Using Citizen Science to Evaluate Home Gardeners' Experiences with Compact Tomato Plants

Daniela Perez-Lugones[1], Catherine G. Campbell[2], and Celina Gómez[3]

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Abstract. **Understanding preferences and challenges of home gardeners is valuable to the consumer-horticulture industry. Citizen scientists in Florida were recruited to grow compact tomato (*Solanum lycopersicum*) plants started from seed, as transplants, or as flowering plants in a 16-week experiment. Participants, who had various gardening experience levels, were provided with a kit containing all materials needed to grow plants to maturity. Project engagement was encouraged with monthly online meetings and a social media page. A survey was delivered at the end of the project and completed by 117 participants. The survey aimed to evaluate participants' preferences, challenges, and experiences with each plant product. Plants started as seed or as flowering plants were equally preferred among participants and were rated higher than transplants. However, participants were least satisfied with the yield, rate of plant growth, fruit taste, and care required to grow plants started from seed. Ninety-one percent of participants said they would be willing to pay more for flowering plants than for transplants. Across plant products, pests and flower/fruit drop were reported as challenges by up to 85% and 18% of participants, respectively. Results from this study highlight the potential of using citizen science to assess gardening experiences and preferences, which can support stakeholders who cater to the consumer-horticulture industry.**

According to the National Gardening Association (NGA), more than 100 million households in the United States participated in at least one gardening or lawn activity in 2021, following an influx of more than 18 million new gardeners in 2020 (Whitinger and Cohen 2021). Quarantine measures from the COVID-19 pandemic are partly responsible for the increased interest in home vegetable gardening in recent years (Whitinger and Cohen 2022), with 75% of independent garden centers reporting increased sales during 2020 (Garden Center Magazine 2021). The NGA found that the average household increased spending by $74 from 2021 to 2022, and one-third of respondents expected their spending in edible gardening products to increase in 2023 (Whitinger 2023). Considering that 89% of the population in the United States is anticipated to reside in urban areas by 2050 (United Nations Department of Economic and Social Affairs, Population Division 2019), there are many opportunities to support consumers interested in urban gardening and to assist industry stakeholders that cater to this growing market segment.

A key to maintaining the increasing interest in home gardening relies on understanding consumer motivations, challenges, and preferences. However, research on this topic is limited, as projects have generally focused on community-gardening efforts, and only a few have evaluated single-household gardening activities (Pollard et al. 2017). Darby et al. (2020) found low-income gardeners were motivated by the belief that growing produce was more affordable than purchasing fruit and vegetables, whereas higher-income gardeners were motivated by a perceived improvement in produce quality and by the enjoyment of being outdoors. Although increasing access to fresh produce is a common gardening incentive, gardening also holds cultural, social, and political significance for many consumers (Darby et al. 2020; Rusnak and Blazek 2020). Social benefits from gardening include community resilience and integration through aesthetic, recreational, spiritual, and cultural services (Camps-Calvet et al. 2016; Darby et al. 2020; Lal 2020). In particular, urban gardening provides environmental benefits such as microclimate modification, cycling and purification of runoff and stormwater, and flood prevention in susceptible areas (Lal 2020).

A reluctance to engage in gardening activities sometimes stems from the fear of potential failure, coupled with a perception of limited time and space (Rusnak and Blazek 2020). Urban gardeners, in particular, tend to have limited access to green spaces and, thus, would benefit from recommendations that facilitate gardening in small areas such as windowsills, balconies, or patios (Cruz and Gómez 2022; Kwon et al. 2019; Lal 2020). Numerous new compact fruiting vegetables have been released in recent years, aiming to support consumers interested in gardening in small, urban spaces (Cruz et al. 2022, 2023). However, these cultivars are sometimes only available for online purchase as seed, which can be problematic for novice gardeners who may struggle when propagating plants. A survey with more than 1000 participants revealed that although the average home gardener loses ~35% of their plants, novice gardeners lose more than double this figure (Home Advisor, Inc. 2021). Other difficulties that are often described by home gardeners include

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[1]Environmental Horticulture Department, University of Florida, Institute of Food and Agriculture Sciences (IFAS), 1549 Fifield Hall, Gainesville, FL 32611-0670, USA

[2]Department of Family Youth and Community Sciences, University of Florida, Institute of Food and Agricultural Sciences, PO Box 110310, Gainesville, FL 32611-0310, USA

[3]Department of Horticulture and Landscape Architecture, Purdue University, 625 Agriculture Mall Dr., West Lafayette, IN 47907-2010, USA

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C.G. is the corresponding author. E-mail: cgomezva@purdue.edu.

