Passionfruit (Passiflora sp.) originated from South American countries, but this crop is gaining interest around the world (Ulmer et al. 2004; Vanderplank 2000). As the fruit and associated value-added products gain popularity, there will be more prospective producers of passionfruit in regions where it currently does not exist or has limited production. The popularity of passionfruit has also expanded in media advertising and various other outlets (Produce News 2022). Much of the passionfruit available to consumers is processed into juice or pulp and comes from countries within South America. The production in the United States is dedicated to fresh fruit, but it is difficult to find it in most grocery stores, and it is usually confined to niche markets (Rettke 2018). Reasons for this are numerous, but the major limitation is the lack of suitable growing regions for the commercial purple passionfruit (Passiflora edulis f. edulis) and yellow passionfruit (P. edulis f. flavicarpa). It is a tropical vine, and cold temperatures limit its cultivation within temperate and subtropical regions. Within the United States, south Florida, southern California, Hawaii, and the territory Puerto Rico are obvious potential production areas. Domestically grown passionfruit is primarily destined for fresh markets. Growers in the United States are generally unable to compete with lower-priced pulp sourced from Central America and South America. However, they can earn premiums for their higher-quality fruit, making these fresh fruit markets an attractive option. Although passionfruit has been sold almost exclusively in local markets, at roadside stands, or farmers markets in Puerto Rico, south Florida, southern California, and Hawaii, marketing opportunities are emerging outside of these localized markets. Demand in these areas for fresh passionfruit is strong and should continue to grow as more consumers across the country become familiar with it. Although some research has examined export markets for passionfruit from Africa, South America, and New Zealand (Rodriguez-Amaya 2012), there has been little research of the potential for fruit grown in the United States, even in domestic markets.

The US passionfruit industry is small, but it has substantial potential to increase rapidly as consumer awareness of the fruit and processed products grow. However, there are immediate needs to be met, such as new cultivar development, advanced production methods, effective and sustainable pest management strategies, and economic analyses with the identification of new markets. Although Florida and California account for most of the fresh-market production in the continental United States, the southeastern United States has a climate that could support passionfruit production.

**Survey of US Passionfruit Growers’ Production Practices and Support Needs**

Eric T. Stafne¹, Trent Blare², Benedict Posadas¹, Laura Downey³, Joshua Anderson², Jonathan Crane², Romina Gazis², Ben Faber⁴, Dara G. Stockton⁵, Daniel Carrillo², J. Pablo Morales-Payan⁶, Manjul Dutt⁷, Alan Chambers², and Dario Chavez⁸

**Keywords.** mechanization, *Passiflora*, pest control, propagation, virus testing

**Abstract.** Passionfruits (*Passiflora* sp.) are widely grown throughout tropical regions of the world. burgeoning new interest in this fruit in both its fresh and processed forms has led to an increase in planting outside of traditional growing zones. Passionfruit production has increased steadily in the United States and its territories since the 2002 US Department of Agriculture Census of Agriculture; however, little is known about how the industry functions across production areas. To assess passionfruit growers’ production practices and support their needs, we conducted a survey during 2021. That survey consisted of 45 questions pertaining to various aspects of passionfruit production, including horticultural practices, pest management, cultivars grown, and industry challenges and needs. The objectives of the survey were to identify where passionfruit is currently grown in the United States, what production practices are being used, and what problems are being encountered so that researchers and extension personnel could provide remedies in the future. Forty-four surveys were complete and allowed for data analyses. Florida had the most responses (21), followed by Puerto Rico (12), California (6), Hawaii, Louisiana, Mississippi, and the Virgin Islands. Most of the passionfruit production in the United States comprises purple passionfruit (*Passiflora edulis f. edulis*) or intraspecific red types at 68.2%. This value is driven by the high amounts of purple passionfruit and red passionfruit in Florida and other states. In contrast, nearly all farms in Puerto Rico grow yellow passionfruit (*P. edulis f. flavicarpa*) and fewer purple types. The main obstacle to obtaining optimum production was labor availability. Managing passionfruit, like many other specialty crops, is labor-intensive and includes many activities that require manual labor, such as weeding, training, pruning, pollination, and harvesting. Other obstacles that were noted were weather variability, vine decline, poor pollination, and availability of high-quality cultivars. Diseases, especially fungal diseases, are of particular concern to growers of passionfruit in the United States, although the identification of specific diseases was limited. Online delivery methods of information ranked high in the list of desired products. Online articles, such as those offered by extension services, are the most preferred, followed by webinars, which comprise a more recently developed method of information delivery. Overall, the survey provided baseline information to further develop initiatives to aid passionfruit production within the United States.

---

**Units**

<table>
<thead>
<tr>
<th>To convert U.S. to SI, multiply by</th>
<th>U.S. unit</th>
<th>SI unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4047</td>
<td>acre(s)</td>
<td>ha</td>
</tr>
<tr>
<td>0.3048</td>
<td>ft</td>
<td>m</td>
</tr>
<tr>
<td>1.1209</td>
<td>lb/acre</td>
<td>kg·ha⁻¹</td>
</tr>
<tr>
<td>2.2417</td>
<td>ton(s)/acre</td>
<td>Mg·ha⁻¹</td>
</tr>
</tbody>
</table>
if a few improvements could be made. The incidence rates of insects and disease and the ability to obtain virus-free plant material are great challenges for passionfruit growers. Still, even with the ability to grow the fruit, the marketability of passionfruit remains a hurdle for producers to identify markets because of a lack of consumer awareness.

Although market expansion is a good outcome for growers, there is a paucity of information about growing passionfruit and how much of it is being grown, especially in subtropical and warm temperate zones. Little is known about who is growing passionfruit in the United States, how much is being grown, and where the production exists. The US Department of Agriculture (USDA) produces the Census of Agriculture every 5 years. Data from 2017 showed that Hawaii (203 farms), California (82 farms), and Florida (73 farms) were the primary states with passionfruit production, but that other states also had varying levels of production (Posadas 2021).

