Focusing Food Safety Training Based on Current Grower Practices and Farm Scale

Anusuya Rangarajan,¹

Marvin P. Pritts,²

Stephen Reiners,³ and

Laura H. Pedersen⁴

ADDITIONAL INDEX WORDS. pathogens, *Escherichia coli* 0157:H7, produce, foodborne illness, manure, compost, irrigation, sanitation, wash water, organic, small farms

SUMMARY. Recent outbreaks of foodborne illness associated with produce have prompted national attention on grower practices and produce handling. In 1998, we conducted a survey of New York fruit and vegetable growers to compare current management practices related to manure, compost and on-farm water quality with federal guidelines to reduce food safety risk. We were able to identify areas requiring additional educational effort, particularly for small farms. The respondents (213 total) represented 36% of the produce acreage in the state and many (54%) farmed less than 100 acres (40 ha). While most growers (60% to 95%) were able to identify meat and fruit as associated outbreaks, fewer (23% to 36%) identified outbreaks associated with vegetables. Of the 76 respondents (36% of total) who applied manure or compost, most (88%) used practices that would reduce food safety risks based on

federal guidelines. However, only 52% of growers identified these practices as reducing food safety risk. Most growers used surface water for irrigation (76%), but few reported testing water quality. However, we do not have standards for surface water quality or cost-effective remediation strategies. Testing ground water for bacteria was more frequently reported by organic growers ($P < 0.01$).

Growers commonly washed produce on farm (92%) but rarely added sanitizers to this water (16%). General food safety training should increase emphasis on past outbreaks associated with produce, manure management practices that reduce risks so that growers can more accurately report on-farm efforts and record keeping of manure and water management for traceback purposes. Small farms specifically required additional training in three key areas: record keeping of manure applications, composting processes to achieve pathogen kill, and sanitation of wash water. Organically certified farms were more frequently in compliance with federal food safety guidelines for manure and water quality management than conventional growers ($P < 0.05$), but required additional training in proper composting to kill pathogens. These results have been incorporated into our current food safety extension efforts, which focus on design of self-assessment tools for small farms, development of bilingual food safety training materials, and dissemination of food safety presentations and resources for extension and other agricultural agencies to use in training programs.

Recent outbreaks of foodborne illness associated with fruits and vegetables produce have indicated the need to reexamine crop production, handling and marketing practices for potential risks (De Roeve, 1998). Produce could be contaminated at any point from planting to retail sale. Areas of concern on the farm include 1) use of manure and other organic fertilizer materials, 2) water quality for irrigation and washing, 3) postharvest handling, and 4) worker hygiene and facilities (Beuchat, 1996). To enhance grower awareness of risks, the Food Safety Initiative Staff (FSIS) at the United States Food and Drug Administration Center for Food Safety and Applied Nutrition (FSIS, 1998) as well as other industry organizations, such as the United Fresh Fruit

and Vegetable Association (Alexandria, Va.) and the California Strawberry Commission (Watsonville), have published guidance documents that focus on prevention of contamination on the farm.

Agriculture in New York and the northeastern and the upper midwestern U.S. is predominately dairy and livestock based. The primary mode of manure disposal in New York is by on-farm land spreading (Poe et al., 1999). Fruit and vegetable farms represent an excellent land base for manure disposal, because of the high nutrient demand and large nutrient exports in harvested crops. Manure, however, can contain microbial pathogens. Concern with manure use on produce farms has been heightened by foodborne illness outbreaks associated with lettuce (*Lactuca sativa* L.) grown near a livestock operation (Hilborn et al., 1999), consumption of unwashed vegetables from a manured home garden (Cieslak et al., 1993) or fresh pressed cider made with dropped apples [*Malus sylvestris* (L.) Mill. var. *domestica* (Borkh.) Mansf.] from a manured orchard (Besser et al., 1993). While encouraging manure use is a wise approach for environmental stewardship, risks to human health suggested a need to reinvestigate practices associated with manure management.

Contaminated irrigation and wash water has been associated with foodborne illness outbreaks on produce. Outbreaks of *Escherichia coli* serotype 0157:H7 (Centers for Disease Control, 1995) and Shigella (Canadian Food Inspection Agency, 2001) were associated with lettuce that may have been irrigated with contaminated water. Microbial contamination has also been traced to unclean wash water used in the post harvest environment (Rushing et al., 1996). Sanitizing treatments (e.g. chlorine) added to wash water were only marginally useful for reducing pathogen numbers on crop surfaces but did reduce risk of cross contamination via wash water (Francis et al., 1999; Nguyen-The and Carlin, 1994).

