COMPARISON OF SEED TREATMENT NEMATICIDES (AERIS AND AERIS + VOTIVO) AND TEMIK 15G ON THE GROWTH AND DEVELOPMENT OF *GOSSYPIUM HIRSUTUM* GROWING IN SOILS INFESTED WITH *ROTYLENCHULUS RENIFORMIS* UNDER GREENHOUSE ENVIRONMENTS

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ABSTRACT

Smith, H. R., R. L. Harkess, P. R. Knight, G. W. Lawrence, C. Overstreet, D. J. Lang, and K. S. Lawrence. 2019. Comparison of seed treatment nematicides (Aeris and Aeris + Votivo) and Temik 15G on the growth and development of *Gossypium hirsutum* growing in soils infested with *Rotylenchulus reniformis* under greenhouse environments. Nematropica 49:181-188.

Reniform nematode (*Rotylenchulus reniformis*) currently infests 36% of Mississippi cotton acreage causing economic losses of $130 million annually. With Temik 15G being removed from the market, there is a need to better understand nematode management programs centered on Nematicide Seed Treatments (NST). Economic threshholds for *R. reniformis* in Mississippi on medium-textured soils range from 1,000 to 5,000 *R. reniformis*/500 cm^3 of soil depending on season. This study aimed to determine effects of *R. reniformis* and efficacy of NST compared to Temik 15G on cotton growth. In greenhouse studies, all plants treated with NST had greater root and shoot biomasses compared to the untreated control within nematode populations. For treatments inoculated with a range of *R. reniformis*/500 cm^3 soil (*Pi),* greatest shoot biomass occurred in plants treated with Temik 15G at 2,500 *Pi*, and greatest root mass occurred in plants treated with Temik 15G whether *Pi* was 2,500, 5,000, or 7,500. Plants treated with Aeris® alone provided suitable root and shoot growth at 2,500 *Pi,* but became less effective at 5,000 P*i*. Plants treated with Aeris® + Votivo® at 2,500 P*i* produced greater root and shoot biomass compared to plants grown in soils with 5,000 or 7,500 *Pi.*

Key words: Aldicarb, *Bacillus firmus,* thiodicarb

RESUMEN

Smith, H. R., R. L. Harkess, P. R. Knight, G. W. Lawrence, C. Overstreet, D. J. Lang, and K. S. Lawrence. 2019. Comparación de nematicidas para el tratamiento de semillas (Aeris y Aeris + Votivo) y Temik 15G sobre el crecimiento y desarrollo de *Gossypium hirsutum* que crece en suelos infestados con *Rotylenchulus reniformis* en ambientes de invernadero. Nematropica 49:181-188.

El nematodo reniforme (*Rotylenchulus reniformis*) actualmente infesta el 36% de la superficie de algodón de Mississippi causando pérdidas económicas de $ 130 millones anuales. Con la eliminación de Temik 15G del mercado, es necesario comprender mejor los programas de manejo de nematodos centrados en los tratamientos con semillas de nematicida (NST). Los umbrales económicos para *R. reniformis* en Mississippi en suelos de textura media varían de 1,000 a 5,000 *R. reniformis*/500 cm^3 de suelo dependiendo de la estación. Este estudio tuvo como objetivo determinar los efectos de *R. reniformis* y la eficacia de los NST en comparación con Temik 15G sobre el crecimiento del algodón. En estudios de invernadero, todas las plantas tratadas con NST tuvieron una mayor biomasa de raíces y brotes en comparación con el control no tratado dentro de las poblaciones de nematodos. Para las poblaciones inoculadas de nematodos reniformes/500 cm^3 de suelo (P*i*), la mayor biomasa de brotes se produjo en plantas tratadas con Temik 15G y 2,500 *Pi*, y la mayor masa de raíces se produjo en plantas tratadas con Temik 15G si los números de nematodos fueron 2,500, 5,000 o 7,500 *Pi*. Las plantas tratadas solo con Aeris® proporcionaron un crecimiento adecuado de raíces y brotes a 2,500 P*i*, pero se volvieron menos efectivas a 5,000 *Pi*. Las plantas tratadas con Aeris® + Votivo® a 2,500 *Pi* produjeron una mayor biomasa de raíces y brotes en comparación con las plantas cultivadas en suelos con 5,000 o 7,500 *Pi*.