To gain a better understanding of the scope of passionfruit production in the United States, a USDA National Institute for Food and Agriculture Specialty Crops Research Initiative grant was funded in 2021 to survey the industry and gain feedback from stakeholders within the US passionfruit industry. A critical part of the survey included asking respondents about current production practices. There are few sources of research-based information available to US growers from university extension services, ostensibly because of the perceived lack of need. However, passionfruit is becoming more visible to consumers; furthermore, as the Hispanic populations continue to grow in the United States and the interest in Latin American-inspired cuisine increases, the demand for this crop will likely follow that expansion (Cohn and Caumont 2016). Although the trend for production is upward (Posadas 2021), with such limited national production, current assessments of stakeholder priorities for the passionfruit industry are undetermined. Therefore, to identify constraints to the development of this industry, a comprehensive survey and needs assessment of the US passionfruit industry is necessary. The objectives of the survey were to identify where passionfruit was currently being grown in the US, what production practices were being used, and what problems were being encountered so that researchers and extension personnel could provide remedies in the future.

Materials and methods

Survey collection. We distributed an online survey to passionfruit growers and those interested in growing passionfruit throughout the tropical and sub-tropical regions of the United States, which are the primary areas where passionfruit is produced in the US, from Mar 2022 through May 2022. The states and territories that were targeted included Puerto Rico, the US Virgin Islands, Florida, Mississippi, Louisiana, California, and Hawaii. Extension agents and specialists in each of the states and territories identified the survey participants through their extension programs based in these regions. Most surveys were completed online. Several participants did not have access to the internet to complete the survey, especially in Puerto Rico, or preferred to complete the interview in person with an extension specialist. These survey answers were collected through in-person interviews and entered into the online survey by the extension specialist.

The survey included 45 questions about the participant’s demographic information, passionfruit plantings (i.e., acreage, cultivars), production practices (i.e., trellis type, spacing, pest management), marketing experiences, and barriers to success. The survey was available in both English and Spanish to potentially reach the broadest possible audience (see Supplemental Table 1 for the text of the survey).

A total of 44 usable surveys were obtained for the analysis. Although more surveys were returned, they were deemed incomplete or duplicates; therefore, they were excluded from the analysis. The numbers of useable survey responses were as follows: California, 6; Florida, 21; Hawaii, 1; Louisiana, 2; Mississippi, 1; Puerto Rico, 12; and Virgin Islands, 1. Survey data were divided into three regions: Florida; California, Hawaii, Louisiana, and Mississippi; and Puerto Rico and the US Virgin Islands. Institutional Review Board approval was granted by the Mississippi State University Office of Research Assurances for the “Exploring the Potential of Passion Fruit in Subtropical North America” project (Institutional Review Board no. 22030). Data were collected digitally using survey data software (Qualtrics XM; Qualtrics, Provo, UT, USA); then, the data were cleaned to remove nontarget responses and coded using spreadsheet software (Microsoft Excel; Microsoft Corp., Redmond, WA, USA). Cleaned ordinal data were analyzed using the chi-square analysis to estimate frequencies and generate tables and figures. Overall and regional averages of the cardinal data across categories were estimated by an analysis of variance.

Results and discussion

Although there were many more partial responses to the survey, 44 surveys were complete and allowed for data fidelity. Florida had the most
responses (21), followed by Puerto Rico (12), California (6), Hawaii, Louisiana, Mississippi, and the Virgin Islands. Many respondents (44.8%) indicated they were commercial growers, and another 20.9% said they were potential growers. Thus, more than 65% of the respondents had some interest in the horticultural aspect of growing passionfruit (Fig. 1). The roles of survey respondents were primarily commercial grower and potential commercial grower, followed by nursery operator and commercial propagator. These were the primary targeted individuals for our survey, and more than 92% of all responses were from those interested in growing and propagating passionfruit as a commercial endeavor (Fig. 1).

When asked what year they first planted passionfruit, the average year of planting for commercial passionfruit in Florida was 2011 (Table 1). Interestingly, the average initial plantings in Puerto Rico occurred in 2017, which was 6 years later than that of Florida, even though the climate of Puerto Rico is tropical and, therefore, better situated for commercial production of passionfruit. This delay may have been caused by earlier virus outbreaks that decimated the industry in Puerto Rico. Other states outside of Florida reported an average planting year of 2012. Prior USDA Census of Agriculture surveys (Posadas 2021) showed that acreage within the United States is growing, although the data are limited in scope.

Florida has the largest acreage per passionfruit farm of the regions surveyed (Table 1). The mean size of a passionfruit farm was 5.6 acres. Puerto Rico had several reporting farms, but they averaged only 1.3 acres each. Availability of labor in Puerto Rico may be a factor because it is an island with finite resources. Florida reported 5.6 acres per farm of passionfruit, but only 63% of it was bearing in 2021. The reason for the nonbearing acreage is unknown, but the recent attractiveness of the passionfruit market (Produce News 2022) may have spurred new plantings.

There has never been a comprehensive survey of passionfruit production in the United States; therefore, little is known about the actual value of this fruit in any of the regions. Typically, a passionfruit vine will begin bearing during the second year. According to the 2017 USDA Census of Agriculture, the total number of farms of bearing age and nonbearing age was 364 on a total of 85 acres, with an average farm on less than one-third of an acre. This statistic is likely far lower than the actual production because Florida production alone is estimated to be on as many as 72 to 100 acres (Crane 2018; Rettke 2018), and California has an estimated 300 acres (Faber unpublished).

**Species and cultivars.** Most of the passionfruit production in the United States involves purple passionfruit or intraspecific hybrids with reddish to purple colors (68.2%) (Table 2). This value is primarily driven by the high rate of purple passionfruit production in Florida. Purple and yellow passionfruit have different flavor profiles, growth habits, and other factors that make them more attractive to different people.