We designed a survey to assess if New York fruit and vegetable grower management of manure and compost, irrigation and wash water quality conformed to federal guidelines (FSIS, 1998). The production practices used by these growers (Reiners, 2001) were similar to other growers in the north-

This research was funded through the 1998 Cornell Research and Extension Integration Grants Program. The authors would like to thank Robert Gravani, Lois Levitan, Ellen Harrison, and Peter Wright for their reviews and Betsy Ingall and Michelle Farnham for their assistance administering the survey.

¹Assistant professor, Dept. of Horticulture, Cornell University, Ithaca, NY 14853.

²Professor, Dept. of Horticulture, Cornell University, Ithaca, NY 14853.

³Associate professor, Dept. of Horticultural Science, Cornell University, NYS Agricultural Experiment Station, Geneva NY 14456.

⁴Formerly of Cornell Cooperative Extension of Ontario County, Canandaigua NY 14424. Current address: 2259 Vogt Road, Stanley, NY 14561.

eastern, mid-Atlantic and midwestern regions of the United States (Foster, 2001; Johnson, 2001; Precheur, 2001). Previous surveys of New York growers have been focused on pesticide use, general productivity or income, and not manure or water management practices (National Agriculture Statistics Service, 1999). Much of our survey analysis focused on small or organic farms. Results suggested specific educational needs for on-farm food safety for these small-scale, direct-to-consumer operations compared with larger farms in New York or other parts of the United States. Survey results have been incorporated into extension materials and a national food safety education program for growers (Bihn, 2001).

Materials and methods

A written survey, containing 44 questions, assessed New York grower practices and attitudes regarding: a) foodborne illness risks (four questions), b) manure and compost management (27 questions), c) irrigation water management (nine questions), and d) produce wash water management (four questions). Individuals in the fields of food science, sociology, risk management, natural resources, animal science, and horticulture, from three institutions and local growers reviewed the survey. The revised survey was mailed in Apr. 1998 to 615 fruit and vegetable growers and a reminder card 3 weeks later. The mailing list was generated from the memberships in fruit and vegetable grower organizations (including organic producer groups) and cooperative extension and from regional farm directories.

Contingency tables were generated for responses using the following categories of growers: 1) total farmed acreage, 2) average annual acreage of produce, 3) predominately producing fruits versus vegetables, and 4) organic certification status. Chi-squared tests were performed to assess independence of response among grower categories (i.e., similar responses despite categorical differences). Responses did not vary among farms that were predominately vegetable or fruit; therefore data was pooled across this category. For the purposes of this discussion, large farms were those with greater than 500 acres (202 ha) of fruits and vegetables, medium sized farms had 100 to 500 acres (40 to 202 ha), and small had less than

100 acres. The frequencies of specific responses were compared to expected values or, in some cases, New York statistics (National Agriculture Statistics Service, 1999; New York Agriculture Statistics Service, 1999) using the one-way Chi-squared goodness-of-fit test. All statistical analysis was conducted using the SAS program (SAS Institute, Cary, N.C.).

Results and discussion

GENERAL INFORMATION ON RESPONDENTS. A total of 213 growers returned completed surveys, representing 35% of the 615 mailed. The majority (62%) of growers were located in central and western New York, the main fruit and vegetable production region. Most grew primarily vegetables [155 of 213 (73%)] rather than fruit [58 of 213 (27%)]. Respondents farmed a total of 95,600 acres (38,240 ha) (including agronomic and other crops) and individual farm size ranged from 1 to 7500 cultivated acres (0.4 to 3000 ha). Respondents farmed 45,061 acres (18,024 ha) of vegetables and 7,672 acres (3,069 ha) of fruit, and total of 371 acres (146 ha) were certified organic. This represented 25% of New York's vegetable acreage and 11% of the fruit acreage, based on 1998 state estimates (New York Agriculture Statistics Service, 1999).