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pest-related problems, changing weather conditions, and struggles with allocating sufficient time to care for plants (Home Advisor, Inc. 2021). Supporting home gardening success and self-efficacy (i.e., the ability to produce a desired result effectively or satisfactorily) is critical, as consumers who succeed in their gardening efforts are more likely to regularly pursue gardening activities (Ornelas et al. 2018).

Citizen science is an effective method for consumer-horticulture research that enables academics to partner with members of the community pursuing common educational, research, and community goals (Roetman and Daniels 2011). This participatory research approach is a reliable avenue for collecting data over broad geographical areas and can provide valuable information describing experiences and preferences among participants (Dickinson and Bonney 2012). Aiming to understand the potential role that urban gardening has as a solution to food insecurity, Pollard et al. (2017) showed that citizen science enabled the quantification of inputs and outputs of single-household gardens. More recently, Sykes et al. (2021) showed that citizen science was an effective method to introduce home gardeners to new crops and cultivars in a multiyear home garden cultivar trial in Tennessee, USA.

The objective of this study was to evaluate preferences, challenges, and experiences using a citizen-science approach in which participants conducted an experiment evaluating compact tomato (*Solanum lycopersicum*) plants started from seed, as a transplant in a small container, and as a flowering plant in a large container, referred to as "products" from here forward. Tomato was selected as the model crop for this experiment as it is the most popular gardening vegetable plant in the United States, found in 86% of home gardens [NGA 2014; US Department of Agriculture (USDA), Economic Research Service 2020]. We hypothesized that the three plant products would differently affect gardening experiences, but preferences would be similarly distributed among products. For example, plants started from seed would require more time to harvest but would enable participants to be more involved in the gardening process, also increasing the risk of encountering challenges. In contrast, plants started at more mature stages would enable earlier harvest and thus, lead to more immediate gardening satisfaction at the expense of limiting overall gardening engagement.

Materials and methods

Recruitment and participant selection. Before beginning recruitment of project participants, all documents related to this study including promotional flyers, digital press releases, a project protocol, and a sign-up questionnaire were approved by the University of Florida Institutional Review Board (IRB202102778). The target population included residents from three urban counties in the north, central, and south regions of Florida, USA, from here forward described as counties A, B, and C, respectively. The sign-up questionnaire was published through an online form (Google Forms; Google LLC, Mountain View, CA, USA) and linked in most promotional materials, which were publicized in radio and televised interviews, a newspaper article, and through word-of-mouth.

The sign-up questionnaire was open for 7 weeks and completed by 559 individuals from 27 Jan to 18 Mar 2022. Respondents were selected based on answers to questions related to their gardening experience level, county of residence, willingness to pick up materials, and willingness to participate in monthly online meetings. In addition, individuals were asked if someone in their household had received food assistance [e.g., Supplemental Nutrition Assistance Program (SNAP) and Women, Infants, and Children Program (WIC)] in the previous 12 months, which was used as an indication of their socioeconomic status, as we aimed to identify participants from limited resource backgrounds. A quota sampling technique was used to prioritize respondents with limited resource backgrounds and to select a similar number of participants to represent each gardening experience level. Initially, 200 individuals (40%, 30%, and 30% from counties A, B, and C, respectively) were invited via e-mail and asked to confirm their participation and ability to pick up project kits at their local extension office. Additional individuals were later invited to account for those who did not reply or who could not pick up kits on time, aiming to include 200 participants in total.

