Production Practices, Grower Concerns, and Plant Biostimulant Use: A Survey of Georgia Blueberry Growers and Implications for the US Blueberry Industry

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Abstract. **The United States is a top world blueberry (*Vaccinium* spp.) producer. Within the United States, Georgia consistently ranks among the top blueberry-producing states. In 2020, a grower survey was conducted to understand production practices and challenges facing the Georgia blueberry industry. Survey responses represent 4046 bearing acres of Georgia blueberry production (15% of the 2020 statewide planted area). Compared with a 1999 survey, respondents reported increased planting of southern highbush cultivars as well as increased irrigation and yield. Scale insects as well as spotted-wing drosophila, an invasive pest not present during the last survey, were major pest concerns. Damage caused by freeze events continues to be an important issue. A majority of respondents expected to expand their production. At present, the use of plant biostimulants within the Georgia blueberry industry is low. While Extension was growers' primary source for information about biostimulants, nearly one-third primarily relied on information from commercial sources. Given the continued growth and existing production challenges, research evaluating the effectiveness of soil health practices and biostimulants may be able to offer growers additional tools to mitigate environmental and production related stresses. Additional research examining how information about biostimulants is communicated to and received by growers could help future Extension and industry outreach efforts.**

Introduction

Over the last century, blueberry (*Vaccinium* spp.) has become a prominent small fruit crop that continues to experience growth in the United States and worldwide. The United States is a leader in world blueberry production. In 2024, the United States produced over 25% of the worldwide blueberry area harvested (123,903 of 488,291 acres) and accounted for over half of the worldwide gross production value, totaling over $1.97 billion of the $3.59 billion worldwide gross. Within the southeastern United States, Georgia is consistently the leader in all three categories of harvested acreage, total utilized production, and utilized production value. Of the top blueberry-producing states in the southeast (Georgia, North Carolina, Florida), Georgia accounted for over 60% of the total harvested acres and utilized production and 49% of the utilized production value (US Department of Agriculture, National Agricultural Statistics Service 2026).

In Georgia, blueberry production has experienced a steady increase over the last two decades. Between the years 2000 and 2020, blueberry acreage increased nearly five-fold, from approximately 5600 acres to 26,441 acres. Over the same period, the farm gate value of blueberry production in Georgia increased more than 13-fold, from $22.0 million to $304.2 million (University of Georgia 2001, 2022). From 2020 to 2024, acreage and farm gate value both increased again by over 5% (27,947 acres) and 26% ($383 million), respectively (University of Georgia 2022, 2026). Within Georgia, blueberry is the most economically important fruit and nut crop. In 2024, blueberry ranked first in fruit and tree nuts and accounted for 39.3% of the total state farm gate value for this category. Blueberry ranked tenth in the state's top commodities accounting for 2.3% of the total state farm gate value (Campbell et al. 2026; University of Georgia 2026).

With Georgia composing a substantial portion of the US blueberry market, production challenges faced by Georgia growers impact the overall blueberry industry, as well as the state's overall agricultural economy. Our study—embedded within a larger project evaluating the impact of plant biostimulants on blueberry production—aimed to characterize production practices and identify key issues of concern within the Georgia blueberry industry. The overarching goal of this work is to guide research and outreach benefiting blueberry growers and the industry as a whole. Our study was guided by the following research questions: What are the key production practices and issues of concern among Georgia blueberry growers? Given that the last statewide survey of blueberry growers was conducted in 1999 (Scherm et al. 2001), how have production practices and concerns changed as the state's industry has expanded?

Background

Four commercial blueberry types are grown in the United States, including lowbush (i.e., wild) (*V. angustifolium*), northern highbush (*V. corymbosum*), southern highbush (species complex of *V. corymbosum* and *V. darrowii*), and rabbiteye (*V. virgatum*), with both highbush types and rabbiteye composing the largest portion of (Itle and NeSmith 2017). Both blueberry types have a large presence in the state's industry, with major cultivars of southern highbush and rabbiteye accounting for 61% and 39%, respectively, of the state's acreage (Chu and Williams 2025).

Southern highbush are closely related to northern highbush and have been adapted to southern climates by breeding with native southern species (Lyrene 2006). Southern highbush cultivars are subjectively perceived to be of higher fruit quality than rabbiteye (Itle and NeSmith 2017) and harvested earlier in the season (mid-April through May). This allows for a higher market price because blueberry is a market-driven crop and grower price points fluctuate within the harvest season (Yeh et al. 2023). Fruit quality considerations and market price have likely been contributing factors to increased southern highbush plantings. However, flowering and fruiting also occur earlier in spring months, making southern highbush prone to damage or high levels of

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crop loss caused by late spring freeze events (Itle et al. 2025), and freeze protection strategies of wind machines or overhead irrigation need to be installed for commercial crop viability, which increases the cost of field establishment (Chu and Williams 2025). Additionally, southern highbush cultivars are generally more susceptible to disease pressures and require intensive management programs (Fontenot et al. 2024), further increasing the input cost in field establishment and maintenance.

Rabbiteye are native to the southeastern United States and perform well in the context of the region's low nutrient soils, climate, and environmental pressures (Scherm and Krewer 2008). Rabbiteye plants are highly vigorous and productive, more disease-tolerant, have stronger root systems, and are longer-lived as compared with southern highbush cultivars (Makus et al. 2018; Smith 2012; Stafne et al. 2024), thus lowering some of the field maintenance costs. Rabbiteye are generally harvested later in the season (late May–June) because of later flowering and fruiting than those of southern highbush cultivars. With a typically later flowering timing, rabbiteye cultivars frequently avoid the late spring freeze events that can cause devastating crop losses. They often are not planted under freeze protection (Chu and Williams 2025), which lowers the cost of commercial field establishment and maintenance. Although they receive a lower market price because of the timing of their ripening in Georgia's harvest window (Fonsah et al. 2011) and perceived fruit quality issues (Itle and NeSmith 2017), rabbiteye cultivars provide more consistent yields because of their attributes of largely flowering outside the freeze window and vigor. In addition, rabbiteye cultivars are largely machine-harvested (Deltsidis et al. 2023), which reduces labor costs and efficiency of harvest (Gallardo et al. 2018), compared with southern highbush types, which are largely hand-harvested at a significant cost to blueberry growers (Deltsidis et al. 2023).

The Georgia blueberry industry faces many unique challenges and uses external resources (e.g., university-based Extension, blueberry breeding programs) and inputs (e.g., fertilizers, pesticides) for part of its success. As Georgia's top fruit crop, the state's blueberry yield per acre is similar to that in many other regions of the United States, yet it is approximately half of some western states (e.g., California, Oregon, Washington), likely because of climatic differences, including humidity and pest/disease pressures (US Department of Agriculture, National Agricultural Statistics Service 2025). Additional factors that may account for this reduction in yield per acre are yearly variation in late spring freeze damage to both southern highbush and rabbiteye cultivars. Late spring freezes often occur in Georgia and other blueberry-producing states in the United States. These freeze events have the potential to greatly reduce yield or cause near complete crop loss depending on the developmental stage of the plant, temperature lows and their duration, and inherent limitations of current freeze protection methods to adequately protect against all freeze events. In recent years, late spring freezes have contributed to significantly lower yields than expected across Georgia. In the past 9 years, three freeze events caused significant crop losses including over 80% crop loss in 2017 (Thompson 2018; US Department of Agriculture, Risk Management Agency 2017), 60% crop loss in 2018 (Thompson 2018), and over 50% loss in 2022 (Chu et al. 2025).

