Management of *Meloidogyne incognita* with Jesup (Max-Q) Tall Fescue Grass Prior to Peach Orchard Establishment

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Abstract

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The effects of two preplant Jesup (Max-Q) tall fescue (*Schedonorus arundinaceus*) ground cover treatments as alternatives to chemical control of *Meloidogyne incognita* were investigated from 2006 to 2013. The experiment was initiated in 2006 in a site known to be infested with *M. incognita*. Treatments included (i) 1 year of peach followed by 1 year of Jesup (Max-Q), (ii) 2 years of continuous Jesup (Max-Q), (iii) 2 years of continuous peach, and (iv) 2 years of continuous peach followed by fumigation with 1,3-dichloropropene (1,3-D). Both Jesup (Max-Q) treatments suppressed ($P \leq 0.05$) population densities of *M. incognita* second-stage juveniles (J2) compared with the 2-year continuous peach treatments (prior to fumigation); no J2 were detected in soil samples taken from 2-year continuous Jesup (Max-Q) plots. Evaluation of the effects of the Jesup (Max-Q) treatments on subsequent peach tree planting was initiated in 2008, when herbicide was applied to the tall fescue treatment plots and half the continuous peach plots were fumigated with 1,3-D (nematicide treatment control). Peach trees were planted into all plots in 2009. By the end of the experiment (48 months after orchard establishment), trunk diameter was greater ($P \leq 0.01$) in both of the Jesup (Max-Q) treatments and in the 1,3-D-fumigated treatment than in the nonfumigated treatment. Moreover, trunk diameter did not differ among the Jesup (Max-Q) and the fumigated treatments. Preplant Jesup (Max-Q) tall fescue was as effective as 1,3-D fumigation in increasing tree growth in an *M. incognita*-infested site.

Root-knot nematodes (*Meloidogyne* spp.) are considered to be the most economically important nematodes in the world and can be found in temperate, tropical, and equatorial areas (18,22). Root-knot nematodes reduce fruit production in several economically important *Prunus* spp., including peach (*Prunus persica* (L.) Batsch). *Meloidogyne incognita (*Kofoid & White, 1919) and *M. javanica* are the predominant species on peach and plum (21). In South Carolina peach orchards, *M. incognita* and *M. javanica* were found in 95 and 5% of orchards sampled, respectively (25). Parasitism by root-knot nematodes on peach often causes typical belowground root galls and the associated aboveground stunting of 1- and 2-year-old peach trees. Other aboveground symptoms include early defoliation, a reduction in tree vigor and yield, and, occasionally, tree death (26). Expression of the aboveground symptoms is increased in sandy soils, especially when trees are exposed to drought conditions.

Preplant nematicides for root-knot nematode control are available in the southeastern United States (12). The current preplant nematicide recommendation for managing this plant-parasitic nematode includes soil fumigation with 1,3-dichloropropene (1,3-D) or metam sodium (12). Of these two preplant nematicides, 1,3-D is the recommended chemical treatment of choice for growers where nematodes are a problem. As a result of reduced availability of and environmental concerns about preplant nematicides, research is being conducted on novel management strategies for preplant nematode suppression that are less hazardous to humans, cheaper, and more environmentally safe. Use of preplant cover crops is recognized as a management practice that reduces plant-parasitic nematode populations and the associated crop damage. In Georgia, Coastal Bermuda grass (*Cynodon dactylon* L.), which can be harvested for hay, is recommended as a rotation crop for control of *Meloidogyne* spp. (19). In Alabama, preplant rotation with Coastal Bermuda grass was beneficial in suppressing *M. arenaria* second-stage juvenile (J2) soil populations in peanut compared with aldicarb-treated soil in a 3-year field trial (27). Another potential ground cover rotation crop for nematode management prior to orchard establishment is tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumont. = *Lolium arundinaceum* (Schreb.) Darbysh., formerly *Festuca arundinacea* Schreb.), which was shown to be a nonhost and poor host to *M. incognita* and *Pratylenchus vulnus*, respectively, under greenhouse conditions; these are two of three primary nematode pathogens of known importance on peach in the southeastern United States (20,24).

