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Social Context Influence on Urban Gardener Perceptions of Pests and Management Practices

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Community gardens are important urban green spaces with a variety of social and ecological benefits, one of which is access to healthy food. Similar to rural agriculture, the quantity and quality of the food produced can be compromised by pest damage. In fact, many urban gardeners report crop damages caused by vertebrate and invertebrate pests. Yet, because the food produced in community gardens is mostly for self-consumption and thus not under market quality standards, the damage thresholds and the point when gardeners perceive a pest problem and how they decide to manage it, may greatly vary from gardener to gardener. Here, we investigated how socio-demographic factors and experience affect whether gardeners report having a pest problem and which pest management practices they use. We surveyed 187 gardeners from 18 different urban community gardens in three counties in the California central coast, USA. We also collected information about gardener socio-demographic factors (age, gender, ethnicity), as well as education, and years of experience in agriculture. The majority of gardeners reported having pests in their plots but their ethnicity, the amount of time they spend in the gardens, and whether they work in agricultural-related employment or not influenced the likelihood of reporting pests. We found that the majority of gardeners use curative, non-synthetic practices for managing pests, but that some use preventive practices and some don't do anything to control pests. The likelihood of using practices that are curative depended on gardeners' ethnicity, the amount of time they spend in the gardeners, and their gender. Our results suggest that the agricultural knowledge of urban community gardeners and the practices they use varies greatly and that, in order to be successful, extension programs may need to take this diversity into account when promoting the agroecological paradigm in urban agricultural (UA) systems.

Keywords: urban agriculture, pest control, conservation biological control, urban community gardens, agroecology

INTRODUCTION

In response to the growing urban population and increased demand for local fresh fruits and vegetables, urban community gardens have expanded dramatically (Reynolds, 2017), especially in low-income and underserved communities (Alig et al., 2004). For the past 50 years, urban agriculture (hereafter UA) has increased by 3.6% annually in developing countries and in the US, and by more than 30% in the past 30 years (Siegner et al., 2018). During the growing season, gardens supply a substantial proportion of gardener fruits and vegetables needs (Gregory et al., 2016). For low-income and food-insecure gardeners, the harvest from community gardens is often their main source of produce in the growing season (Gregory et al., 2016). In addition to food, community gardens provide numerous benefits and can improve the physical and mental well-being of urban residents (Brown and Jameton, 2000), especially for gardeners living in low-income communities with little or no access to other green-spaces for social and physical interactions (Saldivar-Tanaka and Krasny, 2004; Glowa et al., 2019). In addition, UA can be a source of job creation and provide education opportunities (Reynolds, 2017), as well as improve community-building and environmental stewardship (McVey et al., 2018). Furthermore, urban green-spaces, including urban community gardens, can serve as refuges for biodiversity and decrease the negative effects of urbanization (Goddard et al., 2010; Lin et al., 2017).

Similarly to rural farmers, urban farmers and gardeners are met with a variety of challenges related to pests, pollination, soil quality, and water availability (Gregory et al., 2016) and have to continuously adjust their management practices. In rural settings, where often farmers come from families with a long history of farming, agricultural knowledge is passed from generation to generation and farmers build upon it constantly based on their own experiments and experience (Morales and Perfecto, 2000; Curry et al., 2015). In addition, farmers often rely on support from a variety of external sources of information, including extension programs and farmer networks, to build upon their own knowledge (Stallman and James, 2015; Noy and Jabbour, 2020). In contrast, the agricultural background and knowledge of urban gardeners varies greatly (Kim et al., 2014; Oberholtzer et al., 2014; Gregory et al., 2016) and so do their management practices. Pest and disease management, for example, is of major importance in some urban systems and almost ignored in others (Prain, 2006). In a recent survey that asked 315 urban farmers across 15 US cities about their challenges and training needs, the majority of them expressed significant challenges in managing pests (>90% of surveyed urban farmers), and reported critical needs for technical assistance (Oberholtzer et al., 2014). Compared to rural agriculture, there is still relatively sparse technical support for urban agriculture (Cohen and Reynolds, 2015). However, there are a growing number of policies that allow and support urban food production (Reynolds, 2017). The USDA (United States Department of Agriculture), e.g., now funds training to support UA commercial farming (USDA, 2016). Nevertheless, we lack the scientific expertise to inform non-commercial urban gardeners about how their production and management practices impact pest control. Given that challenges in managing pests is a common concern among urban gardeners (Oberholtzer et al., 2014; Gregory et al., 2016), it is vital to have all tools available to promote agroecological pest management practices in urban agriculture.

Agroecological principles, where external inputs are replaced by natural processes, have been applied to improve small scale agriculture for years (Altieri, 1995) and the same principles can be applied to urban gardens and farms (Gregory et al., 2016; Altieri and Nicholls, 2018). In particular, agroecological practices for preventing pests (i.e., avoiding that herbivore populations reach damage thresholds in the first place), can be implemented in urban agroecosystems by managing farms or gardens and surrounding landscapes to conserve biological control agents and minimize herbivore damage (Morales et al., 2018). There is a growing number of studies in urban gardens that investigate the local and landscape factors that affect insect predators and parasitoids (pest control agents or natural enemies) (Gardiner et al., 2014; Egerer et al., 2017, 2018a; Philpott and Bichier, 2017; Lowenstein and Minor, 2018; Morales et al., 2018), providing valuable information that could be disseminated to urban gardeners (Arnold et al., 2019). Because of its high levels of socio-economic and ecological complexity, where top-down approaches have been shown to have little to no impact (Van Veenhuizen et al., 2001; Prain, 2006), the promotion of agroecological methods for pest control in UA should incorporate participatory methods (Morales and Perfecto, 2000). An early step toward this goal is to understand urban gardeners' agricultural knowledge (Prain, 2006) in relation to pests and pest management.