In general, the long growing season and warm, humid climate of the Southeast contribute to the significant pest, weed, and disease pressures commonly found in Georgia blueberry production (Scherm and Krewer 2008) and in production in the southeast. Freezes also cause secondary damage and losses by leaving the plants with damaged flowers, developing fruit, and shoots, which serve as places where fungal pathogens can grow (Oliver 2022). Pressures from pest, disease, and freeze damage as well as others can cause large impacts on the state's blueberry revenue. For example, revenue from blueberry production noticeably decreased from 2012 to 2017, even as the number of acres harvested increased across the state (US Department of Agriculture, National Agricultural Statistics Service 2019).

Disease and insect pressures facing southeastern blueberry growers are ever-growing, with a steady stream of new and emerging viruses (Martin et al. 2009), fungal diseases (Bradshaw et al. 2025), postharvest fruit quality rots (Lameiras 2023), insect pest pressures (Geisert et al. 2026), and pressures from new and herbicide-resistant weeds (Heap 2026). In addition, changing recommendations to cultural management practices and techniques, such as weather-based irrigation scheduling (Carroll et al. 2024), cultivar-specific pruning (Milivojevic et al. 2025), and changing fertilization recommendations (Espinoza et al. 2025), further highlight the need for a survey of grower common practices and an overall needs assessment. A more thorough understanding of growers' production concerns is needed to best serve Georgia blueberry growers and direct Georgia research and Extension efforts. This knowledge will also impact blueberry research, Extension, and production across the United States.

In recent years, plant biostimulants, loosely defined as nonfertilizer additives that promote plant growth and soil health, have begun to be studied for use in blueberry commercial production. As of 2025, biostimulants represent a $4.46 billion market globally and are projected to reach $7.84 billion by 2030 (MarketsandMarkets

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2025). Thus far, studies of blueberry have focused on fruit quality attributes, overall plant growth, and soil properties with the main focus on highbush blueberry cultivars. Various biostimulant applications have shown increases in fruit quality attributes for fruit firmness (Espinoza-Galaviz et al. 2025; Lenart et al. 2022; Lopes et al. 2024, 2026), fruit size (Espinoza-Galaviz et al. 2025; Lenart et al. 2022; Lopes et al. 2024, 2026; Loyola and Muñoz 2009), fruit color lightness and color saturation (Espinoza-Galaviz et al. 2025), soluble solids content (Espinoza-Galaviz et al. 2025; Loyola and Muñoz, 2009), and sensorial sweetness (Lopes et al. 2024). Fruit acidity and fruit organic acid content decreased (Lopes et al. 2024) with biostimulant application. Fruit nutritional traits increased with biostimulant application for traits including anthocyanin content (Espinoza-Galaviz et al. 2025), antioxidant content (Schoebitz et al. 2019; Lopes et al. 2025), and vitamin C content (Lopes et al. 2025).

Plant growth parameters of blueberry, including yield (Boudreau-Forgues et al. 2025; Espinoza-Galaviz et al. 2025; Lenart et al. 2022; Lopes et al. 2024, 2026; Schoebitz et al. 2019), fruit set percentage (Lenart et al. 2022), root growth (Bryla and Vargas 2023; Schoebitz et al. 2019), shoot growth (Bryla and Vargas 2023; Schoebitz et al. 2019), plant height (Bryla and Vargas 2023; Espinoza-Galaviz et al. 2025), plant width, stem diameter, chlorophyll content (Espinoza-Galaviz et al. 2025), nitrogen content, and upright plant growth habit (Bryla and Vargas 2023) have been shown to increase with biostimulant applications. However, not all studies have shown an increase in plant growth parameters, as was observed for all plant growth parameters measured during a study examining southern highbush and rabbiteye (Drocco et al. 2024). Soil properties have been positively influenced by biostimulant applications, including cation exchange capacity, enzyme activities (dehydrogenase, phosphatase, β-glucosidase, urease, and protease), microbial biomass, organic matter, and respiration (Schoebitz et al. 2019). While these reports generally indicate increases in characteristics related to overall plant health and growth in blueberry, the wide variety of products and applications used in these studies reflect the lack of recommendations available for growers, especially in comparison with more traditional fertilizers. Despite the market growth and research interest in plant biostimulants, no prior research has aimed to understand US growers' experience with biostimulants.

Materials and methods

Our instrument was based on a survey conducted by University of Georgia (UGA) researchers in 1999 (Scherm et al. 2001) and included multiple-choice, fill-in-the-blank, and free response questions covering the following topics: general production information (e.g., acreage, cultivars, yield, plans for expansion); production challenges (i.e., disease, insects, weeds, and other horticultural problems); product usage (i.e., fungicides, insecticides, herbicides, and growth regulators); plant biostimulants; and production management (e.g., costs for fertility management and information sources). Most of the questions came directly from the Scherm et al. (2001) survey to strengthen content validity and allow for descriptive comparison of production practices and key issues over time. Specifics, including cultivars, pest and disease concerns, and agrochemical product lists, were reviewed and updated to reflect product usage and availability by Holland, who was the UGA Area Extension Agent for commercial blueberry production at the time of the study. The instrument was piloted and revised before distribution. 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 copies of the survey were also distributed at in-person events. A copy of the survey is included in the Supplemental Materials (Supplemental Appendix A).

Because farmer survey response rates are notoriously low (Pennings et al. 2002), we engaged in sustained efforts to recruit a nonprobability sample through multiple channels over the course of 13 months (Jan 2020–Jan 2021). Initially, the survey was distributed (both paper and online formats) to Georgia blueberry growers at UGA Extension's 2020 Annual Blueberry Update and the 2020 Southeast Regional Fruit and Vegetable Conference. The COVID-19 pandemic occurred early during our data collection phase, thus pausing all social science data collection and disrupting in-person meetings across the Georgia blueberry industry. This exacerbated typical challenges to recruiting participants. In response, we pivoted to online data collection and advertised the survey at two virtual UGA Extension meetings in Oct 2020 and through the UGA Extension blueberry industry listserv in Dec 2020 and Jan 2021. Finally, we directly invited 25 commercial Georgia blueberry growers (identified through online web searches, interviews, and field trial collaborations) to complete the survey.

Ultimately, we received a total of 62 surveys. We reviewed each survey and included the 37 surveys that had (at minimum) completed general information and production concern sections of the survey in our analysis. The mean completion rate of the retained surveys was 94.0% (range, 40%–100%). Of the 25 surveys removed, six were removed because no questions were answered (i.e., no data), six were removed because producers did not indicate any blueberry acreage in Georgia, nine were removed because the survey was <40% complete (i.e., no data regarding production concerns or agrichemical use), and four were identified as duplicates (i.e., multiple surveys representing the same farming enterprise). For duplicates with different completion rates, the more complete surveys were retained and the less complete surveys were removed; for duplicates with equal completion rates, the more recent version was retained and the earlier versions were removed.