While average farm size was 250 acres (102 ha) of produce, most growers [114 of 213 (54%)] farmed small acreages [<100 acres (40 ha)] (Table 1). All of the responding organic growers (42) managed small farms, and most (65%) farmed less than 5 acres (2 ha). In 1997, size distribution of New York fruit and vegetable farms across these same classes was 87% small, 10% medium and 2% large farms (National Agriculture Statistics Service, 1999). Our survey had a greater proportion of responses from medium and large operations compared with the state distribution ($P < 0.01$) (Table 1).

GROWER AWARENESS AND ATTITUDES TOWARDS MICROBIAL CONTAMINATION AND PREVENTION. Four questions explored grower awareness of past foodborne illness outbreaks and attitudes towards regulations to reduce risks from produce. Most growers (78% of respondents) had heard of the virulent strain of *E. coli* O157:H7. There were no significant differences in awareness of this pathogen between fruit and vegetable growers, by farm

size or if a grower used manure or compost on their land. However, a higher percentage of organic growers (93%) were aware of this organism compared with conventional growers (73%) ($P < 0.02$). We expected that a similar percent of growers (78%) would be able to identify food groups associated with recent outbreaks, but this was only true for meat, poultry and seafood (95% of respondents) ($P < 0.01$ significantly different from expected 78%) or small fruit (72%) ($P < 0.90$), and not apple cider (61%) ($P < 0.01$), lettuce or coleslaw (36%) ($P < 0.01$), or melons (*Cucumis melo* L.) (23%) ($P < 0.01$). A higher percentage of organic growers were aware of lettuce related outbreaks compared with conventional growers ($P < 0.001$), perhaps due to an outbreak associated with organic lettuce (Hilborne et al., 1999). Almost all (86%) of the respondents felt growers should be given general (59%) or specific (27%) guidelines on good agricultural practices to minimize risks of microbial contamination rather than regulations (2%) or no guidelines (6%). However, those growers that were applying organic soil amendments were more supportive of guidelines ($P < 0.03$) than those not using organic amendments. Previous emphasis on manure management and food safety appeared to affect the perception of nonamendment users on the breadth of on-farm food safety planning. All of these results suggested the need to enhance education efforts on the history of produce-related outbreaks, with strengthened emphasis on components other than manure.

APPLICATION AND MANAGEMENT OF MANURE AND COMPOST. The application of organic soil amendments (manure, compost, green manure, yard waste, etc.) to agricultural land is generally encouraged to enhance soil quality as well as nutrient and waste recycling. Survey questions assessed the number of farms using manure and compost, source, targeted crops, application strategies and on-farm composting and record keeping. Results were compared to federal guidelines (FSIS, 1998) to determine focal areas for extension education.

In the survey sample, 76 of 213 respondents (36%) incorporated manure (57) or animal manure-based compost (41) into their soil management program, and none applied municipal sewage sludge (Table 1). More

conventional growers [42 of 171 (25%)] reported applying these amendments to their soil than the expected 10% based on grower interviews prior to the survey ($P < 0.001$). Conventional growers applied manure more frequently [38 of 42 amendment users (90%)] than compost [11 of 42 (26%), $P < 0.001$] and frequency did not vary by farm size. Among small farms, organic farms more frequently applied manure ($P < 0.04$) (45%) and compost ($P < 0.001$) (71%) than conventional farms applied manure (25%) or compost (7%) (Table 1). While fewer total organic acres [190 acres (77 ha)] received manure compared with conventional acres [16,000 acres (6,475 ha)], this represented 51% of the organically managed acreage in the survey, compared with 30% of the conventional acreage.

Good agricultural practices for food safety have suggested crop selection should be based on most recent manure application (FSIS, 1998). Raw manure should be applied to allow a minimum of 60 d until harvest of vegetables, and preferably target grain or forage crops, or, upright crops (e.g. sweet corn (*Zea mays* L. var. *rugosa* Bonaf.) or peppers (*Capsicum annuum* L. var. *annuum* Grossum Group). In an open-ended question, many growers who used manure or compost indicated management strategies that they used to reduce the risk of produce contamination [34 of 65 respondents (52%)]. Most timed applications to achieve preharvest intervals of at least 2 months [25 of 34 (74%)] and others (9) composted manure. Organic growers were more likely to suggest practices that reduce food safety risks than

conventional growers ($P < 0.001$). Among growers who said they did not use specific practices to reduce risk (31 of 65 respondents), 23 actually did use good agricultural practices for food safety, such as targeting manure to nonhuman or nonfresh market crops, incorporation, and composting. If these growers had identified these practices as reducing risk, then 88% of the respondents (57 of 65) would have complied with federal guidelines for manure and compost use. This suggested that greater emphasis should be placed on the good agricultural practices for manure and compost to increase grower ability to document their own practices.

