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Resistance to Southern Root-knot Nematode (*Meloidogyne incognita*) in Wild Watermelon (*Citrullus lanatus* var. *citroides*)

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Abstract: Southern root-knot nematode (RKN, *Meloidogyne incognita*) is a serious pest of cultivated watermelon (*Citrullus lanatus* var. *lanatus)* in southern regions of the United States and no resistance is known to exist in commercial watermelon cultivars. Wild watermelon relatives (*Citrullus lanatus* var. *citroides*) have been shown in greenhouse studies to possess varying degrees of resistance to RKN species. Experiments were conducted over 2 yr to assess resistance of southern RKN in *C. lanatus* var. *citroides* accessions from the U.S. Watermelon Plant Introduction Collection in an artificially infested field site at the U.S. Vegetable Laboratory in Charleston, SC. In the first study (2006), 19 accessions of *C. lanatus* var. *citroides* were compared with reference entries of *Citrullus colocynthis* and *C. lanatus* var. *lanatus*. Of the wild watermelon accessions, two entries exhibited significantly less galling than all other entries. Five of the best performing *C. lanatus* var. *citroides* accessions were evaluated with and without nematicide at the same field site in 2007. *Citrullus lanatus* var. *citroides* accessions performed better than *C. lanatus* var. *lanatus* and *C. colocynthis*. Overall, most entries of *C. lanatus* var. *citroides* performed similarly with and without nematicide treatment in regard to root galling, visible egg masses, vine vigor, and root mass. In both years of field evaluations, most *C. lanatus* var. *citroides* accessions showed lesser degrees of nematode reproduction and higher vigor and root mass than *C. colocynthis* and *C. lanatus* var. *lanatus*. The results of these two field evaluations suggest that wild watermelon populations may be useful sources of resistance to southern RKN.

Key words: *Citrullus lanatus* var. *citroides*, *Citrullus lanatus* var. *lanatus*, *Meloidogyne incognita*, plant introduction, resistance, southern root-knot nematode, wild watermelon.

The southern RKN (*M. incognita* (Kofoid and White) Chitwood) is a serious pest of watermelon (*C. lanatus* var. *lanatus*) in the southern United States and worldwide (Thomason and McKinney, 1959; Winstead and Riggs, 1959; Sumner and Johnson, 1973; Thies, 1996; Davis, 2007; Thies et al., 2010). Preplant fumigation of soil beds with methyl bromide has been the primary method for controlling RKN in watermelon for decades; however, use of methyl bromide as a soil fumigant is being phased out (U.S. Environmental Protection Agency, 2012). Prior to its phaseout, approximately 6% of methyl bromide applied for preplant soil fumigation in vegetable crops worldwide was used for watermelon and melon (*Cucumis melo* L.) (USDA, 1993). For example, 'Cooperstown' seedless watermelon grown in *M. incognita*-infested soils in Georgia produced significantly greater fruit yields when grown in methyl bromide–treated soil beds compared to that grown in nontreated soil beds (Davis, 2007). Although other soil fumigants including 1,3-D dimethyl disulfide and chloropicrin are available for RKN management, these fumigants are expensive, more difficult to apply than methyl bromide, and present worker safety concerns (Morris et al., 2015). The phaseout of methyl bromide, and high costs and application difficulties associated with other fumigant nematicides, has resulted in increased interest in the development of resistant varieties as a tool for managing RKN in watermelon in the United States and globally.