To ensure response validity, we screened the data for out-of-range responses and internal consistency. We identified a small number of response errors (e.g., a reported yield of 175,000 lb/acre) that we excluded from analysis. We also conducted cross-field validation (e.g., reviewing and recoding free text or "other" responses). Our analyses were descriptive. We report descriptive differences between our survey and that of Scherm et al. (2001); we did not test the differences inferentially because both surveys drew independent nonprobability samples two decades apart. Descriptive statistics were calculated using Excel (Microsoft 365, version 16.108.3; Microsoft, Redmond, WA, USA) for both quantitative (e.g., acreage and yield, average number of pesticide sprays per year) and categorical variables (e.g., rating disease,

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pests, and horticultural issues as major, moderate, or no problem over the last 3 years). The study was reviewed and approved by the UGA Institutional Review Board (PROJECT00001218). All participants provided consent to participate.

Results and discussion

Sample description. Our survey respondents' experience in blueberry production ranged from 3 to 45 years per grower (mean, 18 years). Blueberry acreage ranged from 2 to 635 acres (mean, 119.9 acres). The completed surveys represent approximately 4046 bearing acres, 4435 acres in total planted area, approximately 17% of blueberry acreage in Georgia in 2020 (University of Georgia 2022) (Table 1), and approximately 16% of acreage in 2024 (University of Georgia 2026). The mean bearing blueberry production area of survey respondents was 68% larger than that in the survey by Scherm et al. (2001).

In 2020, most commercial blueberry production in Georgia occurred in the following six southeastern counties: Bacon (accounting for 30.6%), Pierce (11.8%), Clinch (9.5%), Appling (7.8%), Ware (6.9%), and Coffee (5.7%). Together, these counties contributed over 72% of Georgia farm gate blueberry production value in 2024 (University of Georgia 2026). Within our survey, farms in these counties accounted for 54.1% of survey responses, with 45.9% of respondents indicating that the majority of their acreage was in Bacon county (Fig. 1). The top three blueberry-producing counties also accounted for 61.5% of acres (2729.6 acres) in our survey, with 2201.6 acres in Bacon, 486.0 acres in Clinch, and 42.0 acres in Appling (Fig. 2). The remaining producers indicated that the majority of their blueberry acreage was in the following 12 additional counties: Baker, Brantley, Burke, Candler, Coffee, Colquitt, Jeff Davis, Meriwether, Mitchell, Tift, Ware, and Wilcox counties.

General production information. Across our sample, 59.5% of our respondents reported growing a mix of both rabbiteye and southern highbush blueberry, whereas 40.5% only grew one type. More than half of our respondents' blueberry production area was planted with southern highbush (54.7%), with the remainder planted with rabbiteye (45.3%). This marks a shift from previous surveys in which producers reported planting mostly rabbiteye (Moore 1993; Scherm et al. 2001). This difference could be related to multiple factors, but it was most likely driven by the price points received by growers. The earlier harvest window for southern highbush results in an increase in producer market price during the harvest season and harvesting before summer rain later in the season. Harvesting earlier in the season allows fruit to go onto the fresh market, rather than processing, which has a higher selling point. Earlier season harvests also often lead to improved fruit quality because rain can cause delays in harvesting, which can lead to a reduction of fruit quality overall and more fruit culled out on the packing line, rendering them unmarketable. In contrast, rabbiteye cultivars are harvested later in the season and are more susceptible to wet conditions during harvest. In addition, industry-held subjective perceptions of fruit quality differences between these two blueberry types have also caused reduced grower revenue for rabbiteye cultivars, which also contributed to this shift (Itle and NeSmith 2017). Furthermore, although early southern blueberry breeding efforts primarily focused on rabbiteye development because of their adaptation to the local environment, beginning in the late 1990s, increased research efforts were made to develop southern highbush cultivars to take advantage of the earlier market window and higher price points received by growers (NeSmith 2009). In the industry, there are subjective biases regarding the fruit quality of the two blueberry types. Southern highbush cultivars are often perceived as higher-quality regardless of harvest timing; however, data regarding this is limited at best (Itle and NeSmith 2017). This may be another driver of increased southern highbush production within the state.

The most common rabbiteye cultivars reported by growers were 'Brightwell' (n = 26) and 'Premier' (n = 11), both of which are unpatented and the products of decades-old plant breeding efforts. 'Brightwell' was first released for commercial use in 1981 by UGA, and 'Premier' was first released for commercial use in 1978 by the University of North Carolina. Prior surveys also found widespread use of 'Brightwell', but

Table 1. General production information for the Georgia blueberry industry surveyed in 2020–21 (n = 37).

Variable	Mean (range)	Total	%
Blueberry experience (years)	18 (3–45)	665	
Total blueberry acreage, bearing and nonbearing	119.9 (2–635)	4435.29	
Rabbiteye (RE), bearing acres	53.9 (0–250)	1832.22	41.3
RE, nonbearing acres	2.1 (0–19)	19	0.4
Southern highbush (SHB), bearing acres	65.1 (0–300)	2214.07	49.9
SHB, nonbearing acres	30.8 (0–225)	370	8.3
Irrigated acres	98.6 (0–405)	3548.7	80.0
Planned expansion acres			
Yes, 21 (56.8%)	58.4 (4.5–300)	1225.5	
No, 16 (43.2%)	n/a		
Approximate yield per bearing acre (lb/acre)*	6038.4 (500–13,900)		
RE	5918.5 (500–15,000)		
SHB*	6170.7 (900–10,000)		
Marketable crop (average)			89.6
Fresh*			77.4
Processed*			29.4

*n = 36 because one outlier/irreconcilable response was removed.

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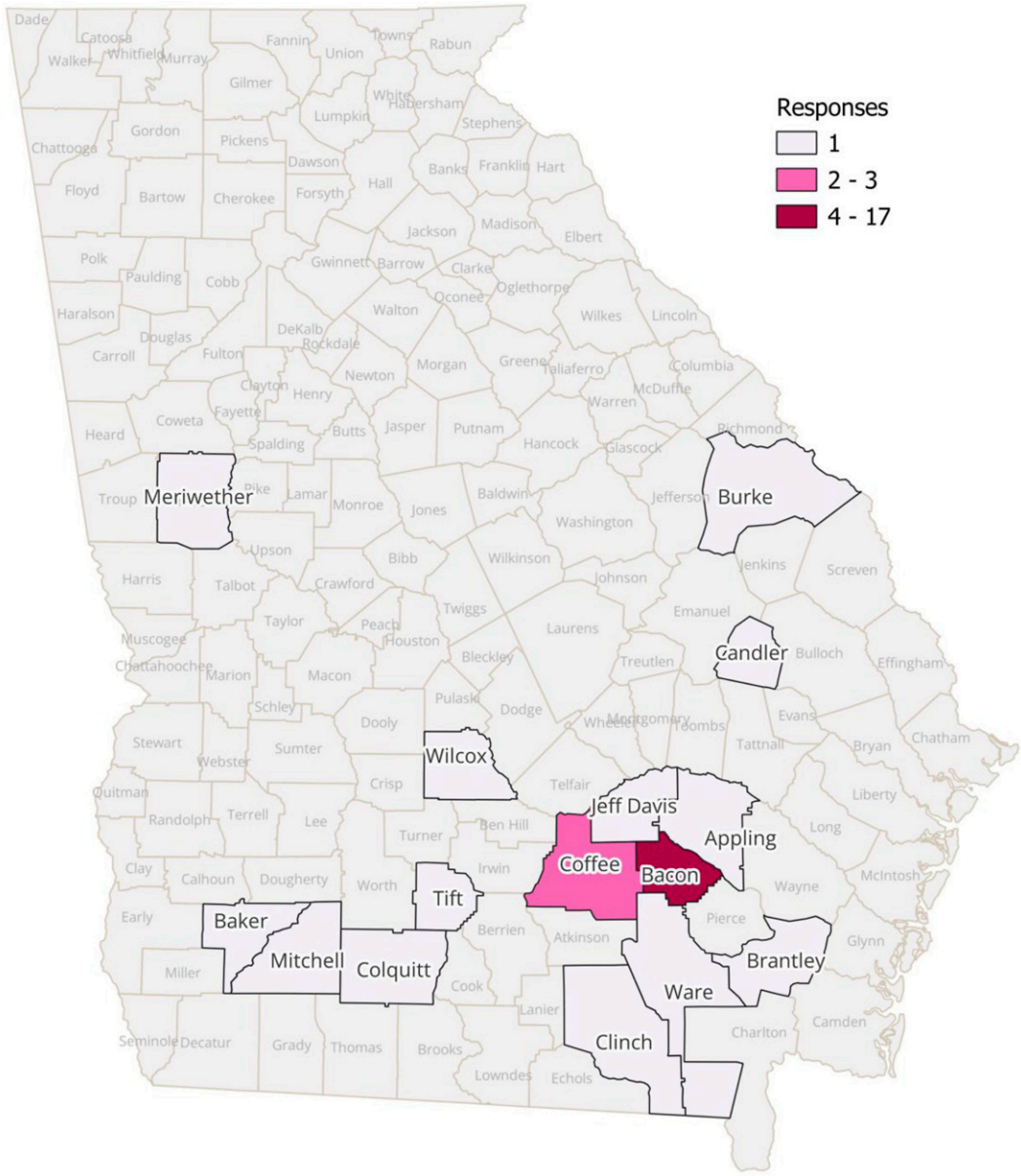