Project kits. Seeds of 'Siam' tomato (PanAmerican Seed Co., West Chicago, IL, USA) were sown on 24 Jan and 14 Feb 2022 for the flowering plant and transplant products, respectively. Seeds were sown into industry-standard 84-cell propagation trays (Blackmore Co., Belleville, MI, USA) filled with a horticultural grade substrate (Pro-Mix HP Mycorrhizae; Premier Tech Horticulture, Quakertown, PA, USA) composed of 79% to 87% peatmoss, 10% to 14% perlite, and 3% to 7% vermiculite (v/v). Seedlings were propagated in a passively ventilated polycarbonate greenhouse with retractable shade curtains in Gainesville, FL, USA (lat. 30°N). Seedlings were irrigated with clear tap water for ~4 weeks. On 18 Feb 2022, 245 seedlings from the flowering plant product were planted into 8-inch-diameter "azalea" plastic containers (BWI, Nash, TX, USA) filled with the same substrate previously described and placed on benches in the same greenhouse compartment used for propagation. One tablespoon of controlled-release fertilizer (CRF) (12N–1.7P–9.1K PLUS calcium nitrate 100-d; Florikan, Sarasota, FL, USA) was top-dressed to each container after transplanting. On 2 Mar 2022, 245 seedlings from the transplant product were planted into 4-inch-diameter plastic containers (BWI) filled with the same substrate previously described and placed on benches in the same greenhouse compartment; no fertilizer was added to these plants. Environmental conditions in the greenhouse were measured with temperature and relative humidity probes (HMP60-L; Campbell Scientific, Logan, UT, USA) and quantum sensors (SQ512; Apogee Instruments Inc., Logan, UT, USA) placed at above-canopy height in the center of a bench and interfaced to a datalogger (CR1000 with AM16/32B multiplexer; Campbell Scientific). Average (±*SD*) daily light integral, ambient temperature, and relative humidity were 13.0 ± 5.4 $mol \cdot m^{-2} \cdot d^{-1}$, 22.2 ± 1.0 °C, and 65% ± 15%, respectively.

Project kits were prepared for distribution at the pick-up locations starting on 7, 8, and 14 Mar 2022 for counties A, B, and C, respectively. At the time, most plants from the flowering plant product had at least one green fruit ≥1 cm. After the pick-up window closed, 173 of

the invited participants (40%, 40%, and 20% from counties A, B, and C, respectively) had picked up a kit.

Each participant received one transplant product in a 4-inch container and one flowering plant product in an 8-inch container. All other materials were placed inside 52-L craft paper bags, which included six 61-cm bamboo stakes, two 8-inch containers, one permanent marker, three blank labeling stickers, one packet with four tomato seeds, one six-cell propagation tray (25 mL individual cell volume), one 6-fl oz spray bottle, five packets with 1 tablespoon of the same CRF previously described, three plastic bags containing 1.2 kg of the same substrate previously described, and a printed project protocol, which detailed the objective, hypothesis, project approach, and instructions for sowing, transplanting, and maintaining plants grown from the different products. In addition, instructions for data collection, a timeline, and details for group engagement activities were included in the protocol.

The project was initiated on the date of material pick-up and was ended on 28 Jun 2022 in counties A and B and 5 Jul 2022 in county C. Throughout the 16-week project, various strategies were employed to encourage participant engagement, including monthly online meetings, a Facebook (Facebook, Menlo Park, CA, USA) community page, and regular e-mail updates. Online meetings served three primary purposes: 1) to connect participants across counties, 2) to troubleshoot challenges and respond to questions, and 3) to provide project updates. The Facebook community page entitled "Citi-Sci: Growing Food for Science" served the same purposes and enabled participants to document experiences. At the end of the project, 76% of participants had joined the community page, with a peak of 99 individuals engaged in 1 d. The page had 518 photographs uploaded, 308 posts, 749 comments, and 2767 reactions.

Data collection and analyses

Survey. The project used a post-experiment survey distributed through an online platform (Qualtrics XM; Provo, UT, USA) using individual links for each participant. The survey was open from 28 Jun to 27 Jul 2022. The first part of the survey asked questions about demographics, including participation in local Master Gardener Volunteer (MGV) programs. The rest of the survey focused on evaluating participants' experiences with the experiment. Throughout the project, participants were asked to collect data on each of the products, including dates of sowing, transplanting, first and final harvests; total number of mature fruit harvested; and number of immature fruit left on each plant. Participants were asked about their satisfaction with several aspects of each plant product, including satisfaction with the amount of fruit harvested; taste of the fruit harvested; how fast each plant grew; and the amount of care required to grow each plant product. Responses about satisfaction were measured using a 5-point ordinal scale between two sets of bipolar descriptors (1 = very unsatisfied; 5 = very satisfied). Participants were asked how much they liked each product, and responses were also measured using a 5-point ordinal scale (1 = strongly disliked; 5 = strongly liked). A question was included about the overall favorite product. When assessing potential interest in purchasing a flowering plant product in an 8-inch container, participants were asked how much more they would be willing to pay compared with a transplant in a 4-inch container from a local store, and response options ranged from \$0.00 to >\$10.00.

