Grafting for Management of Southern Root-Knot Nematode, *Meloidogyne incognita*, in Watermelon

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ABSTRACT

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Four bottle gourd (*Lagenaria siceraria*) cultivars, one squash (*Cucurbita moschata* × *C. maxima*) hybrid, five wild watermelon (*Citrullus lanatus* var. *citroides*) germplasm lines, and one commercial wild watermelon (*C. lanatus* var. *lanatus*) cultivar were evaluated as rootstocks for cultivated watermelon (*C. lanatus* var. *lanatus*) in fields infested with the southern root-knot nematode (*Meloidogyne incognita*) in Charleston, SC in 2007 and 2008, and in Quincy, FL in 2008. Commercial watermelon ‘Fiesta’ (diploid seeded) and ‘Tri-X 313’ (triploid seedless) scions were grafted onto the rootstocks in 2007 and 2008, respectively. In 2007, the plants grafted on rootstock from the wild watermelon germplasm line RKVL 318 had significantly less ($P < 0.05$) root galling than nongrafted ‘Fiesta’ watermelon or plants with the squash hybrid or bottle gourd rootstocks. In 2008, ‘Fiesta’ plants with rootstocks from all five wild watermelon germplasm lines and the commercial watermelon rootstock had significantly less ($P < 0.05$) root galling than plants with the squash hybrid or bottle gourd rootstocks. Root galling of the squash hybrid and bottle gourd rootstocks was severe (78 to 99%) in both years. Root galling for nongrafted ‘Fiesta’ and ‘Tri-X 313’ watermelon was 36 and 50%, respectively. Root galling for the wild watermelon germplasm lines ranged from 11 to 34% and 36 to 44% in 2007 and 2008, respectively. Wild watermelon germplasm lines derived from *C. lanatus* var. *citroides* were identified that may be useful as resistant rootstocks for managing root-knot nematodes in watermelon.

Root-knot nematodes (*Meloidogyne* spp.) cause extensive damage to cucurbit crops, including watermelon (*Citrullus lanatus* var. *lanatus*), melon (*Cucumis melo*), squash (*Cucurbita pepo*), and pumpkin (*Cucurbita moschata*) (10,14,16, 20,23). Root-knot nematodes also increase the severity of soilborne diseases such as Fusarium wilt in watermelon (14). The primary control method for root-knot nematodes in watermelon and other cucur-

bit crops has been soil fumigation with methyl bromide. Approximately 6% of all methyl bromide used for preplant soil treatment in vegetable crops throughout the world has been for watermelon and melon (21). However, methyl bromide is being excluded from use in the United States (13,22). Furthermore, restrictions on the use of other soil fumigants and nematocides also are becoming more stringent. Consequently, managing root-knot nematodes in high-value crops is becoming more difficult, and predicted annual yield losses for watermelon are expected to reach 15 to 20% (8).

Grafting scions of watermelon cultivars onto resistant cucurbit rootstocks is currently being considered by seed company breeders and extension scientists as a practical alternative to preplant soil fumigation with methyl bromide for managing soilborne diseases. Cucurbit grafting has been practiced in Asia (11,12) for many years and has gained acceptance as a production method among growers in the Mediterranean region, including Israel (1,5) and Turkey, which is the world’s second largest

producer of watermelons (25). Grafting has provided a quick and effective solution for managing soilborne diseases such as Fusarium wilt in watermelon (1,9,15, 25,26) and has alleviated the urgency to rapidly develop Fusarium wilt-resistant watermelon cultivars. Until recently, grafting of cucurbits has been considered impractical in the United States because of the high costs associated with grafting and maintaining newly grafted seedlings. However, the reduction of farmland acreage available to U.S. growers for vegetable cultivation along with the ban on methyl bromide has made grafting a realistic alternative for watermelon and melon growers.

