PERFORMANCE OF COMMERCIALLY AVAILABLE *GOSSYPIUM HIRSUTUM* VARIETIES GROWN IN *ROTYLENCHULUS RENIFORMIS* INFESTED SOILS WITH AND WITHOUT NEMATICIDES

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Abstract

Reniform nematode (*Rotylenchulus reniformis* Linford and Oliveira) infests 36% of Mississippi cotton (*Gossypium hirsutum* L.) acres promoting economic losses of $130 million annually. Previously nematodes were managed using Temik 15G at-planting or fumigants, but with label loss of Temik 15G and expense of soil fumigants need arises to develop an integrated nematode management program, which entails understanding which commercial variety exhibit tolerance to *R. reniformis* since no resistance exists. Little tolerance to *R. reniformis* has been reported in cotton varieties; however, studies indicate some varieties perform better than others in *R. reniformis* infested soils. Two field and greenhouse studies at Mississippi State University during 2012 indicated all evaluated variety growth parameters improved with a nematicide but some varieties grew and yielded better than others without nematicides. Early plant growth parameters (plant height, plant height by node, vigor, hypocotyl length) in some varieties were less impacted without nematicide. Tolerance in untreated varieties was further observed in fruit retention during different growth stages especially at fruiting position one. Untreated varieties did have lower fruit retention promoting harvest maturity loss, further displayed in greater number of nodes above cracked boll, lower percent open boll and greater boll diameter differences. Some commercial varieties (Stv 5458 B2RF, FM 1740 B2RF and Phy 499 WRF) evaluated showed tolerance. Greenhouse studies further validated field findings showing *R. reniformis* population increase related to reduced shoot and root growth with varying performance by variety.

Introduction

Cotton remains a significant Mississippi agronomic crop accounting for 1.1 million hectares (MS Agricultural Statistical Service, 2013). A predominant plant parasitic nematode that is most damaging pathogen to cotton is reniform nematode (*Rotylenchulus reniformis* Linford and Oliveira). *R. reniformis*, (Linford and Oliveira, 1940) has become widely distributed through the United States cotton producing region (Lawrence and McLean, 1996; Star, 1998; and Koenning. et al., 1999). Because of rapid in-field development, production of plant symptoms uniformly across fields making identification difficult while reducing yield (Lawrence and McClean, 2001, boll size and lint percent (Jones et al., 1959). In addition, cotton responds poorly to normal agronomic management practices (Birchfield and Jones, 1961) in presence of *R. reniformis* and provide portals for secondary infection (Palmateer et al., 2004). *R. reniformis* has spread through much of the eastern half of the cotton producing region (Heald and Robinson, 1990) and as far north as Lubbock, Texas and the Missouri bootheel (Held and Thames, 1982; Wrather et al., 1992). Today, *R. reniformis* has been associated with yield loss in all states it occupies (Koenning. et al., 1999) accounting for 11.0% annual yield loss totaling nearly $70.0 million loss to the cotton industry in 2014 (Lawrence et al., 2015). In Mississippi, *R. reniformis* caused yield loss of 235,398, 252,023, 56,378 and 58,000 bales in 2004, 2005, 2011 and 2014 respectively (Blasingame, 2004; 2005; 2011; Lawrence et al., 2015). Lawrence, et al. (2002) reported more than 32% of Mississippi cotton acres were infested with *R. reniformis*. Gazaway and Mclean (2003) further reported *R. reniformis* infested 36% of the Alabama cotton acres. A primary reason for shift in population was due to *R. reniformis* ability to reduce egg hatching of *M. incognita* (Diez et al., 2003). Other characteristics promoting rapid spread is ability to reproduce in many soil types (Koenning et al., 1996; Moore and Lawrence, 2013), ability to survive and promote yield loss under low water conditions (Herring et al., 2010), survive in fallow fields (Koenning et al., 1999), complete spread across a field in one season, ability to be moved by equipment and irrigation (Moore et al., 2010*)* and ability to survive deep in the soil profile (Moore et al., 2010; Robinson, 2005).