Fig. 1. Number of Georgia blueberry grower survey responses received in 2020–21, by county. (Map: Jerry Shannon.)

'Premier' was not as commonly grown (Moore 1993; Scherm et al. 2001). In our study, the most common southern highbush cultivars reported were 'Farthing' (n = 25), 'Suziblue' (n = 9), and 'Star' (n = 8). 'Farthing' is a relatively newer blueberry cultivar 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 h), vigorous growth, and earlier ripening window than that of other southern highbush cultivars (e.g., 'Star') (Lyrene 2008). 'Suziblue' was patented by UGA in 2010 and has desirable characteristics similar to those of 'Farthing', including a lower chilling requirement (400 h), vigorous growth, and early ripening period (approximately the first week of May in south Georgia) (Nesmith 2010). Prior surveys found higher planting rates of different cultivars of southern highbush (e.g., 'O'Neal', 'Reveille', and 'Star') than those in our study (Moore 1993; Scherm et al. 2001).

The mean approximate yields reported by producers were 6171 lb/acre for southern highbush blueberry and 5919 lb/acre for rabbiteye blueberry, with a mean overall yield of 6038 lb/acre. This is an increase of 89.9% for southern highbush and 27.6% for rabbiteye since the Scherm et al. (2001) survey, perhaps because of improved cultural management through both irrigation and fertigation, which likely helped both cultivars reach their full growth and, thus, yield potential. It is possible that the greater yield increases reported for southern highbush cultivars over rabbiteye are attributable to the introduction of newer cultivars (e.g., 'Farthing', 'Suziblue') with higher yield capacities than those available during the previous survey when the Georgia blueberry industry was developing more rapidly.

On average, our survey respondents reported being able to market 89.6% of the harvested crop, selling 77.4% of their

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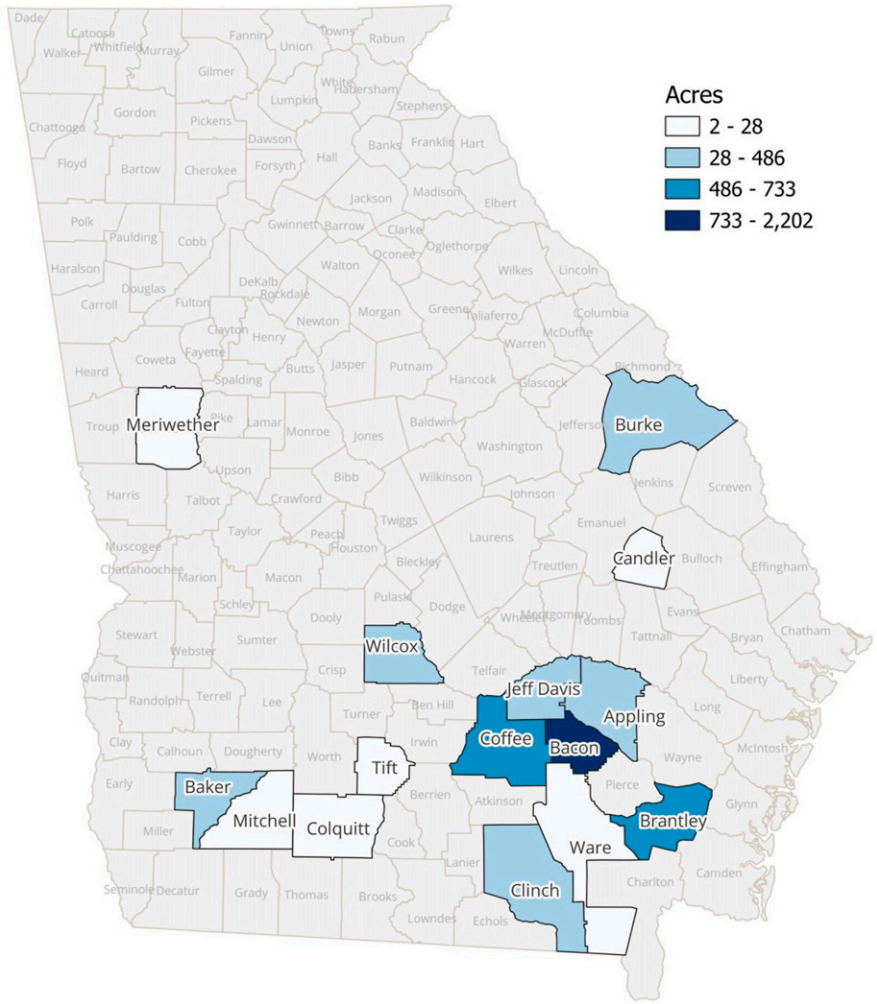


Fig. 2. Number of Georgia blueberry grower acres represented by survey responses in 2020–21, by county. (Map: Jerry Shannon.)

harvest fresh and 29.4% processed. This continues a trend toward more fresh market blueberry production. Scherm et al. (2001) reported 53.4% of producers selling their harvest as fresh, which was an increase from an earlier survey in which 33% of growers did the same (Moore 1993). It is possible that the increase in fresh market production reflects the higher early-season prices that Georgia growers can receive for fresh fruit with newer southern highbush cultivars as well as increased consumer demand for fresh blueberries in general.