Recently, bottle gourds (*Lagenaria siceraria*) and interspecific squash hybrids (*Cucurbita moschata* × *Cucurbita maxima*) were evaluated as rootstocks for commercial watermelon production in the southeastern United States (2). In North Florida field trials, a severe infestation of root-knot nematodes unexpectedly occurred on all bottle gourd and *Cucurbita* rootstocks (unpublished data). In China, where farmland is limited and farmers are being forced to grow the same crop in successive years, root-knot nematodes have become a serious limitation for grafting to bottle gourd and *Cucurbita* rootstocks (Yong Xu, National Engineering Research Center for Vegetables, Beijing, China; *personal communication*). Identifying root-knot-resistant germplasm and developing resistant rootstocks would provide an economical and environmentally friendly method for managing root-knot nematodes in watermelon and melon.

A recent evaluation of 45 U.S. Plant Introductions (PIs) of bottle gourd (*L. siceraria*) collected from different geographic areas of the world indicated that many bottle gourds are highly susceptible to root-knot nematodes (6). However, in recent evaluations of the U.S. PI Watermelon Collection for resistance to root-knot nematodes, we identified several accessions of the wild-type watermelon *Citrullus lanatus* var. *citroides*, which thrives in central and southern regions of Africa, that

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are moderately resistant to *Meloidogyne incognita* and *M. arenaria* races 1 and 2 (17,18).

Our objectives were to (i) compare rootstocks of experimental lines of *C. lanatus* var. *citroides* with commercial rootstocks of *L. siceraria*, *C. moschata* × *C. maxima*, and *C. lanatus* var. *citroides* for managing southern root-knot nematodes in grafted watermelon in Charleston, SC and Quincy, FL; and (ii) identify wild watermelon lines that may be useful for developing superior rootstocks that are resistant to root-knot nematodes and produce high yield and fruit quality on the grafted watermelon cultivars.

MATERIALS AND METHODS

Experiment 1, Charleston, SC, 2007.

The experiment was conducted in a field site at the U.S. Vegetable Laboratory in Charleston, SC that was infested with *M. incognita*. Watermelon scion ‘Fiesta’ plants and rootstock plants were grown in 50-cell pro-trays (TLC Polyform, Inc, Minneapolis, MN). Three weeks after seeding, ‘Fiesta’ watermelon scions were grafted to each of the rootstocks using the one-cotyledon method (2). On 16 July 2007, grafted plants were transplanted into single-row plots on raised white plastic mulch beds on 2.0-m centers. The experimental design was a randomized complete block with six replications and each plot consisted of a single row of six watermelon plants spaced 60-cm apart. Five rootstock populations (designated RKVL) of *C. lanatus* var. *citroides* developed at the U.S. Vegetable Laboratory, United States Department of Agriculture–Agricultural Research Service in Charleston, SC were selected for use in the experiment. Commercial rootstocks or breeding lines also included in the study were four *L. siceraria* rootstocks ‘Emphasis’,

WMXP 3938, WMXP 3944, and WMXP 3945; one *C. lanatus* var. *citroides* cv. ‘Ojakkyo’; one *C. moschata* × *C. maxima* hybrid ‘Strong Tosa’; and nongrafted diploid seeded watermelon ‘Fiesta’ (also used as the scion for all grafted rootstocks). Fruit were harvested and fruit weight and fruit numbers were recorded during the entire growing season. Approximately 12 weeks after planting, shoots of all plants were clipped and roots were lifted from soil and washed. Root systems of each plant were stained using the method of Thies et al. (19) and evaluated for severity of galling and egg mass production. Percentages of root system galled or covered in egg masses were visually estimated and recorded for each plant. Root systems from each plot were bulked, weighed, and cut into 1- to 2-cm pieces, and eggs were extracted in 1.0% NaOCl (3). Eggs were counted using a stereomicroscope. Galling and egg mass percentages were arcsine transformed and eggs per gram fresh root were $\log_{10}(x + 1)$ transformed for analysis of variance to normalize data. Analysis of variance was conducted using the GLM procedure of SAS v.9.1 for Windows (SAS Institute Inc., Cary, NC) and means were separated using Fisher’s protected least significant difference (LSD).

Experiment 2, Charleston, SC and Quincy, FL, 2008.