About half of the manure and compost users [35 of 76 (46%)] targeted applications to land designated for nonhuman crops, such as grain, forage, or pumpkins (*Curcubita pepo* L.), or to biennial or perennial crops, satisfying preharvest waiting periods. The most frequently cited crops receiving manure or compost were pumpkins, followed by other cucurbits, peppers and sweet corn. Awareness of outbreaks from contaminated lettuce, coleslaw, or melons was not correlated to decision to grow lettuce ($P < 0.15$), carrots (*Daucus carota* L.) ($P < 0.094$), cabbage (*Brassica oleracea* Capitata Group) ($P < 0.24$) or melons ($P < 0.35$) on amended land, and responses were similar between conventional and organic growers. Growers of root crops were primarily small scale (82%) ($P < 0.05$) and 70% of these were organic farms. While most growers were applying manure to have preharvest intervals, educational efforts must emphasize the importance of field history

for low growing crops to minimize risks for microbial contamination.

For growers applying manure or compost (76), some (42%) reported these coming from on-farm animal operations (similar across farm size) but the majority used off-farm sources of manure or compost. Primarily dairy (33%) or equine (22%) manure was applied. A recent study suggested that 37% of cattle herds carried *E. coli* 0157:H7 and that young or transitioning animals in these herds were more likely to be shedding this organism (Bolton et al., 1999; Chapman et al., 1997). Among respondents, larger farms were more likely to swap land with neighbors to take advantage of manure applications than small farms ($P < 0.001$). Education programs must emphasize importance of evaluating manure management practices of any source or land base, often extending food safety planning beyond farm boundaries.

Most growers using manure (57 total) broadcasted the manure (62%) and some incorporated immediately (33%). While pathogenic organisms show rapid decrease in numbers when surface applied to soil (Bolton et al., 1999; Wang et al., 1996), dilution by mixing into the soil profile, plus increased exposure to competition by other soil organisms, would be expected to reduce pathogen numbers. Top dressing (applying to an established crop) with manure or compost was occasional reported (7 of 76 users), however, all these growers used fall applications to perennial crops.

Many of the growers using compost (41) (Table 1) produced it on their own farms [31 of 41 users (76%)]

Table 1. Number of responding conventional and organic certified farms (and percent of total) separated by size of produce acreage and the numbers of those farms applying manure or compost, irrigating and sources of irrigation water, and those washing produce on the farm.

Acreage	Farms ^a	Manure applied	Compost applied	Irrigated	Irrigation water source ^y			
					Surface ^x	Drilled well	Municipal	Washed produce
Total small ^w	114 (54)	37 (17)	35 (16)	83 (39)	59	31	12	79 (37)
Conventional ^v	72 (34)	18 (8)	5 (2)	52 (24)	42	13	11	43 (20)
Organic	42 (20)	19 (9)	30 (14)	31 (15)	17	18	1	36 (17)
Medium conventional	71 (33)	14 (7)	5 (2)	60 (28)	41	25	11	58 (27)
Large conventional	28 (13)	6 (3)	1 (.5)	20 (9)	18	4	3	18 (8)
Total for all farms	213 (100)	57 (27)	41 (19)	163 (76)	118	60	26	155 (73)

^aData in parentheses are percentages calculated based on 213 total farms.

^yGrowers often had multiple sources of irrigation water.

^xSurface water included streams, ponds, lakes, or open canals.

^wFarm size categories reflect combined fruit and vegetable acres, as follows: small= <100 acres (40 ha); medium= 101–499 acres (40.1–199.9 ha); large= >500 acres (200 ha).

^vIndicates farms that were not certified as following organic production practices.

from manure, bedding or crop residues. Most compost producers operated small farms ($P < 0.01$) and were organically certified ($P < 0.001$). Composting reduced pathogen levels, provided piles attain high temperatures 140 °F (60 °C) for 5 to 7 d (Droffner and Brinton, 1995). Most growers had been composting for less than 2 years and only 12 of 31 compost producers (39%) monitored their pile temperatures for a target peak heat of 140 °F or higher. The frequency of temperature monitoring and targeted days for peak heating was inconsistent. Composting strategies should complement food safety curriculum for small farms.