In rural agriculture, farmers' perception of crop risk and subsequent crop management decisions depends of a variety of factors including personal (e.g., socioeconomic, experience, social network connections) and external factors (e.g., political conditions, geographic setting), as well as access to extension services (Meijer et al., 2015). Farmers' decisions on pesticide use, for example, depend on perceived health and economic risks as well as trade-offs between crop protection and other objectives (Hashemi et al., 2014). An important factor that most likely drives pest perceptions and pest control practices is the ultimate goal of growing crops. In particular, whether a crop is grown for commercial purposes or self-consumption likely determines the threshold of pest damage that is tolerated by the farmer or gardener. For example, subsistence farmers in Guatemala were less likely to consider insects as pests (and try to control them) and more likely to "share" their crops with insects than farmers that grew cash crops (since companies reject "damaged" produce) (Morales and Perfecto, 2000). In fact, traditional corn farmers only classify insects as pests if they cause economic damage to their crop (Morales and Perfecto, 2000; Girard, 2015). Thus, understanding whether a farmer reports pests in their farm can shed light not only into actual plant damage but to the farmer's perception of pests, their tolerance for having insects on their crops, and an acceptance of some level of damage.

Furthermore, because perceptions vary across socio-cultural contexts, it is important to consider how social factors influence perceptions and management in urban agriculture. Farmers' socio-demographic backgrounds and environment also influence their knowledge and perceptions, and these, in turn, influence their farming practices, including pest management (Wyckhuys and O'Neil, 2007; Curry et al., 2015). In UA, gender and inter-generational relations and sustainability considerations are part of the decision-making processes in management practices (Prain, 2006). Understanding this could, and should, help inform agroecological practices extension and adoption (Girard, 2015; Gregory et al., 2016). For example, a study in rural China found that women farmers use less pesticides than men and more often apply protective measures or behaviors when using pesticides (Wang et al., 2017). The authors thus suggest that gender-sensitive educational programs should be implemented. Integrated Pest Management adoption behaviors in rice-cropping systems in Iran were influenced by farmers' gender and experience level (Veisi, 2012). Thus, the author recommends consideration of these variables as determinant factors in "targeted policy approaches." Among surveyed vegetable rural farmers in Botswana, the farmer age significantly influenced their knowledge of pests, while the proportion of farmers using cultural practices to prevent pests differed among study regions, leading the authors to recommend region-specific education strategies (Obopile et al., 2008).

In urban community or allotment gardens, plots of land are rented by individuals for non-commercial gardening (McVey et al., 2018). Consequently, multiple people from a variety of socio-economic and experience backgrounds grow food, medicinal, and ornamental plants in a common space (Cohen et al., 2012; Egerer et al., 2019) and do so mostly for self-consumption (Egerer et al., 2018d), and non-commercial reasons (McVey et al., 2018). Gardeners have different perceptions on garden properties and risks to crops that influence their management practices (Kim et al., 2014). Thus, these agricultural spaces of high social diversity represent an ideal system in which to investigate how social factors and experience influence perceptions of pests and pest management practices (irrespective of commercial quality standards).

Here we studied how socio-demographic factors and experience of urban community gardeners affect their perception of pest presence and their pest management strategies. We ask two main questions: (1) Does the likelihood of reporting pests depend on gardeners' experience and socioeconomic background? and (2) Does the likelihood of using curative practices (as opposed to preventive practices or doing nothing) vary with gardener's experience and socio-demographic factors?

MATERIALS AND METHODS

Study System

We conducted this study in 18 urban community gardens distributed across three counties in the California Central Coast, USA: Monterey (36.2400° N, 121.3100° W), Santa Clara (37.3600° N, 121.9700° W), and Santa Cruz (37.0300° N, 122.0100° W). This is a region of recent urbanization and industrial agriculture production, in addition to high levels of human diversity. The Central Coast region is increasing in density of built infrastructure to accommodate population growth, and there is a wide spectrum of socio-demographics (ethnicity, education, income) in the region. The region of these gardens varies in socio-economic and socio-demographic composition due to the history of urbanization, industrial agriculture, and corresponding demographic change. Santa Cruz and Monterey Counties – considered the salad bowl of the USA – are leaders in the production of strawberries and leafy greens. Many migrants from Mexico and Latin America left their own rural farming livelihoods to seek work in this region (e.g., through the Bracero Act, or later because of the North American Free Trade Agreement, or NAFTA). Yet, many of the workers that pick these fruits and vegetables live in food insecure neighborhoods (Brown and Getz, 2011). This has made community gardening, and the access to arable land, an appealing opportunity to increase food security, nutrition, and justice in the region (e.g., Mesa Verde Gardens, Watsonville, CA; http://www.mesaverdegardens.org/). Furthermore, because many of these gardeners come from rural traditions and backgrounds, urban agriculture provides a space to practice traditional agricultural knowledge and a range of agroecological practices (Glowa et al., 2019). Santa Clara County is also a diverse socio-demographic region. This region's agricultural history as the "Valley of Heart's Delight" brought populations of Italians, Croatians, Chinese, Japanese, Filipino and Mexican/Central American immigrants to work in the orchard landscape (Pellow and Park, 2002). Furthermore, this region has experienced refugee resettlement from Vietnam, Cambodia, and Bosnia, among others. Now, the region is experiencing another demographic shift as it has transformed into Silicon Valley in the recent decades, bringing skilled technology workers from across the world. The community gardening program in San Jose, the largest city in the Bay Area, supports over a thousand urban gardeners that use urban agriculture to grow a range of ethnic foods, to practice rural traditions, and to grow community (San Jose Parks, Recreation & Neighborhood Services 2017). Thus, the community gardens in this study provide a system to assess how changes in social characteristics affect garden management, pest perceptions, and sustainable pest control practices. The gardens range in size (405–8,134 m^2), years in cultivation (2–39 years), and number of gardeners served (5–105 plots/garden that serve individuals or families). All are managed in an allotment style where households cultivate individual plots within the garden and are relatively well-supported by local organizations or by the city government. All of the gardens have policies to use "organic" practices, prohibiting the use of synthetic pesticides.

Survey Questionnaires

We used paper survey questionnaires in each of the gardens to collect information on gardener experience and socio-demographic information (i.e., *our effect variables*; **Table 1**). To collect information on gardener experience in agriculture, we asked gardeners who taught them how to garden or farm (multiple choice; family member, friend, self-taught, workshop/class, other gardeners, other), how many years they have been gardening (open-ended), and how many hours per week they spend in the garden (open-ended). We also asked them about their main source of employment because many gardeners in this region work in agriculture-related

TABLE 1 | Independent variables derived from surveys, sample sizes, and classification and grouping used for data analysis.