Presently no marketed *R. reniformis* resistant cotton varieties exist, but a resolution is being sought (Usrey et al., 2005; Robinson et al., 2007; Starr, et al., 2007). Some varieties have been shown to possess nematode tolerance (Usry et al., 2004; 2005) at low to moderate nematode populations (Starr et al., 2007; Weaver et al., 2007). Numerous studies have been conducted evaluating commercial variety performance in nematode infested soils. Usery et al. (2004; 2005) and Legee et al. (2007) reported several varieties showed tolerance to high *R. reniformis* infestation and used plant mapping processes to evaluate variety performance in these environments. Luangkhot et al. (2015) reported currently grown varieties responded to nematicides in greenhouse and field environments where *R. reniformis* was present with little variety tolerance. This group did not report plant mapping processes to evaluate variety strengths. Early maturing cotton varieties have been shown to have greater tolerance to *R. reniformis* providing higher yields and lower nematode feeding activity. Further work evaluating commercial varieties in nematode infested soils was reported by Sciumbato et al. (2005) as related to *R. reniformis* where no difference among cotton maturity group existed. Koenning et al. (2005), however, reported late maturing varieties performed better than early varieties in soils infested with Columbia lance nematode (*Hoploaimus columbus*) while Williams et al. (2004) reported similar findings with root knot (*Meloidogyne incognita)*. Phipps and Eisenback (2005) further reported net dollar return was greater when using tolerant cotton varieties planted in *M. incognita* infested fields. They also reported nematicides were still economically beneficial when used with tolerant varieties.

Understanding cotton growth and development is critical in implementing management to maximize yields, profits and understand stress effects. Cotton possesses a unique fruiting pattern making facilitating evaluation of stresses created by nematodes (Jenkins and McCarty, 1995; Kerby et al., 1987; Smith et al., 1996; 1998). Gutherie and Kerby (1993) reported cotton growth maintains a record of its response to environment and management that can be traced by quantifiable plant mapping. Importance of plant mapping has been well documented (Jenkins and McCarty, 1995; McCarty et al., 1994, Albers, 1993). Smith and McCarty (1996) used in-season plant mapping to demonstrate effectiveness of Temik 15G applied at-planting and as a side-dress in *R. reniformis* infested soils. From this methodology they were able to capture fruiting and growth pattern differences and differences in maturity and yield. Turnage and Smith (1998) further used in-season plant mapping to demonstrate how Temik 15G performed compared to Acephate 15G under heavy thrips pressure in PM 1215 BR based on growth parameters and yield in *R. reniformis* infested soils. Lawrence et al. (1998; 2001; 2002) and Lawrence and McLean (2002) further demonstrated influence of nematicide treatments on cotton in *R. reniformis* infested soils via plant mapping processes. The objective was to evaluate and map growth, development and yield of five cotton varieties grown with and without nematicide treatments in *R. reniformis* infested soils to determine if tolerance exists among commercial cotton varieties.

Materials and Methods

Field experiment. Two studies were conducted at R. R. Foil Plant Science Research Center at North Farm of Mississippi State University in Mississippi State, Mississippi containing pre-established population of *R. reniformis*. Location one had a CEC (Cation Exchange Capacity) of 13 and the second consisted of a higher CEC of 16. Both trials consisted of five commercially available varieties (FM 1740 B2RF, Stv 5458 B2RF, Stv 5288 B2RF, Phy 375 WRF and Phy 499 WRF) with and without the nematicide seed treatment, Aeris®, evaluated to determine growth and development in *R. reniformis* infested soils (Table 1). Both plantings occurred May 15 and 16, 2012 using a four-row cone planter to deliver pre-counted seed. Seed were counted using an automated seed counter to deliver four seeds per row foot. Both trial locations had the possibility of furrow irrigation, but was not used due to the abundance of rainfall.

