Proc. Fla. State Hort. Soc. 125:295–299. 2012.

Impacts of Alternative Cropping Systems on Fruit Quality: Opportunities for Collaborative Research

T.G. McCollum*, E.N. Rosskopf, N. Kokalis-Burelle, D. Butler†, and M.G. Bausher

USDA, ARS, U.S. Horticultural Research Laboratory, Fort Pierce, FL 34945

Additional index words. methyl bromide, soil fumigants, grafting

Methyl bromide (MB) is a soil fumigant that has been critical for the production of vegetable crops, cut flowers, and strawberries in Florida. However, the continued phase-out of soil uses of this broad-spectrum fumigant necessitates the implementation of alternatives for controlling soilborne pests. Significant research efforts continue and have resulted in some effective, environmentally less harmful, and more sustainable alternatives to MB soil fumigation. Such research is focused primarily on the effects of MB-alternatives on soilborne pest control and yield of crops of interest, with little attention given to potential effects on product quality. However, it is possible that alternative production practices may have an impact on fruit and vegetable quality. Because significant amounts of produce are generated in mid- to large-scale field trials, the opportunity exists for a collaborative research effort to determine if alternative production practices impact postharvest quality. We have quantified standard fruit quality parameters for tomatoes, eggplant, bell peppers, cantaloupe melons, and watermelons produced in field trials testing alternative fumigants, transplant grafting, and biologically-based alternative cropping systems as alternatives to MB. Important components of these trials will be presented along with perspectives related to conducting such investigations.

As the phase-out of soil uses of methyl bromide (MB) nears its completion, there is a significant void in the availability of effective non-chemical options to manage soilborne plant pathogens and plant-parasitic nematodes in vegetable production systems. This need is compounded by the loss of registration of methyl iodide and limitations of other fumigant alternatives in terms of efficacy, environmental sustainability, and human health and safety (Rosskopf et al., 2005). Given the increasing demand for sustainable and organic agricultural products, non-chemical soil management practices that are easily-adaptable for conventional, organic, or transitional systems are needed for Florida growers.

Among treatments being evaluated as substitutes for MB are: 1) grafting using rootstocks resistant to soil borne pests; 2) alternative soil fumigants; and 3) anaerobic soil disinfestation (ASD). Grafting has long been used with Cucurbitaceae and solanaceous crops to overcome limitations imposed by soilborne pests (Davis et al., 2008; Kubota et al., 2008; Louws et al., 2010). ASD involves creating anaerobic conditions in the soil with the objective of killing soil borne pests. ASD can be utilized in urbanized areas where fumigant buffer restrictions may limit the applicability of alternative fumigants and, unlike many other biologically-based alternatives, there is potential for a broad spectrum of activity, impacting many pests that are currently controlled by MB. This method also has the potential to be combined with other pest management tools, including grafting using pathogen-resistant rootstocks, as well as soil applications of biological control agents.

These novel alternatives to MB are focused on various components of potential systems that will result in the level of broad-spectrum protection against pests that growers have depended on MB to provide up till now. All of the proposed alternative methods require a more thorough understanding of the pest complexes in a given field, as well as attention to fertilization, irrigation management, and cultivar selection.

Apart from production advantages offered by grafting, alternative soil fumigants and ASD, an important, but often overlooked, issue is the effects of such production practices on product quality. It is essential that new production practices not have negative impact on product quality and it would be desirable if there were positive effects resulting as a consequence of these new practices. Results of experiments conducted to determine the effects of grafting on vegetable fruit quality have been reviewed (Davis et al., 2008 and references therein); however, the results have been inconsistent and even contradictory. Although there have been reports regarding the effects of alternative soil fumigants (Kokalis-Burelle et al., 2008) and ASD (e.g., Butler et al., 2012a, 2012b; Goud et al., 2004; Messiha et al., 2007) on soilborne pests and crop productivity, we are not aware of any published research regarding the effects of alternative soil fumigants and ASD on product quality. The objective of the research reported herein was to determine how production practices that appear to be promising alternatives to MB soil fumigation affect product quality. To that end we sought to determine the effects of alternative production practices on fruit quality attributes of watermelons, muskmelons, bell peppers, and eggplant.

