ABSTRACT

Interest in school and community gardens has increased over the past decade as a method to connect students and communities with food production. Although data on gardens as a source for foodborne illness is scarce, growing practices and settings are similar to those in small-scale commercial production. The objectives of this study were to (1) create a set of evidence-based best practices for gardens based on established food safety guidance for fresh produce, (2) create an intervention for delivery, and (3) evaluate the effectiveness of the practices. The guidelines were designed to impact garden organizer and volunteer behavior as well as organizational infrastructure regarding site selection, soil testing, handwashing, water, composting, garden design and fencing, sanitation, and volunteer management. School and community gardens (n = 20, 10 of each) were visited twice, using a pre-post design, and a risk-based observation instrument was administered. Sixteen gardens (80%) improved their overall scores. While the findings demonstrated that handwashing behavior could be altered significantly (P < 0.01) through the provision of the designed intervention, they also suggest a suitable means to take steps toward a safer garden.

INTRODUCTION

The Centers for Disease Control and Prevention (CDC) estimate that 48 million people in the U.S. acquire foodborne illness annually (41, 42). School and community gardens have been shown to improve everything from healthful eating habits to quality of life and attitudes toward food and consumption (6, 15, 19, 20, 24, 27, 29, 30, 33, 35, 38). Used as a means to create a connection between community, food, and healthful eating, community and school gardens have increased steadily in number in the past decade, leading to 2,401 food-producing school gardens and approximately 18,000 food-producing community gardens nationwide in 2014 (4, 16). The produce grown in these gardens is typically ready-to-eat fruits and vegetables, such as leafy greens, which have been linked repeatedly to pathogens. Foodborne illnesses stem from this commodity group at a rate of 46% (34). In many states, including North Carolina,
there are concerns about the safety of school garden harvest; as a result, some schools do not allow the students to eat the foods grown in the garden, nor are the foods allowed to be prepared in the cafeteria unless Good Agricultural Practices (GAP) certification has been obtained.

While the literature does not contain many garden-related studies, it is an emerging field of study. Looking at the conceptual framing of the effects of school gardens and drawing on ecological theory, Ozer (2007) suggests particular components of garden success (33). That is, a garden is successful if it can promote positive attitudes toward fresh produce, knowledge of the health impacts of improved nutrition, peer and family norms that are supportive of healthful eating, and an environment that provides healthful food options (33). Upon analyzing pretest and posttest scores, Lineberger and Zajicek (24) were unable to show any statistically significant change in fruit preference behavior of 111 third and fifth graders as the result of a year of school gardening. Children were more likely, however, to choose a nutritious (fruit or vegetable) snack after exposure to gardening intervention, a step toward consuming the recommended number of fruits and vegetables per day (24).

Compared with farms, production and distribution of products from gardens are informal and are not regulated in many jurisdictions, provided that the food is not sold. The lack of detailed information results in organizational barriers to implementing a positive food safety culture, which has been explained as a choice (50). Yiannas explained that an organization chooses to have a positive food safety culture because of the value it places on the health and safety of its customers and employees (50). To that end, recognition of personal responsibility for food safety is a prerequisite for implementation of proper food safety behaviors (39). Therefore, frequent information sharing and regular communication about foodborne risks with food handlers, using a variety of messages and mediums, is also important to supporting a culture of food safety (49). Communicating to food handlers, in a commercial or volunteer environment, about food safety risks and providing contextualized information has been shown to result in actual, observable behavior changes (12). Leventhal and colleagues (1965) demonstrated the importance of providing context for food handlers in a study of risk communication materials, as well as encouraging a personal connection (23). Schein (1993) found that creating dialogue and generating discussion between members of a team is a necessary condition for teamwork and working toward shared values (43). Generating dialogue has also been shown to promote collective learning and impact collective intentions within a group, which can be precursors to changing behavior (2, 7, 14). In the food handler context, Pragle and colleagues (2007) found that a lack of knowledge of consequences of failure to practice specific food safety practices was a barrier to self-reported behavior change (36).