Survey question	Name of variable	Levels	Type of variable
Who taught you how to garden or farm?	Teacher	Class/workshop ($n = 4$), family ($n = 111$), friend ($n = 10$), other gardeners ($n = 6$), self ($n = 48$), other ($n = 2$), no answer ($n = 6$)	Experience
How many hours per week do you spend at this garden?	Hours gardening	In hours: < 5 ($n = 96$), between 5 and 10 ($n = 54$), more than 10 ($n = 24$), no answer ($n = 13$)	
How long have you been gardening?	Years gardening	In years: < 10 ($n = 91$), between 10 and 30 ($n = 49$), more than 30 ($n = 46$), no answer ($n = 1$)	
What's your occupation?	Employment	Agriculture related ($n = 30$); not related to agriculture ($n = 109$); not working ($n = 45$), no answer ($n = 3$)Ⓛ	
What's your ethnicity?	Ethnicity	Asian Pacific islander ($n = 37$); Black/African American ($n = 4$); Hispanic/latino ($n = 54$); White ($n = 80$); Middle East ($n = 3$); other ($n = 6$); no answer ($n = 3$)*	Socio-demographic
What is your highest level of completed education?	Education	No schooling ($n = 7$), Primary (19), Secondary ($n = 24$), Post secondary ($n = 136$), no answer ($n = 1$)Ⓘ	
What is your gender?	Gender	Male ($n = 87$), female ($n = 97$), no answer ($n = 3$)	

Ⓛ *Ag related employment includes all who marked "Agriculture" as one of their employment options. Not related to ag. included: Construction, Sales, Domestic Service, education, Legal Services, Health Services, Office Administration, Technological Services, Restaurant/Food Service, as well as "other" not related to agriculture.*

**Asian/Pacific islander includes those that marked Asian/Pacific Islander and those that in the "other" category included: Indian, White Asian. Hispanic/Lanino includes those that marked this category and those who in "other" included White Hispanic, Hispanic Native, and White Hispanic.*

Ⓘ *Primary education includes: Elementary school; Secondary education includes: Middle school, Some high school, High school graduate; Postsecondary education includes: Trade/technical/vocational training, Some college, Associate degree, Bachelor's degree, Master's degree, Professional degree, Doctorate degree.*

jobs (including horticulture). This may influence gardening practices and therefore relates to gardening experience. Thus, while we provided 12 options for employment (in addition to an "other" category), we reviewed all responses and created a binary employment variable of either (1) employment in agriculture or (2) non-agriculture employment. To collect information about gardener socio-demographics, we asked a series of questions on highest education level (multiple choice; from no formal schooling, Elementary School, Middle School, High School, Vocation/Associates Degree, Bachelor's Degree, Master's Degree, Professional Degree, Doctorate), gender (multiple choice; male, female), and ethnicity (multiple-choice options of racial categories used in the US Census) (**Table 1**).

Using the surveys, we also collected information on perceptions of pest problems as well as pest control practices (curative and preventative) (i.e., our *response variables*). To measure gardener perceptions of pest problems, we asked gardeners whether they perceive problems with pests or diseases in their gardens (multiple choice; yes, no, don't know). To measure gardener's pest control practices, we asked gardeners which of the following methods they use to protect their crops from pests or diseases: hand remove pests; use organic purchased spray; use homemade sprays; use pesticides; release ladybugs. Gardeners were allowed to choose multiple methods, and we additionally included an open-ended "other" option to allow gardeners to elaborate on their practices.

We surveyed between 6 and 14 gardeners per garden, which represented between 9.5 and 65% of the gardener population in a garden. The surveys were given in English ($n = 142$), Spanish ($n = 38$), Korean ($n = 1$), and Bosnian ($n = 1$), and were either read out loud by the researcher in person ($n = 150$) or via phone ($n = 2$), filled out by the gardener themselves ($n = 27$), or read out loud to the gardener by another gardener ($n = 3$). The surveys were distributed over the course of 4 months during the growing season, from June to the beginning of October 2017.

Data Analysis

We used binomial logistic regression to determine whether gardener socio-demographic background and agricultural experience (effect variables) influence their perceptions of pest problems and pest management practices (response variables). **Tables 1**, **2** provide information on the effect and response variables and their levels used in the analyses. The non-correlated effect variables included the gardener's socio-demographic characteristics (ethnicity, education, and gender), and four effect variables relating to agricultural experience (teacher [who taught you to garden/farm?], hours spent gardening, years of gardening experience, and employment [job related to agriculture or not]).

For the response variables, perceptions of pest problems were reduced to a binary variable (yes, no), because only 5 respondents answered "I don't know" (we removed these cases). For the pest control practices, we reviewed all responses (including open-ended "other" responses) and based on the answers, grouped the reported practices into six categories: hand removal, purchased spray or repellant, homemade spray, trapping, release or habitat manipulation for natural enemies, physical exclosures, and plant, soil, and water management (**Table 2**). Each practice was then further categorized as either "Curative" or "Preventive" (**Table 2**). Because gardeners reported up to four pest control practices, we calculated the proportion of curative, preventive, and "do nothing" practices per gardener. For example, if a gardener only provided one answer that was preventive, they would get 100% preventive, as would a gardener with four preventive practices. If a gardener reported two practices, one preventive

TABLE 2 | Pest control methods described by gardeners and the corresponding categories and groups where they were placed.

Group	Pest method group	Pest method details	# of respondents
Curative	Hand remove pests	Hand remove pests	66
		Picking off the slugs or squishing them	1
		Use water to remove aphids	1
	Homemade sprays	Homemade sprays	37
		Eliminate snails with salt	1
		Lime (calcium carbonate) and water with salt	1
		Soap or soapy water spray	4
		Garlic for voles	1
	Trapping	Mechanical traps for gophers and squirrels	6
		Sticky traps	1
	Organic, purchased sprays/repellents	3 in 1	1
		Neem oil	3
		Baking soda	1
		Sluggo	4
		Copper strip	1
		Granuales for voles	1
		Diotomacious earth	1
Preventive	Physical barrier	Enclose roots with mesh cages to avoid gopher and root insect damage	11
		Eclose plants in cages/fencing to avoid squirrel and possum damage	9
	Plant, Soil, water management	Cut leaves and pull out plants with damage	5
		Create an ecosystem where all microorganisms can live	1
		Moving the drip irrigation hose away from certain plants/roots so that it is less wet, and that helps avoid the "fleas"; that also helps avoid root diseases	1
		Plant disease-resistant crops	1
		Planting green onions as a repellent	1
		Raise the plants higher up (so that the animals cannot get on them)	1
		Relocate plants, roll up newspaper and rolled plants	1
		Water more consistently	1
		Pick neighbors infested crops	1
	Natural enemies	Cats (they eat the gophers)	1
		Leave orb spiders	1
		Release ladybugs	1
		Put water out for lizards (they eat pests)	1

and one curative, they would receive 50% for each category, as would a gardener with four answers, two preventive and two curative.