Two field experiments were conducted in 2008, one experiment in Charleston, SC, at the same field site used in 2007, and another experiment in Quincy, FL. The experimental methods and plant genotypes used were the same as those previously described for the 2007 experiment, except that the seedless watermelon ‘Tri-X 313’ was used as the scion in the 2008 experiments. Plots were laid out as in 2007 and grafted plants were transplanted into the field on 3 June 2008 in Quincy, FL and on 24 June 2008 in

Charleston, SC. The experimental design at each location was a randomized complete block design with six replicates. Numbers of fruit per plot and fruit mass were recorded during the entire growing season. Approximately 12 weeks after transplanting, roots were lifted from the soil. Percentages of root galling and egg masses present on the roots were recorded. Eggs of *M. incognita* were extracted from roots and counted as described for the 2007 experiment. Galling and egg mass percentages were arcsine transformed and eggs per gram fresh root were $\log_{10}(x + 1)$ transformed for analysis of variance to normalize the data. Data were combined from both locations and then analyzed using the GLM procedure of SAS and means were separated by Fisher’s protected LSD.

RESULTS

Experiment 1, Charleston, SC, 2007.

Root-knot nematode infection was severe in the bottle gourd (*L. siceraria*) and the squash hybrid (*C. moschata* × *C. maxima*) rootstocks, with gall indices ranging from 3944 to 99.3% for ‘Strong Tosa’ (Table 1). Percentage of root galling was significantly higher ($P = 0.05$) on the bottle gourd (Fig. 1A) and squash hybrid (Fig. 1B) rootstocks than on the watermelon ‘Fiesta’ (nongrafted) and the *C. lanatus* var. *citroides* lines (Fig. 1C and D). Nematode reproduction was very high in ‘Strong Tosa’ (12,497 eggs/g of fresh root) and reproduction was moderate in the bottle gourds (1,251 eggs/g of fresh root for ‘Emphasis’ to 2,541 eggs/g of fresh root for WMXP 3944). Nongrafted ‘Fiesta’ supported 1,101 *M. incognita* eggs/g of fresh root. The *C. lanatus* var. *citroides* experimental lines and ‘Ojakkyo’ all had fewer than 500 eggs/g of fresh root. Nongrafted cultivated watermelon ‘Fiesta’ and

Table 1. Percentage of root system galled and covered with egg masses of *Meloidogyne incognita*, numbers of *M. incognita* eggs per gram of fresh root, total fruit yield, and total fruit number for ‘Fiesta’ diploid seeded watermelon grafted on rootstocks of *Lagenaria siceraria*, *Cucurbita moschata* × *C. maxima*, *Citrullus lanatus* var. *citroides*, and nongrafted ‘Fiesta’ in Charleston, SC 2007 field study^a

Rootstock or nongrafted scion genotype	Root system galled (%) ^b	Root system covered with egg masses (%) ^b	No. of eggs/g of fresh root ^c	Total yield (kg/plot)	Total fruit no./plot
<i>Lagenaria siceraria</i>					
‘Emphasis’	1.050 c (79.7)	0.825 b (69.5)	2.717 b–d (1,251)	21.287 de	3.67 cd
WMXP 3945	1.269 cd (91.7)	1.051 bc (82.5)	3.184 c–e (2,271)	22.180 de	4.00 de
WMXP 3938	1.432 d (97.4)	1.195 cd (90.3)	2.989 cd (1,598)	18.672 c–e	3.67 cd
WMXP 3944	1.146 c (84.8)	0.817 b (68.4)	3.308 de (2,541)	20.286 de	4.00 de
<i>Citrullus lanatus</i> var. <i>lanatus</i>					
‘Fiesta’ (nongrafted)	0.394 b (36.4)	0.228 a (22.1)	2.345 a–c (1,101)	25.568 e	5.08 e
<i>C. lanatus</i> var. <i>citroides</i>					
‘Ojakkyo’	0.251 ab (24.4)	0.131 a (12.9)	1.660 a (176)	3.830 a	0.67 a
RKVL 301	0.376 b (34.2)	0.169 a (15.9)	1.642 a (182)	10.420 a–c	2.33 bc
RKVL 318	0.112 a (11.1)	0.035 a (3.5)	2.010 ab (186)	7.134 ab	1.67 ab
RKVL 315	0.167 ab (16.5)	0.090 a (9.0)	2.108 ab (190)	5.240 a	1.17 ab
RKVL 303	0.206 ab (20.1)	0.148 a (14.4)	2.012 ab (440)	3.267 a	0.83 ab
RKVL 302	0.237 ab (23.2)	0.119 a (11.8)	1.954 ab (382)	2.457 a	0.67 a
<i>Cucurbita moschata</i> × <i>C. maxima</i>					
‘Strong Tosa’	1.519 d (99.3)	1.506 d (99.0)	4.023 e (12,497)	15.783 b–d	3.33 cd

^a Means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Fisher’s protected least significant difference.