Palabras clave: Aldicarb, *Bacillus firmus*, tiodicarb

INTRODUCTION

The reniform nematode (*Rotylenchulus reniformis*) (Linford and Oliveira, 1940), a plant-parasitic nematode, has become the most damaging pathogen of *Gossypium hirsutum*. *Rotylenchulus reniformis*, first described in 1931, is a tropical and subtropical pest present throughout the United States *G. hirsutum*-producing region (Heald and Robinson, 1990; Kinloch and Sprenkel, 1994; Starr, 1998; Koenning *et al*., 1999; Lawrence *et al*., 2001). Since 1960, *R. reniformis* has shown an adaptive capability to survive colder environments allowing colonization of much of the eastern half of the *G. hirsutum* belt (Heald and Robinson, 1990) and as far north as Lubbock, TX, and the Missouri boot-heel (Heald and Thames, 1982; Wrather *et al*., 1992). Today, *R. reniformis* has been identified and associated with a 7% annual *G. hirsutum* yield loss totaling nearly $126 million in Mississippi, Alabama, Tennessee, Texas, Missouri, Florida, North Carolina, Louisiana, South Carolina, Arkansas, and Georgia (Koenning *et al*., 1999; Blasingame and Patel, 2004; 2005; 2011). In Mississippi, an annual yield loss of 235,398, 252,023 and 56,378 bales occurred in 2004, 2005 and 2011, respectively (Blasingame and Patel, 2004; 2005; 2011). By 2002, more than 32% of the *G. hirsutum* acres in Mississippi were infested with *R. reniformis* causing a 5.5% yield reduction (Lawrence and McLean, 2002). Gazaway and McLean (2003) reported *R. reniformis* infested more than 36% of Alabama *G. hirsutum* acreage and was increasing.

In 2004, the cotton industry began moving away from granular, at-planting treatments for nematode management. Prior to this time, and for more than 40 years, Temik 15G was a mainstay for nematode management in the cotton industry. However, in 2012, production of this product ceased and Nematicide Seed Treatments (NST) replaced Temik 15G. Padgett and Overstreet (2004) reported some NST were as effective as Temik 15G and reduced galling over the untreated control (UTC), but did not improve maturity or yield, indicating lack of longevity compared to Temik 15G. This was further verified by Faske and Star (2007). Monfort *et al.* (2006) reported NST did not differ from Temik 15G 14 to 35 days after planting (DAP). In addition, they reported NST applied at 100 g ai/kg of seed were similar to Temik 15G applied at 0.84 kg ai/ha. Unlike previous research, Kemerait *et al*. (2007) reported Temik 15G provided better yields and return on investment when compared to NST in nematode-infested soils.

The objectives of this study were to determine if NST under controlled greenhouse environments could provide enough suppression of *R. reniformis* to maintain adequate growth and development of cotton compared with Temik 15G; to determine at what population density of *R. reniformis* NST became less effective compared to Temik 15G; and to determine if there was a need for further research exploring applications of foliar chemistries like Vydate C-LV® in an integrated approach to improve cotton fruit retention where NST were used in soils infested with *R. reniformis*.