Previous to this study, only a few food safety resources for garden organizers or managers existed, none of which were evaluated for efficacy using behavior-based impacts with the target audience. Most food safety information related to growing of produce, commonly known as good agricultural practices (GAPs) and was targeted at commercial growers (and their buyers). The federal government has food safety guidance for gardens (45), as does Cooperative Extension in New Hampshire (31), New York (37), and California (47, 48). These documents are based on GAPs standards derived from U.S. Food and Drug Administration’s Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (17) but are strictly prescriptive and not overly based on any sort of communication theory.

Similar studies to evaluate garden practices appear to be non-existent. The objective of this study was to examine school and community practices regarding food safety and handling and the mitigation of risk with the provision of garden-specific guidelines.

**MATERIALS AND METHODS**

**Creation of garden guidelines**

In a 2011 public session of the North Carolina Sustainable Local Food Advisory Council, food safety concerns were cited as a barrier to increasing the number of school and community gardens across the state (32). Yet the council did not know how much information the gardeners had about food safety and handling, or what information they might require to improve practices. As a first step, a literature review of existing best practice recommendations for gardens, coupled with a collection of risk factors related to produce-related outbreaks and illnesses, was completed.

Subsequently, semi-structured interviews with garden managers (n = 7) in five North Carolina counties were carried out as part of a needs assessment in the summer of 2011; this action allowed the researchers to be able to best develop an adult education program (8). Numerous types of gardens were visited: established and new, school and community, large and small, in rural, suburban, and urban areas. Initially, seven gardens in the Piedmont and Triad regions of North Carolina were visited; the managers were interviewed onsite, allowing the researcher to capture overall garden procedures. The garden managers detailed the “story of the garden,” touching on all included components of garden practices and types of soil, fencing and its cost, water sources (cisterns, barrels, wells, municipal), composting and its “doneness,” handwashing and hand sanitizer use, and land access. To make the guidelines as usable as possible, those comments, as well as the design and layouts of the gardens, were considered in addition to the scientific literature.

The aim was to create a new document, based on the best available guidance, incorporating communication theory and past evidence, and to deliver it using a traditional face-to-face extension model (with high trust).
Based on the GAPs guidelines and the U.S. Food and Drug Administration’s Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (17), initial focus areas were identified. Several parts of a garden are particularly likely to be associated with pathogens and foodborne illness: compost, water, animals, and soil. Information regarding each identified risk factor topic was created, and guidelines (in the form of a booklet) were created following the risk communication-based pragmatic structure and the Theory of Planned Behavior employed by Chapman and colleagues (2011) and adjusted for the school and community garden audience (13). Topics included garden design, irrigation methods, water sources, food safety plans and procedures, composting methods, equipment and cleaning, harvesting and sanitation, pesticides and fertilizers, and animals.

Although it was initially created and distributed in the form of a hard copy booklet, the best practices guide, “Food Safety for School and Community Gardens” (Fig. 1) has since been posted at www.growingsafegardens.com. The following focus areas are explained and in Table 1.

Following a draft of the best practices guide, six additional gardens in the same region were visited to review the contents with the garden coordinators and discuss the feasibility of using it. The managers were asked about each topic in the document: the practicality of the suggested guideline, whether they thought they could implement the guidance, and any barriers to implementation. It was at this point that the team of researchers in the fields of food science, horticulture, nutrition, public policy, and fruit and vegetable production reviewed and revised the document for distribution. After review, the document was published in print by NC State University and North Carolina Cooperative Extension.