No cultivated watermelons are known to be resistant to RKN. Winstead and Riggs (1959) evaluated 78 watermelon cultivars and 5 breeding lines for reaction to RKN and found all genotypes were susceptible. In Puerto Rico, 10 watermelon cultivars were evaluated against *M. incognita* and all cultivars were susceptible (Montalvo and Esnard, 1994). Thies and Levi (2003, 2007) developed and evaluated a core collection of *Citrullus* spp. from the U.S. Plant Introduction Watermelon Collection for response to *M. incognita* and *Meloidogyne arenaria* races 1 and 2 in greenhouse tests. They identified several accessions of *Citrullus lanatus* (Thunb.) Matsum. & Nakai var. *citroides* (L. H. Bailey) Mansf. that were moderately resistant to *M. incognita* and *M. arenaria* races 1 and 2. Germplasm lines derived from some of these *C. lanatus* var. *citroides* accessions have performed well as rootstocks for grafted watermelon (Thies et al., 2010, 2015a, 2015b). The objectives of the studies reported in this paper were (i) to evaluate the potential contribution of moderately resistant watermelon accessions to suppression of RKN and associated damage in fields infested with *M. incognita* and (ii) to compare selected watermelon accessions in nematicide-treated and nontreated soils to determine the effectiveness of host resistance for managing *M. incognita*.

Materials and Methods

2006 Field experiment. Characterization of resistance to root-knot nematode in Citrullus lanatus var. citroides accessions: A field site at the U.S. Vegetable Lab in Charleston, SC, was infested with *M. incognita* by planting experimental plots with 'PA 136' pepper (*Capsicum annuum* L.) grown and inoculated with

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M. incognita in the greenhouse. Pepper plants were grown in 50-cell pro-trays (TLC Polyform, Inc, Minneapolis, MN) and inoculated approximately 25 d postemergence with 3,000 eggs of *M. incognita* race 3. On 4 May 2006, pepper plants were transplanted into single-row plots on raised white plastic mulch beds on 2.0-m centers. Each plot contained a single row of 12 pepper plants spaced 60 cm apart. On 10 July 2006, pepper plants were cut to ground level and a single 4-wk-old seedling of each watermelon entry was transplanted adjacent to each of six pepper plants in the center of every plot. Watermelon plants were grown in the greenhouse as previously described for pepper plants, except not inoculated with *M. incognita*. The experimental design was a randomized complete block with six replications and each plot consisted of six watermelon plants. Twenty-three accessions from the U.S. Plant Introduction (PI) Watermelon Collection of *C. lanatus* var. *citroides*, *C. lanatus* var. *lanatus*, and *C. colocynthis* (L.) Schrad. were evaluated (Table 1). Four watermelon cultivars (Ojakkyo, Dixie Lee, Charleston Gray, and Crimson Sweet) were selected as reference entries (Table 1). The reproductive indices ranged from <1.0 to 5.5 for the *C. lanatus* var. *citroides* accessions, 5.4 for 'Charleston Gray' (*C. lanatus* var. *lanatus*), and 8.45 for the *C. colocynthis* accessions (Thies and Levi, 2007). In prior studies, *C. colocynthis* and the cultivars Charleston Gray, Crimson Sweet, and Dixie Lee were determined to be susceptible to *M. incognita* race 3 (Thies and Levi, 2003). Ojakkyo is a *Citrullus* spp. cultivar, which is used as a rootstock for watermelon (Zhang, 2008). Approximately 10 wk 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. (2002) and evaluated for severity of galling, egg mass production, and root system fibrosity. Percentages of root system galled or covered in egg masses were recorded for each plant. Fibrous root ratings and root vigor ratings were assigned on a 1 to 5 qualitative scale (1 = best, 5 = poorest). Root systems from each plot were bulked, weighed, cut into 1- to 2-cm pieces, and eggs were extracted with 1.0% NaOCl (Hussey and Barker, 1973). 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) at $P \leq 0.05$.

2007 Field experiment. Evaluation of RKN resistance with and without nematicide treatment: The 2007 field study was conducted at the same field site used in 2006. The experimental design was a split-plot design with nematicide treatment as the whole plot factor and *Citrullus* genotype as the sub-plot factor. No further

TABLE 1. *Citrullus* spp. accessions evaluated in field trials at Charleston, SC, in 2006 and 2007. All entries listed were evaluated in 2006 and entries denoted by "*" were also evaluated in 2007.