This research was supported by in part by two NIFA, Methyl Bromide Transitions Grants, 2007-03298 "Use of grafted seedlings for methyl bromide transition in open-field fresh vegetable production" and 2007-02952 "Optimizing anaerobic soil disinfestation as an alternative to methyl bromide fumigation."

Mention of a trademark or proprietary product is for identification only and does not imply a guarantee or warranty of the product by the U.S. Department of Agriculture. The U.S. Department of Agriculture prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation, and marital or family status.

*Corresponding author; phone: (772) 462-5836; email: greg.mccollum@ars.usda.gov

†Current position: Department of Plant Sciences, University of Tennessee

Materials and Methods

Experimental treatments

Two field experiments were conducted; the first to determine the effects of grafting and alternative fumigants on muskmelon (2008) and watermelon (2009) production; the second to determine the effects of ASD on bell pepper (2009) and eggplant (2010) production. Details regarding treatments and experimental design for the grafting/fumigant trial and for the ASD trials have been published elsewhere (Kokalis-Burelle et al., 2008 and Butler et al. 2012a, respectively). Briefly, a split plot experiment was used to evaluate grafted melon (*Cucumis melo* or *Citrullus lanatus*) in soil fumigated with MB (200 lb/acre, 67:33 MB:chloropicrin), iodomethane (100 lb/acre, 50:50 iodomethane:chloropicrin, Midas®, Arysta LifeScience Corp.), dimethyl disulfide (50 gal/acre, 79:21 DMDS:chloropicrin, Paladin™ + chloropicrin, United Phosphorous, Inc.), and an herbicide-only control (Dual Magnum™, Syngenta Crop Protection; Matrix®, DuPont; and Sandea®, Gowen Co.). The ASD approach investigated in Florida involves the incorporation of a nitrogenous organic amendment, in this case, composted broiler litter and a labile carbon source, molasses. The materials are bed-incorporated, tarped with clear film to allow for soil solarization, and water for soil saturation. The experiment described here utilized a factorial design with three water levels, 0, 2, and 4 inches; with or without broiler litter; and with or without molasses. A pepper–eggplant double-crop followed the 3-week treatment period.

Harvesting/maturity indices

Cantaloupes were harvested when the fruit had begun to abscise and reached at least the "one quarter slip" stage. Watermelons (2009) were harvested based on visual estimation of maturity, which included size, rind color and color of the ground spot.

Due to the uneven time of maturity among the muskmelons, harvests were conducted on 4 d with 2–4 d between harvests, over a total harvest period of 10 d; data for the harvests were pooled rather than including harvest time as a variable. Watermelons were harvested from all plots on a single day. Eggplant and bell pepper were harvested based on visual estimates of fruit size and there were three harvests for each crop.

Regardless of experiment, crop, or harvest, fruit were inspected and any showing defects or damage were excluded from further analyses.

Fruit quality parameters

All fruit quality parameters were measured within 24 h of harvest. The numbers of fruit evaluated by treatment for muskmelons was 18. Significant plot to plot variation in watermelon production resulted in unequal numbers of fruit for analysis, however in no case were fewer than 7 fruit and no more than 18 fruit evaluated for each treatment. 15 fruit per harvest per treatment were evaluated for bell pepper and eggplant.

Fruit quality parameters measured for muskmelons and watermelons included: external color, internal color, total soluble solids, pH and titratable acidity.