It is apparent from the survey that numerous cultivars are being grown, but some unknown selections and hybrids and privately selected types are also being grown (e.g., ‘Panama Red’; data not shown). Florida growers preferred ‘Possum Purple’, whereas growers in other states grew more ‘Frederick’. Fifty percent of passionfruit grown in Puerto Rico was Hawaiian, likely a yellow type such as ‘Lilikoi’. It is interesting that 28.6% was reported as maypop (Passiflora incarnata) in other states outside of Florida and Puerto Rico. This suggests some interest in this wild vine as a potential crop. Although it grows well in more temperate areas, it has some deficiencies that prohibit commercial production, including short postharvest life, lack of consistent cultivars, questionable fruit quality, and large seed size (Stafne 2022a). Yet, the potential exists for hybridization with *P. edulis* cultivars to produce vines that are more cold-hardy and have suitable fruit quality (Stafne 2022a).

Passionfruit breeding efforts are relatively recent and have been limited to a few programs in countries with significant commercial production, such as Columbia, Brazil (Reis et al. 2012; Ribeiro et al. 2019; Rosado et al. 2019), and Australia; however, Israel, China (Liu et al. 2017; Xu et al. 2019), Kenya, and Uganda are also performing breeding research. No passionfruit breeding program has persisted in the United States; however, Knight (1972) worked

![Fig. 1. Individual respondent role among surveyed regions within the United States in the passionfruit industry.](image-url)

Table 1. First commercial year of planting, mean number of acres in 2021, and mean number of bearing acres in 2021 of passionfruit vines for each of three regions within the United States.

<table>
<thead>
<tr>
<th>Region</th>
<th>First commercial year of planting</th>
<th>Mean production area (acres)</th>
<th>Mean bearing production area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>2011</td>
<td>5.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Other states</td>
<td>2012</td>
<td>1.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>2017</td>
<td>1.3</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1 acre = 0.4047 ha.
in this area for many years. This is partly because of the lack of commercial production of passionfruit (Morton 1987) despite having some level of cultivation since at least 1887 (Knight 1972). Significant losses caused by defective or diseased fruit, typically 50% of harvested fruit, have been reported since early during the production history in the United States (Knight 1992). ‘Possum Purple’ had been the established cultivar at that point because of consumer preference for purple fruit, even though it has significant disease susceptibility and pollination issues, which were also reported in this survey (Table 3). Winters and Knight (1975) crossed different cold-hardy species, including maypop, to hopefully transfer their traits to an edible cultivar; this eventually led to ornamental cultivar releases, but none for fruit production. Several passionfruit cultivars were developed during short-lived breeding efforts in Hawaii (Nakasone et al. 1967), Australia, and elsewhere (Morton 1987); however, most, if not all, are unavailable in the current US market.

Survey respondents were asked to rank their biggest needs in terms of new cultivars (Fig. 2). The number one most desired trait was larger fruit, followed by disease resistance, higher yields, and better fruit quality. Lower on the list were insect resistance, sweeter fruit, self-fertile cultivars, and other fruit colors. The desire for larger fruit was not anticipated to be among the most needed upgrades, but this list does give breeders a place to start. Somewhat surprisingly, self-fertile cultivars were low on the list. This result suggests that pollination is not as problematic as anticipated based on previous literature (Bailey et al. 2021; Deshmukh et al. 2020; Hammer 1987; Knight 1992, 1994; Knight and Winters 1962; Morton 1987); however, this deserves further scrutiny because recognition of poor pollination effects may not be well understood.

Production practices. Although there is substantial information about international passionfruit production in India (Joy 2010), Colombia (Cardona et al. 2014), Brazil (Ruggiero 1987), and Australia (Rigden and Newett 2011), horticultural research in the United States is more limited. In Hawaii, detailed passionfruit cultural recommendations were made many years ago (University of Hawaii 1972). More recently, Paull and Duarte (2012) developed a fertilizer application regimen for *P. edulis* grown in Hawaii, but more research is needed to improve growing methods and establish best practices. In Florida, previous investigations of the pollination biology (Hammer 1987; Knight and Winters 1962, 1963), effect of biostimulants on propagation (Morales-Payan and Stall 2004), incidence of viruses in commercial plantings (Baker et al. 2014; Elliott et al. 1991), and a sudden wilt fungal pathogen (*Fusarium* sp.) (Ploetz 1991) were conducted. However, little research of sustainable nutrient and water management, integrated pest management (insect, disease, and weed management), and marketing has been done. Optimum plant spacing and pruning for warm subtropical and protected agriculture (high tunnels) passionfruit plantings are unknown. More recently, Bailey et al. (2021) developed guidelines for Florida production, although gaps in knowledge still exist.

According to the survey data collected, vines were planted at similar distances, from approximately 8 to 10 feet apart within a row, in each area (Table 4). This is consistent with recommendations found in production guides (Bailey et al. 2021; Rigden and Newett 2011). Distance between rows is often dictated by the equipment necessary to perform the work in the planted area. Florida and Puerto Rico had similar row distances at 10 feet and 11 feet, respectively. Other states had closer spacing (7 feet). This may be an indication of growing less vigorous vines such as maypop, or that more of the work is performed by hand and, thus, not dictated by equipment size. The vine spacing reported in Table 4 would lead to a total vine acre count of 409 in Florida, which would be 4.8 acres per planting. This is less than the size of 5.6 acres reported in Table 1, and more than 3.5 bearing acres. Participants from other states reported a total vine count of 386.9, which equates to 0.49 acre of vines and is far fewer than the size of 1.8 acres in Table 1. The 358 total vines from Puerto Rico are equal to 0.87 acres, which is less than that reported in Table 1. Evidently, the actual acreage needs to be verified by on-farm visits.