Participants were asked to indicate the level of difficulty with different activities in the project, including difficulties with keeping plants watered and alive. These responses were also measured using a 5-point ordinal scale between two sets of bipolar descriptors (1 = very difficult; 5 = very easy). Participants were asked to select one or more challenges experienced with each product using a multiple-choice format, which included critters or large animals, insect pests, flower/fruit drop, and other. In addition, participants were asked to select one or more resources used to research solutions to challenges faced during the project, including the Citi-Sci Facebook community page; internet searches; family, friends, and neighbors; study organizers; and other. A question pertaining to the types of products that were applied when faced with challenges included homemade pest deterrent, protective structure (e.g., cage, netting, or barrier), store-bought products, no products applied, no challenges faced, and other. An open-ended response box was provided to expand on the "other" choice for each question. When reviewing open-ended responses, adjustments to the data were manually made when the text entered best reflected an existing answer option. For example, if respondents chose "other" but indicated in the open-ended response box they had used neem (*Azadirachta indica*) oil as a product to address challenges, the response was marked as "store-bought products" instead of "other." All data analyses were performed using JMP statistical software (JMP version 16; JMP Statistical Discovery LLC, Cary, NC, USA). Descriptive statistics were used for most data, except for results describing yield and satisfaction with the different plant products, which compared treatment means from the three plant products using Tukey's honestly significance difference test ($P \leq 0.05$).

Results and discussion

Demographics. From the 173 participants who picked up a kit, 117 (68%) completed the post-experiment survey (Table 1). Among those, gardening experience levels ranged from very inexperienced (3%), somewhat inexperienced (15%), neither experienced nor inexperienced (9%), somewhat experienced (61%), to very experienced (12%). The high percentage of experienced participants (73%) is likely attributed to their involvement with local gardening programs, as 64% and 21% of very experienced and somewhat experienced participants, respectively, indicated they were MGV (data not shown), even though only 20% of all participants indicated to be current members of the program. The MGV program requires participants to complete extensive training in gardening-related activities. According to Waliczek et al. (2002), gaining horticultural information is a major motivation for becoming a MGV. Accordingly, Fletcher et al. (2006) showed that participants in a MGV program showed improvements in both perceived and tested horticultural knowledge. In contrast, participants without experience in these types of programs may be less experienced with gardening. Accordingly, a survey of more than 1000 home gardeners showed that 24% of respondents

Table 1. Demographic characteristics of participant respondents to a post-experiment survey in a citizen-science research project conducted in Florida evaluating preferences, challenges, and experiences with growing compact tomato plants (n = 117).

Demographic characteristics	Responses [no. (% of total)]
County in Florida, USA	
A	46 (39)
B	42 (36)
C	29 (25)
Age (years)	
18–29	7 (6)
30–39	22 (19)
40–49	30 (26)
50–59	18 (15)
60–69	27 (23)
70 or older	13 (11)
Sex	
Female	99 (85)
Male	18 (15)
Non-binary	0 (0)
Gardening experience level	
Very inexperienced	4 (3)
Somewhat inexperienced	17 (15)
Neither experienced nor inexperienced	11 (9)
Somewhat experienced	71 (61)
Very experienced	14 (12)
Receipt of household food assistance	
Yes	13 (11)
No	102 (87)
I do not know	2 (2)
Master Gardener Volunteer	
Yes	23 (20)
No	88 (75)
No response	6 (5)

who had ≤6 months of experience found gardening to be more difficult than they had expected (Home Advisor, Inc. 2021).

Most participants identified as female (85%) and were between 40 and 49 years of age (26%) (Table 1). Similar results were reported in a survey directed to customers of an independent garden center, which showed that most respondents were female (82%) and older than 40 years (79%) (Mason et al. 2008). Other studies have shown that female volunteers are more likely to support horticulture programs (Dorn et al. 2021) and tend to represent demographics older than 50 years (Dorn et al. 2018). However, younger generations have become increasingly involved in gardening activities in recent years. For example, an industry report evaluating gardening trends in both the United States and Canada showed a 65% and 44% increase in millennial and Gen Z consumers, respectively (Garden Center Magazine 2021). Therefore, efforts to engage with younger populations are necessary in future gardening projects to ensure representation from this growing market segment in horticulture.