Consumer demand for blueberry in the United States has steadily increased since 2010, leading to both seasonal and geographical expansion of blueberry production (Kramer et al. 2020). In the survey, a majority (56.8%) of growers reported plans for expanding production over the next 5 years, with a mean expected increase of 58.4 acres and projected increase equivalent to 27.6% of the current total planted area represented by our sample. According to the most recent Georgia farm gate report, acreage has already increased by 1506 acres (5%) during the 4-year period comprising 2020–24 (University of Georgia 2026). Both figures highlight the continued expansion of the Georgia blueberry industry.

On average, our survey respondents reported irrigating 88.3% of their total planted area (totaling 80.0% of overall reported blueberry acreage). 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). This reflects a general trend of southeastern growers' increased adoption of agricultural technology for improving yield and resource use efficiency. Growers continue to express an understanding that adoption of current and future technologies, such as complete machine harvesting, is an important way of remaining competitive with other markets (Kirkland 2019). One study of agricultural producers across Alabama, Florida, Georgia, and North Carolina showed increased irrigation use between 2012 and 2017 (Combs 2019). Although many of our respondents reported that drought had not been a problem over the last 3 years at the time of this survey, 45.9% considered drought a "major" (10.8%) or "moderate' (35.1%) issue. Increased irrigation may help to explain the decreased rates of concern about drought in comparison with the previous survey in which a majority of Georgia blueberry growers considered drought a major concern (Scherm et al. 2001).

Horticultural production challenges. Respondents rated common horticultural problems as a major problem, moderate problem, or no problem over the last 3 years (Fig. 3). Producers identified freezing weather as the most important horticultural production issue, with 43.2% of producers identifying freeze injury to flowers as a major problem and 48.6% identifying it as a moderate problem. Similarly, 32.4% and 45.9% of producers rated freeze injury to fruit as a major or moderate problem, respectively. Throughout the last century, winter surface temperatures have continually increased globally, with recent years reaching new record highs (National Oceanic and Atmospheric Administration, Home National Centers for Environmental Information 2026). Warmer winters with fewer frost-free days combined with the use of southern highbush cultivars with low chill requirements have led to earlier flowering and fruiting in the Georgia blueberry industry overall. While this can be a boon for early harvests, increasing uncertainty and extreme weather events related to climate change are also resulting in late freezes following warmer winters that can cause severe production damage for southeastern producers (Powers 2024). It is possible that while freeze injury remains a constraint for many blueberry growers, some may be adjusting, as there was a small decrease in growers' level of concern compared with that in the previous survey in which 100% of growers viewed freeze injury as a significant problem (Scherm et al. 2001). Southeastern

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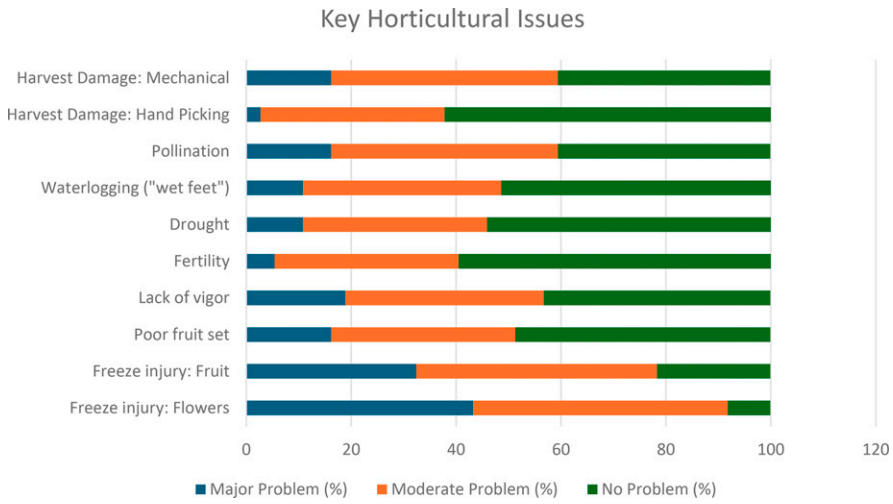


Fig. 3. Georgia Blueberry growers' assessment of horticultural issues, 2020–21 (n = 37).

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 that 88% use some form of frost protection (e.g., irrigation, wind machines, covers, heat) and 98% use overhead irrigation (Conlan et al. 2018). However, overhead irrigation is ineffective at protecting flowers and fruit when temperatures drop more than a few degrees below freezing (to approximately 28 °F/−2 °C) or when there are high winds (Smith 2019).

Gibberellic acid has also been explored as an option for promoting fruit set after freezing weather events cause flower injury. This plant hormone promotes fruit development in the absence of successful flower pollination and resulting seed fertilization, thus leading to normal fruit set. When the reproductive structures of the flower are damaged because of freeze events, this normal process is not always possible; however, gibberellic acid may help in these cases. Gibberellic acid has also been shown to promote ripening of the freeze-injured fruit in some cases. Overall, the use of gibberellic acid in experimental settings can 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 (Supplemental Table S1 in Appendix B presents data regarding agrichemical use).

Large numbers of producers also identified poor pollination (major, 16.2%; moderate, 43.2%) and fruit set (major, 16.2%; moderate, 35.1%) as important production issues. Fruit set concerns can be caused by flower freeze injury, whereby the stigma and style of the flower are damaged in the freeze, hindering proper pollination and fertilization necessary to induce fruit set. Commercial blueberry production further depends on insects (typically bees) to achieve enough pollen transfer for adequate fruit set (MacKenzie 1997). The pollination needs of small blueberry fields are primarily fulfilled by wild bees; however, larger operations require managed bees brought in from external suppliers (Isaacs and Kirk 2010). In recent years, several US commercial beekeepers have reported declines in bee populations; this issue is referred to as colony collapse disorder (Evans and Chen 2021). Increased awareness about colony collapse disorder may be spurring growers' interest in beehive health as well as weather during pollination, which can affect bee activity, pollination, and subsequent fruit set/yield (Holland, personal communication). Although producers' overall concerns about fruit set appear slightly less great compared with the previous survey (Scherm et al. 2001), nearly three of five producers expressed concern about poor pollination, an issue not included in that survey.

Diseases. A wide array of diseases can affect blueberry production, with several new diseases emerging in recent years (Saad et al. 2021). In our study, leaf spots were indicated as a major (8.1%) or moderate (64.9%) concern by the highest number of growers (Fig. 4). There are a few different pathogens that can cause leaf spots. Septoria leaf spot (*Septoria albopunctata*) and Gloeosporium leaf spot (*Gloeosporium minus*) are the most prevalent and most severe in Georgia blueberry production, found in approximately 50% and 25% of the samples, respectively (Scherm et al. 2008). In southeastern blueberry production, Septoria leaf spot tends to first appear between April and mid-June, with disease severity rapidly increasing into the fall (Ojiambo and Scherm 2005). Effects of the disease may include premature defoliation, reduced photosynthesis on affected leaves, and reduced fruit yield (Ojiambo et al. 2006). In blueberry, the fungicide Indar 2F (fenbuconazole; Corteva Agriscience LLC, Indianapolis, IN, USA) and other systemic triazole fungicides have been shown to significantly reduce defoliation and increase yields (Cline 2002). In our survey, 31.4% of producers (representing 29.5% of the total bearing area) reported using fenbuconazole with a mean of 1.7 sprays per treated area.