The relatively few responses in each region made it difficult to interpret yields (Table 5). Florida reported a little more than 1 ton/acre, whereas Puerto Rico reported close to 3 tons/acre. However, other states, which include Hawaii, California, and a few others, reported nearly 5 tons/acre; however, this number was taken from only from three responses. Environmental conditions within growing regions can significantly affect yields (Deshmukh et al. 2020). Areas with high rainfall and humidity rates, such as Florida, would have high fungal disease pressure and likely more insect pests that could result in vector viral diseases (Elliott et al. 1991). This supposition is supported by the data in Table 5, which shows that Florida had the highest percentage of unmarketable fruit. Yet, Puerto Rico, which is also a wet, humid location, had the lowest (7.4%); this difference could be why Puerto Rico had nearly three-times the reported yields compared with Florida. A more plausible explanation may be related to the cultivar being produced because Florida largely produces purple types and Puerto Rico produces mostly yellow (Table 2). Yellow passionfruit is better-adapted to lowland tropical environments, has shown more resistance to soil-borne diseases, and may be more heat-tolerant than purple passionfruit (Knight 1992).

Most passionfruit vines were planted into the soil (nearly 75%) (Fig. 3). A smaller percentage were grown in containers. This would indicate opportunities to explore other options for growing passionfruit that do not include in-ground plantings. Passionfruit vines are known to be susceptible to soil-borne diseases such as Fusarium (*Fusarium* sp.), Phytophthora root rot (*Phytophthora* sp.), and parasitic nematodes (Bailey et al. 2021); therefore, growing the crop in a controlled substrate could exclude these pests and might be a viable option for growers.
There is no clear, dominant trellising system for passionfruit among surveyed producers (Table 6). The largest percentage of respondents reported harvesting wild vines. This could mean “unmanaged” or “untrellised” rather than wild. The next largest percentage reported using two top wires, similar to a Geneva double curtain trellising system common for grapevines.

Table 3. The main pests of concern in passionfruit plantings as reported by growers across all surveyed states within the United States. Respondents could list multiple pests.

<table>
<thead>
<tr>
<th>Insect response</th>
<th>Scientific name</th>
<th>Frequency (no.)</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caterpillars</td>
<td>Dione sp.</td>
<td>10</td>
<td>24.4</td>
</tr>
<tr>
<td>Worms</td>
<td>Lepidoptera</td>
<td>7</td>
<td>17.0</td>
</tr>
<tr>
<td>Mites</td>
<td>Tetranychus mexicanus</td>
<td>4</td>
<td>9.8</td>
</tr>
<tr>
<td>Aphids</td>
<td>Aphididae</td>
<td>3</td>
<td>7.3</td>
</tr>
<tr>
<td>Scale</td>
<td>Coccoidea</td>
<td>3</td>
<td>7.3</td>
</tr>
<tr>
<td>Sucking insects</td>
<td>Leptoglossus sp.</td>
<td>3</td>
<td>7.3</td>
</tr>
<tr>
<td>Ants</td>
<td>Formicidae</td>
<td>2</td>
<td>4.9</td>
</tr>
<tr>
<td>Grubs</td>
<td>Scarabaeida</td>
<td>2</td>
<td>4.9</td>
</tr>
<tr>
<td>Thrips</td>
<td>Thysanoptera</td>
<td>2</td>
<td>4.9</td>
</tr>
<tr>
<td>Beetles</td>
<td>Coleoptera</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Fruit fly</td>
<td>Anastrepha sp.</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Leaf miners</td>
<td>Agromyzidae</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Mealy-bugs</td>
<td>Pseudococcidae</td>
<td>1</td>
<td>2.4</td>
</tr>
<tr>
<td>Snails</td>
<td>Gastropoda</td>
<td>1</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Disease response

<table>
<thead>
<tr>
<th>Disease response</th>
<th>Scientific name</th>
<th>Frequency (no.)</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fusarium wilt</td>
<td>Fusarium oxysporum f. sp. passiflorae</td>
<td>9</td>
<td>25.0</td>
</tr>
<tr>
<td>Fruit scab</td>
<td>Cladosporium cladosporioides complex</td>
<td>4</td>
<td>11.1</td>
</tr>
<tr>
<td>Leaf spots</td>
<td>Alternaria, Colletotrichum</td>
<td>4</td>
<td>11.1</td>
</tr>
<tr>
<td>Root rot</td>
<td>Phytophthora sp.</td>
<td>3</td>
<td>8.3</td>
</tr>
<tr>
<td>Nematodes</td>
<td>Meloidogyne incognita</td>
<td>2</td>
<td>5.6</td>
</tr>
<tr>
<td>Stem rot</td>
<td>Fusarium solani complex</td>
<td>2</td>
<td>5.6</td>
</tr>
<tr>
<td>Viruses</td>
<td>Potyvirus, Carlavirus</td>
<td>2</td>
<td>5.6</td>
</tr>
<tr>
<td>Alternaria</td>
<td>Alternaria sp.</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Bacterial spot</td>
<td>Xanthomonas axonopus pv. passiflorae</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Blight</td>
<td>Unknown</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Botrytis</td>
<td>Botrytis cinerea</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Brown spot</td>
<td>Alternaria sp.</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Fruit rot</td>
<td>Colletotrichum gloeosporioides complex</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Fruit spots</td>
<td>Unknown</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Fungus</td>
<td>Unknown</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Mildew</td>
<td>Erysipheaeae</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>Mold</td>
<td>Unknown</td>
<td>1</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Weed response