To determine whether the likelihood of reporting pests or use of curative vs. preventive practices vary with gardener socio-demographic characteristics or agricultural experience, we used binomial logistic regressions (response variable is either yes/no; or proportion of practices that were curative). We created two global models with either (1) pest perception (yes/no), or (2) proportion of practices that were curative as the response variables, and ethnicity, education, gender, teacher, hours gardening, years gardening, and employment as effect variables. For the latter, we only used data for the gardeners that reported pests in their plots. We checked the variable inflation factor with the "vif" function in the "car" package version 3.0-2 (Fox and Weisberg, 2011). For all global models, all VIF scores were below 2.4 (**Supplementary Tables 1**, **2**). We then used the "dredge" function in the "MuMIn" package version 1.42.1 (Barton, 2012) to run all iterations of predictor variables, and ran model selection with the AIC scores to select the best models. If any models were within 2 AIC scores of the best model, we use the "model.avg" function to average these top models. All statistical analysis was conducted in RStudio version 1.1.456 (R Development Core Team, 2018).

RESULTS

We had a total of 187 respondents. **Table 1** summarizes the total number of respondents for each of the gardening experience and socio-demographic effect variables. After removing 7 "I don't know" or "no answers" to the "do you have pests?" question, and

TABLE 3 | Results of GLMM model selection for models examining relationships between gardener socio-demographic factors and gardening experience with the likelihood of reporting pests in their plots.

Model	Intercept	Education	Employment	Ethnicity	Hours gardening	df	logLik	AICc	Delta
1	0.49			+		6	−80.95	174.5	0
2	0.75			+	+	8	−79.02	175	0.55
3	0.57	+	+	+		11	−75.78	175.4	0.92
4	−0.30	+		+		9	−78.11	175.5	0.97
5	0.18	+		+	+	11	−76.06	176	1.48
6	1.40		+	+		8	−79.52	176	1.54

All models within two AIC points of the top model are shown and were included in the averaged model. A plus (+) indicates that a variable was present in that model.

TABLE 4 | GLMM model results for averaged best model (**Table 2**) pairwise comparisons examining differences in the odds of reporting pests based on gardeners' sociodemographic factors and experience gardening.

Ethnicity (6)

	Hispanic	Asian Pacific islander	Black/African American	Middle eastern
White	−0.90 ($z = 1.67$, $p = 0.09$)	−1.20 ($z = 2.27$, $p = 0.02$)	14.89 ($z = 0.01$, $p = 0.99$)	−18.33 ($z = 0.01$, $p = 0.99$)
Hispanic		−0.30 ($z = 0.51$; $p = 0.60$)	15.80 ($z = 0.011$, $p = 0.99$)	2.30 ($z = 51$, $p = 0.60$)
Asian Pacific islander			16.09 ($z = 0.01$, $p = 0.99$)	−17.43 ($z = 0.01$, $p = 0.99$)
Black/African American				−33.23 ($z = 0.12$, $p = 0.99$)

Education (3)

	Primary	Secondary	Post-Secondary
No school	1.15 ($z = 1.15$, $p = 0.25$)	−0.24 ($z = 1.75$; $p = 0.81$)	1.01 ($z = 1.04$, $p = 0.30$)
Primary		−1.39 ($z = 1.70$, 0.08)	−0.14 ($z = 1.18$, $p = 0.86$)
Secondary			1.25 ($z = 2.13$, $p = 0.03$)

Hours Gardening (2)

	5–10	10+
< 5	−0.38 ($z = 0.84$, $p = 0.40$)	−1.09 ($z = 1.96$, $p = 0.05$)
5–10		−0.71 ($z = 1.2$, $p = 0.230$)

Employment (2)

	Job not ag. related	Not working
Ag. related job	−1.24 ($z = 1.75$; $p = 0.07$)	−0.83 ($z = 1.05$; $p = 0.29$)
Job not ag. related		0.40 ($z = 0.75$, $p = 0.45$)

Numbers show model coefficient and z and p-values for pairwise comparisons of different levels for each variable. In parenthesis next to the variable, are the number of models (which went into the averaged model) in which the variable was present (out of 6 models).

any rows with "no answers" for the independent variables, 154 surveys were used for the final analysis.

1) Does the likelihood of reporting pests depend on gardeners' experience, and socioeconomic background?

Out of the final 154 surveys analyzed, 113 of the responding gardeners reported or perceived pests in their gardens compared to 41 gardeners that reported no pests in their gardens. The likelihood of reporting pests depended on gardeners' experience, and socioeconomic background. *Ethnicity* was the only variable present in all the six top models (within 2 AIC of best) that went into the averaged model (**Table 3**). White people were more likely to say that they have pests in their plots compared to Hispanics and Asian/Pacific islanders (**Table 4**, **Figure 1**). *Education* appears in 3 of the 6 top models (within 2 AIC of best) that went into the averaged model (**Table 3**). Gardeners with Secondary education (middle school and high school) were less likely to say that they have pests in their plots than gardeners with Primary education and those with Post-secondary education (**Table 4**). Both *hours gardening* and *employment* (both related to experience in agriculture or gardening) appeared in two of the 6 top models (**Table 3**). Gardeners employed in an agricultural-related job were more likely to say they have pests in their plots compared to those with jobs that are not agricultural-related (**Table 4**, **Figure 1**). Gardeners who spend 10 h or more in gardens were less likely to say they have pests in their plots compared to gardeners who spend < 5 h in the gardens (**Table 4**, **Figure 1**).