MATERIALS AND METHODS

Trial establishment and experimental design

Two separate greenhouse studies were conducted (June 4 to September 4 and September 10 to December 10, 2013) at R. R. Foil Plant Science Research Center, Mississippi State University (MSU) in Starkville, MS, using the cotton variety Phytogen 375 WRF (Dow Agro Sciences, Indianapolis, IN) planted at two seeds per 7.6 cm-diam. clay pot into an autoclaved loamy sand (72.5% sand, 25.0% silt, 2.5% clay pH 6.5) (Usrey *et al.,* 2005). All pots were filled with 500 cm^3 soil. Seeds were planted 1.3 cm deep. Upon emergence, seedlings were thinned to one plant per pot. Treatments included Temik 15G (Aldicarb: [2-methyl-2- (methylthio)propionaldehyde-O-(methylcarbamoyl)oxime (Bayer Crop Sciences-Raleigh, NC) at an equivalent rate of 0.84 kg ai/ha (0.0068mg ai/pot) was applied topically to the soil and followed by a thorough watering. Aeris® (Thiodicarb: Dimethy N,N'[thiobis[[methylimino)cabonyloxy]]bis[ethan imidotothioate] (Bayer Crop Sciences-Raleigh, NC) was applied at 0.075 mg ai/seed rate and Aeris® + Votivo® (*Bacillus firmus*) (Bayer Crop Sciences-Raleigh, NC) was applied at 0.424 mg ai/seed rate (Table 1). Seed were treated with Aeris® and Votivo® at the Bayer Crop Science facility in Leland, MS. *Rotylenchulus reniformis*, collected and reared at R. R. Foil Plant Science Research Center, Mississippi State University (MSU) in Starkville, MS, were applied in a liquid solution using a graduated pipette and included 0, 2,500, 5,000, or 7,500 *R. reniformis*/500 cm^3 soil. Despite 7,500 *R. reniformis*/500 cm^3 of soil being higher than generally found in most cotton soils, the number was used to establish a threshold for nematicide efficacy. Each study was conducted for 90 days. Greenhouse conditions were maintained at a constant 30°C daytime temperature and 20°C nighttime temperature using cooling fans during summer months with full sun exposure. During the winter months, temperatures were maintained using heating units to facilitate these temperatures and supplemental lighting by halide lights was used. Watering was conducted on a daily basis. Fertilizer applications were applied weekly using a general water-soluble fertilizer at 300 mg N/L (Miracle Gro 24-8-16; Scotts Miracle-Gro Co., Marysville, OH). Insecticides for whitefly and thrips were applied on an as-needed basis. Experimental design was a randomized complete block design with four single plant replications. Data were analyzed via the ANOVA for a RCB (ARM 8 statistical software-Gylling Data Management, Brookings, SD, and verified using SAS; SAS Institute, Cary, NC) where block and treatment effects were evaluated to minimize degree of error and improve confidence intervals among experimental units. Means were separated using Fisher's Protected Least Significant Difference (LSD) at 0.05 probability level. Since year was not significantly different and no interactions across years occurred, data were pooled. MIXED procedure in SAS 9.4 (SAS Institute, Cary, NC) was conducted prior to pooling to determine if any interactions occurred between tests.

Evaluation criteria

Before harvest evaluations included total nodes (TN), plant height (PH), node of first fruiting branch (NFFB), and height to node ratio (HNR). At harvest evaluations included root and shoot biomass and nematode extraction (eggs and juveniles). At harvest, shoot biomass was separated from root biomass using hand pruners. The shoot was then weighed and recorded. Roots were extracted from soil by immersing the plant in a bucket filled with water to dislodge the soil. Soil-free roots were soaked in 10% NaOCl and stirred

Table 1. Treatment list for greenhouse nematicide study where cotton cultivar Phytogen 375 was grown under varying populations of *Rotylenchulus reniformis* in an autoclaved soil.

Treatment	Rate	Mode of Application	Inoculated reniform numbers
Aeris®	0.075 mg ai/seed rate	Seed treatment	0, 2,500, 5,000, 7,500
Aeris® + Votivo®	0.075 mg ai/seed rate + 0.1424 mg ai/seed rate	Seed treatment	0, 2,500, 5,000, 7,500
Temik 15G	0.84 kg ai/ha	At-planting/soil applied	0, 2,500, 5,000, 7,500
Untreated	-	-	0, 2,500, 5,000, 7,500

in solution for 3 min, roots removed, and then weighed. The remaining NaOCl solution was poured through stacked 55 µm over 25 µm pore size screens to obtain eggs. The remaining soil was mixed with 1,000 ml of water and processed through stacked 250 µm over 44 µm pore size screens to obtain vermiform nematodes and centrifuged for 6 min at 2,500 rpm. Excess water was removed, and the pellet mixed with a sucrose mixture (454 g sucrose/1,000 ml water) followed by a 1 min centrifuge at 2,500 rpm. The supernatant was poured through a 44 µm pore size screen and the sample refrigerated at 1.6°C until counted (Byrd *et al*., 1976). Nematodes were counted via stereo microscope for vermiform stages of *R. reniformis* and for eggs by pipetting 20 ml of liquid into a quadrated petri dish.