<table>
<thead>
<tr>
<th>Weed response</th>
<th>Family</th>
<th>Frequency (no.)</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass</td>
<td>Poaceae</td>
<td>9</td>
<td>17.6</td>
</tr>
<tr>
<td>Vines</td>
<td>Unknown</td>
<td>8</td>
<td>15.7</td>
</tr>
<tr>
<td>Sedges</td>
<td>Carex sp.</td>
<td>7</td>
<td>13.7</td>
</tr>
<tr>
<td>Broadleaf weeds</td>
<td>Unknown</td>
<td>6</td>
<td>11.8</td>
</tr>
<tr>
<td>Johnsongrass</td>
<td>Sorghum halepense</td>
<td>4</td>
<td>7.8</td>
</tr>
<tr>
<td>Parthenium</td>
<td>Parthenium hysterophorus</td>
<td>2</td>
<td>3.9</td>
</tr>
<tr>
<td>Pigweed</td>
<td>Amaranthus sp.</td>
<td>2</td>
<td>3.9</td>
</tr>
<tr>
<td>Bitter melon</td>
<td>Momordica charantia</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Carolina horsenettle</td>
<td>Solanum carolinense</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Grapevine</td>
<td>Vitis sp.</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Guinea grass</td>
<td>Megathyrsus maximus</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Hairy fleabane</td>
<td>Conyza bonariensis</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Itch weed</td>
<td>Veratrum viride</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Lambquarters</td>
<td>Chenopodium album</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Maypop</td>
<td>Pasiflora incarnata</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Pepperweed</td>
<td>Lepidium sp.</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Rosary pea</td>
<td>Abrus precatorius</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Smilax</td>
<td>Smilax sp.</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Spurge</td>
<td>Euphorbia sp.</td>
<td>1</td>
<td>2.0</td>
</tr>
<tr>
<td>Thistle</td>
<td>Asteraceae</td>
<td>1</td>
<td>2.0</td>
</tr>
</tbody>
</table>
Propagation of passionfruit vines is commonly performed by cuttings, but it is also performed through seeds; it is uncommonly performed with tissue-cultured plants (micropropagation) (Table 7). Few sources of tissue-cultured plants exist, and cultivar choices for fruit production are very limited in the nursery trade. Although cuttings are easy to propagate and result in a high percentage of viable plants (Deshmukh et al. 2020; Faleiro et al. 2019), they may carry viruses (discussed in more detail in the following section). Seeds are easy to germinate (Deshmukh et al. 2020; Faleiro et al. 2019), but the resulting vines are not true-to-type. Seeds were the primary source of propagated material in Puerto Rico and the secondary source in Florida. Other areas did not report using seeds (Table 7).

The main obstacle to obtaining optimum production was labor availability (Table 8). Managing passionfruit, like many other specialty crops, is labor-intensive and involves several activities that are often performed by hand, such as weeding, vine training, pruning, and harvesting (Rigden and Newett 2011). Other obstacles were weather variability, vine decline, poor pollination, and availability of quality cultivars. Hand pollination is not as common as anticipated based on reported pollination issues (Bailey et al. 2021; Knight 1994). Only 17% of growers reported hand pollination as a common cultural practice (Table 9).

Mechanization is important on farms where the labor pool is small or too expensive to employ. Based on the survey, it appears that tasks during the production of the passionfruit vines, such as pruning and harvesting, are more important to the focus of mechanization than those during the processing and post-harvest activities (data not shown). The processing side is likely already more advanced in terms of mechanization; therefore, less need was reported. Equipment to perform tasks related to field production of passionfruit could be modified from existing technology for other crops. Grapevines have experienced significant advancements in technology for managing vines in the field, in some cases with little or no human intervention (Gray 2020; KURTURAL AND FIDELIBUS 2021).

**Pest Management.** Diseases are of much concern to growers of passionfruit in the United States. However, the identification of specific diseases is limited. Some growers identified diseases caused by *Alternaria* (brown spot), *Fusarium* (suited vine decline), and *Botrytis* (Table 3). Some of the other diseases listed were based on symptoms rather than on pathogens (e.g., leaf spots, root rot, fruit rot) and could potentially be lumped in with the previously listed disease pathogens. *Fusarium*-associated and *Phytophthora*-associated diseases can be problematic to domestic passionfruit production and cause premature vine death (Knight 1972; PLOETZ 1991); however, these diseases can be managed with proper cultural practices and the judicious implementation of a fungicide program. Other diseases mentioned include anthracnose on foliage and fruit caused by *Colletotrichum* and *Alternaria* species.

Most postharvest diseases have not been thoroughly studied, but *Lasiodiplodia theobromae* has been documented to cause fruit rot, and several viruses in the Potyvirus group can lead to vine and fruit malformations. Some level of resistance to soil-borne pathogens has been reported in Florida (Knight 1972;...
Fig. 3. Percentage of US-based survey respondents who grew passionfruit vines with various soils and containers.

Table 6. Trellis system types used by passionfruit growers across all surveyed states within the United States.

<table>
<thead>
<tr>
<th>Trellis type</th>
<th>Frequency (no.)</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wild</td>
<td>13</td>
<td>31.4</td>
</tr>
<tr>
<td>2 top wires</td>
<td>12</td>
<td>23.5</td>
</tr>
<tr>
<td>1 top wire</td>
<td>7</td>
<td>13.7</td>
</tr>
<tr>
<td>T-type support</td>
<td>4</td>
<td>9.8</td>
</tr>
<tr>
<td>3 top wires</td>
<td>3</td>
<td>7.8</td>
</tr>
<tr>
<td>Pergola</td>
<td>3</td>
<td>5.9</td>
</tr>
<tr>
<td>Pots</td>
<td>1</td>
<td>2.0</td>
</tr>
</tbody>
</table>

Table 7. Percentage of passionfruit growers who propagated their own vines with these methods as reported by each region surveyed within the United States.