In our study, 11% of participants had received food assistance within the past 12 months (Table 1). This question was intended to support comparisons of potential response differences among participants from different socioeconomic status. However, the low percentage of respondents from limited resource backgrounds did not enable a distinction from the analyses. In a survey focused on gardener consumer preferences, Mason et al. (2008) found that the median household income was more than ≥$75,000, whereas Das and Ramaswami (2022) found that most respondents across a three-city survey focused on urban gardening had a household income of ≥$50,000. Nonetheless, large urban areas tend to have a high percentage of individuals living in low-income housing (Waliczek et al. 1996), which suggests that results from this project may not reflect overall experiences and preferences from the average urban population. Considering low-income minority groups are disproportionately affected by food insecurity, untreated mental health disorders, and other health-related issues, gardening research efforts should prioritize inclusion of populations from limited resource backgrounds (Chilton and Rose 2009; Sareen et al. 2011), which can particularly benefit from gardening efforts, as shown in a study examining quality of life of community gardeners (Waliczek et al. 1996). Accordingly, Ambrose et al. (2023) showed that low-income participants had the highest benefits in a study comparing the emotional well-being of household and community gardeners.

Yield and satisfaction. Participants reported that the time to first harvest and length of harvest for the seed, transplant, and flowering plant products were 84 and 24, 64 and 42, and 44 and 58 d, respectively (Table 2). Fruit from the tomato cultivar used in this study reportedly takes 70 to 84 d to reach maturity from transplant (Pan-American Seed 2023). However, our findings are similar to those of Cruz et al. (2022), who reported 55 d from transplant to harvest in a greenhouse located in Florida, or 88 to 90 d from seed to harvest. The total numbers of mature fruit harvested at the end of the project were 14, 26, and 46 for the seed, transplant, and flowering plant products, respectively, but there were no differences in the average number of immature fruit left on any of the plant products.

In a cultivar evaluation with 20 compact tomato cultivars, Cruz et al. (2022) found that most plants were generally well-suited for home gardeners, producing from 34 to 200 fruit in a greenhouse used as a proxy from common gardening spaces, with growth index (i.e., volume) ranging from 0.006 to 0.13 m^3. This is supported by a report that showed 40% of participants older than 35 years felt they did not have enough space to garden (National Garden Bureau 2019). Earlier yields from compact fruiting vegetables can potentially become an attractive quality attribute for home gardeners. Accordingly, Kwon et al. (2019) described multiple benefits of producing compact tomato plants for urban agriculture, including their suitability

Table 2. Yield and satisfaction with different plant products evaluated in a citizen-science research project conducted in Florida evaluating preferences, challenges, and experiences with growing compact tomato plants started from seed, as a transplant in a small container, and as a flowering plant in a large container.

	Seed	Transplant	Flowering plant
Fruit yield			
Days to first harvest (d)	84 a[i]	64 b	44 c
Length of harvest (d)	24 c	42 b	58 a
Mature fruit (no.)	14 c	26 b	46 a
Immature fruit (no.)	6 a	6 a	6 a
Level of likeness[ii]			
Likeness	3.8 b	4.2 a	4.4 a
Level of satisfaction[iii]			
Yield	2.7 c	3.6 b	4.3 a
Plant growth	3.3 c	3.7 b	4.2 a
Taste	3.3 b	3.9 a	4.2 a
Care	3.2 b	3.8 a	3.9 a
Favorite (%)	35	30	35

[i] Means within rows followed by the same letter are not different based on Tukey's honestly significant difference test at $P \leq 0.05$ (n = 117).
[ii] 1 = 1.00 to 1.49 = strongly disliked; 1.50 to 2.49 = disliked; 2.50 to 3.49 = neither liked nor disliked; 3.50 to 4.49 = liked; 4.50 to 5.00 = strongly liked.
[iii] 1.00 to 1.49 = very unsatisfied; 1.50 to 2.49 = unsatisfied; 2.50 to 3.49 = neither satisfied nor unsatisfied; 3.50 to 4.49 = satisfied; 4.50 to 5.00 = very satisfied.

for space-limited environments and early fruiting. However, preferences among home gardeners tend to heavily favor fruit quality (e.g., flavor, firmness, and color) (Jones 2008) and aesthetic uniqueness. Therefore, "specialty" cultivars have become particularly popular in recent years (Halleck 2022; Sparks 2020), so identifying cultivars with rare characteristics and high-quality attributes can potentially help growers produce plants that are more attractive to consumers.

Ratings for the level of satisfaction for both yield and rate of plant growth were highest for the flowering plant product, followed by those grown from transplants (Table 2). In contrast, overall likeness was similar between the flowering plant product and transplant, and lowest for plants grown from seed. Similarly, the seed product rated lowest in satisfaction for the level of care required to grow plants and for fruit taste. Interestingly, flowering plants and those grown from seed were equally rated as the favorite product by 35% of participants, whereas transplants were preferred by 30% of participants. This suggests that although participants were not as satisfied with certain aspects of the seed product, the experience of germinating, transplanting, and caring for the plant in its entirety had perceived benefits. Successfully growing plants from seed offers several benefits to home gardeners, including lower costs, greater variety of cultivar availability, and greater satisfaction from more gardening engagement (Bubel and Nick 2018).