Figure 1. Front page of “Food Safety for School and Community Gardens” document.
**TABLE 1. Explanation of guidelines and reasoning for inclusion**

<table>
<thead>
<tr>
<th>Section</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site selection</td>
<td>It is pertinent to know the history of the garden's location—whether it was once a parking lot or industrial site, bringing a risk of contaminated soil, or if neighboring industries might be a source of polluted runoff (45). A visual site assessment can enable one to observe if it has animal habitats or is in an area likely to flood; a manager of a potential garden should also consider learning about the location and risk of floodplains.</td>
</tr>
<tr>
<td>Soil testing</td>
<td>The best practice, even before planting, is to perform a soil test for heavy metals in addition to the soil test provided by the state. Urban gardens should test for lead, among other heavy metals, due to a concern about the transfer of lead and cadmium into the crops, especially those in which the stalks, stems, roots, and leaves are edible (3, 5).</td>
</tr>
<tr>
<td>Handwashing</td>
<td>The U.S. Centers for Disease Control and Prevention explains that handwashing education can reduce the number of people who get sick with diarrhea by 31% overall and by 58% in people with weakened immune systems (11). While many schools provide hand sanitizer to their teachers and students, the best way to prevent Norovirus is for each individual to wash his or her hands with soap and clean, running water and dry using a single-use towel both before entering the garden and after one leaves (10). For a greater decrease of pathogen numbers, one should first scrub nails with a brush full of non-antibacterial soap (44). In the event that there is no running, potable water available, single-use gloves should be worn while harvesting.</td>
</tr>
<tr>
<td>Water and irrigation</td>
<td>Many gardens, especially those in areas with water restrictions due to drought, are using water collected in rain barrels or from a well for the garden (21). Without analyzing the safety of the source, including rooftop runoff, the pathogens, chemicals, and metals could be introduced into the garden while watering the crops (25). By ensuring the use of safe water for irrigation, the potential of microbial contamination of fruits and vegetables is minimized.</td>
</tr>
<tr>
<td>Compost</td>
<td>The Environmental Protection Agency states that, for within-vessel or static aerated pile composting, the temperature must remain at or above 55°C (131°F) for four hours of five days (1). As a result, the best practices guide includes the recommendation that compost must generate temperatures over 130°F for at least five days to kill pathogens such as <em>E. coli</em> and <em>Salmonella</em>. Compost thermometers cost approximately $25 and are available at any garden store and online. The best practice is to place the compost bins downhill and as far away as possible from the garden to minimize the likelihood of contamination. In the event that the bins can be placed only in a particular location, barriers or French drains can be used to prevent their contents from entering the garden. While animal manure has long been considered an acceptable material to compost, the best practice is not to use it in the garden compost, as it requires extra steps and care to determine its safety.</td>
</tr>
<tr>
<td>Garden design</td>
<td>Animal manure is a major source of foodborne illness-causing pathogens (<em>Salmonella</em>, <em>Campylobacter</em>, <em>Shigella</em>, pathogenic <em>E. coli</em>), and keeping animals, from deer to birds, out of the garden is the best way to prevent the pathogens from contact with the harvest (17).</td>
</tr>
<tr>
<td>Tools and sanitation</td>
<td>Cross-contamination is the utmost concern once the harvesting process begins. While many gardeners use their hands for harvesting, some may use scissors, knives and other tools to harvest. Gardeners should wash and sanitize tools and equipment using a bleach or quaternary ammonium solution (50–200 ppm) after each use (18).</td>
</tr>
<tr>
<td>Volunteer management</td>
<td>Not everyone learns in the same way; some are hands-on, and some are auditory learners, so exploratory research is required to identify the most effective communication tools (49). The best way to ensure safety procedures are enacted is to explain why they must be done. People are more likely to perform a task if they know why they should do it, be in the mission of the garden or its history (28). Similarly, make it easy for the volunteers to obtain answers to questions by providing a reference guide for days when the garden manager is unavailable. And set the standard: garden participants are likelier to wash their hands if the gardens managers do so as well (28).</td>
</tr>
</tbody>
</table>
Study sample and data collection

To evaluate the efficacy of providing guidance to garden organizers, a mixed-methods pre-post approach was utilized. Given the lack of a comprehensive listing of school and community gardens, the chosen gardens are a convenience sample. Two researchers scoured the Internet for articles on local community and school gardens. They examined neighborhood and school district information to create a list of the operating gardens in three counties. They then contacted garden managers, arranged to visit the garden, and recorded responses as well as visually observed the focus areas outlined in the instrument. Each garden manager was sent the same E-mail, which explained that the researchers would like to talk about food safety, the contents of the “Food Safety for School and Community Gardens” document, and procedures currently in place.