^b Data was arcsine transformed before analysis. Nontransformed data are shown in parentheses.

^c Data was $\log_{10}(x + 1)$ transformed before analysis. Nontransformed data are shown in parentheses.

'Fiesta' grafted on bottle gourd (WMXP 3938, WMXP 3944, WMXP 3945, and 'Emphasis') or squash hybrid ('Strong Tosa') rootstocks produced the heaviest fruit yields (range of 15.8 to 25.6 kg/plot of six plants) and the greatest numbers of fruit (3.33 to 5.08 fruit/plot of six plants). 'Fiesta' grafted on *C. lanatus* var. *citroides* rootstock produced the lowest fruit yields and fewest numbers of fruit ($P = 0.05$). 'Fiesta' grafted on *C. lanatus* var. *citroides* rootstocks produced highly vigorous vegetative growth but few fruit. We attribute the low yield of the *C. lanatus* var. *citroides* to the late planting date (16 July).

Experiment 2, Charleston, SC and Quincy, FL, 2008. Results of the analysis of variance showed that there were no cultivar-test interactions; therefore, analyses of the combined data sets are shown (Table 2). Root-knot nematode infestation was severe at both test sites in South Carolina and Florida. The bottle gourd and squash hybrid rootstocks were highly susceptible, with root galling percentages ranging from 78.0% for WMXP 3945 to 96.1% for WMXP 3944. The bottle gourd and squash hybrid rootstocks had significantly higher percentages of root galling ($P = 0.05$) than 'Tri-X 313' watermelon (nongrafted and self-grafted, 49.7 and 50.5%, respectively), and all of the *C. lanatus* var. *citroides* accessions (range: 36.3% for RKVL 301 and RKVL 302 to 43.9% for RKVL 315). Nematode reproduction was high for the bottle gourds (2,792 eggs/g of fresh root for WMXP 3944 to 5,192 eggs/g of fresh root for WMXP 3938) and for the squash hybrid 'Strong Tosa' (3,279 eggs/g of fresh root). Nongrafted and self-grafted 'Tri-X 313' supported 386 and 587 *M. incognita* eggs/g of fresh root, respectively. All of the *C. lanatus* var. *citroides* experimental lines

had fewer than 350 eggs/g of fresh root and 'Ojakkyo' had 711 eggs/g of fresh root. WMXP 3944 had significantly fewer surviving plants per plot than all of the other rootstock entries, including 'Tri-X 313' (self-grafted and nongrafted). 'Strong Tosa' had significantly fewer surviving plants per plot than RKVL 301 and RKVL 303. No significant differences were detected for total fruit yield (kilograms per plot) and total fruit number per plot.

DISCUSSION

Results of the present studies indicate that watermelon plants grafted on rootstocks of the wild watermelon (*C. lanatus* var. *citroides*) germplasm were resistant or moderately resistant to the southern root-knot nematode, *M. incognita*. In 2007, plants with the *C. lanatus* var. *citroides* rootstocks exhibited significantly less root galling than plants with the squash hybrid and bottleneck gourd rootstocks. Overall, the 2007 field experiment in Charleston, SC produced relatively low yields with all rootstock types. Although there was more nematode damage to their root systems, the bottle gourd and the squash hybrid rootstocks had a clear advantage in inducing fruit development over *C. lanatus* var. *citroides* rootstocks. In 2007, *C. lanatus* var. *citroides* produced highly vigorous vegetative growth but few female flowers and fruit. We attribute the low yield of *C. lanatus* var. *citroides* to the late planting date (16 July 2007). Typically, the bottle gourd and squash hybrid rootstocks perform well under high temperatures such as occur in August in Charleston, SC.

