

[ ] First planting

[ ] Tight bud/dormant bud (Stage 1)

[ ] Bud swell (Stage 2)

[ ] Bud break (Stage 3)

[ ] Tight cluster (Stage 4)

[ ] Early green tip (leaves)

[ ] Late green tip (leaves)

[ ] Shoot expansion (leaves)

[ ] Early pink bud (early Stage 5)

[ ] Late pink bud (late Stage 5)

[ ] Early bloom (early Stage 6)

[ ] Full bloom (late Stage 6)

[ ] Petal fall (Stage 7)

[ ] Green fruit

[ ] Fruit coloring

[ ] 10% blue

[ ] ~25% blue

[ ] ~75% blue

[ ] Flower bud set for following year

4.5 Do you use biostimulants as an addition or replacement for other products?

[ ] I use biostimulants as an addition to other products.

Please specify other products:

____

[ ] I use biostimulants as a replacement for other products.

Please specify other products:

____

[ ] I do not consider other products when using biostimulants

[ ] Not sure

[ ] Other: (please specify):

____

4.6 Where would you go for information on **biostimulants** in particular?

[ ] County extension agent
[ ] University extension specialist
[ ] Extension publications (e.g., spray guide, newsletters, handbooks)
[ ] Pesticide / fertilizer dealer
[ ] Commercial consultant
[ ] Trade Magazines Name of magazine: _________________ (optional)
[ ] Other growers
[ ] Other (please specify):

____

4.7 How much would you estimate on average you spend per year on biostimulants?

~ _________________ dollars per year

4.8 How much does the **cost** of biostimulants impact your decision in using them?

[ ] Very Much [ ] Somewhat [ ] Not sure [ ] Not Really[ ] Not At All

4.9 What effects have you seen from using biostimulants? (Check all that apply)
[ ] Increased vegetative growth
[ ] Increased root growth
[ ] Increased bud set

[ ] Increased flower set
[ ] Increased fruit set
[ ] Improved fruit characteristics (texture, flavor, sweetness, etc.)
[ ] Increased shelf-life
[ ] None
[ ] Other (please specify):

____

4.10 What methods do you use for purchasing biostimulants?
[ ] Local vendor
[ ] Online – Direct from company
[ ] Online – Agricultural supply store
[ ] Other (please specify):

____

5. Has your **knowledge of biostimulants changed** at all over the last year? [ ] Yes [ ] No

5.1 If so, how?

____

6. Indicate to what degree you employ the following practices in your blueberry operation (check only one box per row):

	Never	Sometimes	Often	Always
6.1 Do you conduct soil tests or foliar analysis to determine fertilizer needs?	[ ]	[ ]	[ ]	[ ]
6.2 Do you select cultivars with improved yields?	[ ]	[ ]	[ ]	[ ]
6.3 Do you maintain records of field history and pest problems?	[ ]	[ ]	[ ]	[ ]
6.4 Do you scout fields once a week or more during the main growing season?	[ ]	[ ]	[ ]	[ ]
6.5 Do you use mechanical cultivation, (hoe rotary hoe, disk) to remove weeds?	[ ]	[ ]	[ ]	[ ]
6.7 Do you use mulch?	[ ]	[ ]	[ ]	[ ]

7. List any non-chemical control method(s) you used to control **insects** in your blueberry fields (example: crushing):

____

8. List any non-chemical control method(s) you used to control **diseases** in your blueberry fields (example: pruning):

____

9. List any non-chemical control method(s) you used to control **weeds** in your blueberry fields (example: rotary hoe, mulching):

____

10. Please indicate your level of concern about the following issues (check only one box per row):

		None	Slight	No Opinion	Moderate	High
10.1	Effects of fertilizer/biostimulant application on ground water quality	[ ]	[ ]	[ ]	[ ]	[ ]
10.2	Effects of fertilizer/biostimulant application on surface water quality	[ ]	[ ]	[ ]	[ ]	[ ]
10.3	Effects of fertilizers/biostimulants of applicator health	[ ]	[ ]	[ ]	[ ]	[ ]
	Government regulations	[ ]	[ ]	[ ]	[ ]	[ ]
10.4	Cost of fertilizer application	[ ]	[ ]	[ ]	[ ]	[ ]
10.5	Risk of introducing new biostimulant product	[ ]	[ ]	[ ]	[ ]	[ ]

11. What development(s) in soil fertility research would help you the most?

____
____
____

12. Would you be willing to participate in an interview/focus group to help shape this research?

[ ] Yes [ ] No

If yes, please provide contact information for us to reach out to you in the future.

Name____________________________________

Phone____

Email____

-- Please See Back Page --

In order to receive compensation for participating in our survey, please provide the following information if filling the survey out at home/as a later date. *This information will only be used for compensation. It will not be included in any analysis.*

Name ________________________________

Address____

City _______________________________________ State________________ Postal Code ______

Thank you for your help in this survey. Your participation is important in improving biostimulant use in Georgia blueberries.