Most (91%) participants were willing to pay more for the flowering plant product compared with the transplant (Fig. 1), with 37% willing pay from $1.00 to $2.49 more, closely followed by those who would be willing to pay between $2.50 and $4.99 more (36%). The rest of the participants were willing to pay <$1.00 (14%) or between $5.00 and $7.49 (4%) more for the flowering plant product compared with the transplant, but no participants were willing to pay $7.50 or more. This willingness-to-pay trend, coupled with the overall satisfaction and preference for the flowering plant product indicates an opportunity for growers to provide consumers with alternative value-added options compared with the typical transplants available in most "big-box" or nursery supply stores, which tend to be sold in a purely vegetative state. However, product price-point is an important factor when determining willingness to pay for gardening supplies (Phillips et al. 2007). Earlier-yielding, compact, and disease-resistant cultivars are some examples of value-added plant products on the market to date, and a gardening survey showed that respondents older than 35 years valued plants with disease resistance, whereas those younger than 35 years preferred higher-yielding plants (National Garden Bureau 2019).

Needs and challenges. The greatest challenge that participants faced was managing insect pests, with 67%, 82%, and 85% reporting challenges with the seed, transplant, and flowering plant products, respectively (Fig. 2). Accordingly, results from other surveys have shown that respondents often cite insect pests as their greatest struggle (Gregory et al. 2015; Home Advisor, Inc. 2021). Flower/fruit drop was also reported as a challenge with all plant products by ~20% of participants. Hochmuth and Hochmuth (1995) stated that the most common challenges with growing tomatoes in Florida include high temperatures and high humidity, both of which create a conducive environment for pests and diseases. High temperatures are also known to cause flower drop in tomato plants (Jones 2008). Participants selected "critters/large animals" as the lowest-rated challenge across products, describing problems with iguanas (*Iguana iguana*) and deer (*Odocoileus virginianus macrourus*) in the Facebook community page. Other challenges stated in the open-ended response box included issues concerning plant mortality, which was particularly high for the seed product (data not shown), extreme heat, and heavy rains or overwatering.

Although participants were given the option to apply products not included in the project kit, or to use control measures not mentioned in the protocol, more than 41% selected "no products applied" when asked about strategies used to address challenges (Fig. 3). This selection was followed by "homemade pest deterrent" (25%), "store-bought products" (24%), "protective structure" (11%), and "no challenges faced" (5%). Participants who selected "other" (22%) cited cultural management practices in the open-ended response box, such as hand-picking pests, scouting, leaf removal, or moving plants to other locations. Similar to our findings, results from a community garden study in New York, NY, USA showed that 27% of participants did not attempt to control pests, even though pests were

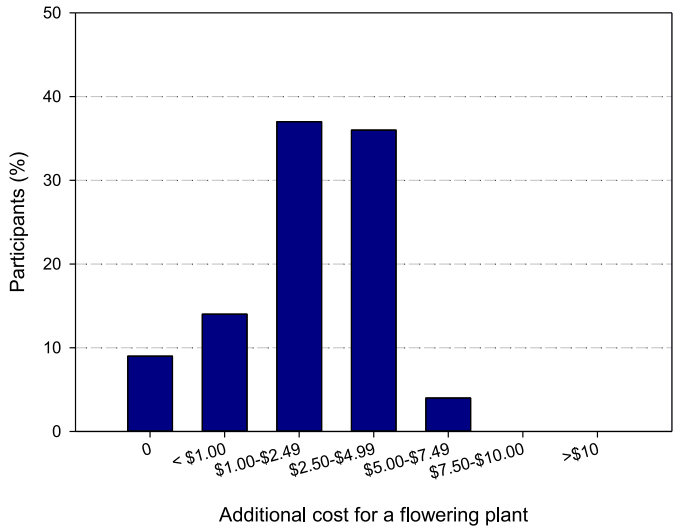

Fig. 1. Willingness to pay by participants in a citizen-science research project for a value-added flowering plant in an 8-inch container compared with a transplant in a 4-inch container (n = 117).

cited as a top challenge (Gregory et al. 2015).