Record keeping of farm management practices is essential to federal guidelines (FSIS, 1998) and to traceback investigations. Many growers [51 of 76 users (67%)] kept application records of fields treated with manure or compost. Among conventional growers, large farms more frequently kept records of manure use than small farms ($P < 0.05$). All organic growers kept records of manure and compost applications, but only 6 of 21 (30%) small-scale conventional growers reported keeping these records. Those growers keeping records were more likely to monitor manure application rates ($P < 0.001$) and to adjust nutrient inputs accordingly ($P < 0.001$). Organic growers were more aware of the rates of applied than conventional growers ($P < 0.02$). Education programs should encourage small, conventional growers to maintain better records of manure and compost applications for both food safety and environmental management.

IRRIGATION WATER QUALITY. Food safety programs currently advocate irrigation water testing (FSIS, 1998), yet sampling and testing methods, target organisms and remediation strategies for surface water used for irrigation remain difficult to define. Fecal coliform count (a common water quality test) has a high positive correlation with fecal matter contamination from warmblooded animals (Geldreich and Bordner, 1971) and Salmonella contamination (several species) (Nguyen-The and Carlin, 1994). However, positive fecal coliform counts do not indicate contaminant source (municipal sewage, wild or domestic animal), pathogenicity of detected bacteria, and do not correlate with *E. coli* 0157:H7

incidence in 50% of water tests (Kramer et al., 1996). Municipal and ground water generally are viewed as having lower risk for pathogen contamination than surface water. However, a recent outbreak in British Columbia, Canada was associated with irrigation of spinach with well water that had been contaminated by a poorly maintained septic system (Canadian Food Inspection Agency, 2001). Survey questions assessed irrigation water sources, quality testing, and grower attitudes about surface water quality and contamination sources. This information will be used to target educational efforts on irrigation water testing and management, once more concrete recommendations are available.

The majority of respondents [163 of 213 (76%)] irrigated their produce (Table 1). This irrigated land corresponded to 68% of the vegetable acreage and 93% of the fruit acreage in the survey which was significantly higher than the state percentages for vegetable (28%) and fruit (11%) growers ($P < 0.001$) (NASS, 1999). Among the respondents using irrigation, 51% were small, 37% were medium, and 12% were large farms (Table 1). Sources included streams [60 of 163 (37%)], ponds [81 of 163 (50%)], wells [60 of 163 (37%)], or municipal water [26 of 163 (17%)]. Only one third of the growers using surface water also used ground water for irrigation, suggesting limited options among most growers for irrigation water source. A higher proportion of large farms reported drawing from streams compared with small farms ($P < 0.001$), but farm size was not correlated to pond or well use. Conventional small farms more frequently used surface water for irrigation than organic farms ($P < 0.05$). Of those growers using surface water to irrigate, 85% never tested their irrigation water for nutrients, chemicals or bacteria, and occasionally tested water pH if used in pesticide sprays. Well water was more frequently tested ($P < 0.01$). Organic growers more frequently tested irrigation water for bacteria (19 of 32 who tested) compared with conventional growers ($P < 0.001$). These results reflected the ability to interpret water quality tests from well water (often farm drinking water) compared to surface water. Testing and record keeping of well water should be emphasized in food safety trainings.

Among growers using surface

water for irrigation, few felt that municipal waste treatment (11%) or agriculture (13%) negatively affected their surface water quality. Yet, 47% of respondents (88 of 188) believed that other growers in their area were concerned with nitrates leaching into ground water, suggesting that respondents recognized the impact of watershed activities on ground water quality. Fruit and vegetable grower participation in local watershed or other agricultural stewardship groups could enhance awareness of potential sources of contamination of streams or other surface water used for irrigation.

POSTHARVEST WATER QUALITY.