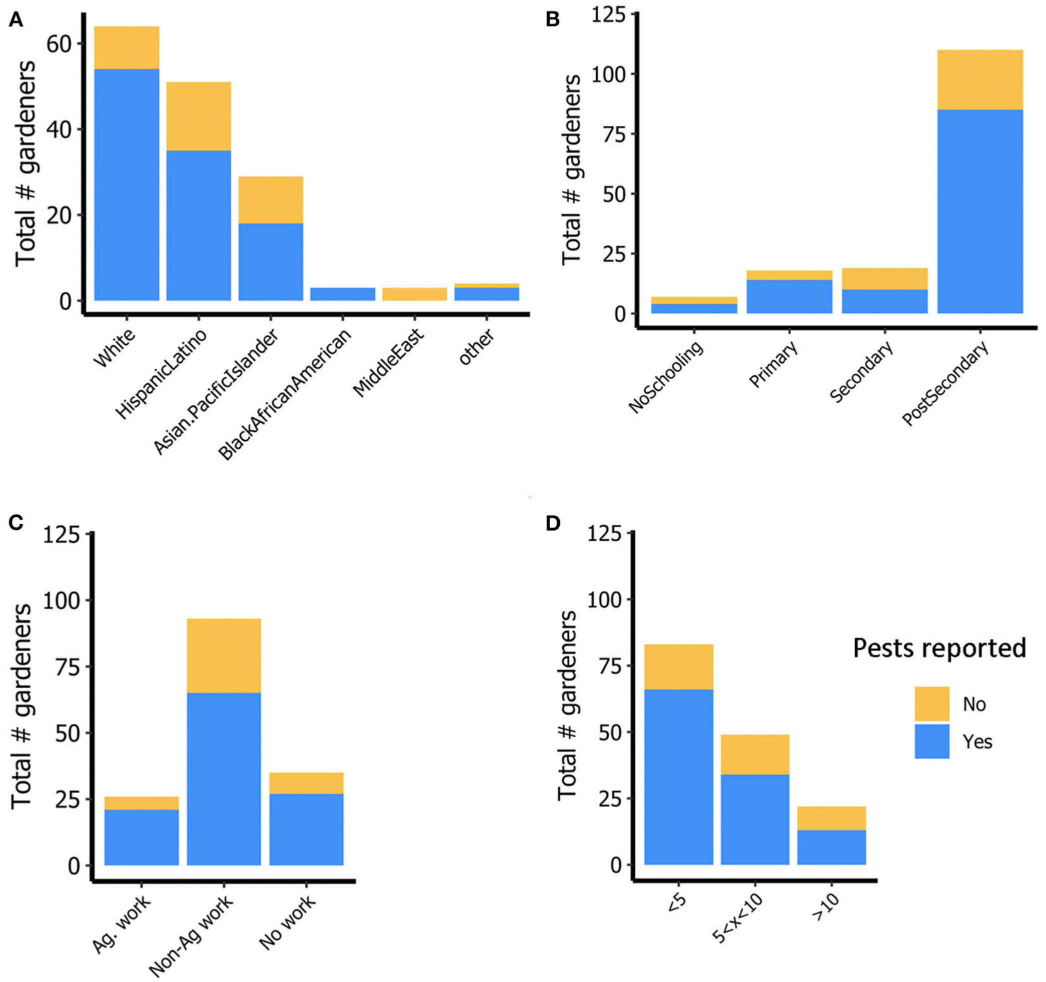

FIGURE 1 | Relative frequencies of gardeners reporting pests and no pests in their plots in community urban gardens in California. Panels represent the four variables present in the averaged best GLMM model explaining the likelihood that a gardener reported pests in their plot: **(A)** gardener ethnicity, **(B)** education, **(C)** employment, and **(D)** hours per week spent in the garden. See **Table 1** for explanation of variables.

2) Does the likelihood of using curative practices (as opposed to preventive practices or doing nothing) vary with gardener's experience and socio-demographic factors?

No gardener reported using pesticides but they reported a variety of preventive and curative practices (**Table 2**). Of all the gardeners, only eight directly stated that they do not do anything to control pests (e.g., "there's nothing I can do," "I have to accept my fate"). However, an additional 52 respondents, including gardeners that reported pests in their plots, did not report any pest control practices (**Figure 2**). The majority of gardeners that reported having no pests in their plots did not provide any answer for the pest control question ($n = 33$) but some did (**Figure 2**). Most of the gardeners that did report pests, reported using at least one pest control practice (**Figure 2**). For the gardeners that did report pests, *hours gardening* explained the proportion of practices that were curative in the top models that were included in the averaged model (**Table 5**). Gardeners who spend more than 10 h in gardens, reported using a higher proportion of curative practices (**Table 6**, **Figure 3**). In addition, *ethnicity* was included in 2 of the four top models that were included in the averaged model (**Table 5**). Asian-pacific islanders reported using a lower proportion of curative practices than Hispanics (all others are not significantly different) (**Table 6**, **Figure 3**). Lastly, *gender* also explained the proportion of curative practices used in two of the top four models (**Table 5**); however, the pairwise comparisons were not statistically significant (**Table 6**).

DISCUSSION

In urban agriculture, gardeners and farmers face a range of challenges in maintaining their crops. One such challenge is to protect plants from insect pests and diseases that may have unique ecological interactions in urban environments (Faeth et al., 2005; Eriksen-Hamel and Danso, 2010; Egerer et al., 2020). In response, gardeners may employ a range of methods and practices to reduce crop damage or loss and to promote crop production. Yet the practices that gardeners choose, and whether they even perceive "pests" in their gardens, is likely related to their social background, experience, and agricultural knowledge (among many other factors). Here, we show that the majority of surveyed gardeners report that they have pests in their plots but that this significantly relates to the gardener's ethnic background. Furthermore, gardeners are using many different practices to combat pests, but the proportion of those practices that are curative (vs. preventive) is most related to the amount of time gardeners spend in their garden. In the following, we discuss how our findings inform the relationships between socio-demographics, education and experience, and pest management tactics by small-scale, non-commercial urban gardeners. Furthermore, we discuss how urban gardeners (and small-scale urban agriculture broadly) may further advance a prevention paradigm for sustainable pest management.