Tall fescue is an extensively grown, perennial, cool-season turf and forage grass that is well-adapted to many areas of the United States. The leading tall fescue cultivar grown throughout the United States is ‘Kentucky 31’, because of its excellent characteristics, which include increased vigor, ability to withstand poor soil and drought conditions, and resistance to pests, including some plant-parasitic nematodes (2,3,5). These enhanced qualities associated with Kentucky 31 have been attributed to the presence of the symbiotic fungal endophyte, *Neotyphodium coenophialum* [(Morgan-Jones & Gams.) Glenn, Bacon & Hanlin], which naturally infects the grass (2,7). For example, *M. marylandi* reproduction was lower in the presence *N. coenophialum*-infected tall fescue than in endophyte-free tall fescue (9,15). Unfortunately, this strain of *N. coenophialum* also produces ergot alkaloids that cause fescue toxicosis in grazing animals (1,29). To overcome the problem of

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fescue toxicosis, researchers discovered a novel, nontoxic endophyte strain of *N. coenophialum* that provides the same agricultural benefits as Kentucky 31 but does not produce the ergot alkaloids associated with fescue toxicosis. The commercially registered product, identified as AR542 endophyte, was incorporated into 'Jesup' tall fescue and marketed under the brand name Jesup (Max-Q) (6,28).

When evaluated for host susceptibility against the root-knot nematode species most often encountered in southeastern U.S. peach production, Jesup (Max-Q) was shown to be a nonhost for *M. incognita* (isolates BY-peach and GA-peach) and a poor host for *M. javanica* under greenhouse conditions (24). Suppression of *M. incognita* reproduction did not appear to be influenced by the presence of the fungal endophyte *N. coenophialum*; wild-type Jesup (ergot alkaloid-producing endophyte present), endophyte-free Jesup, and Jesup (Max-Q) were all poor hosts or nonhosts for this species. Subsequent studies by Meyer et al. (17) demonstrated that *M. incognita* suppression was attributed to a combination of factors that include (but are not all inclusive) (i) low infective J2 penetration rate and failure of infective J2 to complete their life cycle, (ii) root compounds that inhibited egg hatch, and (iii) root compounds that were nematostatic or nematotoxic to J2. The aims of the present study were to evaluate the effects of 1- and 2-year tall fescue Jesup (Max-Q) treatments as preplant management strategies for suppressing population densities of *M. incognita* on peach and to determine the influence of a preplant tall fescue Jesup (Max-Q) rotation on peach tree growth.

Materials and Methods

Field site establishment. The experiment was initiated in August 2003 at the United States Department of Agriculture–Agricultural Research Service Southeastern Fruit and Tree Nut Research Laboratory in Byron, GA. The study was conducted on a Faceville sandy loam soil (74% sand, 18% silt, 8% clay, pH 4.9; 1.40% organic matter) with a previous history of *M. incognita* infestation (designated *M. incognita* [BY-peach isolate]). A peach orchard had previously been established on and removed from this site (1999 to 2003). That orchard had been planted to peach 'Redhaven' on 'Lovell' rootstock (*M. incognita* susceptible) and nematode galling was detected on the roots during tree removal. The site had no previous history of tall fescue grass production. Immediately following tree removal in May 2003, the test site was subsoiled (approximately 81 cm deep) and rotovated. Dolomitic limestone was broadcast (4,535 kg/ha) over the site in August 2003 to increase the soil pH to 6.0. The test site was rotovated again in March 2004, and herbicide applied on 29 April and 15 October 2004 (paraquat at 0.78 kg a.i./ha and glyphosate at 4.49 kg a.i./ha, respectively) and 3 May 2005 (paraquat) to control weeds.