Color measurements were conducted using a CR-300 Minolta Chorma meter (Konica Minolta, Osaka, Japan) in the CIELAB (*L*a*b**) color space. Muskmelon rind color was measured at three spots equidistant around the fruit equator. Watermelon rind color was measured at three spots on the green portion of the rind and at three spots on the ground color section of the fruit. To measure flesh color, a 2-cm-thick longitudinal section was cut from the equator of each fruit. Muskmelon flesh color was measured at three spots equidistant around the circumference of the mesocarp; watermelon flesh color was at three spots in the center of the placenta.

Muskmelon whole fruit compression and flesh puncture force were measured with an Instron Universal Testing Machine (Model 4411, Instron Corp., Canton, MA). Whole fruit compression, at the fruit equator, was measured as the force (N) to compress a whole melon 2 mm using a flat 5-cm-diameter probe at a crosshead speed of 50 mm/min. Two measurements, at 90° angles, were measured on each fruit. Muskmelon flesh puncture was measured as the force (N) to puncture the flesh to a depth of 3 mm using a 0.8-cm-diameter probe at a crosshead speed of 3 mm/min. Flesh puncture measurements were made at three points about 0°, 120°, and 360° around the middle mesocarp of a 2-cm-thick slice cut from the fruit equator.

Total soluble solids (TSS) were measured with a refractometer (Atago RX-5000a; Atago Co. Ltd., Bellevue, WA). Titratable acidity (TA) was determined by titrating 25 mL of juice to pH 8.2 with 0.1 N NaOH using an autotitrator (Metler Toledo DL50); data are expressed as percent citric acid.

Fruit quality parameters measured for eggplant included: diameter at the largest and smallest sections of the fruit, external color, internal color, whole fruit compression, and flesh puncture force. Diameter at the largest (blossom end) and smallest (stem end) portions of the fruit were measured using a ruler. External and internal colors were measured as described above. Whole fruit compression and flesh puncture force were measured using an Instron Universal testing machine. Eggplant flesh puncture was measured as the force (N) required to puncture the flesh using a 2-mm-diameter probe at a cross head speed of 5 mm per minute.

Fruit quality parameters measured for bell peppers included: height and diameter, number of lobes, external color and pericarp wall thickness. External color was measured as described above. Pericarp wall thickness was measured to the nearest mm using an electronic caliper (Mitutoyo Model no. CD67-S8"PS; Mitutoyo Corp., Kawasaki, Japan); two measurements were made on an equatorial section of the fruit.

Results and Discussion

Pest control and yield data for the two experiments described in this report suggest that alternative soil fumigants, grafting and ASD treatments had significant favorable effects on populations of soilborne pests, disease incidence, and yield for each of the four crops considered (Butler et al., 2012a; Kokalis-Burelle et al., 2008). Here we extend those results with data regarding the effects of the treatments on product quality.

Grafting, alternative soil fumigants, muskmelon, watermelon

In this experiment the effects of grafting and alternative soil fumigants on watermelon and muskmelon production were determined. For each crop, analysis of variance was conducted for the effects of rootstock, soil fumigation and their interaction on muskmelon and watermelon fruit quality parameters (Table 1). Among the fruit quality parameters evaluated for muskmelon and watermelon, main effects of rootstock and fumigant were significant for TSS, pH, and TA. Muskmelon TSS averaged about 8.3% overall, which is lower than the 12% to14% typical of commercial muskmelons (Lester et al., 1994; Pratt, 1971). Although harvesters were instructed to harvest fruit only at the

Table 1. Analysis of variance for main effects of rootstock, fumigant and their interactions on watermelon and muskmelon fruit quality parameters.