Citrullus spp. Plant Introduction (PI) or cultivar	Species	Country of origin	Source
Ojakkyo	*Citrullus* spp.	N/A	Syngenta
Charleston Gray*	*C. lanatus* var. *lanatus*	N/A	USDA-ARS, U.S. Vegetable Lab
Dixie Lee	*C. lanatus* var. *lanatus*	N/A	Willhite
Crimson Sweet*	*C. lanatus* var. *lanatus*	N/A	Kansas State University/KAES
PI 189225*	*C. lanatus* var. *citroides*	Zaire	USDA-ARS, U.S. Vegetable Lab
PI 244017*	*C. lanatus* var. *citroides*	South Africa	USDA-ARS, U.S. Vegetable Lab
PI 244018*	*C. lanatus* var. *citroides*	South Africa	USDA-ARS, U.S. Vegetable Lab
PI 244019	*C. lanatus* var. *citroides*	South Africa	USDA-ARS, U.S. Vegetable Lab
PI 248774	*C. lanatus* var. *citroides*	Namibia	USDA-ARS, U.S. Vegetable Lab
PI 271769	*C. lanatus* var. *citroides*	South Africa	USDA-ARS, U.S. Vegetable Lab
PI 271773	*C. lanatus* var. *citroides*	South Africa	USDA-ARS, U.S. Vegetable Lab
PI 288313	*C. lanatus* var. *citroides*	India	USDA-ARS, U.S. Vegetable Lab
PI 296341	*C. lanatus* var. *citroides*	South Africa	USDA-ARS, U.S. Vegetable Lab
PI 299378	*C. lanatus* var. *citroides*	South Africa	USDA-ARS, U.S. Vegetable Lab
PI 386015*	*C. colocynthis*	Iran	USDA-ARS, U.S. Vegetable Lab
PI 386016	*C. colocynthis*	Iran	USDA-ARS, U.S. Vegetable Lab
PI 386024*	*C. colocynthis*	Iran	USDA-ARS, U.S. Vegetable Lab
PI 482259*	*C. lanatus* var. *citroides*	Zimbabwe	USDA-ARS, U.S. Vegetable Lab
PI 482303	*C. lanatus* var. *citroides*	Zimbabwe	USDA-ARS, U.S. Vegetable Lab
PI 482319	*C. lanatus* var. *citroides*	Zimbabwe	USDA-ARS, U.S. Vegetable Lab
PI 482324*	*C. lanatus* var. *citroides*	Zimbabwe	USDA-ARS, U.S. Vegetable Lab
PI 482338	*C. lanatus* var. *citroides*	Zimbabwe	USDA-ARS, U.S. Vegetable Lab
PI 482379	*C. lanatus* var. *citroides*	Zimbabwe	USDA-ARS, U.S. Vegetable Lab
PI 485583	*C. lanatus* var. *citroides*	Botswana	USDA-ARS, U.S. Vegetable Lab
PI 500331	*C. lanatus* var. *citroides*	Zambia	USDA-ARS, U.S. Vegetable Lab
PI 526231	*C. lanatus* var. *citroides*	Zimbabwe	USDA-ARS, U.S. Vegetable Lab
PI 459074	*C. lanatus* var. *lanatus*	Botswana	USDA-ARS, U.S. Vegetable Lab

USDA-ARS = United States Department of Agriculture-Agricultural Research Service.

preplant infestation of soil was conducted as *M. incognita* population levels were considered sufficient from the 2006 study. Five *C. lanatus* var. *citroides* accessions from 2006 were compared with two *C. colocynthis* accessions and two watermelon cultivars (*C. lanatus* var. *lanatus*). Plots were laid out as in 2006 with the exception of preplant methyl bromide/ postplant oxamyl treatment applied to designated plots. On 26 June 2007, one-half of the plots were fumigated with 98% methyl bromide: 2% chloropicrin broadcast at 442 kg/ha. *Citrullus* spp. entries were sown in the greenhouse on 13 June 2007, as previously described, and transplanted into the field on 16 July 2007. Oxamyl (Vydate L, E. I. du Pont de Nemours and Company) was applied through a drip irrigation system (37.4 l/ha) on 20 July 2007, 7 August 2007, and 20 August 2007 to the same beds that had been preplant treated with methyl bromide. Numbers of mature fruit per plot and fruit mass were recorded weekly beginning 11 October 2007. On 8 November 2007, vines were rated for vigor and roots were lifted from the soil. Root galling, egg mass, and fibrous root scores were recorded. Eggs of *M. incognita* were extracted from roots as described for 2006. Data were analyzed using the GLM procedure of SAS; when whole and sub-plot effects resulted in a significant interaction, plant genotype by nematicide treatment means were separated by Fisher's protected LSD at $P \leq 0.05$.