<table>
<thead>
<tr>
<th>Propagation technique</th>
<th>Florida (%)</th>
<th>Other states (%)</th>
<th>Puerto Rico (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cuttings</td>
<td>58.8</td>
<td>87.5</td>
<td>23.1</td>
<td>52.6</td>
</tr>
<tr>
<td>Seeds</td>
<td>23.5</td>
<td>0.0</td>
<td>76.9</td>
<td>36.8</td>
</tr>
<tr>
<td>Tissue culture</td>
<td>11.8</td>
<td>12.5</td>
<td>0.0</td>
<td>7.9</td>
</tr>
</tbody>
</table>

Another major limitation to passionfruit production is viral diseases. Virus complexes affecting passionfruit in the United States and their insect vectors have not been characterized. Viral infections are more difficult to manage because curative approaches do not exist; therefore, pathogen exclusion is the only option. Because many growers populate their fields with cuttings from their own field, the cycle is never broken, and virus-infected vines are perpetuated in the field. *Cowpea aphid-borne virus* that causes passionfruit woodiness disease is a problem (Baker et al. 2014; Bailey et al. 2021), along with other viruses inducing similar symptomatology. There are no effective control measures for these diseases. With limited options, growers have turned to frequently replanting to maintain productivity and mitigate the loss of vigor observed in infected vines. However, the use of certified virus-free planting stock and material is lacking, thus leading to the establishment or re-establishment of passionfruit plantings with infected vines. This substantially increases production costs without resolving the underlying issues. Scouting for pests in passionfruit plantings was performed by 80% of growers; however, only 20% tested for viruses (Table 9). As mentioned previously, viral diseases are among the most damaging to vines and often reduce the life span of the vines. Virus testing is also important when it comes to propagation; 78% of growers propagate their own vines (Table 9), presumably from vines they currently grow. This means that much of what is being propagated may already be virus-infected. Few respondents identified viruses as a problem; therefore, this could indicate a priority area for education.

Insect pests can cause considerable damage to passionfruit vines and developing fruit (Bailey et al. 2021). Passionfruit vines harbor a great diversity of arthropods. Juno longwing (*Dione junon*) and gulf fritillary (*Dione vanillae* [synonym *Agraulis vanillae]*) are lepidopteran pests that can defoliate entire vines if not controlled. Two species of leaf-footed bugs, *Leptoglossus concolor* and *Leptoglossus phyllopus*, have been found to damage fruit. Feeding produces unsightly punctures that result in malformed fruit. Banded cucumber beetles (*Diabrotica balteata*) also feed on passionfruit flowers and leaves. The spidermite, *Tetranychus mexicanus*, is an important pest of passionfruit in South America, and it was recently found infesting passionfruit in Florida (Bailey et al. 2021).

One issue with allowing survey respondents to answer open-ended questions is that they may not know the proper terminology. Such was the case with this survey, during which caterpillars, grubs, and worms were identified separately but could represent that same pest (Table 3). This is undoubtedly the gulf fritillary or Juno longwing and their larva. The gulf fritillary butterfly does not directly damage the vine, flowers, or fruit, but it deposits eggs that result in larvae that can destroy leaves and fruit if left unchecked. Because passionfruit vines are a nectar source for these butterflies and the primary food source for their larva (May 1992), it is not surprising that they are of significant concern. Other insects such as mites and scales appear to be localized or minor pests compared with caterpillars.
Table 8. Main obstacles to obtaining optimum production ranked from 1 to 12, with 1 being most important across all surveyed states within the United States.

<table>
<thead>
<tr>
<th>Obstacle</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor availability</td>
<td>4.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Annual weather variability</td>
<td>5.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Vine decline</td>
<td>5.5</td>
<td>3.9</td>
</tr>
<tr>
<td>Pollination</td>
<td>5.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Lack of quality cultivars</td>
<td>5.9</td>
<td>3.1</td>
</tr>
<tr>
<td>Long-term climate change</td>
<td>6.2</td>
<td>3.1</td>
</tr>
<tr>
<td>Capital investment</td>
<td>6.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Food safety regulation</td>
<td>6.9</td>
<td>3.3</td>
</tr>
<tr>
<td>Supply chain shortages</td>
<td>7.7</td>
<td>2.9</td>
</tr>
<tr>
<td>Other business or tax regulations</td>
<td>7.9</td>
<td>3.0</td>
</tr>
<tr>
<td>Market demand</td>
<td>8.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Lack of available pest control substances</td>
<td>8.7</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Weeds are also of concern, with most respondents indicating grasses as the most important (Table 3). Grasses (Poaceae), weedy vines, and sedges (Carex sp.) were identified as problematic and difficult to control. There are limited herbicides available to control these weeds, but labeling may not allow for spraying in all states. Weed removal by hand is a labor-intensive process, but it was most common among the passionfruit growers surveyed, with more than 50% using this method (data not shown). Herbicides were the next most used method, followed by mechanical equipment and groundcovers. Reasons for hand-weeding being the most popular method are not known, but the lack of available herbicides, costs of herbicides and equipment, and ready availability of suitable labor are possible reasons. Passionfruit can be easily damaged by improper spraying, and mechanical removal of weeds with equipment can also cause root injury. Growers may view hand-weeding as a safer alternative despite the labor-intensive nature of the activity.

**GROWER SUPPORT.** Extension interactions in Florida have suggested major constraints to successful passionfruit production include clean and disease-free propagation material, lack of self-compatible cultivars, insect and/or disease resistance, high-quality passionfruit cultivars, insect and disease identification and management strategies, sustainable nutrient and irrigation management recommendations, and identification and evaluation of alternative fresh fruit and/or specialty markets (Stafne 2022b). These observations in Florida are also common in other states involved in this survey; however, because of limited production, little is known about the most prevalent pests, cultivar recommendations, and best management practices. Extension programs in Mississippi have generated some interest from potential growers, propagators, and consumers, but more research is necessary to guide recommendations.