The first-round sample included a total of 28 gardens; two members (one researcher per visit) of the project team visited and interviewed each garden manager onsite to collect the pre-intervention data. Each interview lasted between 45 minutes and 2 hours. At the end of the visit, the garden managers were asked if the researcher could come back in two months to check on progress. No garden managers declined at that time.

Managers were revisited after two months, allowing time for implementation of any procedures addressed in the curriculum. However, eight of the original 28 gardens were not revisited. Two of the gardens had not been replanted, the manager of one did not want a return visit, three garden managers wanted the researcher to revisit but could not schedule the meeting (two because of the large number of people involved), one garden had been turned over to non-English speakers, and one manager never responded to the E-mails. The analysis in this paper includes only the gardens that were visited twice.

In the pre- and post-intervention visits, the researchers asked the exact same questions, but in the first visit, the garden managers were also handed a copy of the curriculum, along with hand soap and a nailbrush. The managers asked the researchers questions of varied detail and the researchers provided extra attention to the procedures unpracticed at the time. Other questions were deemed “non-applicable” for some gardens; for example, if the garden does not use pesticides or herbicides, then it was not necessary to document where they were kept when not in use, and if a garden did not compost, then the subsequent series of questions related to composting were not asked. The total number of points possible was not the same for all gardens because of differences in practices, and the overall risk score is a percentage of the total possible points.

Survey instrument development

The survey questions asked at each visit were based on USDA’s Good Agricultural Practices/Good Handling Practices Audit Verification Checklist (46). Each question was scored based on the same number of points as assigned in the checklist. As in the USDA checklist, the questions are weighted based on risk; the riskier procedures are assigned more points. The questions were reviewed and verified by experts in food safety and nutrition before the study was performed. As in the USDA Good Agricultural Guidelines, the survey was broken into seven categories: site history; garden design and compost; soil and pesticides; handwashing; water and irrigation; sanitation and harvest; and volunteers and students. The garden managers knew that the gardens were being scored but did not know the point structure or the basis for scoring. The researchers who conducted the survey have expertise in garden procedures and GAP standards. To determine inter-grader agreement at the beginning of the project, the researchers visited three gardens, one of which was not part of the sample, at the same time. Each person independently rated each garden, and a high rate of consistency was found. They then discussed the discrepancies and achieved consensus on those particular gardens, as well as setting standards for future scoring.

RESULTS

The data were initially compiled in Microsoft Excel (Microsoft Corporation, Redmond, Washington, 2011) with unique identifiers, according to the exemption by the University of North Carolina—Chapel Hill Institutional Review Board. After both visits were completed, the researchers used Stata11.2 (Statacorp LP, College Station, Texas, 2009) to observe trends related to garden practices, as well as differences in school and community gardens. Of the total questions, 33 were point-based continuous variables and eight were dichotomous.

The 20 gardens that completed both the pre- and post-visits included nine from Orange County, six from Wake County, and five from Durham County, North Carolina. Given the small sample size, they were not further stratified based on county, school district, or any other descriptive statistic.

Within-garden, rather than across-garden, comparisons were carried out in this study. Each garden can be compared only to itself because all gardens do not have the same procedures; thus, any improvements or decreased scores are relative only to each garden. The managers of community gardens consistently explained that summer is not the best time to make any drastic changes, because of the busy nature of the work in the garden; the managers of school gardens indicated that summer would be a preferable time for change, with fewer scheduled activities. The garden managers had only approximately two months to make any changes, a short time period, creating a limitation to this study.

Paired t-tests were performed on the results for each guideline, as well as overall total scores, shown in Table 2. The overall average score of the 20 gardens increased by 10.01 percentage points statistically significant at the 99%
confidence level. The average score before the intervention was 54.75%, while post-intervention it was 64.76%. The analysis of the averages has limitations. The scores are not weighted; that is, a 70% in one garden is not the same as 70% in another. Overall, 16 gardens had an improved score, three had lower scores, and one was unchanged.