RESULTS AND DISCUSSION

Egg and juvenile R. reniformis *populations across nematicide treatments*

Populations of juveniles of *R. reniformis* were similar for untreated plants, plants treated with Temik 15G, or Aeris® + Votivo® at *Pi* 2500. Both untreated plants and plants treated with Aeris® had similar vermiform stage nematodes numbers at *Pi* 5,000. Plants treated with Temik 15G had the fewest vermiform nematodes, and plants treated with Aeris® + Votivo® had the most. At *Pi* 7,500, untreated plants and plants treated with Aeris® + Votivo® had more vermiform nematodes compared to plants treated with Temik 15G or Aeris® (Table 2). Plants treated with Temik 15G continued to have the lowest numbers of vermiform nematodes compared to all other treatments or untreated plants. Nematode populations can be associated with root volume where there is a direct correlation between root growth and nematode population development (Lawrence and McLean, 1996). Temik 15G reduced the population of *R. reniformis* in greenhouse environments and prevented normal nematode reproduction. Egg production in pots treated with Temik 15G was similar to untreated pots regardless of *Pi*, less than Aeris® at any *Pi* 2,500, and less than Aeris® + Votivo® at *Pi* 2,500, or 5,000 (Table 2). Temik 15G prevented nematode reproduction, but populations of *R. reniformis* were similar as *Pi* increased. Across

Table 2. Effect of nematicides on reproduction of *Rotylenchulus reniformis* and shoot and root biomass development of cotton cultivar Phytogen 375 under varying population densities of *R. reniformis* grown under greenhouse environments at 90 days after emergence.

Treatment	Initial nematode population [v]	Vermiform number/500 cm^3 [w]	Egg number/500 cm^3 [w]	Shoot biomass (g) [x]	Root biomass (g) [x]
Untreated	0	0 g [y]	0 d	48.0 fgh	46.6 d
Temik 15G [z]	0	0 g	0 d	68.5 ab	52.5 b
Aeris®	0	0 g	0 d	70.3 a	55.6 a
Aeris® + Votivo®	0	0 g	0 d	64.5 bc	57.0 a
Untreated	2,500	1,597 fg	1,123 cd	46.9 gh	35.0 f
Temik 15G	2,500	901 fg	438 d	70.2 a	51.6 b
Aeris®	2,500	7,892 c	4,282 ab	56.0 d	46.7 d
Aeris® + Votivo®	2,500	1,597 fg	5,214 a	60.9 c	49.7 c
Untreated	5,000	3,901 e	1,975 cd	45.7 h	34.5 f
Temik 15G	5,000	1,087 f	1,306 cd	62.6 c	51.4 b
Aeris®	5,000	5,021 de	2,639 bc	51.7 ef	45.3 d
Aeris® + Votivo®	5,000	9,754 b	5,163 a	53.3 de	45.6 d
Untreated	7,500	5,995 d	1,442 cd	41.4 i	25.1g
Temik 15G	7,500	1,576 f	1,391 cd	52.9 de	51.4 b
Aeris®	7,500	4,172 e	1,759 cd	46.2 h	39.8 e
Aeris® + Votivo®	7,500	5,459 d	2,820 bc	50.6 efg	44.6 d
LSD (0.05)		1,236	2196.5	4.1	2.7

[v] *R. reniformis* added to soil at planting using a pipette via a graduated factor.

[w] Vermiform and eggs of *R. reniformis* extracted from the 500 cm^3 of soil via elutriator and centrifuge process.

[x] Shoot and root biomass were acquired from the one plant grown in a 7.6 cm-diam. pot. Two seed per pot planted 1.3 cm deep and one removed after emergence. 7.6 cm-diam. pot represented 500 cm^3 of soil.

[y] Means with same letter within column are not significantly different.

[z] Temik 15G applied at 0.07584 kg ai/ha to soil at planting, Aeris® applied 0.075 mg ai/seed rate and applied at 0.424 mg ai/seed rate applied to the seed prior to planting by Bayer Crop Science.

NST, egg production of *R. reniformis* was greater at *Pi* 2,500 compared to plants treated with Temik 15G or untreated plants, but few differences occurred between treatments as *Pi* increased.

Aeris® alone provided adequate *R. reniformis* control at *P*i 2,500 but began declining as populations rose to *Pi* 5,000. Addition of Votivo as a seed treatment partner improved control of *R. reniformis* as the population increased to *Pi* 5,000. This indicated that Aeris® as a stand-alone may provide acceptable early season control of *R. reniformis* under populations present in many cotton soils. However, as populations of *R. reniformis* increased, addition of Votivo® to Aeris® improved control as the population approached 5,000 nematodes/500 cm^3 of soil as observed by Faske and Star (2007). This may explain why Votivo® as a stand-alone product in cotton has been inefficient under moderate to high populations of *R. reniformis*. Because Votivo® is a plant growth promoting rhizobacteria activated by temperature and using root exudates as a source of nourishment for colonization, there is a time delay necessary to encompass the entire cotton plant root system (Bugg, 2010). This delay creates a need for a product like Aeris® to provide early season control of *R. reniformis*. Therefore, combination of Aeris® with Votivo® overcomes the limitations of both products promoting a synergistic effect. Such combinations were observed necessary by Castillo *et al.* (2013) making the effectiveness of biologicals similar to Temik 15G®.