Results

2006: Percentages of root galling and egg mass production, fibrous root scores, and root vigor scores all differed significantly ($P \leq 0.05$) among the plant genotypes in the 2006 study (Table 2). Root galling percentages were generally very high (59.5%–90.5%), indicating high nematode disease pressure at the field

Table 2. Response of 27 *Citrullus* spp. genotypes to *Meloidogyne incognita* in field tests in Charleston, SC, 2006.

Citrullus genotype [Plant Introduction (PI) or cultivar]	Percentage root system galled[a]	Percentage root system with egg masses[a]	Fibrous root index[b]	Root vigor index[c]	Eggs/g fresh root[d]
C. lanatus var. *citroides*					
PI 482559	59.5 a[e]	51.0 bc	3.38 a–c	3.09 a–d	36 b–d
PI 244018	60.5 a	26.1 a	3.23 a	2.94 a–c	32 b–d
PI 189225	79.2 b	66.7 cd	3.49 a–c	3.50 b–f	34 a–d
PI 244017	81.2 bc	58.4 bc	3.77 b–f	2.90 ab	48 b–e
PI 296341	84.7 b–d	50.4 bc	4.19 d–h	3.95 e–h	116 b–f
PI 482379	85.2 b–d	55.0 bc	3.42 a–c	3.50 b–f	35 ab
PI 482324	86.3 bc	49.4 bc	2.90 a	2.58 a	7 a
PI 485583	86.3 b–d	66.9 cd	3.98 c–g	3.79 d–h	49 b–e
PI 482303	86.9 b–d	62.2 bc	3.68 b–e	3.50 b–f	24 a–c
PI 482338	86.8 b–d	63.1 c	3.22 ab	2.92 ab	507 b–f
PI 271769	87.2 b–d	70.4 cd	4.41 g–j	4.38 hi	208 d–g
PI 288313	87.5 b–d	59.4 bc	4.50 g–j	4.31 g–i	268 c–f
PI 271773	87.9 cd	70.2 cd	4.46 g–j	4.39 hi	81 b–d
PI 248774	88.3 cd	55.5 bc	3.80 b–f	3.65 c–g	99 b–e
PI 482319	88.3 cd	58.8 bc	3.55 bc	3.77 d–h	81 b–f
PI 299378	88.3 cd	62.2 c	3.71 b–e	3.95 e–h	41 b–d
PI 500331	89.8 cd	55.2 bc	3.62 b–d	3.70 d–h	61 b–e
PI 526231	89.9 cd	66.9 cd	3.57 bc	3.35 b–e	295 f–h
PI 244019	89.9 cd	60.2 bc	3.63 b–d	3.49 b–f	65 b–e
C. colocynthis					
PI 386015	90.5 d	90.5 d	4.93 ij	5.00 i	527 gh
PI 386016	90.5 d	90.5 d	5.00 i	5.00 i	870 h
PI 386024	90.5 d	90.5 d	5.00 j	4.97 i	238 e–h
Citrullus spp.					
'Ojakkyo'	90.5 d	58.4 bc	3.62 b–d	3.32 b–e	152 d–g
C. lanatus var. *lanatus*					
PI 459074	90.5 d	64.3 c	4.25 e–h	3.65 c–g	110 b–f
'Dixie Lee'	86.7 b–d	58.7 bc	4.55 g–j	4.17 f–h	171 d–g
'Charleston Gray'	87.1 b–d	38.5 ab	4.35 f–i	4.12 f–h	158 d–g