The field site (44.5 by 38.1 m) contained the test site (36.6 by 33.5 m) that was divided into six adjacent blocks (planting rows), each measuring 36.6 by 3.1 m. The distance from the center of one block to the next adjacent block was 6.1 m. The block centers were located in the approximate vicinity of the old orchard tree rows where *M. incognita* populations would be most concentrated. In August 2005, tomato (*Solanum lycopersicon*) 'Rutgers' seedlings (40 tomato plants per 36.6 m of row) were planted in a line down the center of each block in order to increase *M. incognita* soil population density. In December 2005, it was determined that four of the six blocks had tomato roots that were rated as positive for *M. incognita* infection (presence of root galls). In June 2006, tomato seedlings were again planted down each of the six adjacent block centers (80 tomato plants per 36.6 m of row) in a zig-zag pattern approximately 0.61 m wide to further increase the *M. incognita* population density within the test site. Supplemental irrigation via drip tape (372 liter/h) was also installed down each tomato row and utilized throughout the growing season as needed. Fifteen days after planting, the soil infestation was augmented by pipetting approximately 800 *M. incognita* (BY-peach isolate) eggs directly into a hole (7.6 cm deep) located 10.2 cm from each tomato plant stem. The holes were covered and additional water applied to settle the soil around the eggs. Prior to establishing the respective preplant treatment plots (see below), the drip irrigation tape was removed and it was determined by visual observation that all six blocks had tomato roots throughout that were rated as positive for *M. incognita* infection.

Preplant treatment establishment. Four treatments were arranged in a randomized complete block design with six replications per treatment. To do this, the four treatment plots (each measuring 9.2 by 3.1 m) were arranged in a randomized linear configuration down each of the six planting rows. The four treatments were (i) peach-peach (P-P): 2 years of continuous peach (negative control), with the trees planted in February 2007 and removed in October 2008; (ii) peach-peach-fumigation (P-P-F): 2 years of continuous peach followed by fumigation with 1,3-D (positive control) (same planting and removal dates but 1,3-D fumigation applied in November 2008); (iii) peach-Jesup (Max-Q) (P-MQ): 8 months of peach trees (planted February 2007 and removed in October 2007) followed by 1 year of Jesup (Max-Q) (planted in November 2007 and removed in September 2008); and (iv) MQ-MQ: 2 years of continuous Jesup (Max-Q) (planted in November 2006 and removed in September 2008). Jesup (Max-Q) was seeded (28.5 kg/ha) into the P-MQ and MQ-MQ plots using an EV-N-SPRED broadcast spreader (Earthway Products, Inc.). One-year-old Redhaven peach trees (76.2 to 91.4 cm tall) on 'Halford' peach rootstock (root-knot nematode susceptible) was used in all treatments where peach was planted. Peach tree spacing in the P-P, P-P-F, and P-MQ plots was 1.8 m between trees, with six trees per plot. All Jesup (Max-Q) and peach tree plots received annual applications of selected fertilizers and herbicides as recommended by the Georgia Cooperative Extension Service for the respective crops (11,12,13,16). Fertilizer was applied to the tall fescue plots at 28.5 kg/ha as 10-10-10 (N-P-K) at planting and top-dressed with N at 73.8 kg/ha as 10-10-10 (N-P-K) in the spring. Fertility rates for peach trees were according to the schedule outlined for nonbearing trees using 10-10-10 and 34-0-0 (16). Weeds in all plots were controlled initially with glyphosate at plot establishment. Subsequently, volunteer weeds in tall fescue plots were eliminated with triclopyr (0.80 kg a.i./ha). Paraquat and oryzalin (4.5 kg a.i./ha) were used to control weeds in peach plots.

An estimate of the initial population density (Pi) of *M. incognita* infective J2 was determined on 20 February 2007 from four soil cores (2.5 cm in diameter by 30 cm deep) collected within each replicate throughout the test site. In peach plots, soil cores were obtained between the four inner trees where peach roots were not yet present, and in Jesup (Max-Q) plots (i.e., MQ-MQ) from soil where plants had not yet become established. *M. incognita* soil population densities were determined also on 13 December 2007 and 1 April 2008. On these dates, in the P-P and P-P-F plots, four soil cores were collected from within the foliage drip line of the four inner trees of each experimental unit, whereas in Jesup (Max-Q) plots (P-MQ and MQ-MQ), four cores were arbitrarily obtained in the area where tomato plants were previously grown and where peach trees would eventually be planted in the pretreatment evaluation phase of the experiment. Soil probes were disinfested with 95% ethanol to prevent soil and nematode movement between plots. The soil cores were composited by plot within each replicate or tree row, and *M. incognita* were extracted from a 100-cm^3 soil subsample with a semiautomatic elutriator (8) and centrifugal flotation (14) and counted.