Effects of R. reniformis *on shoot biomass development*

Treatments without *R. reniformis* had greater stem biomass across all nematicide treatments compared to untreated plants (Table 2). At *Pi* 2,500, all nematicide treatments resulted in plants with greater shoot biomass compared to untreated plants. Plants treated with Aeris® + Votivo® or Temik 15G had greater shoot biomass compared to plants grown with Aeris®. Plants treated with Temik 15G at *Pi* 5,000 had greater shoot biomass compared to NSTs. Untreated plants had less biomass when compared to plants receiving nematicides. At *Pi* 7,500, plants treated with Temik 15G or Aeris® + Votivo® had similar shoot biomass, but pots treated with any nematicide had greater shoot biomass compared to untreated plants. Plants treated with Temik 15G or Aeris® + Votivo® had greater shoot biomass development compared to plants treated with Aeris®.

In all treatments, except Temik 15G, as population of *R. reniformis* (vermiform and eggs) increased, root mass decreased, which correlated to a reduction in shoot biomass (Table 2) (Lawrence and McLean, 1996). Root biomass reduction for both NST started at *Pi* 2,500, but at *Pi* 5,000 Aeris® + Votivo® provided greater control of *R. reniformis* than Aeris® similar to findings by Kemerait *et al*. (2007). Shoot biomass was also greater with Temik 15G or Aeris® + Votivo® treated plants as *R. reniformis* population increased. Plants treated with Aeris® + Votivo® or Aeris® had greater root biomass compared to plants treated with Temik 15G or untreated plants at *Pi* 0 indicating root development suppression by Temik 15G. Under *Pi* 2,500, plants treated with Aeris® or Aeris® + Votivo® had lower root biomass compared to plants treated with Temik 15G. Addition of Votivo® to Aeris® did improve root biomass compared to plants treated with only Aeris. At *Pi* 5,000 and 7,500 plants treated with any nematicide had greater root biomass compared to untreated plants. However, plants treated with Temik 15G had greater root biomass compared to plants treated with either NST. NST did not differ from each other at *Pi* 5,000 but Aeris®+ Votivo® did improve root biomass development at *Pi* 7,500. As *R. reniformis* numbers increased, root biomass development declined for plants treated with Aeris® or Aeris® + Votivo®, but plants treated with Temik 15G did not decline. Aeris® + Votivo® provided better growth at higher *R. reniformis* populations than Aeris®. In addition, in the greenhouse, small container size and reduced length of growing time may have impacted overall root growth since cotton has a long taproot. However, Temik 15G maintained greater root biomass at *Pi* 7,500 compared to NST agreeing with Keramit *et al*. (2007). All nematode treatments improved root biomass compared to untreated plants.

Effect of nematicide treatments on cotton growth at varying R. reniformis *populations under greenhouse environments*

Under the controlled greenhouse environment, fruit initiation (NFFB) occurred later in plants treated with Temik 15G compared to untreated plants or plants treated with Aeris® with or without Votivo® when *Pi* is 0, but the opposite occurred at *Pi* 2,500 (Table 3). When *Pi* was 5,000 or 7,500, nematicides hastened fruit initiation compared to untreated plants. In the absence of *R. reniformis,* Phytogen 375 was able to initiate fruiting at fruiting node six, the genetically controlled NFFB for this variety. The largest differences in NFFB occurred at *Pi* 2,500 where Temik 15G had fruit initiation similar to *Pi* 0. Plants treated with NST at this population did not differ from untreated plants and initiated fruiting one node higher than plants treated with Temik 15G. Within *Pi* 5,000 and 7,500, plants treated with any nematicide treatment fruited at nodes lower than untreated plants, but at these populations, plants initiated fruiting one node higher than the genetically controlled NFFB. Initiation of fruiting began two nodes higher at *Pi* of 5,000 and 7,500 for untreated plants. Even with use of nematicides, *R. reniformis* at higher *Pi* delayed fruit initiation; however, NFFB remained one node lower than untreated plants.