In contrast with 2007, the two fields planted in 2008 produced comparable yields for all rootstock types. Furthermore, the *C. lanatus* var. *citroides* rootstocks were significantly more resistant to root-

knot nematodes, having significantly less nematode reproduction and galling symptoms on their root systems, compared with the *L. siceraria* and squash hybrid rootstocks. These results indicate that the wild watermelon *C. lanatus* var. *citroides* lines, such as RKVL 315 and RKVL 318, could be useful rootstocks for watermelon. Further studies are underway to identify additional potential *C. lanatus* var. *citroides* rootstocks for watermelon.

The results in this study confirmed that the *Citrullus* accessions tested here showed durability of resistance to root-knot nematode in the field. These results are consistent with our earlier findings in the evaluation of seedlings of *Citrullus* accessions in greenhouse experiments (17,18). Grafting allows a rapid response to the development of new races of a pathogen if resistant rootstocks are available and provides an alternative to breeding new resistant watermelon cultivars for controlling soilborne diseases. In Japan and other parts of Asia, watermelons have been grafted on cucurbit rootstocks to suppress Fusarium wilt caused by *Fusarium oxysporum* f. sp. *niveum* W.C. Snyder and H. N. Hansen that causes Fusarium wilt in watermelon but not in the cucurbit rootstocks (1,9). However, the cucurbit rootstocks presently used for grafting watermelon are highly susceptible to root-knot nematodes. Here, the *C. lanatus* var. *citroides* rootstocks may offer a solution for suppressing root-knot nematodes and be useful to rotate with the cucurbit rootstocks if watermelon is grown in successive years in the same fields. The *C. lanatus* var. *citroides* rootstocks may also contribute to enhanced tolerance to abiotic stresses, more efficient water and nutrient use, and improved fruit yield and quality.

Table 2. Percentage of root system galled and covered with egg masses of *Meloidogyne incognita*, numbers of *M. incognita* eggs per gram of fresh root, final plant stand count, total fruit yield, and total fruit number for 'Tri-X 313' triploid seedless watermelon grafted on rootstocks of *Lagenaria siceraria*, *Cucurbita moschata* × *C. maxima*, *Citrullus lanatus* var. *citroides*, and self-grafted and nongrafted 'Tri-X 313' in Charleston, SC and Quincy, FL 2008 field studies^a

Rootstock or nongrafted scion genotype	Root system galled (%) ^y	Root system covered with egg masses (%) ^y	No. of eggs/g of fresh root ^z	Final stand count	Total yield (kg/plot)	Total fruit no./plot
<i>Lagenaria siceraria</i>						
'Emphasis'	1.097 bc (79.1)	0.937 bc (70.2)	3.620 a (4,871)	4.18 bc	46.16 a	7.73 a
WMXP 3945	1.055 b (78.0)	0.813 b (68.7)	3.438 a (3,255)	4.167 bc	43.73 a	7.83 a
WMXP 3938	1.292 b-d (90.9)	1.046 b (77.6)	3.575 a (5,192)	4.667 bc	18.27 a	4.17 a
WMXP 3944	1.413 d (96.1)	1.273 d (90.6)	3.442 a (2,792)	2.167 a	23.96 a	5.17 a
<i>C. lanatus</i> var. <i>lanatus</i>						
'Tri-X 313' nongrafted	0.592 a (49.7)	0.472 a (39.6)	2.358 b (386)	4.083 bc	42.16 a	7.08 a
'Tri-X 313' self-grafted	0.552 a (50.5)	0.381 a (35.9)	2.645 a (587)	4.500 bc	46.33 a	7.83 a
<i>C. lanatus</i> var. <i>citroides</i>						
'Ojakkyo'	0.428 a (37.7)	0.276 a (23.4)	2.515 a (711)	4.933 bc	45.29 a	7.40 a
RKVL 301	0.375 a (36.3)	0.186 a (18.2)	2.215 b (300)	5.231 c	40.00 a	7.15 a
RKVL 318	0.485 a (43.5)	0.304 a (26.3)	2.377 b (300)	4.875 bc	51.19 a	7.86 a
RKVL 315	0.542 a (43.9)	0.395 a (29.8)	2.380 b (283)	4.667 bc	15.27 a	3.50 a
RKVL 303	0.443 a (39.3)	0.307 a (26.5)	2.047 b (310)	5.143 c	35.66 a	5.64 a
RKVL 302	0.410 a (36.3)	0.307 a (26.5)	2.516 a (346)	4.800 bc	41.27 a	6.13 a
<i>Cucurbita moschata</i> × <i>C. maxima</i>						
'Strong Tosa'	1.370 cd (94.9)	1.195 cd (87.7)	3.455 a (3,279)	3.750 b	44.47 a	7.50 a