Overall analysis for 2006

Source	df	Percent root system galled[a]	Percent root system with egg masses	Fibrous root index[b]	Root vigor index[c]	Eggs/g fresh root[d]
Citrullus genotype	26	***	***	***	***	***

[a] Data were arcsine transformed before analysis. Nontransformed data are shown in table.
[b] Amount of fibrous roots rated using a 1 to 5 scale where 1 = root system very fibrous and 5 = no fibrous roots.
[c] Root vigor rated using a 1 to 5 scale where 1 = best and 5 = poorest.
[d] Data were $\log_{10}$ (x+1) transformed before analysis. Nontransformed data are shown in table.
[e] Means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Fisher's protected least significant difference.
*** Significant at the 0.001 probability level.

site. Despite the high degree of root galling, two genotypes (PI 244018 and PI 482559) had significantly less galling ($P < 0.05$) than the other entries evaluated. Plant genotype affected the percentage of root system covered with egg masses and PI 244018 had significantly lower ($P < 0.05$) egg mass production than all genotypes except 'Charleston Gray' (Table 2). Fibrous root scores ranged from 2.9 to 5.0 and several of the *C. lanatus* var. *citroides* accessions had lower ($P \leq 0.05$) fibrous root scores (i.e., more fibrous roots) than the susceptible reference genotypes. Several *C. lanatus* var. *citroides* accessions had more vigorous ($P \leq 0.05$) root systems than the susceptible genotypes as evidenced by the root vigor scores. Despite the severity of the nematode pressure at the field site, plant death over the duration of the study was not significant. *Meloidogyne incognita* egg recovery from root tissue ranged from 7 to 870 eggs/g of tissue with the greatest numbers of eggs per gram fresh root weight observed for *C. colocynthis* (PI 386016). Root mass was generally greater for *C. lanatus* var. *citroides* genotypes than *C. colocynthis* and *C. lanatus* var. *lanatus* genotypes (data not shown).

2007: Nematicide treatment and genotype significantly affected most variables (Table 3). The effect of nematicide treatment differed among genotypes for percentage of galling, percentage of egg mass production, and vine vigor scores. Remaining live plants, number of fruit, and fruit weight did not differ among treatments in the 2007 field evaluation (data not shown). As in 2006, *C. lanatus* var. *citroides* generally performed better than susceptible entries in the untreated plots. *Citrullus lanatus* var. *citroides* accessions exhibited less root galling, had fewer egg masses per root system, and produced more fibrous roots in 2007 than in 2006, yet 'Charleston Gray', 'Crimson Sweet', and the *C. colocynthis* genotypes (PI 386015 and PI

TABLE 3. Response of nine *Citrullus* spp. accessions and cultivars to *Meloidogyne incognita* in a field test with and without nematicide treatment, Charleston, SC, 2007.