Plant height increased across all nematode population densities for plants treated with nematicides compared to untreated plants (Table 3). Greatest height reduction occurred in untreated plants at *Pi* 5,000 and 7,500. In absence of *R. reniformis*, plant height was improved when nematicides were used with Aeris® + Votivo®, Aeris® and Temik 15G resulting in similar plant heights at *Pi 0*. In the presence of *R. reniformis* at *Pi* 2,500, all nematicide-treated plants were taller than untreated plants with no difference among nematicides. At *Pi* 5,000, all nematicides improved plant height over untreated plants. Temik 15G and Aeris® + Votivo® were similar while Aeris® plants were shorter than other nematicide treated plants. All nematicide treated plants were taller at *Pi* 7,500 than untreated plants. At this population, Temik 15G treated plants had greater plant height compared to plants treated with NST, but NST plants were still taller than untreated plants. Temik 15G offered greater management of *R. reniformis* across a greater nematode population than NST. This indicates a need for additional pesticide treatments, *e.g.,* Vydate C-LV®, to maintain *G. hirsutum* growth under high populations of *R. reniformis* when using NST.

All nematicide treated *G. hirsutum* had improved growth compared to untreated plants. Negative effects of *R. reniformis* on *G. hirsutum* were reflected in plant height (Table 3) which can be associated with reductions in root development

Table 3. Effect of nematicides on growth of cotton cultivar Phytogen 375 WRF grown under varying population densities of *Rotylenchulus reniformis* under greenhouse environments at 90 days after emergence.

Treatment	Initial nematode Population[v]	NFFB (number)[w]	Plant height (cm)[x]
Untreated	0[y]	6.0 d[z]	54.4 de
Temik 15G	0	7.0 c	58.4 abc
Aeris®	0	6.0 d	59.4 ab
Aeris® + Votivo®	0	6.0 d	60.5 a
Untreated	2,500	7.3 b	40.6 g
Temik 15G	2,500	6.0 d	59.4 ab
Aeris®	2,500	7.0 b	56.6 bcd
Aeris® + Votivo®	2,500	7.0 b	58.9 abc
Untreated	5,000	8.0 a	35.6 h
Temik 15G	5,000	7.0 b	57.4 abc
Aeris®	5,000	7.0 b	53.3 e
Aeris® + Votivo®	5,000	7.0 b	55.9 cd
Untreated	7,500	8.0 a	36.6 gh
Temik 15G	7,500	7.0 b	54.1 de
Aeris®	7,500	7.0 b	48.8 f
Aeris® + Votivo®	7,500	7.0 b	48.3 f
LSD (0.05)		0.1	3.12

[v]*R. reniformis* added to soil at planting using a pipette via a graduated factor.
[w]Node of First Fruiting Branch
[x]7.6 cm-diam. pot represented 500 cm^3 of soil.
[y]Growth parameters were acquired from the one plant grown in a 7.6 cm-diam pot. Two seed per pot planted 1.3 cm deep and one removed after emergence.
[z]Means with same letter within column are not significantly different.

(Table 2), agreeing with findings by Monfort *et al.* (2006). As populations of *R. reniformis* increased, NST provided greater growth of above ground plant parts compared to untreated plants (Table 3) but were less effective compared to Temik 15G treated plants at higher populations of *R. reniformis* as observed in findings by Kemerait *et al.* (2007) and Padgett and Overstreet (2004) but disagreeing with findings by Monfort *et al*. (2006) .

CONCLUSION

All nematicides tested tended to decrease root biomass as population densities of *R. reniformis* increased. Reductions in root biomass began early for both NSTs at *Pi* 2,500 but began segregating at *Pi* 5,000 where Aeris® + Votivo® provided greater control of *R. reniformis* than Aeris® alone. This was further verified in increased shoot biomass with Temik 15G or Aeris® + Votivo® treated plants as *R. reniformis* population increased. Early control of this pest by nematicides is needed to enhance adequate root development to improve above ground plant growth. Because NST, compared to Temik 15G, did not offer suitable *R. reniformis* control as populations increased, there is a need for additional timely management decisions to enhance *R. reniformis* control to maximize *G. hirsutum* performance in nematode-infested soils.

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