Although USDA uses 80% as a passing score for its GAP audit, few gardens were able to achieve that score. However, the garden managers were not working to achieve any particular score. While they were encouraged to use the guidelines at the conclusion of the first visit, each garden manager chose whether or not to read the document, implement any new practices, or change current ones. Unlike farms that “pass” the audit, the gardens would not see any additional markets open up to them or be able to command a higher price for the harvest based on the certification. Given the increased scores for so many procedures, even those that do not show a statistically significant difference are discussed.

<table>
<thead>
<tr>
<th>Guidelines Suggested as a Best Practices in Food Safety for School and Community Gardens</th>
<th>Total Potential Points</th>
<th>Average Score Pre-Guidelines</th>
<th>Average Score Post-Guidelines</th>
<th>No. of Additional Gardens Following Guideline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtained site history</td>
<td>5</td>
<td>2.76</td>
<td>3.55</td>
<td>4*</td>
</tr>
<tr>
<td>Compost bins moved to an area with minimized flooding</td>
<td>5</td>
<td>4.17</td>
<td>4.50</td>
<td>3</td>
</tr>
<tr>
<td>Checked temperature of compost before use in garden</td>
<td>10</td>
<td>2.75</td>
<td>4.375</td>
<td>5</td>
</tr>
<tr>
<td>Provided bathroom or handwashing station</td>
<td>15</td>
<td>10.40</td>
<td>12.25</td>
<td>4</td>
</tr>
<tr>
<td>Required and performed handwashing before harvesting</td>
<td>10</td>
<td>1.16</td>
<td>3.95</td>
<td>9**</td>
</tr>
<tr>
<td>Made hand sanitizer or single-use gloves available</td>
<td>10</td>
<td>1.82</td>
<td>2.35</td>
<td>6</td>
</tr>
<tr>
<td>Tested non-municipal water source or switched to municipal water</td>
<td>15</td>
<td>11.25</td>
<td>13.05</td>
<td>6*</td>
</tr>
<tr>
<td>Switched to single-use containers for harvesting</td>
<td>10</td>
<td>1.65</td>
<td>2.82</td>
<td>3</td>
</tr>
<tr>
<td>Sanitized tools</td>
<td>10</td>
<td>1.82</td>
<td>2.35</td>
<td>4</td>
</tr>
<tr>
<td>Used clean and sanitized packing containers</td>
<td>10</td>
<td>4.69</td>
<td>7.31</td>
<td>7</td>
</tr>
<tr>
<td>Garden rules and procedures explained to volunteers</td>
<td>15</td>
<td>11.15</td>
<td>13.05</td>
<td>4</td>
</tr>
<tr>
<td>Resources made available even if manager is not present</td>
<td>15</td>
<td>3.60</td>
<td>4.30</td>
<td>6</td>
</tr>
</tbody>
</table>

*P < 0.05  
**P < 0.01  
The column entitled “Number of additional gardens following guidelines” refers to gardens in addition to those that stayed the same through the study or were already completing these actions before the study.
As reported in Table 2, the largest increases in scores were associated with questions regarding handwashing and handwashing availability. The Centers for Disease Control and Prevention deem handwashing to be one of the best ways to prevent the spread of infection and illness (11). In addition to the gardens where it was already required, nine gardens began to require the students and volunteers to wash their hands before harvesting any crops, the sole improvement statistically significant at the 99% confidence level. This action lessens the chance of cross-contamination with pathogenic bacteria on one’s hands. Additionally, respondents from four gardens (20%) reported that they made a bathroom or handwashing station accessible to the gardeners, a task that sometimes required having the keys to a school on the weekend or bringing water to the garden specifically for washing. Even though every garden manager was provided with a nail scrub on the first visit, only six gardens claimed to have one by the second visit. In the event that no handwashing facility was available, six gardens chose to make hand sanitizer available to the gardeners. As sanitizers cannot eliminate Norovirus, it is not considered to be the best practice, but use of hand sanitizer is described in the curriculum as superior to not washing the hands at all.