	Parameter		
Factor	Total soluble solids	pH	Titratable acidity
	Watermelon		
Rootstock	**	**	**
Fumigant	**	*	
Interaction			
	Muskmelon		
Rootstock	**	**	**
Fumigant			
Interaction			

[z]Main effects significant at $P \leq 0.05$ (*) or $P \leq 0.01$ (**).

one-quarter slip or greater stage, it is possible that the fruit were closer to the one-quarter slip than full slip stage meaning that the fruit tended to be less ripe than more ripe at the time of harvest. It is well known that muskmelon TSS continues to increase as long as the fruit is attached to the parent plant (Pratt, 1971); the low TSS observed in our experiment suggests that the muskmelons were harvested earlier than optimum for highest TSS. Effects of grafting on muskmelon TSS were not consistent. Muskmelons produced on rootstock B had the highest TSS, those produced on rootstock C were intermediate , and non-grafted plants were lowest in TSS (Table 2). In other reports the effects of grafting on muskmelon TSS have also been inconsistent with some suggesting significant effects of grafting on TSS and other suggesting no difference; inconsistencies may either be a result of rootstock scion combinations considered in various experiments or perhaps differences in fruit maturity at the time of harvest (Davis et al., 2008; Davis and Perkins-Veazie, 2005). Muskmelon pH was lower for non-grafted plants than for grafted plants; however, only fruit produced on rootstock C had significantly higher pH than fruit from non-grafted plants. Titratable acidity, as expected based on pH, was highest in muskmelons produced on non-grafted plants and significantly lower from grafted plants on either rootstock.

Watermelon TSS averaged 10.6% in this experiment, a value typical for watermelons in other reports (Davis and Perkins-Veazie, 2005; Karaca et al., 2012; Pardo et al., 1997). Rootstock effects on watermelon TSS were significant (Table 1) with highest TSS in fruit produced on rootstock B lowest TSS on rootstock C and intermediate TSS on non-grafted plants (Table 3). Watermelon pH was significantly lower in fruit produced on rootstock C than for fruit produced on non-grafted plants or plants grown on rootstock B. Watermelon TA did not differ significantly between fruit produced on non-grafted plants and fruit produced on rootstock B, but for both was significantly lower than for rootstock C.

Table 2. Main effects of rootstock and fumigation treatments on muskmelon total soluble solids, pH, and titratable acidity. Six fruit were measured for each rootstock × fumigant combination.

	Parameter		
Factor	Total soluble solids (%)	pH	Titratable acidity (% citric)
Rootstock			
Own	7.9 b[z]	6.7 b	0.064 a
B	8.6 a	6.8 ab	0.056 b
C	8.3 ab	6.9 a	0.056 b
Fumigant			
MB	8.3	6.8	0.061
DMDS	7.9	6.7	0.064
Midas	8.3	6.9	0.055
None	8.5	6.9	0.057

[z]Parameter means within factors not followed by the same letter differ significantly by Duncan's Multiple Range test, $\alpha = 0.05$.

Anaerobic soil disinfestation, bell pepper, eggplant

In this experiment the effects of anaerobic soil disinfestation treatments on bell pepper and eggplant product quality were determined. For each crop there were three harvest times for which fruit quality was analyzed. Analysis of variance was conducted for the main effects of harvest, ASD treatment (factorial combinations of water, chicken litter, and molasses) and their interaction on bell pepper fruit quality parameters (Table 4). Bell pepper fruit quality parameters that were measured included: height and diameter, number of lobes, external color and pericarp wall thickness. Harvest had significant effects on bell pepper fruit quality parameters. ASD treatment effects were significant only for fruit height and external color, with significant interactions between harvest and ASD treatment only for external color.

Main effects means of bell pepper fruit quality parameters are presented in Table 5. Bell pepper fruit height was significantly reduced from the first harvest to the last. Bell pepper fruit height decreased consistently with time of harvest; with each harvest significantly different from the others. Curiously, although the height of bell pepper fruit showed such a consistent change with harvest, fruit weight did not show the same trend. Bell pepper fruit weights were significantly different at each harvest and were greatest for the second harvest, least for the third harvest

Table 3. Main effects means for rootstock and fumigation treatments on watermelon total soluble solids, pH, and titratable acidity. A minimum of 7 and maximum of 18 fruit were measured for each rootstock × fumigant combination.