Perceptions of Pest Problems

Our study confirms that urban gardeners are challenged by pests in their garden plots: 73% of gardeners report pests in their plots. Gardeners' perception of the severity of pest damage may correlate with actual herbivore infestation levels (Wyckhuys and O'Neil, 2007). A study conducted in the same gardens and year that our surveys were done, found a great abundance and diversity of herbivores in Brassica plants (a common crop at almost all study gardens). Herbivore abundance, however, depended on Brassica density in gardens and the amount of agriculture in the landscape (Philpott et al., 2020). Pest damage in our study sites varies greatly (Egerer et al., 2020) and brassica plants can have large aphid infestations (Egerer et al., 2018b). However, we do not have direct pest damage data for the year of the surveys to corroborate a direct correlation between gardeners' perception of pest damage and actual pest damage. Future studies should pair gardener questionnaires with herbivore population assessments and herbivory damage estimations.

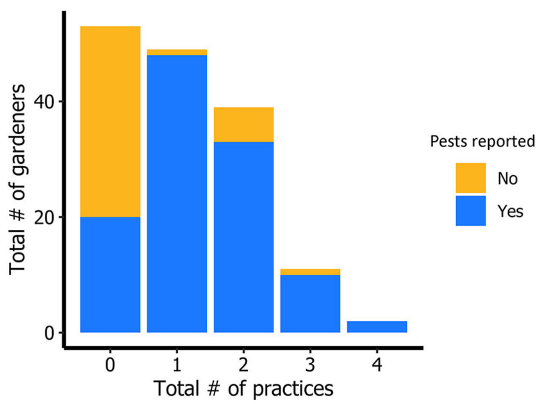

FIGURE 2 | Histogram of the number of pest control practices (curative and preventive) used by urban community gardeners who reported having pests in their plots (blue) and gardeners who did not report pests in their plots (yellow) ($n = 154$).

Whether gardeners report pests in their plots does not always reflect the actual pest infestations or plant damage and largely relates to gardeners' perceptions of what pests are and the problems they cause. In a study about pest control knowledge in Guatemala, Morales and Perfecto (2000) found that subsistence farmers were more likely to say that they "share" the crops with insects and thus less likely to report pests than commercial farmers. Similar to other studies in urban community gardens, gardeners in our study system use the produce that they harvest mostly for their own consumption, or for sharing with family and friends (Kim et al., 2014; Egerer et al., 2018c). Thus, their produce does not need to meet the same quality standards required for commercial growers. As such, gardener perceptions of pest problems might be related to (a) the gardener's attentiveness or observation levels, (b) preconceived notions of what represents a pest, or (c) their own tolerance for herbivory damage to their crops.

Whether a gardener reports pests or employs pest control practices may depend on whether they notice the herbivores in the first place (Obopile et al., 2008). Gardeners that spend more time in the gardens may have more time to scout their plants, and thus are more likely to detect herbivores and report pests. This would be especially true for difficult to observe herbivores like thrips and mites (Van Mele et al., 2002). In our study, gardeners who spend more than 10 h in gardens were actually less likely to say that they have pests in their plots than gardeners who spend 5 h or less. But we also found that gardeners who spend more than 10 h in the gardens use a higher proportion of curative practices to reduce pests. On the one hand, lower pest reporting for those who spend more than 10 h per week in the gardens may be because gardeners are not only tending plants but may be performing a multitude of garden tasks, or may spend time at

TABLE 5 | Average best models for the proportion of curative practices used by gardeners who reported pests in their plots ($n = 113$).

Model	Intercept	Ethnicity	Gender	Hours gardening	df	logLik	AICc	Delta
1	0.3261			+	3	−74.168	154.6	0
2	0.2504	+		+	7	−70.238	155.5	0.99
3	0.4451	+	+	+	8	−69.494	156.4	1.82
4	0.3955		+	+	4	−74.061	156.5	1.94

Results show GLMM model selection for models examining relationships between gardener socio-demographic factors and gardening experience with the likelihood of pest control practices that were curative. All models within two AIC points of the top model are shown and were included in average models. A plus (+) indicates a variable was present in that model.

TABLE 6 | GLMM model results for averaged best models (**Table 4**) pairwise comparisons examining differences in the odds of pest control practices that were curative based on gardeners' sociodemographic factors and experience gardening.

Hours Gardening (4)				
	5-10	**10+**		
< 5	0.1349 ($z = 0.302$, $p = 0.763$)	1.6418 ($z = 1.789$, $p = 0.07$)		
5-10		1.5070 (1.58, $p = 0.11$)		
Ethnicity (2)				
	Hispanic	**Asian Pacific islander**	**Black/African American**	**Other**
White	0.66 ($z = 1.32$, $p = 0.18$)	−0.50 ($z = 0.89$, $p = 0.30$)	15.94 ($z = 0.012$, $p = 0.99$)	−1.20 ($z = 0.89$, $p = 0.3742$)
Hispanic		−1.1657 ($z = 1.792$, $p = 0.07$)	15.2840 ($z = 0.012$, $p = 0.99$)	−1.8569 ($z = 1.34$, $p = 0.24$)
Asian Pacific islander			16.4497 ($z = 0.012$, $p = 0.993$)	−0.6912 ($z = 0.494$, $p = 0.976$)
Black/African American				−17.1409 (z=0.013, p=0.993)
Gender (2)				
	Male			
Female	−0.1126 ($z = 0.366$, $p = 0.4515$)			

Numbers show model coefficient and z and p-values for pairwise comparisons of different levels for each factor. In parenthesis next to the variable, are the number of models (which went into the averaged model) in which the variable was present (out of 4 models).