Another critical topic for school and community garden food safety is the creation and use of compost in the garden. Seventeen of the 20 gardens (85%) were creating compost with food and plant waste onsite. Over the course of the two months, three garden managers chose to move the composting bins to a new location further away from the garden or downhill in an effort to minimize contamination during a potential flood. Five garden managers purchased a compost thermometer and began taking the temperature of the composting materials before incorporating them into the garden; they indicated that they made sure that the compost had reached a high enough temperature (130°F for 5 days) to kill any pathogens in it.

Similarly, washing and sanitizing tools and harvest containers can prevent cross-contamination. While no positive or negative change was reported from 16 gardens, 3 garden managers began using single-use containers for harvesting. Seven garden managers chose either to use new containers or to sanitize reusable ones when packing the harvest after introduction to the curriculum.

The fourth part of the curriculum focuses on the water source, recommending “a regulated, treated water source.” If the source is not municipal water, then the water should be tested and kept up to U.S. Environmental Protection Agency standards. Between the two visits, six gardens chose to shift away from using the water from its rain catchment system or well for edible crops, statistically significant at the 95% confidence level. The cost of water testing is not covered by the state, as soil testing is, and the gardens that switched to municipal water did so rather than test the rain barrels.

**DISCUSSION**

To ascertain the food safety practices of the community and school gardens of North Carolina, researchers visited each of 20 gardens two times over the course of three months, asking the same questions at each visit. However, the analysis is limited, given that eight gardens did not complete the study as well as the propensity for garden managers to make an initial change but not carry it out in the long term. The curriculum stresses volunteer management, the creation of garden rules, the following of standard operating practices, and having available resources; all of these items were associated with statistically significant improvements. Unless the researcher observed the garden in operation, it would be hard to understand completely the extent to which these actions occurred, especially in terms of following standard operating practices.

The handwashing results align with the literature on student handwashing. Scheduled handwashing has been shown to reduce gastrointestinal illnesses in elementary school age children, which make up the majority children exposed to the school gardens in this sample (26). Similarly, hand hygiene instruction has been found to reduce absenteeism for those students (22). However, the same people do not necessarily participate in a community garden each week and many maintain individual plots, making instructions harder to enforce. More importantly, unlike many of the guidelines, no partial scores were possible for handwashing; a garden could receive only all 10 points or zero points, resulting in a statistically significant ($P < 0.01$) but low average score.

No gardens built a fence in the time provided; in the early questions about the guidelines, the managers indicated that cost was a barrier to implementation of this suggestion. Yet, deer feces have been found to be a source of *E. coli* O157:H7, killing one person in Oregon in 2011 (40). Garden managers who had not seen evidence of deer in the garden at the time of the study are plausibly less likely to build a fence until they do see such evidence.

Additionally, it was found that it was more difficult and costly for those with rain barrels to have them tested, leading some of the garden managers to make the decision to use the captured water only for non-edible plants. The CDC maintains a Web site on private ground water wells, detailing quality and testing, but does not offer guidance as to how often this should occur (9). Four garden managers obtained its site history in the time provided, allowing the managers to assess how to move forward in terms of heavy metals testing and animal prevention.

Of the total 28 garden managers, five changed over the course of the summer. The high rate of turnover allows for potential shifts in policy outside the curriculum. Lastly, the managers had no ability to complete any financial planning, leading to few improvements in tasks with a high cost, such as building a fence or testing rain barrels.
Changes seen by the passive delivery of the intervention were somewhat few, and future work will focus on different additional training methods, including online and in-person classroom workshops to evaluate whether other delivery strategies can impact behavior and infrastructure change within the garden setting. With readily available information and practical guidelines, school and community gardens are able to take steps towards greater safety. Following this project, two school gardens in North Carolina used the elements of this document to establish site-specific guidelines and achieved a USDA GAP certification (Part 1), allowing garden harvest to be served in their respective cafeterias. Garden programs are often aimed at vulnerable populations, from young children to senior citizens, making food safety not necessarily at the forefront of garden concerns, but the managers are able to make critical, simple changes with the new curriculum.

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