Preplant treatment evaluation. In September 2008, Jesup (Max-Q) vegetation in all ground-cover plots was eliminated with glyphosate. Peach trees growing in all continuous peach plots (P-P and P-P-F) were pulled out with a tractor and chain and removed in October 2008. All tree root systems throughout each P-P and P-P-F plot were infected with *M. incognita*, as indicated by the presence of root galls. The galled secondary and tertiary roots from each tree were cut off and left in each respective P-P and P-P-F plot.

Prefumigation *M. incognita* J2 populations in soil were determined on 14 October 2008 (prior to tree removal) from four soil cores (2.5 cm in diameter by 30 cm deep) collected within each plot throughout the test site, as previously described for the December 2007 and April 2008 nematode sampling dates in the preplant treatment establishment phase above. The four soil cores were composited by plot within each block for a total of 24 samples. *M. incognita* were extracted from a 100-cm^3 soil subsample and counted as described above.

The P-P-F plots were then rotovated on 16 October 2008, in preparation for preplant fumigation. 1,3-D (Telone II) was applied (Hendrix & Dail, Inc.) in a strip (2.4 m wide, 113.6 liter/ha in row) on 20 November 2008. Soil moisture (at 10 to 15 cm in depth) was adequate for fumigation; when the soil was compressed in the hand, it formed a ball that was easily broken with little disturbance (50 to 70% available soil moisture) (30). In December 2008, any reoccurring vegetation in Jesup (Max-Q) or nonfumigated plots was eliminated with glyphosate.

Orchard establishment. All plots were planted to peach (1-year-old trees, 61.0 to 76.2 cm tall, 'Rubyprince' on Halford rootstock [root-knot nematode susceptible]) at a tree spacing of 1.5 by 6.1 m in January 2009. Each plot had seven trees, the outer two of which served as borders with the five center trees as the experimental unit. Using shovels, trees were planted into the preplant treatment plots in the following order: 1,3-D fumigated (P-P-F), MQ-MQ, P-MQ, and nonfumigated soil (P-P). All border trees were planted last. Shovels were dipped in an approximately 1.05% NaOCl solution and rinsed with water between uses while planting trees in each experimental plot. To prevent accidental movement of *M. incognita*-infested soil throughout all phases of planting and later during the study, care was taken not to unintentionally mix the soil from different treatment plots.

All trees received annual applications of fertilizer (10-10-10 and 15.5-0-0 N-P-K), insecticides, fungicides, and herbicides, and were commercially pruned as recommended by the Georgia Cooperative Extension Service. Application rates followed the schedule outlined in the guidelines for nonbearing and bearing trees (12,13,16).

Postplant treatment evaluation. Seventeen days after planting, an estimate of the *M. incognita* J2 populations in soil was determined on 11 February 2009 from five soil cores collected within each plot throughout the test site. One soil core was collected between each of the first five test trees (four probes total) and between the last test tree and border tree (one probe) in the planting row where no peach roots were yet present, thus representing a preplant soil zone. The five soil cores were composited by plot within each block for a total of 24 samples. Later postplant population densities of *M. incognita* J2 were determined on 29 December 2009, 24 March, and 28 December 2010; 8 March and 30 November 2011; 14 March and 3 December 2012; and 21 March 2013 from one soil core collected within the drip line of each of five test trees of each experimental unit. The five soil cores were composited and *M. incognita* were extracted from a 100-cm^3 subsample, as described above. Trunk diameters were measured at 20.3 cm above the soil surface on 8 February 2010, 20 January 2011, 12 January 2012, and 16 January 2013.

Statistics. *M. incognita* data were transformed to $\log_{10}(x + 1)$ values and subjected to analysis of variance with the general linear models procedure of SAS (SAS Institute). For the preplant sampling date (February 2007), nematode density means were compared among the four designated treatments according to Fisher's protected least significant difference (LSD) test, following a significant F test. For the initial preplant treatment evaluations (prior to orchard establishment), appropriate preplanned single degree-of-freedom comparisons were performed in December 2007 and April and October 2008 data (means following P-P [future nonfumigated plots] and P-P-F [future fumigated plots] versus P-MQ and MQ-MQ) following a significant F test. On these same three sampling dates, means for P-MQ and MQ-MQ were compared according to Fisher's protected LSD test. At the completion of the experiment (after orchard establishment), *M. incognita* population and trunk diameter means were compared according to Fisher's protected LSD test following a significant F test. Only significant differences ($P \leq 0.05$) will be discussed, unless stated otherwise. Nontransformed data are used for table presentation.