Darby et al. (2020) showed that many gardeners have environmental and human health concerns when applying pesticides. Accordingly, Thomas et al. (2020) found that reducing the use of pesticides was the preferred eco-friendly gardening practice among a group of outdoor home gardeners in Tennessee, USA. Considering the general aversion of using pesticides among home gardeners, educational efforts that can help minimize pest issues in the garden are needed. Extension specialists, who are often familiar with local conditions, can be a reliable resource for home gardeners seeking horticultural advice, including strategies to produce healthy plants (Sykes et al. 2021; Yue et al. 2017). Furthermore, educational materials such as care and maintenance guides often offered through retail and garden centers may prove beneficial for home gardeners struggling with challenges such as pests. Accordingly, Mason et al. (2008) conducted a consumer preference survey and found that 76% of respondents were willing to buy a container garden with an extensive care guide, and 85% were willing to visit a website with care and maintenance information.

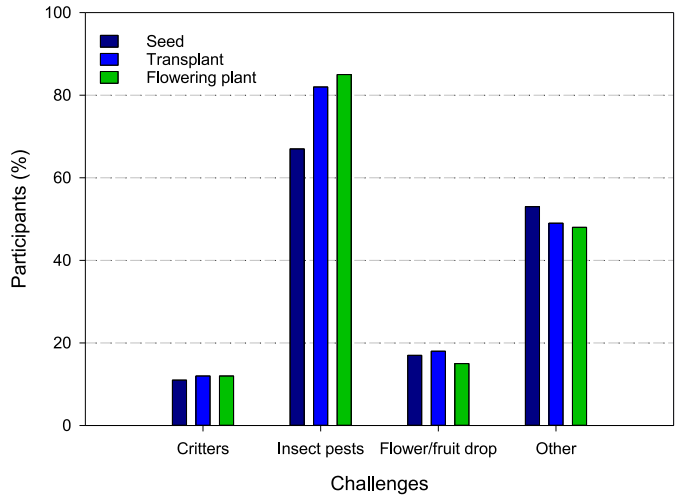

Fig. 2. Challenges faced by participants in a citizen-science research project conducted in Florida evaluating preferences, challenges, and experiences with growing compact tomato plants started from seed, as a transplant in a small container, and as a flowering plant in a large container (n = 117).

When asked about resources used to address challenges over the course of the project, "Citi-Sci Facebook group" was the most common response (57%), followed by "internet searches" (50%), and "family, friends, and neighbors" (21%) (Fig. 4). Although participants were encouraged to contact study organizers with questions and concerns, this was the least common response (9%). Another survey-based study found that respondents younger than 35 years cited social media and the internet as the top resources for gardening information, whereas those older than 35 years cited retailers as their top resource (National Garden Bureau 2019). In a study evaluating response accuracy in online communities, Solis-Toapanta et al. (2020) found that responses to common gardening questions had less than 50% accuracy. Therefore, gardening educators should leverage a variety of engagement tools such as research-based factsheets and presentations to share vetted and reliable resources that minimize misinformation commonly found in social media.

Considerations and opportunities for future gardening projects. Increasing self-efficacy in home gardeners from limited resource backgrounds has great potential to become an integral component of future citizen-science research programs. According to a 2021 report from the USDA, 13.5 million households in the United States are food insecure, with 4% experiencing very low food security (Coleman-Jensen et al. 2022). Consumption of fresh foods can be especially difficult and inaccessible for consumers with limited resources (Hiza et al. 2013). The USDA found that the average adult in the United States does not meet the daily recommended consumption of at least 2 cups of fruit and vegetables per day (USDA, Department of Health and Human Service 2020). However, Algert et al. (2016) found that participants doubled their fresh fruit and vegetable intake after engaging in home or community-gardening programs. Therefore, future gardening programs have potential to support food-security initiatives by providing access to fresh produce through gardening education.

Despite efforts to ensure representation of individuals from limited resource backgrounds, only 11% of participants had recently received food

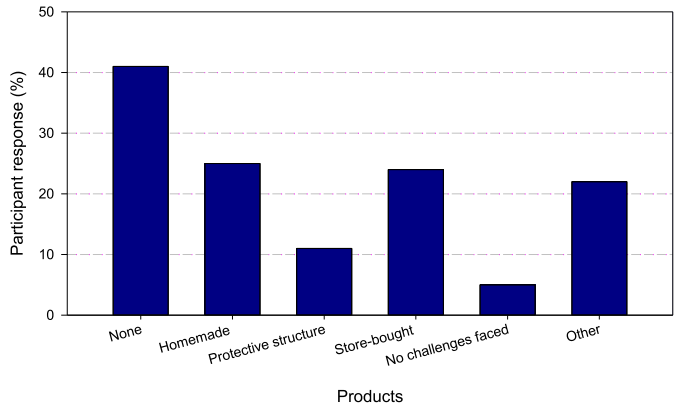

Fig. 3. Products applied to address challenges faced by participants in a citizen-science research project conducted in Florida evaluating preferences, challenges, and experiences with growing compact tomato plants (n = 117).