According to our survey, growers were also concerned about a variety of additional diseases. Over two-thirds of producers considered Phytophthora root rot (*Phytophthora cinnamomi*) an issue (major, 13.5%; moderate, 56.8%). *Phytophthora* disease presence may cause chlorosis, defoliation, and root necrosis, and it has been shown to increase with the frequency of flooding (Silva et al. 1999). Leaf defoliation reduces the photosynthetic leaf tissue area of the plant and reduces carbon assimilation (Scherm et al. 2008), and chlorosis degrades chlorophyll and affects its synthesis (Cheaib and Killiny 2025). Both negatively affect the plant's ability to photosynthesize and grow properly. Necrosis directly affects the blueberry root system and impacts water and nutrient uptake and subsequent yield (Gauthier and Bell 2014).

Nearly 60% of producers also considered Botrytis flower blight (*Botrytis cinerea*; major, 8.1%; moderate, 51.4%) and blueberry rust (*Pucciniastrum vaccinii*; major, 10.8%; moderate, 48.6%) threats. In our survey, 48.6% of producers (representing 68% of the total bearing acreage) reported using cyprodinil and fludioxonil, which are ingredients in the fungicide Switch (Syngenta, Basel, Switzerland), to treat Botrytis gray mold (Oliver 2022), with a mean of 1.9 sprays per treated area. Botrytis gray mold disease susceptibility increases as blueberry flower develops, with research indicating

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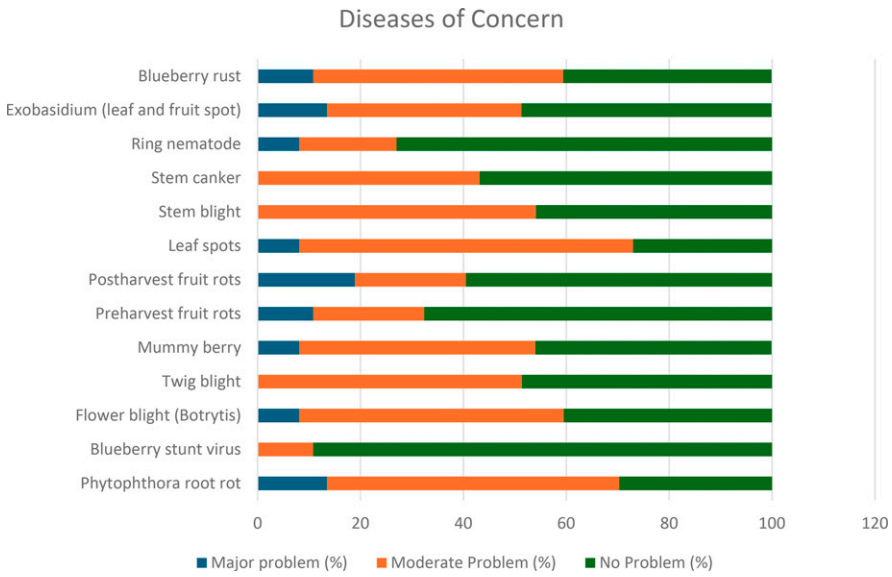


Fig. 4. Georgia Blueberry growers' assessment of diseases of concern, 2020–21 (*n* = 37).

that southern highbush is more greatly affected than rabbiteye (Smith 1998). Botrytis flower blight (gray mold) is of particular concern after freeze events, while blueberry rust (formerly a postharvest issue) has occurred much earlier in the season (e.g., March) in more recent years in southern highbush. Research demonstrates that certain cultivars such as 'Climax' (rabbiteye) and 'Bluecrisp' (southern highbush) are more likely to experience severe rust disease incidence (Scherm et al. 2008). Azoxystrobin is a recommended treatment for blueberry rust, and 54.3% of producers (representing 67.1% of the total bearing acreage) reported using it at a mean rate of 2.2 sprays per treated area.

Mummy berry (*Monilinia vaccinii-corymbosi*) was considered a concern by 54% of producers (major, 8.1%; moderate, 45.9%), which is a decrease from the previous survey in which 79.3% of growers considered it 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; however, it can cause greyish hardened berries, thus downgrading fruit quality (Scherm and Copes 1999). Mummy berry can remain in the field over winter, persisting in fallen fruit on the soil surface. In response, some agricultural advisors recommend reducing disease presence by burying affected fruit in the soil through mechanical cultivation

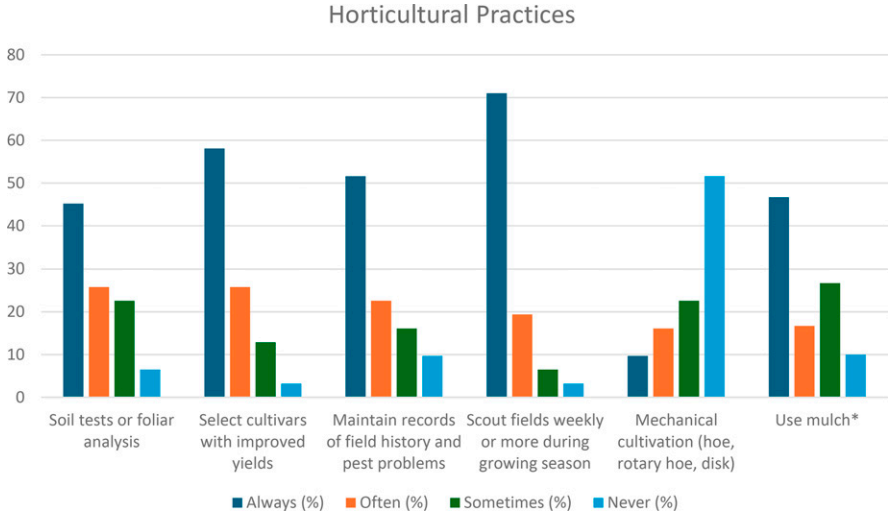


Fig. 5. Georgia Blueberry growers' use of horticultural practices, 2020–21 (*n* = 31). **n* = 30 for this item only.

(Schilder et al. 2008), which is a practice that 25.8% of our survey respondents reported using "always" (9.7%) or "often" (16.1%) (Fig. 5).

In addition to disease pressures, prolonged wet field conditions can be conducive to rapid pathogen development and spread for bacterial and fungal diseases in blueberry (Oliver 2024). High moisture conditions can also lead to limitations for healthy plant growth and development. 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 addition, there has been a 27% increase in heavy precipitation events across the southeast from 1958 to 2012 (US Environmental Protection Agency 2016). In our study, nearly half of growers considered waterlogging a concern (major, 10.8%; moderate, 37.8%). Waterlogging causes a lack of oxygen available to the root system, known as hypoxia, which affects overall plant growth, development, and normal metabolic activity (Loreti and Perata 2020). Blueberry roots can start to suffocate if submerged in water for more than a few days. In some areas of the state's commercial growing region, loamy sand and sand topsoils with a sandy clay loam subsoil can cause limited drainage because of a high water table (Rubio Ames and Espinoza 2023).