Results

Preplant treatment establishment. The mean soil population densities of *M. incognita* J2 did not differ among the four treatments in February 2007 (Table 1), which was 111 days postplant for Jesup (Max-Q) (MQ-MQ) plots and 8 days postplant for all peach plots (P-P, P-P-F, and P-MQ). This was the result of soil samples being obtained in areas within the respective plots where peach or Jesup (Max-Q) roots were not yet present and, therefore, represents an estimate of the Pi of *M. incognita* in this test. In December 2007, the population density of *M. incognita* was lower ($P \leq 0.01$) in the MQ-MQ plots (13 months after planting) and the P-MQ plots (37 days after planting to grass) than in plots planted to continuous peach (P-P and P-P-F; Table 1). Similar suppression of *M. incognita* J2 populations was also observed in the P-MQ and MQ-MQ plots on subsequent sampling dates compared with the continuous peach (P-P and P-P-F) plots in April 2008 (approximately 5 and 17 months after planting Jesup (Max-Q) in P-MQ and MQ-MQ plots, respectively) and October 2008 (approximately 11 and 23 months after planting Jesup (Max-Q) in plots, respectively). Additionally, P-MQ plots supported greater ($P \leq 0.05$) numbers of *M. incognita* than the MQ-MQ plots in December 2007 and April 2008 but not in October 2008.

Postplant treatment evaluation. In February 2009 (19 days after planting trees and 83 days after application of 1,3-D treatment), the nematode population density was greater ($P \leq 0.05$) in the nonfumigated plots (P-P) than in both Jesup (Max-Q) plots (MQ-

Table 1. Soil populations of *Meloidogyne incognita* as influenced by 1- and 2-year Jesup (Max-Q) tall fescue (*Schedonorus arundinaceus*) ground cover plantings or by continuous peach in Byron, GA[u]

	Number of *M. incognita* J2 per 100 cm^3 of soil[v]			
	2007		2008	
Crop sequence[w]	February	December	April	October
P-P (future nonfumigated plots)	15 a[x]	683[y]	444[y]	412[y]
P-P-F (future fumigated plots)	13 a	585	138	364
P-MQ	10 a	93 a[z]	43 a[z]	5 a[z]
MQ-MQ	10 a	0 b	0 b	0 a

[u] Data are means of six replications per crop sequence.
[v] Nematode data were transformed to $[\log_{10}(x + 1)]$ for analysis and nontransformed data are presented in this table.
[w] Crop sequence: P = Redhaven/Halford peach (Halford = root-knot nematode-susceptible rootstock); MQ = Jesup (Max-Q) tall fescue grass; P-P and P-P-F= continuous peach from 12 February 2007 to 14 October 2008; P-MQ = peach from 12 February 2007 to 31 October 2007, then removed and planted to MQ from 6 November 2007 to 18 September 2008; and MQ-MQ = continuous MQ from 1 November 2006 to 18 September 2008.
[x] Estimate of preplant nematode population. Nematode means within a column followed by the same letter are not different ($P \leq 0.05$) according to Fisher's least significant difference (LSD).
[y] Single degree of freedom comparisons of P-P (future nonfumigated plots) and P-P-F (future fumigated plots) versus P-MQ and MQ-MQ are different ($P \leq 0.01$).
[z] *M. incognita* means for P-MQ and MQ-MQ within a column followed by the same letter are not different ($P \leq 0.05$) according to Fisher's LSD.

MQ and P-MQ) or in the fumigated plots (P-P-F) (Table 2). No differences in *M. incognita* populations were detected among the MQ-MQ, P-MQ, or P-P-F (fumigated) plots at this time. Eleven months (December 2009) after planting peach trees, *M. incognita* populations were greatest ($P \leq 0.05$) in the nonfumigated (P-P) and P-MQ plots, intermediate in MQ-MQ plots, and lowest in the fumigated (P-P-F) plots. On all seven subsequent sampling dates (i.e., March 2010 to March 2013), no differences in nematode populations were detected between the nonfumigated (P-P) and P-MQ plots or between the MQ-MQ and P-MQ plots. However, during this same 3-year time period, *M. incognita* populations were always greatest in the nonfumigated (P-P) plots and lowest in the fumigated (P-P-F) plots. By December 2012 (47 months after orchard establishment) and March 2013 (50 months after orchard establishment), MQ-MQ plots had fewer *M. incognita* than nonfumigated (P-P) plots and no differences in nematode populations were detected between the MQ-MQ and fumigated (P-P-F) plots (Table 2).