	Parameter		
Factor	Total soluble solids (%)	pH	Titratable acidity (% citric)
Rootstock			
Own	10.6 ab[z]	5.7 a	0.12 b
B	10.7 a	5.7 a	0.13 b
C	10.4 b	5.5 b	0.14 a
Fumigant			
MB	10.7 a	5.7 a	0.13
DMDS	10.6 a	5.6 ab	0.13
Midas	10.5 a	5.7 a	0.12
None	10.1 b	5.5 b	0.12

[z]Parameter means within factors not followed by the same letter differ significantly by Duncan's Multiple Range test, $\alpha = 0.05$.

Table 4. Analysis of variance for main effects of harvest, anaerobic soil disinfestation (ASD) treatment and their interactions on bell pepper fruit quality parameters.

	Parameter				
Factor	Wt	Ht	Lobes/fruit	Wall thickness	Hue
Harvest	**[z]	**	**	**	**
Treatment		**			**
Interaction					*

[z]Effects significant at $P \leq 0.05$ (*) or $P \leq 0.01$ (**).

Table 5. Main effects means for harvest and anaerobic soil disinfestation (ASD) treatment for bell pepper fruit quality parameters.

	Parameter					
Factor	Ht (mm)	Diam (mm)	Wt (g)	Lobes	Wall thickness	Hue
Harvest						
1	94.0 a[z]	84.2	212.1 b	3.6 b	5.8 c	131.3 a
2	85.5 b	84.3	222.4 a	3.7 a	6.6 a	129.2 b
3	80.3 c	84.1	203.5 c	3.8 a	6.4 b	127.8 c
Water						
0	86.1	84.3	208.9	3.7	6.2 b	129.2
2	87.2	83.7	216.1	3.7	6.3 a	129.5
4	86.5	84.5	213.1	3.7	6.3 a	129.6
Litter						
–	88.3 a	84.0	214.9	3.6 b	6.3	130.1 a
+	84.9 b	84.3	210.6	3.8 a	6.3	128.8 b
Molasses						
–	86.8	84.9 a	217.8 a	3.7 a	6.3	129.6
+	86.4	83.4 b	207.5 b	3.6 b	6.2	129.3

[z]Parameter means within factors not followed by the same letter differ significantly by Duncan's Multiple Range test, $\alpha = 0.05$.

Means were calculated based on 15 fruit at each harvest time for each treatment.

and intermediate for the first harvest. Number of lobes per fruit increased with harvest; fruit from the second and third harvests had significantly more lobes than did fruit from the first harvest. Wall thickness was greatest at the second harvest, least at the first harvest and intermediate at the third harvest. Hue angle showed a consistent decrease from the first to the third harvest, with each harvest significantly different from the others. Main effects of initial volume of water applied on bell pepper wall thickness with levels 2 and 4 being similar, but both significantly greater than 0 water. Litter had significant effects on bell pepper fruit height, lobe number and external color. Plants treated with litter had lower height, more lobes and lower hue angle than did plants not treated with litter. Molasses treatment significantly reduced fruit diameter, weight and lobe number compared with plants that were not treated with molasses.

Results of the analysis of variance for effects of harvest, ASD treatment and their interactions on eggplant fruit quality parameters are presented in Table 6. Main effects of harvest for top and bottom fruit diameter, whole fruit compression, hue and L* were significant; ASD treatment effects were significant for top and bottom fruit diameter and flesh puncture. No harvest by ASD treatment interaction was significant. Main effects means of eggplant fruit quality parameters are presented in Table 7. Eggplant fruit weight and height were greatest at the first harvest,

Table 6. Analysis of variance for main effects of harvest, anaerobic soil disinfestation (ASD) treatment and their interactions on eggplant fruit quality parameters.