Survey conducted by:

The UGA Blueberry & Biostimulant Research Team

Dr. Mussie Habteselassie - Associate Professor of Soil Microbiology
Dr. Jennifer Jo Thompson - Associate Research Scientist of Agricultural Anthropology
Dr. Rachel Itle – Assistant Research Scientist of Fruit Production and Genetics
Renee Allen - Area Blueberry Extension Specialist
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Joel Kirksey - Graduate Research Assistant

If you have any additional questions or comments, please contact Joel Kirksey at jkirksey@uga.edu

APPENDIX B

Grower Interview Guide

<u>Introduction:</u>

Thank you for taking the time to talk with me today. As a quick reminder, this study is about biostimulant use in Georgia blueberry production. We do not expect the folks who participate in our interviews to be experts in biostimulants, although they very well may be. Rather, we are interested in learning about the unique perspective that growers have on biostimulants in relation to blueberry production. We want to learn what information growers seek in order to make decisions on whether/how to use biostimulants in their production. Additionally, the knowledge gathered in this study will help guide UGA greenhouse and field research studying the effects of biostimulants on Georgia blueberry production.

You may skip any questions that you do not wish to answer and may choose to not participate in this study at any time. All information provided here today will be kept strictly confidential and used for university research purposes only. Your answers will not be connected to you in any way, and you will not be identified in any materials resulting from this study.

Before we get started with the interview, do you have any questions? [Answer any questions]

Are you willing to participate in this study?

[If yes:] I will now turn on the audio recorder to record your verbal consent and then we'll get started with the interview.

[Turn on recorder]

Today is ______ 2020 And I am on the phone with ____.

This next part I am going to repeat verbatim.

- Mr. ____ do you acknowledge that you have been presented with sufficient information regarding the conditions of this study?
- Have you had all your questions answered?
- Do you give your voluntary consent to participate in this study?

Great. Let us get started.
--

A. *Background Information/Rapport Building*

1. I want to begin by getting a bit of background information on you and your history growing blueberries. For how long have you grown blueberries?

2. Why did you start growing blueberries?

    a. Before growing blueberries, did you grow other crops? If so, what?

3. Do you grow any other crops aside from blueberries? If so, what?

4. In terms of blueberry production, what is the biggest challenge you have on the farm?

5. What major changes you have had to implement on the farm over the last few years?

B. *Areas of shared understanding and differences that Georgia blueberry growers and other stakeholders have around the concept of biostimulants:*

1. Next, I want to transition to a few questions about biostimulants. There doesn't seem to be a clear definition about what a biostimulant is.

    Have you heard about biostimulants? And if so, how would you, in your own words, define biostimulants?

    a. What would you say biostimulants do?

    b. Can you give me an example of a product that you would consider to be a biostimulant? (Why?)

    c. How would say biostimulants are different from pesticides, fertilizers, growth regulators?

    d. If you could pick one, what key characteristic would you say all biostimulant products share?

C. *How Georgia blueberry growers perceive biostimulants fitting into their production practices:*

i. *How growers are using biostimulants in the context of their production (i.e., when, what, how much)*

ii. *How growers decide to incorporate biostimulants into their production practices*

1. Do you use biostimulants in your production?

[If yes]

a. What has been your experience using biostimulants?

b. Can you give me a <u>specific example</u> of <u>*how you use them*</u>*?*

   i. Why did you decide to use a biostimulant in this case? (What challenge/issue are they potentially addressing?)

   ii. Practically speaking: When are you applying them? What are you using? How much of the product?)

   iii. How did/do you figure out/decide how to use them?

      1. Where did you get info/advice about how to use them?

      2. Why do you turn to this source?

   iv. What are you using (paying attention to) to figure out whether they are working, or what their impact is?

[If no]

c. Why not? [… then go to D]

D. *Why Georgia blueberry growers choose to use/not use biostimulants:*

i. *What Georgia blueberry growers perceive are the benefits and risks of biostimulant use*

**If yes in C:*

1. What challenges have you found in using biostimulants?

2. What is the biggest benefit you have found from using biostimulants?

3. What is the biggest drawback you have found from using biostimulants?

4. Are there any biostimulant products that you have tried but then discontinued?

a. Tell me about that. (Why? What factors impacted that decision? E.g., impact on the plant, fruit, soil? Cost? Etc.)

**If no in C:*

2. Have you tried, or considered, using biostimulants in the past?

If tried:

a. Tell me about that. What impacted your decision to stop using biostimulants? (e.g., impact on the plant, fruit, soil? Cost? Etc.?)

If considered:

b. Tell me about that. What's kept you from using biostimulants?

3. What do you feel like you would like to know about biostimulants?

E. *Sources that growers rely on for trusted information regarding biostimulants:*

i. *How Georgia blueberry growers perceive other stakeholders (i.e., industry, extension, researchers) as resources*

1. Where do you go for reliable information about agricultural products (like biostimulants, pesticides, fertilizers, growth regulators, etc.)

2. What information from vendors do you find to be most trustworthy or useful to you?

3. What role, if any, do Extension agents or specialists play in helping you make decisions about which products to use?

F. *Information around biostimulants that Georgia blueberry growers want/need from researchers:*

1. What information or developments in blueberry research would help you the most?

2. Is there anything else you think we need to know?

3. What is your view on sustainable agriculture?

4. Is there anyone else you would recommend reaching out to, who you think would be a good fit for this study?

[End Recording]

Post questions

1. Thank you for participating in this interview. Regarding payment, as you know, we are happy to compensate you for your time. Due to the way the payment process works with the University of Georgia, it would be easiest for us to send you a $60 gift card. Options we have include Walmart, Amazon, and Kroger. Would any of those options work for you?

    a. Choice: ______________________

2. Would it be okay to contact you for any follow up questions?

Great. Thank you for your time and input. That will be it. If you have any questions, please feel free to reach out to me. Have a wonderful_____.