Differences in trunk diameters occurred among some of the treatments on all four measurement dates (Table 3). In February 2010 (13 months after orchard establishment), trunk diameter was smallest ($P \leq 0.01$) in nonfumigated (P-P) plots, intermediate in P-MQ plots, and greatest in MQ-MQ and fumigated (P-P-F) plots. Twenty-four months after orchard establishment (January 2011), tree growth was still greatest ($P \leq 0.01$) in the MQ-MQ and fumigated (P-P-F) plots, intermediate in P-MQ plots, and lowest in the nonfumigated (P-P) plots. However, trees growing in fumigated (P-P-F) plots did not differ in size compared with trees growing in the MQ-MQ or the P-MQ plots. Tree diameter 36 months (January 2012) and 48 months (January 2013) after orchard establishment was greater ($P \leq 0.01$) in both tall fescue (P-MQ and MQ-MQ) and fumigated (P-P-F) plots than in the nonfumigated (P-P) plots. Furthermore, trunk diameter did not differ among the MQ-MQ, P-MQ, and P-P-F (fumigated) plots during these same time periods.

Discussion

During the preplant treatment establishment phase of this field study, the estimate of the Pi of *M. incognita* was similar among the four treatment plots (February 2007). However, in December 2007, 13 months after establishing the MQ-MQ plots (approximately one annual grass cycle) and only 1 month after establishing tall fescue in the P-MQ plots (much less than one annual grass cycle), *M. incognita* J2 soil populations were significantly less than in the continuous peach plots (P-P and P-P-F). These results substantiate the suppressive effect that Jesup (Max-Q) has on *M. incognita* soil populations, as previously reported under greenhouse conditions (24). Also, even though *M. incognita* J2 populations were significantly lower in the MQ-MQ plots than in the P-MQ plots in both the December 2007 and April 2008 samplings, no differences between these two Jesup (Max-Q) treatments were detected in October 2008 (i.e., after the P-MQ cycle was completed and the grass had been growing about 1 year). Therefore, it appears that growing Jesup (Max-Q) for at least 1 year is sufficient to suppress *M. incognita* J2 populations to almost nondetectable populations in the soil. According to Meyer et al. (17), Jesup (Max Q) produces root and shoot compounds that inhibit *M. incognita* egg hatch and that are nematostatic or nematotoxic to the J2. The unknown nematotoxic compounds detected in the root extracts and exudates may play a role in suppression of J2. Additionally, it was determined that the nature of resistance in Jesup (Max-Q) to *M. incognita* was associated with inhibition of nematode development and failure to complete its life cycle (17). This nonhost status in Jesup (Max-Q) would result in suppressed nematode populations.

During the early stages of the postplant treatment evaluation phase (February 2009; 19 days after planting trees), the *M. incognita* population density was greater ($P \leq 0.05$) in the nonfumigated (P-P) plots than in the two Jesup (Max-Q) treatment (P-MQ and MQ-MQ) plots and in the plots that had been fumigated with 1,3-D (83 days after treatment; P-P-F). Additionally, no differences were detected among the two Jesup (Max-Q) plots and fumigated (P-P-F) plots. However, 11 months (December 2009) after orchard establishment, the Jesup (Max-Q) nematode-suppressive effect on J2 soil population densities was diminished so that no differences were detected between the nonfumigated (P-P) plots and the P-MQ plots. This result was observed on all subsequent sampling dates

Table 3. Effect of 1- and 2-year preplant Jesup (Max-Q) tall fescue (*Schedonorus arundinaceus*) ground cover plantings or preplant fumigation with 1,3-dichloropropene (1,3-D) on trunk diameter of peach trees (*Prunus persica* 'Rubyprince'/'Halford') in Byron, GA[x]

	Trunk diameter (mm)			
Treatment[y]	**February 2010**	**January 2011**	**January 2012**	**January 2013**
P-P (nonfumigated)	16.3 c	37.4 c	50.8 b	61.9 b
P-P-F (1,3-D)[z]	25.4 a	53.5 ab	64.4 a	76.2 a
P-MQ	19.9 b	49.5 b	63.4 a	78.7 a
MQ-MQ	27.8 a	56.8 a	65.7 a	77.8 a

[x] Data are means of six replications per treatment. Means within a column followed by the same letter are not different ($P \leq 0.01$) according to Fisher's least significant difference.