Citrullus genotype [Plant Introduction (PI) or cultivar]	Nematicide treatment	Percentage root system galled[a]	Percentage root system with egg masses[a]	Fibrous root index[b]	Vine vigor index[c]	Eggs/g fresh root[d]
C. lanatus var. *citroides*						
PI 482324	+	1.3 a[e]	0.1 a	1.74 a	2.15 a–c	226 a–d
PI 482259	+	1.7 a	0.2 a	2.07 a–c	1.80 a	35 ab
PI 244017	+	1.8 a	0.4 a	2.23 a–c	2.18 a–c	40 a–c
PI 244018	+	2.4 a	0.1 a	2.10 a–c	1.81 a	9 ab
PI 189225	+	5.6 a	0.9 a	2.66 c–e	2.74 cd	100 a–d
C. colocynthis						
PI 386015	+	15.9 a–c	6.1 a	3.52 f–h	2.15 a–c	284 b–d
PI 386024	+	30.6 bc	10.0 a	3.32 fg	3.13 de	326 b–d
C. lanatus var. *lanatus*						
'Charleston Gray'	+	10.8 ab	3.2 a	3.06 d–f	3.88 g	323 a–d
'Crimson Sweet'	+	2.1 a	0.3 a	3.50 f–h	3.47 e–g	18 ab
C. lanatus var. *citroides*						
PI 482324	0	9.1 a	3.1 b	1.74 a	2.19 a–c	15 a
PI 482259	0	8.0 a	2.5 b	1.77 ab	2.39 a–c	22 ab
PI 244017	0	23.0 a–c	5.1 b	2.42 b–d	2.69 b–d	14 ab
PI 244018	0	9.6 a	1.7 b	1.83 ab	2.09 ab	347 b–d
PI 189225	0	9.0 a	2.4 b	1.89 ab	3.19 d–f	8 a
C. colocynthis						
PI 386015	0	84.8 d	47.8 b	2.62 c–e	3.78 fg	359 de
PI 386024	0	77.8 d	38.8 b	4.02 h	3.71 e–g	423 c–e
C. lanatus var. *lanatus*						
'Charleston Gray'	0	55.9 d	43.9 b	3.11 ef	3.56 e–g	950 e
'Crimson Sweet'	0	39.4 cd	13.2 a	3.84 gh	3.76 fg	333 c–e

Overall analysis of variance for 2007

Source	df	Percentage root system galled[a]	Percentage root system with egg masses[a]	Fibrous root index[b]	Vine vigor index[c]	Eggs/g fresh root[d]	Total number of fruit	Fruit mass[f]	Root mass
Citrullus genotype	8	***	***	**	***	***	NS	-	**
Nematicide treatment	1	***	***	***	***	**	NS	NS	***
Citrullus genotype × nematicide treatment	8	***	***	NS	**	NS	NS	-	NS

[a] Data were arcsine transformed before analysis. Nontransformed data are shown in table.
[b] Amount of fibrous roots rated using a 1 to 5 scale where 1 = root system very fibrous and 5 = no fibrous roots.
[c] Vine vigor rated using a 1 to 5 scale where 1 = best and 5 = poorest.
[d] Data were $\log_{10}$ (x+1) transformed before analysis. Nontransformed data are shown in table.
[e] Means within a column followed by the same letter are not significantly different ($P < 0.05$) according to Fisher's protected least significant difference.
[f] Analysis of variance for fruit mass was conducted as paired *t*-tests for each genotype, therefore only significance level of nematicide treatment effects are reported.
*** Significant at the 0.001 probability level.
** Significant at the 0.01 probability level.
* Significant at the 0.05 probability level.
NS = not significant.

386024) all exhibited susceptible reactions. Root galling percentages ranged from 1.3% to 84.8% for both the treated and untreated plots with all five of the *C. lanatus* var. *citroides* acessions (PI 189225, PI 244017, PI 244018, PI 482259, and PI 482324) performing equivalently with and without nematicide treatment. Egg mass percentages were the highest for the two *C. colocynthis* entries and 'Charleston Gray' in the untreated plots, as expected, with no other treatment by genotype differences. Fibrous root scores ranged from 1.74 to 4.02 with PI 244017, PI 244018, PI 482259, and PI 482324 performing equally well with or without nematicide treatment. PI 244017, PI 244018, PI 482259, and PI 482324 performed better than the susceptible check 'Charleston Gray', regardless of nematicide treatment for above ground vigor scores. Numbers of *M. incognita* eggs per gram of root tissue were highest in the susceptible check genotypes in the untreated plots, however, the only significant pair-wise differences between nematicide and untreated in the check were observed in 'Charleston Gray' and 'Crimson Sweet'. All five *C. lanatus* var. *citroides* accessions showed no significant difference in numbers of eggs per gram fresh root between nematicide treatment and the control plots, and performed generally better than the susceptible check entries.