Table 9. Percentage of passionfruit growers who applied horticultural practices to their operation in each region within the United States.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Florida (%)</th>
<th>Other states (%)</th>
<th>Puerto Rico (%)</th>
<th>Total (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regularly scout for pests</td>
<td>83.3</td>
<td>80.0</td>
<td>76.9</td>
<td>80.5</td>
</tr>
<tr>
<td>Test vines for viruses</td>
<td>33.3</td>
<td>0.0</td>
<td>15.4</td>
<td>19.5</td>
</tr>
<tr>
<td>Propagated own vines</td>
<td>72.2</td>
<td>60.0</td>
<td>100.0</td>
<td>78.1</td>
</tr>
<tr>
<td>Hand-pollinated vines</td>
<td>22.2</td>
<td>10.0</td>
<td>15.4</td>
<td>17.1</td>
</tr>
</tbody>
</table>

Online methods of information delivery rank high on the list of desired products (Table 10). Online articles, such as those offered by extension services, are most preferred, followed by webinars, which comprise a more recently developed method of information delivery. In-person meetings are still popular, but individual visits and field days are not. This could represent a change in dynamics induced by the COVID-19 pandemic as universities switched to more online delivery of information, or it could be a result of a gradual acceptance of online material as convenient and just as edifying as in-person activities.

The lack of ability to reach stakeholders appears to be a limitation. If someone does not know that a program exists, then how can they take advantage of it? Growers also desire more grant programs to help the passionfruit industry grow, as well as more training programs, cost-share assistance, insurance protection, and loans (Table 11). Based on these results, it appears that local, state, and federal governments need to become better at communicating the availability of their programs to aid passionfruit growers. Language translation services to reach non-English-speaking passionfruit growers should be included in this effort. Targeted coordination among all three governmental agencies should be a priority to develop the best communication outlets for reaching growers.

**Conclusions**

Several notable results of this study were obtained and have implications for future research and extension activities. Critical aspects of passionfruit production were identified, including significant pest problems, gaps in information delivery, and needs associated with future breeding endeavors. Based on the
Table 11. Preferred actions that local, state, and federal governments can perform to support passionfruit production as reported by survey respondents within the United States. Respondents were allowed to choose multiple actions.

<table>
<thead>
<tr>
<th>Preferred actions</th>
<th>Frequency (no.)</th>
<th>Proportion (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge of existing programs</td>
<td>27</td>
<td>20.6</td>
</tr>
<tr>
<td>Grant programs</td>
<td>25</td>
<td>19.1</td>
</tr>
<tr>
<td>Training</td>
<td>24</td>
<td>18.3</td>
</tr>
<tr>
<td>Cost-share programs</td>
<td>20</td>
<td>15.3</td>
</tr>
<tr>
<td>Insurance programs</td>
<td>15</td>
<td>11.5</td>
</tr>
<tr>
<td>Loan programs</td>
<td>23</td>
<td>9.9</td>
</tr>
<tr>
<td>Low costs</td>
<td>3</td>
<td>2.3</td>
</tr>
<tr>
<td>Limit imports</td>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>Experimentation</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Mechanization</td>
<td>1</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Survey results, new research priorities would include the development of new passionfruit cultivars, pest control (e.g., viral and fungal diseases, lepidopteran insects, and weedy grass species), optimization of trellis systems, plant propagation methods, and containerized production. Potential extension and outreach products could include webinar series, online articles (e.g., extension fact sheets, production guides), and the identification of market opportunities. Overall, the survey provided baseline information to further develop initiatives to aid passionfruit production within the United States as well as other subtropical and temperate zones that could support passionfruit as a viable, high-value specialty crop.

References cited


Ulmer T, MacDougal JM, Ulmer B. 2004. Passiflora passionflowers of the world. Timber Press, Portland, OR, USA.


Supplemental Table 1. Survey sent in Mar 2022 to passionfruit growers across the United States; this survey ended in Jul 2022.

LETTER OF RECRUITMENT
Dear Owner or Operator:

What is this survey all about?

This survey is the first attempt to assess the passionfruit industry in the United States. The results of the survey will give researchers and educators baseline data to inform decision-making about future endeavors to help the passionfruit industry grow.

Who should complete this survey?

Anyone who is presently growing passionfruit commercially, propagating passionfruit vines, or is interested in growing passionfruit as a commercial operation.

This survey is for individuals over the age of 18. If you are under the age of 18, please do not complete this survey.

What are the benefits of completing this survey?

This survey will provide the research team with important data on production and marketing challenges, marketing trends, and industry expectations that will be compiled and reported to the passionfruit industry. Presently this information does not exist. All results will be reported back to survey participants and other stakeholders in the passionfruit industry to provide insight into how to better support growers and the industry.

This survey is voluntary, and you can stop anytime. The results of this survey will be kept confidential. Only the summary of results will be shared with the industry.

This survey was approved by the Institutional Review Board (no. 22-030).

For any questions about the survey, please call Dr. Eric Stafne 662-769-9708 or e-mail at eric.stafne@msstate.edu.

Do you agree to continue with the survey?

a. Yes
b. No

Thank you for agreeing to participate in our research. Before you begin, please note that the data you provide may be collected and used by Qualtrics as per its privacy agreement. Qualtrics has specific privacy policies of their own. You should be aware that these web services may be able to link your responses to your ID in ways that are not bound by the data confidentiality procedures used in this study. If you have concerns you should consult these services directly.

INSTRUCTIONS TO OWNER OR OPERATOR ON HOW TO COMPLETE THIS SURVEY.