	Parameter							
			Diam					
Factor	Wt	Ht	Top	Bottom	Compression	Puncture	Hue	L
Harvest			**[z]	**	**	nd	*	**
Treatment			*	*		**		
Interaction								

[z]Effects $P \leq 0.05$ (*); $P \leq 0.01$(**) ; nd, not determined, puncture was measured only for a single harvest.

Table 7. Main effects of anaerobic soil disinfestation (ASD) treatments and harvest on eggplant fruit quality parameters.

	Parameter						
			Diam				
Factor	Wt (g)	Ht (mm)	Top (mm)	Bottom (mm)	Compression (N)	Hue	L
Harvest							
1	500.2 a[z]	176.7 a	67.1 a	86.3 a	12.8 c	388.4 a	84.8 a
2	369.9 b	157.6 b	62.8 b	80.5 b	24.5 b	335.9 ab	84.7 a
3	312.3 c	135.7 c	62.3 b	78.7 b	33.8 a	322.1 b	83.9 b
Water							
0	391.1	156.8	63.4	81.5	24.2 ab	338.7 ab	84.5
2	411.5	156.7	64.0	82.2	24.3 a	323.0 b	84.6
4	417.3	159.8	64.5	80.5	22.8 b	349.8 a	84.2
Litter							
–	372.2 b	154.7 b	62.2 b	79.6 b	23.5	330.8	84.1 b
+	438.6 a	160.4 a	65.7 a	83.4 a	24.2	339.7	84.8 a
Molasses							
–	403.2	156.6	64.1	82.0	23.2	334.4	84.4
+	409.4	158.5	63.7	81.0	24.5	336.2	84.6

[z]Parameter means within factors not followed by the same letter differ significantly by Duncan's Multiple Range test.

Means were calculated based on 15 fruit at each harvest time for each treatment.

intermediate at the second harvest and least at the third harvest. Diameter at the stem end (top) and blossom end (bottom) were significantly greater at the first harvest than at the second and third harvests, which did not differ significantly from each other. Eggplant whole fruit compression differed significantly among the harvests and was least at the first harvest and greatest at the third harvest. This increase in compression force may be a reflection of the decrease in fruit size that occurred during harvest. Hue angle and L* values were greatest at the first harvest, least at the third harvest and intermediate at the second harvest.

Neither initial amount of water applied nor application of molasses had significant effect on fruit size. In contrast, effects of litter were significant for fruit weight, height, and top and bottom diameters. Water treatments had significant effects on both on compression force and hue angle. Fruit produced with water level 2 having the greatest compression force and level 4 the lowest, fruit from plots receiving no water treatment were intermediate in compression force. Fruit produced with water level 4 had the greatest hue angle whereas those at water level 2 had the lowest hue angle, and fruit from plots receiving no water were intermediate in hue angle. For each size parameter, fruit from plots treated with litter were significantly larger than were fruit from plots that were not treated with litter. Fruit L* values, a measure of lightness, were also significantly increased by treatment with litter.

Conclusion

Results of this study demonstrate that production practices developed to provide alternatives to methyl bromide pre-plant soil disinfestation can have significant impacts on product quality. Our data, taken together with other recent reports (Abu-Sahara, 2011; Davis et al, 2008; Diass et al., 2008; Gisbert et al., 2011), indicate that evaluation of product quality should be included as a component of research in the development of novel production practices. Conducting meaningful experiments to determine the effects of production practices on product quality presents challenges including regard for the appropriate maturity indices, harvest time, numbers of treatments (frequently greater than five), and volume of product available from each experimental unit. It is important that follow-up trials be conducted, with fewer numbers of treatments, to confirm results and to evaluate additional variables such as shelf-life, nutritional components, and consumer preference.

Literature Cited

Abu-Sahara, A. 2011. Influence of agricultural practices on fruit quality of bell pepper. Pak. J. Biol. Sci. 14:876–881.