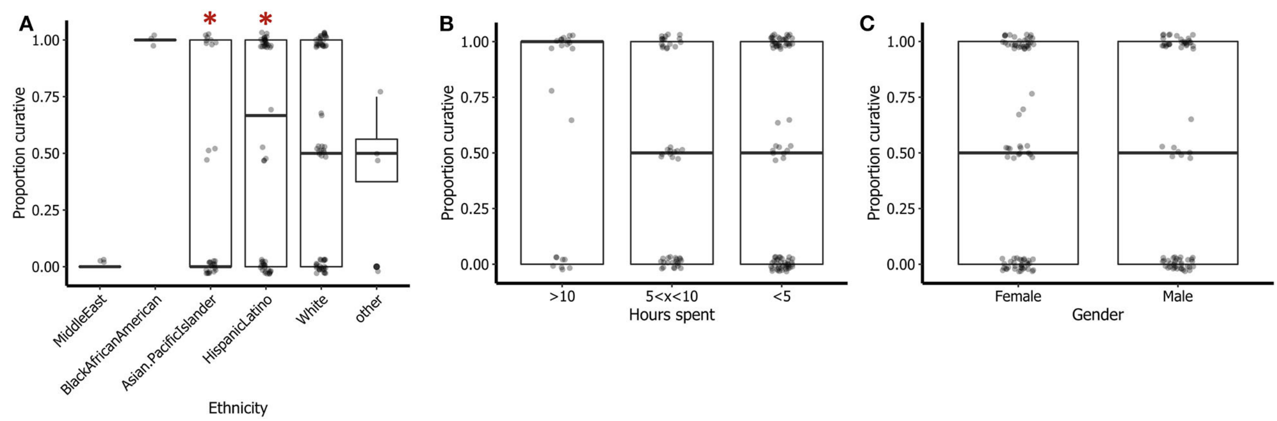

FIGURE 3 | The proportion of pest control practices that were curative used by urban community gardeners in California. The panels show the three variables that were present in the averaged best GLMM model explaining the proportion of practices that were curative: **(A)** ethnicity, **(B)** number of hours per week spent in the garden, and **(C)** gardeners' gender. See **Table 1** for explanation of variables. *Pairwise comparison significant at the $p = 0.07$ level.

the garden for non-gardening activities such as socializing with family or friends (e.g., Egerer et al., 2018c). More socializing can lead to more opportunities for knowledge and practices sharing between gardeners (McVey et al., 2018). On the other hand, gardeners that spend more than 10 h per week in their gardens may be able to control pests more effectively, due to more use of curative practices, and thus, less likely to report having pests in the first place. Additionally, more time in the gardens may also allow more detailed observations of ecological interactions that lead to the realization that not all animals present on the plants are herbivores and that not all herbivores do major damage.

Farmers and gardeners have preconceived notions of what represents a "pest" and the meaning of "pest" can have variable interpretations (Kogan and Jepson, 2007). For example, "pest" could be interpreted as any animal seen on plants or as only those doing significant herbivore damage (Morales and Perfecto, 2000). Our results suggest that these preconceived notions may depend on gardeners' ethnicity, education, and whether they work in agriculture-related jobs.

Another factor influencing whether a gardener reports pests or not may be how much damage to the crops the gardener is willing to accept before deeming the produce inedible. Reporting "pests" may thus relate to how much of the harvest is unacceptable to eat and this can vary greatly among growers as well as among consumers (of which gardeners are both). For example, social and demographic variables influence consumer attitudes and preferences toward sensory characteristics of organic produce (Yiridoe et al., 2005) and there is great variation in consumer willingness to accept insect damage in the produce they purchase (Goldman and Clancy, 1991). Accordingly, we found that the likelihood of reporting pests was influenced by gardeners' ethnicity. Small scale rural farmers employ their own economic and damage thresholds and not those assigned by scientists (Stonehouse, 1995; Wyckhuys and O'Neil, 2007; Obopile et al., 2008; Curry et al., 2015). Similarly, urban community may gardeners decide, based on their own personal preferences and attitudes toward consuming "imperfect" produce, when herbivores become "pests" (i.e., when damage levels render the produce inedible). In our study, this could suggest that gardeners who identified as Hispanic/Latino and Asian/Pacific Islander have a higher tolerance for herbivory damage to their crops than gardeners who identify as White.

Curative vs. Preventive Practices

Synthetic pesticides have a suite of negative ecological (biodiversity loss) and social (health) impacts. In fact, one important motivation for growing fruits and vegetables in urban gardens is to avoid consuming synthetic pesticides present in conventional store-bought produce (Wakefield et al., 2007; Pourias et al., 2016). In addition, most gardens in our study prohibit the use of chemical pesticides. Thus, it is not surprising that no gardener in our study reported using synthetic pesticides, corroborating other studies in urban community gardens (Kim et al., 2014). Few gardeners reported zero pest control methods or that they do nothing to control pests. In contrast, the majority of gardeners reported a variety of pest management practices. These included curative practices like hand picking or crushing pests, cages and traps, and the use of homemade or purchased organic sprays as well as preventive practices such as enhancing habitat for natural enemies, using pest and disease resistant varieties, using plants as repellents, and crop rotation. This all shows the wide diversity of practices that urban gardeners use to manage their plots.

The majority of gardeners that reported having no pests failed to provide answers about how they control pests, which could mean that they actually do not do anything to prevent or control pests, but also that since they reported no pests, that they did not feel like they needed to respond or were not prompted to provide further answers about pests. Alternatively, these gardeners may be using gardening practices that prevent herbivore populations from becoming pests in the first place. It is thus possible that some gardeners may inadvertently be preventing pest damage but do not consider their used practices to be "pest control."

Of the listed attributes for control methods preferred for rural farmers in California, methods that were quick and inexpensive were highly preferred among farmers (Baldwin et al., 2014). Accordingly, the majority of gardeners in our study reported using curative practices to manage pests in their plots. Curative practices like using purchased or home-made sprays are quick and, in the case of home-made sprays, inexpensive options to manage pests. Furthermore, these practices align well with input-substitution organic agriculture, where the focus is to substitute chemical pesticides and fertilizers with organic alternatives (Rosset and Altieri, 1997).

Socio-demographic factors, like gender (Hovorka, 2005) and education (Nyirenda et al., 2011), can affect the type of pest control practices used in rural agriculture. For example, in vegetable farms in Malawi and Zambia, female respondents and respondents with more education were both more likely to report using preventive pest control practices like including plants with pest repellent properties (Nyirenda et al., 2011). In our study, although gender was present in the best averaged model, there was no statistically significant difference in the likelihood of using of curative vs. preventive practices between males and females. Furthermore, in our study, education was not related to pest control practices. The lack of agriculture-related materials in the curriculum in urban schools compared to rural ones may explain this difference (Hess and Trexler, 2011; Kovar and Ball, 2013). Instead, in our study, hours gardening was positively related to the likelihood of using curative practices. As stated above, more time spent in the gardens may increase social interactions between gardeners (McVey et al., 2018) and thus increase knowledge sharing about pests and pest control practices. This may explain the increased likelihood of using curative practices among gardeners who spend more than 10 h in the gardens.