Potable water plus chlorine is recommended for all postharvest washing of produce (FSIS, 1998), yet potable water washes alone have been demonstrated to reduce levels of pathogenic organisms by 10 to 100 fold (Bartz, 1999; Bracket, 1987). Of the 73% (155 of 213) of growers who reported washing produce on their farm (Table 1), 80% were vegetable growers. Wash water sources included wells (69%) or municipal water (31%), and in most cases (92%) was also farm drinking water. Organic growers more frequently reported washing produce compared with small conventional growers ($P < 0.01$) (Table 1). Among growers of fresh market crops, frequency of washing varied by crop ($P < 0.001$). Crops most often washed included: tomato (*Lycopersicon esculentum* Mill.) (81% of growers), pepper (90%), cucurbits (85%), leafy greens (90%), potato (*Solanum tuberosum* L.) (75%), and apple (48%). Crops rarely washed included berries (5%), brassicas (7%), or onions (*Allium cepa* L.) (0%).

While sanitizers (e.g. chlorine) are only minimally effective at reducing surface contamination of produce by human pathogens (Beuchat, 1999; Francis et al., 1999; Sapers et al., 1999), they reduce chances of cross contamination of produce via water in flumes or dump tanks. The survey results suggested that growers needed additional extension education on post harvest water sanitation, based on variability of responses to questions. Only 16% of growers (26 of 159 responding) reported adding chlorine to produce wash water. Target levels for chlorine were quite variable, ranging from 50 to 200 ppm (mg·L⁻¹). Monitoring of the level of disinfectant was common

among those users (17 of 26), but the frequency varied one to four times per day. Large and medium produce operations were more likely to add chlorine to wash water than were small farms ($P < 0.001$). Among small farms, 75 of 82 (91%) respondents washed produce, but only four used sanitizers. Development and extension of standardized, economical post harvest sanitation strategies are needed for small farms growing fresh market crops.

Conclusions

The survey results suggested that educational programs on food safety, particularly for small produce farms, should focus more specifically on the following areas.

- 1) Maintaining detailed records of manure and irrigation water applications for both food safety and environmental management. For those growers who swap fields with neighbors or use off-farm manure sources, record keeping should include management histories from these other farmers.
- 2) Sanitizing postharvest wash water, with addition and monitoring of chlorine or other sanitizers approved for organic certification, such as peracetic acid and hydrogen peroxide, to reduce potential cross contamination.
- 3) Educating all growers about past outbreaks associated with fruits and vegetables and the diversity potential contamination sources.
- 4) Training organic growers on proper composting strategies to reduce pathogen numbers.
- 5) Testing ground water used for irrigation of crops. Surface water testing remains too undefined to develop meaningful evaluations (P. McDonough, personal communication).

The highly diversified nature of farms in New York and the northeastern U.S., and their small to medium size requires design of economical, scale-appropriate post harvest sanitation strategies. These farms commonly use direct marketing, are not capital rich, and are not included in third party certification programs targeting larger wholesale growers. Sanitation strategies for these farms may require site-by-site design. After foodborne illness outbreak associated with unpasteurized apple cider, many northeastern growers were faced with the deci-

sion of whether to continue cider production, since most pasteurization equipment was unaffordable at their scale of production. While our survey did not explore cold storage facilities on these farms, extension efforts should not disregard this important strategy for minimizing pathogen growth on produce surfaces (Beuchat, 1996; Richert et al., 2000).

Organic growers were more aware of pathogens, primarily used composted manure, could identify strategies that reduced risks from manure applications, washed produce and kept records more frequently than conventional growers. Some of these positive food safety practices were related to certification requirements. The primary area requiring additional educational effort for organic growers was in composting strategies to achieve pathogen kill. The survey suggested that if the good agricultural practices recommended by federal guidelines are dependable in reducing risk, then organic producers were in compliance more frequently than conventional growers. A voluntary, peer review similar to organic certification, could enhance food safety planning for all small farms.

Based on the survey results, we have developed self-assessment worksheets to enhance the ability of small farms to plan for food safety. These worksheets review practices from seed to farm gate and allow growers to compare their current practices with recommended good agricultural practices to identify changes that may reduce food safety risks. These worksheets follow the format used in voluntary farm environmental evaluations, such as Farm-A-Syst (University of Wisconsin Extension, 2000). In addition, a brochure and pamphlet (available in English, Spanish, and Chinese) on food safety planning were designed with needs of small farmers in mind (Bihn, 2001). For educators, we have released a series of educational presentations and a resource manual on food safety. Topics include basic food microbiology, production and post harvest good agricultural practices, crisis management, and creating a food safety plan. It is hoped that these materials will emphasize the importance of a comprehensive approach to ensuring food safety of produce regardless of farm scale or diversity.