assistance (Table 1). Common barriers for low-income populations to participate in gardening research studies often include lack of access to transportation, child-care responsibilities, limited communication services, unstable housing, and a lack of awareness of program availability or existence (Schnirer and Stack-Cutler 2012). In addition, long-term commitments with research programs often pose challenges with scheduling conflicts and demands on time. Furthermore, demographic characteristics relating to language, literacy, and health are common barriers for individuals from limited resource backgrounds to participate in coordinated research studies (Schnirer and Stack-Cutler 2012). According to Bennett (2022), broader collaboration with food pantries, community gardens, and community centers can improve representation in gardening projects. Thus, in future studies, researchers could partner with local organizations to maximize reach of individuals from limited resource backgrounds during the initial recruitment process.

Although considerable effort was put into receiving responses to the survey, our project had a return rate of 68%. It is plausible that for some participants, a perceived failure to produce a positive result (e.g., caused by plants dying or not setting fruit) affected their willingness to complete the survey. For example, Sykes et al. (2021) speculated that participants in citizen-science gardening projects may be reluctant to return surveys when plants fail to mature. Although the authors attempted to improve survey response rates by emphasizing the value of documenting perceived failure, response rates were unaffected when compared with previous years (Sykes et al. 2021). Future projects should consider using incentives to increase response rates of post-experiment surveys.

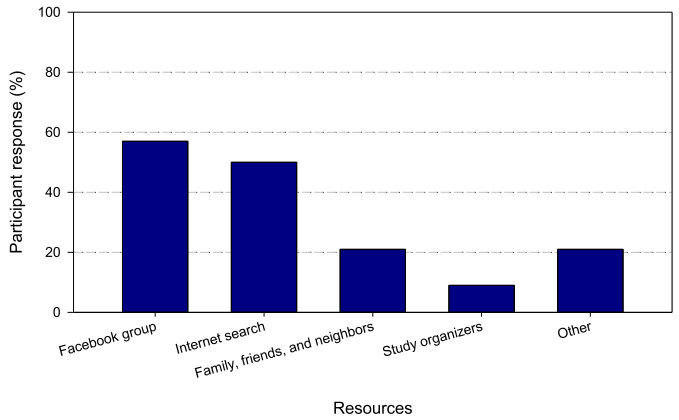

Fig. 4. Resources used to address challenges faced by participants in a citizen-science research project conducted in Florida evaluating preferences, challenges, and experiences with growing compact tomato plants (n = 117).

This could be accomplished by providing participants with gardening opportunities after the completion of a project (e.g., by donating plant material for subsequent gardening efforts), sharing of information about the long-term implications of their participation in citizen-science research, or by communicating opportunities about local gardening activities such as MGV programs.

Last, as more individuals move to urban environments, future citizen-science projects could focus on addressing needs of consumers growing indoors, where space and lighting may be limited. Providing adequate lighting, which can be 50% to 99% lower in indoor environments, is a common issue that many indoor gardeners face (Solis-Toapanta et al. 2020). This is particularly important for plants like tomato, which generally require more light than what is typically available indoors for adequate growth and yield (Cruz and Gómez 2022).

Conclusions

Most participants who completed the post-experiment survey were female, somewhat experienced in gardening, and between 40 and 49 years of age. Although equal portions of participants favored the seed and flowering plant products, satisfaction with different gardening aspects ranked plants grown from seed as the least satisfactory product, and flowering plants as the most satisfactory. The vast majority of participants indicated they would be willing to pay more for a flowering plant in an 8-inch container than a vegetative transplant in a 4-inch container, and most participants were willing to pay between $1.00 and $2.49 more. Although insect pests posed the greatest challenge to participants across all plant products, a large percentage of participants chose not to address this challenge. The internet and Facebook community page were the two most common resources used when researching solutions to challenges. Our results highlight an opportunity for growers to provide consumers with value-added products such as flowering plants. These additional options may be attractive to less experienced gardeners, or those wishing to experience a faster return on investment. Overall, our findings suggest that understanding how to enable

and empower home gardening success may provide valuable consumer-horticulture data to share with industry stakeholders.

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