Pest concerns. Scale insects (members of the superfamily *Coccoidea*), which feed on blueberry leaves and stems, were reported as the most important pest concern among growers in our study (major, 10.8%; moderate, 67.6%) (Fig. 6). This is a notable increase from the 1999 survey, in which less than half (42.8%) of producers indicated scale insects as a substantial concern (Scherm et al. 2001). The increase in scale insect pressure may be related to reduced natural biological control populations in response to increased use of insecticides to treat spotted wing drosophila (*Drosophila suzukii*), a more recent pest. When present in high concentrations, scale insects may weaken the plant by producing honeydew exudates that attract sooty mold growth subsequently covering the plant, including photosynthetic leaf tissue area (Sial et al. 2019). Managing scale insects in blueberry requires the annual pruning of old wood to remove infestations, with applications of horticultural

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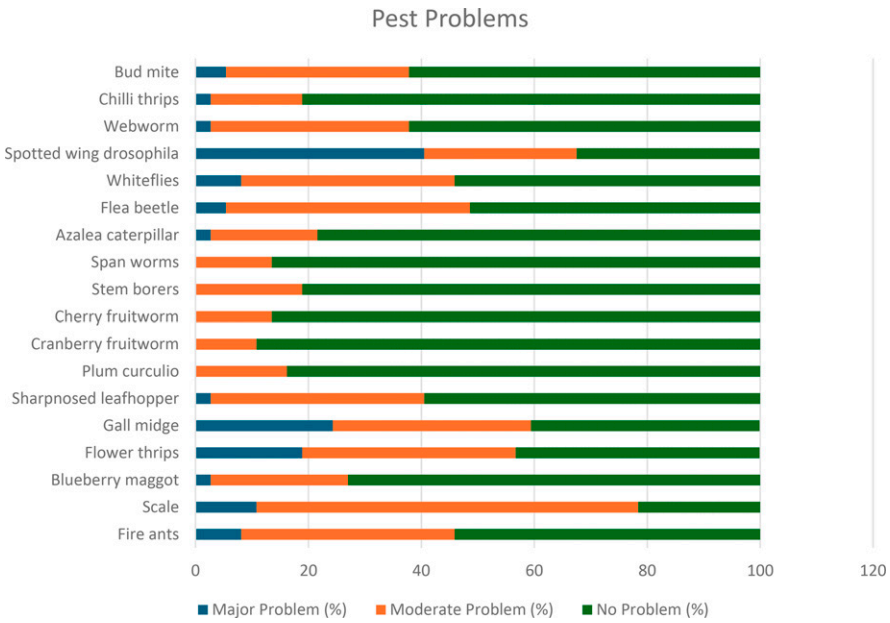


Fig. 6. Georgia Blueberry growers' assessment of pest problems, 2020–21 (*n* = 37).

oil recommended in the case of severe infestations after winter pruning and before bloom (Hahn 2011; Sial 2025). When applied to a plant with insects present on the surface, horticultural oil causes suffocation of the insect and eggs (Skelly 2013). In the present survey, 37.1% of producers (representing 38.2% of total bearing area) reported using horticultural oil with a mean of 1.0 sprays per treated area. This is an increase from 20% of producers reporting the use of horticultural oil in the previous survey (Scherm et al. 2001).

Spotted-wing drosophila (*Drosophila suzukii*) was reported as a pest of concern by 67.5% of producers, with a notable 40.5% reporting it as a major concern (27% moderate). This invasive pest was first detected in the United States in 2008, and it has since become a severe nuisance by infecting berries during harvest and causing load rejections at packing plants (Drummond et al. 2019). Several conventional insecticides have proven to be effective treatments for Spotted-wing drosophila, including malathion and spinosad (Sial et al. 2019; Van Timmeren and Isaacs 2013). However, experimental studies have shown that rainfall soon after the application of insecticides may lead to reduced effectiveness (Gautam et al. 2016). In our survey, 51.4% of growers (73.6% of total bearing area) reported using malathion in their production system with a mean of 2.1 sprays per treated acre. This is up from 32.1% of growers reporting the use of this product in the previous survey (Scherm et al. 2001). A smaller proportion of producers (25.7%; representing 29.1% of total bearing area) reported using spinosad to treat insect pressure, with a mean 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 pests of concern by more than half of growers surveyed. Both species garnered increased concern in the current survey compared with the previous survey (Scherm et al. 2001). Gall midge, considered a major problem by 24.3% of respondents and a moderate problem by 35.1%, may greatly affect floral buds, reducing fruit set and yield (Liburd and Finn 2002). Effective treatment options for gall midge include acetamiprid and zeta-cypermethrin (Collins and Drummond 2018). In the present survey, 28.6% of growers (44.5% of total bearing area) reported treating their blueberry crops with acetamiprid, with a mean of 1.4 sprays per treated area. Furthermore, 54.3% of growers (66.7% of total bearing area) indicated using zeta-cypermethrin in their production, with a mean of 2.1 sprays per treated area.

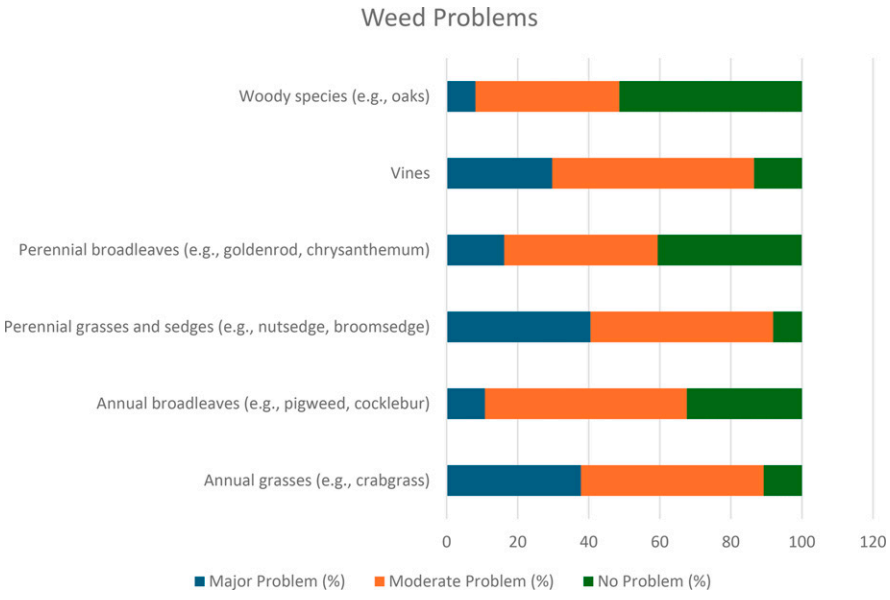


Fig. 7. Georgia Blueberry growers' assessment of weed problems, 2020–21 (*n* = 37).

Weed pressures. Weed pressure has the potential to be a sizable issue in Georgia blueberry production, especially among organic systems in which treatment options are limited (Krewer and Walker 2006). Maintaining vegetation-free areas is critical for the establishment and growth of thriving blueberry plants (NeSmith and Krewer 1995). Growers who responded to our survey considered perennial and annual grasses the most noxious weeds in their production system, with an overwhelming majority indicating them as a problem (Fig. 7). Perennial grasses and sedges were viewed as a major problem by 40.5% of respondents and a moderate problem by 51.4%; annual grasses were reported a major problem and a moderate problem by 37.8% and 51.4% respectively. Vines

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were also reported as major weeds, with 86.4% (major, 29.7%; moderate, 56.8%) of growers reporting them as an issue. More than half of survey respondents also 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 commercially available chemical herbicides, glyphosate was the most common treatment option used by 48.6% of growers (55.9% of total bearing area), with a mean of 2.4 sprays per treated area. Oryzalin was similarly identified as a common treatment option used by 45.7% of growers (59.5% of total bearing area) at a mean of 2.5 per treated area. Other herbicides used by growers in substantial amounts include flumioxazin (40% of growers), paraquat (37.1% of growers), glufosinate (34.3% of growers), and simazine (31.4% of growers).