Literature cited

- Bartz, J.A. 1999. Washing fresh fruits and vegetables: Lessons from treatment of tomatoes and potatoes with water. *Dairy Food Environ. Sanitation* 19:853–864.
- Besser, R.E., S.M. Lett, and J.T. Webber. 1993. An outbreak of diarrhoea and haemolytic uraemic syndrome from *Escherichia coli* 0157:H7 in fresh pressed apple cider. *J. Amer. Medical Assn.* 269:2217–2220.
- Beuchat, L.R. 1996. Pathogenic microorganisms associated with fresh produce. *J. Food Protection* 59:702–705.
- Beuchat, L.R. 1999. Survival of enterohemorrhagic *Escherichia coli* 0157:H7 in bovine feces applied to lettuce and the effectiveness of chlorinated water as a disinfectant. *J. Food Protection* 62:845–849.
- Bihn, E.A. 2001. Cornell University good agricultural practices project. 25 Oct. 2001. <<http://www.gaps.cornell.edu/>>.
- Bolton, D.J., C.M. Byrne, J.J. Sheridan, D.A. McDowell, and I.S. Blair. 1999. The survival characteristics of a non-toxigenic strain of *Escherichia coli* 0157:H7. *J. Appl. Microbiol.* 86:407–411.
- Bracket, R.E. 1987. Antimicrobial effect of chlorine on *Listeria monocytogenes*. *J. Food Protection* 50:999–1003.
- Canadian Food Inspection Agency. 2001. Health hazard alert—Fresh spinach may contain *Shigella*. 23 Oct. 2001. <<http://inspection.gc.ca/english/corppaffr/recarapp/20010622e.shtml>>.
- Centers for Disease Control. 1995. Epidemic intelligence service report on outbreak of *Escherichia coli* 0157:H7, northwestern Montana. EPI-AID Rpt. 1995–68.
- Chapman, P.A., C.A. Siddons, A.T. Cerdan-Malo, and M.A. Harkin. 1997. A 1-year study of *Escherichia coli* 0157 in cattle, sheep, pigs and poultry. *Epidemiol. Infection* 119:245–250.
- Cieslak, P.R. T.J. Barrett, P.M. Griffin, K.F. Gensheimer, G. Beckett, J. Buffington, and M.G. Smith. 1993. *Escherichia coli* 1057:H7 infection from a manured garden. *Lancet* ii:367.
- De Roeve, C. 1998. Microbiological safety evaluations and recommendations on fresh produce. *Food Control* 9(6):321–347.
- Droffner, M.L. and W.F. Brinton. 1995. Survival of *Escherichia coli* and *Salmonella* populations in aerobic thermophilic composts as measured with DNA gene probes. *Zentralblatt fuer Hygiene und Umweltmedizin* 197:387–397.

Food Safety Initiative Staff (FSIS). 1998. Guide to minimize microbial food safety hazards for fresh fruits and vegetables (HFS-32). U.S. Food and Drug Admin. Ctr. for Food Safety and Appl. Nutr., Wash., D.C.

Foster, R. 2001. Midwest vegetable production guide for commercial growers. Purdue Univ. Ext. Bul. 07094-G0.

Francis, G.A., C. Thomas, and D. O'Beirne. 1999. The microbiological safety of minimally processed vegetables. Intl. J. Food Sci. Technol. 34:1-22.

Geldreich, E.E. and R.H. Bordner. 1971. Fecal contamination of fruits and vegetables during cultivation and processing for market: A review. J. Milk Food Technol. 34:184-195.

Hilborn, E.D., J.H. Mermin, P.A. Mshar, J.L. Hadler, A. Voetsch, C. Wojtkunski, M. Swartz, R. Mshar, M. Lambert-Fair, J.A. Farrar, K. Glynn, and L. Slutsker. 1999. A multistate outbreak of *Escherichia coli* 0157:H7 infections associated with consumption of mesclun lettuce. Archives Internal Medicine 159:1758-1764.

Johnson, S. 2001. Commercial vegetable production recommendations for New Jersey. Rutgers Coop. Ext. Bul. E001Q.