Discussion

The present studies are the first to evaluate wild watermelon (*Citrullus* sp.) for response to RKN in field studies. In these studies, 23 different PI accessions representing *Citrullus lanatus* var. *citroides*, *C. lanatus* var. *lanatus*, and *C. colocynthis*, originating from eight different countries, were evaluated in a field infested with *M. incognita*, and several of the *C. lanatus* var. *citroides* accessions evaluated exhibited resistance to that nematode. There are no prior reports in the literature of the response of wild watermelon genotypes to *M. incognita* in field experiments, other than studies with grafted watermelon. However, none of the grafting studies included the response of nongrafted wild watermelon to RKN. Additionally, in the present study, we demonstrated that the resistant *C. lanatus* var. *citroides* accessions performed similarly when grown with and without nematicide treatment.

Analyses of the 2006 data suggest differential responses to southern RKN infestation exist in wild watermelon genotypes. Although root galling was severe in all entries included in this study, it was still possible to determine differences in resistance to southern RKN in *C. lanatus* var. *citroides* genotypes. Other resistance characteristics such as fibrous root scores, vigor scores, and low recovery of eggs from root tissue also indicate that several of the wild watermelon accessions evaluated exhibited resistance relative to the susceptible *C. colocynthis* accessions and reference watermelon cultivars. Results of the 2007 field studies demonstrated that several of the *C. lanatus* var. *citroides* accessions evaluated in 2006 performed equally well with and without nematicide treatments with regard to RKN resistance traits evaluated. Based on the results of these studies, PI 189225, PI 244018, PI 482559, and PI 482324 are considered resistant and PI 244017 is moderately resistant.

As further restrictions are enacted to reduce nematicide use, identification of potential sources of host resistance to RKN becomes of greater importance for the development of resistant watermelon cultivars. To date, there has been no progress in the introgression of RKN resistance traits into commercially acceptable watermelon, yet these studies indicate progress may be possible using wild watermelon relatives in directed breeding approaches. In most cases, crosses between cultivated watermelon and *C. lanatus* var. *citroides* readily produce fruit with viable seeds. We have developed several populations resulting from crosses of *C. lanatus* var. *citroides* × cultivated watermelon (*Citrullus lanatus* var. *lanatus*) for use in the study of mode of inheritance of resistance to RKN (unpublished data). Additionally, grafting commercial watermelon cultivars onto resistant rootstocks has proved a successful approach in combating fungal and viral diseases where no resistance is known (Oda, 2002; Miguel et al., 2004; Cohen et al., 2007) and has become a widely accepted practice in Asia and in the Mediterranean region, including Israel and Turkey (Yetisir et al., 2007). Selected germplasm lines of *C. lanatus* var. *lanatus* have been tested as rootstocks for grafted watermelon and found to be useful for managing *M. incognita* in grafted watermelon (Thies et al., 2010; Thies et al., 2015a, 2015b). Grafting the seedless watermelon scion 'Tri-X 313' on the RKN-resistant rootstock RKVL 318 derived from PI 482324 resulted in significantly higher watermelon fruit yields compared to 'Tri-X 313' grafted on the commonly used RKN-susceptible commercial cucurbit rootstocks, 'Strong Tosa' interspecific squash hybrid (*Cucurbita maxima* × *Cucurbita moschata*) and 'Emphasis' bottle gourd (*Lagenaria siceraria*) when grown in *M. incognita*-infested fields (Thies et al., 2015c). Although high labor costs associated with grafting and maintenance of newly grafted seedlings have made grafting impractical in the United States, the loss of methyl bromide from the market, and reductions in farm land acreages have made grafting a potentially useful practice in cucurbit culture, especially in areas where losses due to soil-borne pathogens such as *Fusarium oxysporum* and RKN occur. *Citrullus lanatus* var. *citroides* germplasm lines have proved useful as resistant rootstocks in minimizing RKN damage, but are not yet used by the watermelon industry (Thies et al., 2015a, 2015c). Further studies need to be undertaken to assess the plausibility of wild watermelons as suitable rootstock materials for commercial watermelon production and in mitigating the effects of RKN in production scenarios.

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