^a Means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Fisher's protected least significant difference.

^y Data was arcsine transformed before analysis. Nontransformed data are shown in parentheses.

^z Data was $\log_{10}(x + 1)$ transformed before analysis. Nontransformed data are shown in parentheses.

Fig. 1. Watermelon grafted onto cucurbit rootstocks grown in a field infested with southern root-knot nematode, *Meloidogyne incognita*, Charleston, SC. **A**, 'Emphasis' bottle gourd (*Lagenaria siceraria*) rootstock exhibiting severe root galling caused by root-knot nematodes. **B**, 'Strong Tosa' squash hybrid (*Cucurbita moschata* × *C. maxima*) rootstock exhibiting severe root galling. **C**, RKVL 301 wild watermelon (*C. lanatus* var. *citroides*) rootstock resistant to root-knot nematodes. **D**, RKVL 302 wild watermelon (*C. lanatus* var. *citroides*) rootstock resistant to root-knot nematodes.

It has been difficult to establish resistance to root-knot nematodes in cucurbit crops, including squash, pumpkin, melon, and cucumber. The resistance identified here and in previous studies among the *C. lanatus* var. *citroides* accessions (17,18) might be a result of co-evolution of this species with root-knot nematodes in its center of origin in central Africa (4,7). The *C. lanatus* var. *citroides* accessions can be used not only as rootstocks but also in plant breeding programs to enhance watermelon cultivars for resistance to root-knot nematodes. Studies with different plant species indicated that resistance to root-knot nematodes in many host plant species are the result of gene-for-gene interactions. Still, there is not sufficient data from our preliminary experiments in watermelon to confirm or reject this assumption. The resistant accessions identified here are presently being used in genetic studies to ascertain the mode of

inheritance for defense response to root-knot nematodes in watermelon.

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LITERATURE CITED

1. Cohen, R., Burger, Y., Horev, C., Koren, A., and Edelstein, M. 2007. Introducing grafted cucurbits to modern agriculture. The Israeli experience. *Plant Dis.* 91:916-923.
2. Hassell, R., Memmott, F., and Liere, D. 2008. Grafting methods for watermelon production. *HortScience* 43:1677-1679.
3. Hussey, R. S., and Barker, K. R. 1973. A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. *Plant Dis. Rep.* 57:1025-1028.
4. Jarret, R. L., Merrick, L. C., Holms, T., Evans J., and Aradhya, M. K. 1997. Simple sequence repeats in watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]. *Genome* 40:433-441.
5. Koren, A., and Edelstein, M. 2004. Advantages and limitations of grafted vegetable transplants in Israel. *HortScience* 39:873.
6. Levi, A., Thies, J., Ling, K., Simmons, A. M., Kousik, C., and Hassell, R. 2009. Genetic diversity among *Lagenaria siceraria* accessions containing resistance to root-knot nematodes, whiteflies, ZYMV or powdery mildew. *Plant Genet. Resour.* 7:216-226, Cambridge University Press, doi:10.1017/S1479262109225354.
7. Levi, A., Thomas, C. E., Keinath, A. P., and Wehner, T. C. 2001. Genetic diversity among watermelon (*Citrullus lanatus* and *Citrullus colocynthis*) accessions. *Genet. Resour. Crop Evol.* 48:559-566.
8. Lynch, L., and Carpenter, J. 1999. The economic impacts of banning methyl bromide: where do we need more research? 1999 Annual Research Conference on Methyl Bromide Alternatives and Emissions Reductions. <http://mbao.org/mbpr99.html>
9. Miguel, A., Maroto, J. V., Bautista, A. S., Baixauli, C., Cebolla, V., Pascual, B., Lopez, S., and Guardiola, J. L. 2004. The grafting of triploid watermelon is an advantageous alternative to soil fumigation by methyl bromide for control of Fusarium wilt. *Sci. Hortic.* 103:9-17.
10. Montalvo, A. E., and Esnard, J. 1994. Reaction