Butler, D.M., N. Kokalis-Burelle, J. Muramoto, C. Shennan, T.G. McCollum, and E.N. Rosskopf. 2012a. Impact of anaerobic soil disinfestation combined with soil solarization on plant-parasitic nematodes and introduced inoculum of soilborne plant pathogens in raised-bed vegetable production. Crop Protection 39:33–40.

Butler, D.M., E.N. Rosskopf, N. Kokalis-Burelle, J.P. Albano, J. Muramoto, and C. Shennan. 2012b. Exploring warm-season cover crops as carbon sources for anaerobic soil disinfestation (ASD). Plant Soil 355:149–165.

Davis, A.R., P. Perkins-Veazie, R. Hassell, A. Levi, S.R. King, and X. Zhang. 2008. Grafting effects on vegetable quality. HortScience 43:1670–1672.

Davis, A.R. and P. Perkins-Veazie. 2005. Cucurbit Gen. Coop. Rpt. 28–29:39–42.

Diass, N., M.G. Lobo, and M. Gonzalez. 2008. Changes in postharvest quality of Swiss chard grown using 3 organic pre-harvest treatments. J. Food Sci. 73:S314–320.

Gisbert, C., J. Prohens, M. Raigon, J.R. Stommel, and F. Nuez. 2011. Eggplant relatives as sources of variation for developing new rootstocks: Effects of grafting on eggplant yield and fruit apparent quality and composition. Sci. Hort. 128:14–22.

Goud, J.K.C., A.J. Termorshuizen, W.J. Blok, and A.H.C. Van Bruggen. 2004. Long-term effect of biological soil disinfestation on Verticillium wilt. Plant Dis. 88:688–694.

Karaca, F., H. Yetisir, I. Solmaz, E. Candir, S. Kurt, N. Sari, and Z. Guler. 2012. Rootstock potential of Turkish *Lagenaria siceraia* germplasm for watermelon: Plant growth, yield and quality. Turk. J. Agr. For. 36:167–177.

Kokalis-Burelle, N., E.N. Rosskopf, M. Bausher, G. McCollum, and C. Kubota. 2008. Alternative fumigants and grafting for tomato and double-cropped muskmelon production in Florida. Proc. Annu. Intl. Res. Conf. on Methyl Bromide Alternatives and Emissions Reductions 63.1–63.2.

Kubota, C., M. A. McClure, N. Kokalis-Burelle, M.G. Bausher, and E.N. Rosskopf. 2008. Vegetable grafting: History, use, and current technology status in North America. HortScience 43:1664–1669.

Lester, G.E., N.F. Oebker, and J. Coons. 1994. Preharvest furrow and drip irrigation schedule effects on postharvest muskmelon quality. Postharvest Biol. Tech. 4: 57–63.

Louws, F.J., D.L. Rivard, and C. Kubota. 2010. Grafting fruit vegetables to manage soilborne pathogens, foliar pathogens, arthropods, and weeds. Sci. Hort. 127:127–146.

Messiha, N., A. Van Diepeningen, M. Wenneker, A. Van Beuningen, J. Janse, T. Coenen, A. Termorshuizen, A. Van Bruggen, and W. Blok. 2007. Biological soil disinfestation (BSD), a new control method for potato brown rot, caused by *Ralstonia solanacearum* race 3 biovar 2. Eur. J. Plant Pathol. 117:403–415.

Pardo, J.E., R. Gomez, M. Tardaguila, and R. Varon. 1997. Quality evaluation of watermelon varieties (*Citrullus vulgaris* S.). J. Food Qual. 20:547–557.

Pratt, H.K. 1971. Melons, p. 207–232. In: A.C. Hulme (ed.). The biochemistry of fruits and their products. Vol. 2. Academic, New York.

Rosskopf, E.N., D. O. Chellemi, N. Kokalis-Burelle, and G.T. Church. 2005. Alternatives to methyl bromide: A Florida perspective. Plant Health Prog. (online) doi:10.1094/php-2005-1027-01-rv.