Kramer, M.H., B.L. Herwaldt, C.F. Craun, R.L. Calderon, and D.D. Juranek. 1996. Surveillance for waterborne-disease outbreaks, United States, 1993-1994. Morbidity Mortality Weekly Rpt. Centers for Disease Control Surveillance Summ. 45:1-33.

National Agriculture Statistics Service. 1999. 1997 Census of agriculture-New York State and county data. Natl. Agr. Stat. Serv. Publ. AC97-A-32.

New York Agriculture Statistics Service. 1999. New York agricultural statistics 1998-1999. N.Y. Agr. Stat. Serv. Albany.

Nguyen-The, C. and F. Carlin. 1994. The microbiology of minimally processed fresh fruits and vegetables. Critical Rev. Food Sci. Nutr. 34:371-401.

Poe, G., N. Bills, B. Bellows, P. Crosscombe, M. Kreher, and P. Wright. 1999. Documenting the status of dairy manure management in New York: Current practices and willingness to participate in voluntary programs. Cornell Univ. Dept. Agr., Resource and Managerial Econ. Bul. SP:99-03.

Precheur, R. 2001. Ohio vegetable production guide. Ohio State Univ. Ext. Bul. 672-01.

Reiners, S. 2001. Integrated crop and pest management guidelines for commercial vegetable production. Cornell Coop. Ext. Bul. 142RV.

Richert, K.J., J.A. Albrecht, L.B. Bullerman, and S.S. Sumner. 2000. Survival and growth of *Escherichia coli* 0157:H7 on broccoli, cucumber and green pepper. Dairy Food Environ. Sanitation 20:24-28.

Rushing, J.W., F.J. Angulo, and L.R. Beuchat. 1996. Implementation of a HACCP program in a commercial fresh market tomato packinghouse: A model for the industry. Dairy Food Environ. Sanitation 16:549-533.

Sapers, G.M., R.L. Miller, and A.M. Matrazzo. 1999. Effectiveness of sanitizing agents in inactivating *Escherichia coli* in Golden Delicious apples. J. Food Sci. 64:734-737.

University of Wisconsin-Extension. 2000. Farm*A*Syst Home*A*Syst. 18 Oct. 2001. <<http://www.uwex.edu/farmasyst/fmain.html>>.

Wang, G., T. Zhao, and M.P. Doyle. 1996. Fate of enterohemorrhagic *Escherichia coli* 0157:H7 in bovine feces. Appl. Environ. Microbiol. 62:2567-2570.

Effects of Urea and Nitric Acid on Water and Medium Quality and on Response of Anthurium

Yuncong Li and Min Zhang

ADDITIONAL INDEX WORDS. bicarbonate, acidified water, nitrogen, plant nutrition, pH

SUMMARY. Excessive bicarbonate concentrations and high irrigation water pH affect the growth and appearance of nursery plants in southern Florida. A greenhouse experiment consisting of five nitrogen (N) rates of urea or nitric acid was conducted to evaluate the influence of N sources and rates in irrigation water on bicarbonate concentrations, medium pH, and growth and appearance of anthurium (*Anthurium andraeanum* Lind.) plants. Pot medium pH, dry weight, plant appearance and N uptake by plants were significantly affected by N rates in irrigation water amended with either liquid urea or nitric acid, but the differences between the two N sources were not significant. The optimum growth and the best appearance of anthurium were achieved when N was added to irrigation well water as either urea or nitric acid at a rate of 20 mg·L⁻¹ (ppm) and an electrical conductivity in a range of 0.36 to 0.42 dS·m⁻¹. Nitrogen rates at 80 and 120 mg·L⁻¹ induced adverse plant growth because of the greater salinity of the solutions and the lower pH of the medium.

Southern Florida is underlain by a shallow limestone aquifer. The groundwater contains a high concentration of calcium bicarbonate, commonly more than 100 mg·L⁻¹ with water pH as high as 8.0 (Herr and Shaw, 1989). This source of

University of Florida, Institute of Food and Agricultural Sciences, Tropical Research and Education Center, 18905 SW 280 Street, Homestead, FL 33031.

University of Florida Agricultural Experiment Station journal series R-07774. We thank Shaoxiang Huang and Xiuping Sun for their assistance on conducting experiment and Jim Georgusis, Fancy Flora, Inc., Miami, Fla., for providing anthurium seedlings.