- of ten cultivars of watermelon (*Citrullus lanatus*) to a Puerto Rican population of *Meloidogyne incognita*. *J. Nematol.* 26 (Suppl.):640-643.
11. Oda, M. 1993. Present state of vegetable production using grafted plants in Japan. *Agric. Hortic.* 63:1190-1196.
 12. Oda, M. 2002. Grafting of vegetable crops. *Sci. Rep. Agric. Biol. Sci. Osaka Pref. Univ.* 53:1-5.
 13. Osteen, C. 2003. Methyl bromide phase-out proceeds: user request exemptions. *Amberwaves* 1:22-27. (www.ers.usda.gov/amberwaves).
 14. Sumner, D. R., and Johnson, A. W. 1973. Effect of root-knot nematodes on Fusarium wilt of watermelon. *Phytopathology* 63:857-861.
 15. Taylor, M., Bruton, B., Fish, W., and Roberts, W. 2006. Cost benefit analysis of using grafted watermelon for disease control and fresh cut market. Pages 277-285 in: *Proc. Cucurbitaceae 2006*. G. J. Holmes, ed. Universal Press, Raleigh, NC.
 16. Thies, J. A. 1996. Diseases caused by nematodes. Pages 56-58 in: *Compendium of Cucurbit Diseases*. T. A. Zitter, D. L. Hopkins, and C. E. Thomas, eds. American Phytopathological Society, St. Paul, MN.
 17. Thies, J. A., and Levi, A. 2003. Resistance of watermelon germplasm to the peanut root-knot nematode. *HortScience* 38:1417-1421.
 18. Thies, J. A., and Levi, A. 2007. Characterization of watermelon (*Citrullus lanatus* var. *citroides*) germplasm for resistance to root-knot nematodes. *Hortscience* 42:1530-1533.
 19. Thies, J. A., Merrill, S. B., and Corley, E. L., Jr. 2002. Red food coloring stain: New, safer procedures for staining nematodes in roots and egg masses on root surfaces. *J. Nematol.* 34:179-181.
 20. Thomason, I. J., and McKinney, H. E. 1959. Reaction of some Cucurbitaceae to root-knot nematodes (*Meloidogyne* spp.). *Plant Dis. Rep.* 43:448-450.
 21. U.S. Department of Agriculture. 1993. USDA workshop on alternatives for methyl bromide. 29 June-1 July 1993. Crystal City, VA.
 22. U.S. Environmental Protection Agency. 2000. Protection of stratospheric ozone: Incorporation of Clean Air Act amendments for reductions in Class I, Group VI controlled substances. *Fed. Regist.* 65:70795-70804.
 23. Winstead, N. N., and Riggs, R. D. 1959. Reaction of watermelon varieties to root-knot nematodes. *Plant Dis. Rep.* 43:909-912.
 24. Yetisir, H., Caliskan, M. E., Soylu, S., and Sarkar, M. 2006. Some physiological and growth responses of watermelon [*Citrullus lanatus* (Thunb.) Matsum., and Nakai] grafted onto *Lagenaria siceraria* to flooding. *Environ. Exp. Bot.* 58:1-8.
 25. Yetisir, H., and Sari, N. 2007. Rootstock potential of Turkish *Lagenaria siceraria* germplasm for watermelon: plant growth, graft compatibility, and resistance to Fusarium. *Turk. J. Agric. For.* 31:381-388.
 26. Yetisir, H., Sari, N., and Yucel, S. 2003. Rootstock resistance to Fusarium wilt and effect on watermelon fruit yield and quality. *Phytoparasitica* 31:163-169.