[y] P = Redhaven/Halford peach (Halford = root-knot nematode-susceptible rootstock); MQ = Jesup (Max-Q) tall fescue grass; P-P and P-P-F = continuous peach from 12 February 2007 to 14 October 2008; P-MQ = peach from 12 February 2007 to 31 October 2007, then removed and planted to MQ from 6 November 2007 to 18 September 2008; and MQ-MQ = continuous MQ from 1 November 2006 to 18 September 2008. All four treatment plots were planted back to Rubyprince/Halford (Halford = root-knot nematode-susceptible rootstock) in January 2009.

[z] 1,3-D was applied at a rate of 113.6 liter/ha (in row) on 20 November 2008.

Table 2. Soil populations of *Meloidogyne incognita* on peach (*Prunus persica* 'Rubyprince'/'Halford'), as influenced by 1- and 2-year preplant Jesup (Max-Q) tall fescue (*Schedonorus arundinaceus*) ground cover plantings and preplant fumigation with 1,3-dichloropropene (1,3-D) in Byron, GA[u]

	M. incognita **J2 per 100 cm³ of soil**[v]								
	2009		**2010**		**2011**		**2012**		**2013**
Treatment[w]	**February**	**December**	**March**	**December**	**March**	**November**	**March**	**December**	**March**
P-P (nonfumigated)	303 a[x]	100 a[x]	110 a[x]	385 a[x]	343 a[x]	536 a[x]	267 a[y]	560 a[x]	390 a[x]
P-P-F (1,3-D)[z]	0 b	8 b	5 b	75 b	25 b	110 c	45 b	98 b	88 c
P-MQ	8 b	160 a	233 a	150 ab	328 a	260 ab	193 a	198 ab	218 ab
MQ-MQ	0 b	33 ab	125 a	195 a	300 a	175 bc	245 a	90 b	90 bc

[u] Data are means of six replications per treatment.

[v] Nematode data were transformed to $[\log_{10}(x + 1)]$ for analysis and nontransformed data are presented in this table.

[w] P = Redhaven/Halford peach (Halford = root-knot nematode-susceptible rootstock); MQ = Jesup (Max-Q) tall fescue grass; P-P and P-P-F = continuous peach from 12 February 2007 to 14 October 2008; P-MQ = peach from 12 February 2007 to 31 October 2007, then removed and planted to MQ from 6 November 2007 to 18 September 2008; and MQ-MQ = continuous MQ from 1 November 2006 to 18 September 2008. All four treatment plots were planted back to Rubyprince/Halford (Halford = root-knot nematode-susceptible rootstock) in January 2009.

[x] *M. incognita* means within a column followed by the same letter are not different ($P \leq 0.05$) according to Fisher's least significant difference (LSD).

[y] *M. incognita* means within a column followed by the same letter are not different ($P < 0.10$) according to Fisher's LSD.

[z] 1,3-D was applied at a rate of 113.6 liter/ha (in row) on 20 November 2008.

(March 2010 to March 2013) until the end of the study. Similarly, there were no differences in *M. incognita* population densities between the nonfumigated (P-P) and the MQ-MQ treated plots on four of the same seven sampling dates. However, compared with the nonfumigated (P-P) treatment, nematode population densities were suppressed in the MQ-MQ plots by 82.5% in December 2012 and 76.9% in March 2013. Preplant fumigation with 1,3-D continued to suppress *M. incognita* J2 soil population densities throughout this entire study, from February 2009 to March 2013 (50 months after orchard establishment and 52 months after fumigation treatment), with 77.4% suppression on March 2013. Generally, the effect of preplant fumigation diminishes over time. In South Carolina, control of the ring nematode *Mesocriconema xenoplax* with a preplant application of 1,3-D was not effective for more than 2 years following initial treatment (32). In Georgia, preplant fumigation with methyl bromide to manage *M. xenoplax* in peach was reported to have lasted for up to 28 months after application (23). The reason for the extended period of *Meloidogyne incognita* control in the fumigated plots in the current study is unknown at this time but may be related to optimum soil conditions at the time of treatment or to the difference in 1,3-D efficacy toward different nematode genera. Also, it is not known why *M. incognita* J2 populations would increase a year after peach planting but then decrease again after several years in plots that had originally been in the preplant MQ-MQ treatment.