Which practices are used, curative vs. preventive, may also relate to what specific pests gardeners are most challenged by, and on what particular crop plants. Here, because we only asked about pest management practices, but not specific pests, we can only infer the pest from the response to practices. Thus, future studies to further investigate how curative vs. preventive practice implementation relates to particular pests and particular crops to better inform pest management suggestions.

Facilitating the Agroecological Paradigm in Urban Agriculture

In accordance with this research topic, we discuss how small-scale urban gardeners can participate in and advance the field of agroecological pest management which would entail shifting from a curative to a more preventative pest management paradigm. Gardens are interesting spaces in cities where gardeners adopt and experiment with agricultural practices due to the combination of environmental challenges, social organization, and garden to city level policies (Lin and Egerer, 2020). Many community gardens prohibit the use of synthetic pesticides and, in response, gardeners come up with different and unique ways to manage herbivory in their plots, and such creativity and experimentation may fuel knowledge generation in cost-effective and environmentally-sound management tactics.

It is important to recognize that not all UA practices increase sustainability (Mougeot, 2000; Weidner et al., 2019) and that some can have negative environmental impacts, especially in cities with no regulations regarding synthetic fertilizer and pesticide use (Lee et al., 2010). In the efficiency-substitution-redesign (ESR) framework, for instance, the transformation to a more sustainable agriculture is recognized as a process with three stages: *efficiency*, where the consumption and waste of inputs is reduced; *substitution*, where environmentally destructive inputs are substituted by more benign ones (organic fertilizers and pesticides, etc.); and *redesign*, where the root of causes of the ecological problems are identified and prevented (Hill and MacRae, 1996). In the case of pest control, an ecologically sound agricultural system, which is often attained with increased biodiversity and complexity, leads to autonomous pest control where no external inputs are needed (Vandermeer et al., 2010). Here, the goal should be to promote more biodiversity-enhancing practices that prevent herbivore populations from reaching damaging levels in the first place, so that curative practices are less needed. For sustainable UA, this implies that even in cities with strong regulations against synthetic inputs, like the ones where our study was conducted, practices that prevent herbivores from becoming pests in the first place should be promoted. And this should be done with a participatory approach (Weidner et al., 2019) that starts with understanding current knowledge about potential pests and pest management practices used by UA practitioners.

In our study, we found that even if the majority of gardeners use curative practices, many also use preventative practices. These include practices used by traditional rural farmers worldwide including crop resistance, weed management, harvest residue management, natural enemies management, mechanical control, repellents, and traps (Morales, 2002). For example, one gardener reported providing water and habitat for lizards in their plot to support this natural enemy. Another gardener reported creating an ecosystem where all microorganisms can live. Gardeners also reported improving plant health and resistance to reduce pests (moving the drip irrigation hose away from certain plants / roots so that it is less wet, and that helps avoid the "fleas"). Gardeners also reported using repellent plants (planting green onions as a repellent) and selecting disease-resistant crops, as well as mechanical control (such as clipping infested plants or part of plants) and crop rotation (moving plants), and traps or barriers (mostly for gophers, birds, and ground squirrels). These responses lend new insights into the ways that urban gardeners perceive and manage the biodiversity within their plots for pest control services. Other practices reported by rural traditional farmers like soil management, timing of planting and harvesting, and intercropping (Morales, 2002) were not directly reported by our surveyed gardeners as part of their pest control strategies. However, many gardeners are very likely using these practices (personal observations) even if not fully aware that these are helping to prevent herbivore population build up. This all shows that agricultural knowledge and managing practices of some urban gardeners is comparable to those of traditional rural farmers, and suggests that, similarly to farmer-to-farmer exchanges, more gardener-to-gardener activities and interactions may be very beneficial in the promotion of agroecological practices.

In addition to farmer-to-farmer exchanges, participatory interaction with agricultural outreach professionals (e.g., "Cooperative Extension" in the US) and scientists is also necessary for the promotion of agroecological practices. In rural communities in Honduras, for example, farmers who had attended pest control workshops delivered by a diversity of national and international institutions knew more about arthropod natural enemies and about pesticide alternatives than farmers who hadn't (Wyckhuys and O'Neil, 2007). Very few gardeners in our study reported to have learned to garden from classes or workshops. This may point to the lack of such activities or that those that are offered are not successfully advertised or are not accessible to the different needs (time and language constraints, e.g.).

Some gardeners in our study were familiar with the idea of enhancing habitat to promote natural enemies. This suggests that preventative pest control practices like conservation biological control, which is the conservation and augmentation of natural enemies that are already in the area or nearby areas (Barbosa, 1998), could be promoted and disseminated in community garden activities. This would help urban agriculture to follow a true agroecological transformation instead of staying in the input-substitution stage which emphasizes on alternatives to agrochemical inputs (Hill and MacRae, 1996; Rosset and Altieri, 1997). By considering the wide diversity of knowledge and needs of the urban gardeners, these activities would have to be readjusted to create a truly participatory learning process (Girard, 2015). Extension programs will need to adjust to local realities and, importantly, rely on trusted and deep-rooted members of the community to pass on the information (Noy and Jabbour, 2020). This may prove particularly challenging in urban community gardens where gardeners from such a diverse socio-economic and ethnic backgrounds work side-by-side in the same garden.

CONCLUSION

Given the many failures of the current food system, the increasing interest in UA is likely to continue. Yet, despite the importance of UA generally, and community gardens specifically, for food security and access, there is still minimal research on pest prevention and sustainable pest management strategies for urban practitioners, especially for non-commercial ones. Our study contributes to this knowledge gap by showing how urban gardeners perceive pests and the range of strategies that they use to prevent and combat perceived pests. Our results also support studies in rural agricultural systems, which demonstrate the importance of integrating social context. In our case, identified ethnic/racial background, gardening experience, and time spent in gardens, were significant drivers of urban gardeners' decisions around pest management methods.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of California Santa Cruz IRB Protocol # 2569. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

HL, ME, and SP conceived the ideas and designed the methodology. ME, SP, PB, and CS collected the field data. HL analyzed the data and led the writing of the manuscript. All authors contributed critically to the drafts and gave final approval for publication.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2020.547877/full#supplementary-material

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