Along with mechanical cultivation, mulching has been used as an effective tool for managing weed populations (Fig. 5). Mulch types used by blueberry producers include black plastic, sawdust, landscape fabric, compost pine leaves, and pine bark (Forge et al. 2013; Krewer and Walker 2006). In the present study, 63.4% of producers identified as those who "always" or "often" use mulch in their production system (Fig. 4). This is a notable increase compared with a past survey of Georgia blueberry growers in which only 13.7% reported using mulch (Scherm et al. 2001).

Plant biostimulants. In recent years, the agricultural industry has begun to explore plant biostimulants for their potential use as a crop management resource (Calvo et al. 2014), and blueberry is no exception. Among participants in our survey, 30.3% reported currently using plant biostimulants in their production (Table 2). When asked if their knowledge of plant biostimulants has changed at all within the last year, two-thirds (67.7%) reported no change in their level of understanding. Participants' primary source for information about biostimulants was Extension (46.4%), including university-based specialists, county agents, or Extension publications, followed by pesticide or fertilizer dealers (25.0%), other growers (10.7%), and commercial or cooperative consultants (10.7%). Prior work has demonstrated that farmers rely on a wide range of information sources when making management decisions, including crop consultants, seed and input suppliers, farm magazines and media, other farmers and farming cooperatives, and university-based Extension (Stuart et al. 2018). University-based Extension in the US functions to extend nonbiased research-based information and resources to the public through educational publications and programming (Extension Foundation 2006); nevertheless, recent studies indicated that farmers are increasingly reliant on private, for-profit, information sources (Beethem et al. 2023; Edge et al. 2017).

Among those using biostimulants, 55.6% reported that the cost "very much" impacted their decision to use them, whereas 33.3% said "somewhat" and 11.1% were "not sure." Prior research has shown that on-farm decision-making is highly complex and influenced by a wide range of intrinsic and extrinsic factors, including farm and operator characteristics, farmer attitudes and values, risk perception, and information networks (Hayden et al. 2021; Prokopy et al. 2019; Swart et al. 2023; Tancredi et al. 2026). Notably, in a review of 35 years of conservation adoption literature, Prokopy et al. (2019) found that farmers who self-identify as not being primarily motivated by finances are more likely to adopt conservation practices.

Eighty percent of respondents reported applying plant biostimulants using foliar methods and 50% via drip irrigation. Eighty percent identified purchasing plant biostimulants from a local vendor, while the remaining 20% identified other sources for obtaining plant biostimulants, including a "biostimulant consultant" and directly from the chemical manufacturer. At present, plant biostimulant manufacturers can market their products without Environmental Protection Agency registration as long as the products do not claim to be a plant growth regulator, pesticide, defoliant, desiccant, or nitrogen stabilizer because these claims would subject them to regulation under the Federal Insecticide, Fungicide, and Rodenticide Act (US Environmental Protection Agency 2025). In 2025, bills were introduced to both houses of congress (Plant Biostimulant Act of 2025 S.1907 and H.R.3783; 119th Congress 2025) that would create a federal definition of plant biostimulants and exempt them from Federal Insecticide, Fungicide, and Rodenticide Act regulation.

Table 2. Plant biostimulant use, knowledge of, application, and associated costs for the Georgia blueberry industry surveyed in 2020–21.

Variable	Count	%
Current biostimulant use (n = 33)		
No	23	69.7
Yes	10	30.3
Biostimulant knowledge change over the last year (n = 31)		
No	21	67.7
Yes	10	32.3
Primary information source (n = 28)		
Extension (university specialist, county agent, extension publication)	13	46.4
Pesticide/fertilizer dealer	7	25.0
Other growers	3	10.7
Commercial/cooperative consultant	3	10.7
Trade magazines	1	3.6
Online resources	1	3.6
Application methods (among users; n = 10)		
Foliar application	8	80
Drip irrigation	5	50
Impact of cost on use (among users; n = 9)		
Very much	5	55.6
Somewhat	3	33.3
Not sure	1	11.1
Purchasing method (n = 10)		
Local vendor	8	80
Other (consultant, manufacturer)	2	20

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Limitations

We descriptively reported differences between our survey and that of Scherm et al. (2001). We did not test these differences inferentially because the studies drew independent nonprobability samples of different producers two decades apart. As such, these samples differ systematically, and significance testing would confound changes in the industry with changes in who responded to our study. Because we used nonprobability recruitment, we are unable to calculate a nonresponse error for our sample. The 37 surveys included in our analysis represent 4046 bearing acres, or 15% of Georgia's 2020 planted area, indicating strong statewide coverage. Nevertheless, when we compared county-level distribution of survey responses to UGA Farm Gate data for 2020, we observed indications of a response bias. Specifically, survey respondents who operated in Bacon County were over-represented in our sample. Notably, we asked participants to report the single county with the majority of their blueberry acreage and did not collect data regarding blueberry acreage across counties; therefore, we are unable to determine whether these growers were operating in multiple counties or calculate the distribution of acres across multiple counties. Future surveys should consider strategies for probability sampling and collect data that allow for a more accurate comparison of the sample with available benchmarks.

Despite our effort to update our survey to include current pest and disease threats, we neglected to include bacterial leaf scorch (*Xylella fastidiosa*) and its vector, the glassy-winged sharpshooter (*Homalodisca vitripennis*), which has been documented as a potential threat to Georgia blueberry production since at least 2008 (Brannen et al. 2026; Sorrow 2010). Although we included an "other" option for participants to add pests and diseases we may have missed, no participants mentioned bacterial leaf scorch or the glassy-winged sharpshooter. Nevertheless, this is an oversight on our behalf; therefore, the inability to report on this as an issue of concern to growers is a limitation of our study.

Conclusions

The Georgia blueberry industry has expanded considerably over the last 25 years, 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 4600 acres in 1999 to more than 27,947 acres in 2024 (Scherm et al. 2001; University of Georgia 2026). According to our survey, 56.8% of growers expected to increase their planted area by a mean of 58.4 acres over the next 5 years (2020–25). Compared with a similar survey conducted in 1999 (Scherm et al. 2001), Georgia blueberry growers have increasingly adopted new early-season southern highbush cultivars developed through university research and breeding efforts, likely because of their increased disease resistance, machine harvestability, and broader market window. Plant injury caused by late spring freezes remains a problematic issue for many. Disease issues 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 that affects a majority of growers who responded to our survey. Growers continue to use a wide range of chemical options for pest, disease, and weed management. Currently, the use of biostimulants within the Georgia blueberry industry is low. Growers who do use them primarily purchase these products from local chemical providers, with cost impacting use. While Extension was growers' primary source of information about biostimulants, nearly one-third primarily relied on information from private commercial sources, including pesticide and fertilizer dealers and consultants. Overall, responses from this survey indicate that several issues that posed challenges for growers during earlier periods of Georgia blueberry industry development remain, and that new problems have arisen; therefore, growers need to adapt by using the tools and resources available. Given the low level of biostimulant use reported by respondents, additional research evaluating their effectiveness in addressing key production challenges may help inform future research, Extension, and industry efforts across the blueberry industry.

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