Passionfruit Survey

FARM CHARACTERISTICS
1. Where is your passionfruit planting located in the U.S.?
   a. State
   b. County

2. How big (acres) is your farm in total?
   a. ___ acres

3. How many acres are planted with passionfruit?
   a. ___ acres

4. How many acres had fruit-bearing passionfruit in 2021?
   a. ___ acres

5. How many acres did you dedicate to passionfruit in 2019 and 2020?
   a. ___ 2019 acres, ___ 2020 acres

6. What is the vine and row spacing in the planting?
   a. Number of feet between vines
   b. Number of feet between rows

7. How many total vines are in the planting?

8. How many acres of land is available for expansion in passionfruit?
   a. ___ acres

9. What year did you plant your first commercial passionfruit vines?

10. What type of passionfruit do you grow? Choose all that apply.
    a. Purple
    b. Yellow
    c. Both
    d. Other, specify

11. What varieties of passionfruit do you have on your farm? Specify

12. What are the biggest needs for new varieties? Rank by importance (1, 2, 3, etc.).
    Rank
    a. Better disease resistance
    b. Better insect resistance
    c. Larger fruit size
    d. Better overall fruit quality
    e. Different fruit colors
    f. More fruit sweetness
    g. Higher yields
    h. Self-fertile varieties
    i. Other, specify

13. How are your vines grown? Choose all that apply.
    a. In-ground
    b. In containers with artificial media
    c. In raised beds
    d. Others, specify

14. What kind of trellis system do you use?
    a. 1 top wire
    b. 2 top wires
    c. Pergola
    d. Other, specify

15. What other crops do you grow?

16. What are the top obstacles to obtaining optimum production? Rank by importance (1, 2, 3, etc.)
    Rank
    a. Labor
    b. Food safety regulation
    c. Other business or tax regulations
    d. Pollination
    e. Long-term climate change
    f. Supply chain shortages
    g. Market demand
    h. Lack of quality varieties
    i. Annual weather variability
    j. Lack of available pest control substances
    k. Capital to start or expand the business
    l. Vine decline (health/vigor)
    m. Other, specify

17. What farm jobs would be desirable for mechanization on passionfruit farms? Specify

18. What are the top insect pests of concern? Specify

19. What are the top disease pests of concern? Specify

20. What are the top weed pests of concern? Specify

21. How do you control weeds? Choose all that apply
    a. Herbicides
    b. Removal by hand
    c. Mechanical equipment
    d. Other, specify

For any questions about the survey, please call Dr. Eric Stafne 662-769-9708 or e-mail at eric.stafne@msstate.edu.
22. Do you regularly scout for pests?
   a. Yes
   b. No

23. Do you test your vines for viruses?
   a. Yes
   b. No

24. Do you propagate your own vines?
   a. Yes
   b. No

25. How are your vines propagated?
   a. Cuttings
   b. Seeds
   c. Other, specify ________

26. Do you hand pollinate vines?
   a. Yes
   b. No

27. What was the passionfruit yield from your farm in 2021?
   a. _____ pounds per acre

28. What was the box flat count(s) used for passionfruit harvested in 2021? (List all that apply)
   Box flat size (i.e., 28, 32, 36, etc.)

29. What was the average price received per box flat in 2021? $_____

30. What percentage of harvested fruit:
   a. Is unmarketable (culls)? ______%
   b. Is sold as fresh? ______%

31. Where is the fruit sold? Choose all that apply.
   a. Direct to store
   b. Direct to a restaurant or winery
   c. Packing house
   d. Direct in-person to consumers
      (i.e., Farmers’ market, CSA, roadside stand, U-pick, etc.)
   e. Online
   f. Other, specify ___________

32. What additional agricultural activities do you or your family participate in (i.e., U-pick, farm stand, tourism, education, etc.)?
________________________

33. Do you produce value-added products from passionfruit (i.e., jellies, juice, pulp, etc.)?
   a. Yes
   b. No

34. What new markets are you considering entering? Specify ___________

35. What is your outlook for the future of the passionfruit industry in the USA?
   a. Positive
   b. Neutral
   c. Negative
   Why? Specify ___________

36. What support do you need from university Extension and Research in relation to passionfruit production? Rank by priority (1, 2, 3, etc.).
   a. Information/research on pests and control___
   b. Information on infrastructure needed to grow passionfruit___
   c. New variety development___
   d. Information on fertilizer management___
   e. Information on irrigation management___
   f. Information on frost/freeze protection___
   g. Information on economics of passionfruit production___
   h. Market intelligence___
   i. Training/education___
   j. Information on pruning techniques___
   k. Other, specify _____________

37. How would you prefer to receive information regarding passionfruit production? Select all that apply.
   a. Print factsheets
   b. Books
   c. Online articles
   d. Webinars
   e. Videos (e.g., YouTube, TikTok, other)
   f. In-person meetings
   g. Other, specify ____________

38. What actions can the local, state, or federal government take to better support you in passionfruit production? Choose all that apply.
   a. Insurance programs
   b. Knowledge of existing programs
   c. Cost share programs
   d. Loan programs
   e. Grant programs
   f. Training
   g. Other, specify ____________

39. What actions can the brokers of passionfruit take to better support you? Please specify

40. What is your interest in passionfruit? Choose all that apply.
   a. Commercial Grower
   b. Potential Grower
   c. Commercial Propagator
   d. Nursery Operator
   e. Other, specify ______________

41. In what year were you born? ________

42. Do you consider yourself to be Hispanic, Latino/Latina, or of Spanish Origin?
   a. Yes
   b. No

43. What race do you identify with?
   a. White
   b. Black or African American
   c. Asian
   d. Native Hawaiian or Other Pacific Islander
   e. American Indian or Alaska Native
   f. Multiple, specify ____________
   g. Other, specify ______________

44. What gender do you identify with? Choose one.
   a. Male
   b. Female
   c. Other, specify ______________

45. What is your highest level of education?
   a. Less than high school graduate (less than 12 years)
   b. High school graduate (12 years)
   c. Vocational (13-14 years)
   d. College degree (16 years)
   e. Advance or professional degree (more than 16 years)
   f. Other, specify ______________

---

Research Participant Satisfaction Survey

In an effort to ensure ongoing protections of human subjects participating in research, the MSU HRPP would like for research participants to complete this anonymous survey to let us know about your experience. Your opinion is important, and your responses will help us evaluate the process for participation in research studies.

OWNER/OPERATOR CHARACTERISTICS

40. What is your interest in passionfruit? Choose all that apply.
   a. Commercial Grower
   b. Potential Grower
   c. Commercial Propagator
   d. Nursery Operator
   e. Other, specify ______________