Preplanting Jesup (Max-Q) tall fescue was as effective as preplant fumigation in increasing tree growth compared with the nonfumigated treatment under the conditions of this orchard study. Parasitism by *M. incognita* on peach often causes aboveground stunting of newly planted trees within 1 to 2 years following orchard establishment (26). In the current study, stunted peach trees were first detected 13 months after orchard establishment. At 13 months (February 2010) and 24 months (January 2011) after orchard establishment, trees growing in MQ-MQ-treated plots were larger than trees in P-MQ plots and in nonfumigated (P-P) plots but comparable with those in fumigated (P-P-F) plots, even though the *M. incognita* J2 soil population densities were not different among the MQ-MQ, P-MQ, and nonfumigated (P-P) plots during this same time period (December 2009 to March 2011). However, at 36 months (January 2012) and 48 months (January 2013) after orchard establishment, trees in the two Jesup (Max-Q) (MQ-MQ and P-MQ) and fumigation (P-P-F) plots were comparable in size, and all were larger than trees in the nonfumigated (P-P) treatment. These results demonstrate the importance of managing *M. incognita* prior to orchard establishment. Also, the results substantiate a previous observation that, if a peach orchard is established on a site with low initial *M. incognita* J2 soil population levels, this will allow the trees to develop a more extensive root system and, thus, grow normally even if the nematode population increases over time (4). In addition to controlling *M. incognita*, the presence of the killed tall fescue sod may have also contributed to the increase in tree growth. According to Welker and Glenn (31) and Evert and Bertrand (10), tree growth was increased in trees planted in killed sod. It is believed that killing the ground cover with a herbicide increased tree growth as a result of improved water infiltration rates, inhibition in soil organic matter depletion, increased aggregate stability and macroporosity, and enhanced microbial respiration; changes in soil structure which lasted for up to 3 years (31). Additionally the nematostatic or nematotoxic plant compounds associated with the decomposing killed tall fescue sod may have played an additional postplant role in nematode suppression during the early stages of the postplant treatment evaluation period, thus resulting in the observed increase in tree growth over time.

It should be emphasized that utilizing Jesup (Max-Q) as a preplant integrated pest management tool for *M. incognita* in peach may have some limitations. There are several factors to consider (but are not all inclusive). (i) A grower must determine whether tall fescue grass can be grown and is adaptable to his or her specified region of the country. (ii) Not all plant-parasitic nematodes that are pathogens on peach are suppressed by tall fescue grass. In the southeastern United States, Jesup (Max-Q) was suppressive against the root-lesion nematode *P. vulnus* but not the ring nematode *Mesocriconema xenoplax* (20). (iii) Establishing a good Jesup (Max-Q) tall fescue stand that is mostly weed free is important in order to prevent the target nematodes from finding alternate hosts on which to reproduce prior to orchard establishment. A number of selective herbicides are available that manage various perennial and broadleaf weed species but do not kill tall fescue grass. Because state recommendations for herbicide management may not be the same, current local sources of information should be consulted for updated recommendations.

In summary, we showed (i) the effects and potential usefulness of a preplant Jesup (Max-Q) tall fescue as a nonchemical management strategy to reduce the population density of *M. incognita* prior to establishing a peach orchard, (ii) the benefit of tall fescue in preventing *Meloidogyne incognita* stunting of tree growth, and (iii) that tree growth in preplant Jesup (Max-Q) tall fescue soil was comparable with tree growth in preplant 1,3-D fumigation soil 4 years after orchard establishment. Future studies could determine how other tall fescue cultivars compare with Jesup (Max-Q) as a preplant management tool against peach nematode pathogens in the southeastern United States.

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