The trial design used was a randomized complete block (RCB) established consisting of five replications. Data was analyzed using Analysis of Variance (ANOVA) for a 5 by 2 Factorial with RCB factor using ARM 8 (ARM 8 statistical software-Gylling Data Management; Brookings, South Dakota). Means were separated using Least Significant Difference (LSD) at 0.05 probability. Individual plot length consisted of two-row plots of 12.16 meters and 7.6 meters with 3.04 meter alleys. Row spacing consisted of solid planting pattern being planted on 14.96 cm.

Nematode soil samples were collected prior to planting and further monitoring occurred during square, bloom and open boll. Samples were acquired at six samples per plot simultaneously using a fluted probe designed to collect multiple samples per plot. Probe dimensions were 8.75 cm at the top and tapering to 1.91 cm at the bottom facilitating multiple samples without loss of soil. Length of sample device was 27.94 cm to guarantee the acquisition of 500 cc of soil. Samples were acquired from row side at a distance of 15.24 cm in a zig-zag method allowing samples to be obtained at three samples per row. Depth of sample was conducted at an approximate depth of 10.16 cm. Nematodes were extracted using semi-automatic elutriator and centrifugal flotation and resulting nematodes enumerated using a stereo-microscope.

Visual plant vigor and plant population were evaluated at 14 days following emergence. Vigor was established using two processes; 1. Visual assessment on a scale of one to five where one had greatest growth and five the lowest and, 2; hypocotyl measurement. Hypocotyl measurement involved measurement from seed embryo axis to cotyledonary node. Hypocotyl distance provides a quantifiable method to analyze vigor. Plant population was determined by counting every plant in all plots to determine plants per hectare. Growth parameters monitored during mid-square included, plant height (PH), node of first fruiting branch (NFFB), total nodes (TN), height to ratio (HNR), retention by position along sympodial branch and average plant height by node measurements. Average plant height by node measurements were conducted by measuring each internode length separately from cotyledons to terminal leaf that was 2.54 cm wide in a manner where overall length cumulated in a final height (Kerby, et al., 2003). Six consecutive plants possessing a normal terminal were sampled destructively per plot providing a total of 30 plants sampled plants. Evaluation time was two weeks following initial square initiation.

Growth parameters (from six consecutive plants per plot) were evaluated during bloom included the following: PH, TN, HNR, nodes above white flower (NAWF), node of white flower (NOWF), retention by position and by zone as stated previously and average plant height by node measurements conducted at both locations. In addition, caliper readings were taken at cotyledonary node to obtain basal stalk diameter and from unopened first position bolls at node 9 and 12 below terminal. Evaluation parameters during open boll included the following criteria on six consecutive plants: PH, TN, cumulative plant height, node above cracked boll (NACB), fruit retention by position and percent open boll. The monitoring phase began when the cotton bolls of the earliest treatment was approximately 30% open collectively. Defoliation was conducted based on visual assessments of 60% open boll with harvest aids applied using high clearance ground equipment. Harvest was conducted using a John Deere 9965 (Moline, Illinois) harvester equipped with a Rice Lake 9201i weighing system (Rice Lake Weighing Systems-Rice Lake, WI) to measure seed cotton by plot. Seed cotton weights were converted to lint pounds per acre using historical lint percentages established via the University Official Variety Trials at Mississippi State University.

Greenhouse experiment. Two separate greenhouse studies were established using above listed varieties planted at two seeds per 3.0” clay pot into a sterile Free Stone fine sandy loam. All pots were brought to same soil level. Planting depth for all seed was 0.5 inch. Upon emergence, one plant was removed. Treatments included Temik 15G at an equivalent rate of 5.0 lbs/Ac, Aeries, Aeries + Votivo and UTC (Table 2.0). Nematode populations were applied to soil in a liquid solution using a graduated pipette and included *Pi* of 0, 2,500, 5,000, 10,000 *R. reniformis* per 500 cc of soil (Table 2.0). Each study was conducted for 90 days. Experimental design was established as a RCB consisting of four replications. Data was analyzed using an ANOVA for a RCB (ARM 8 statistical software-Gylling Data Management- Brookings, South Dakota). Means were separated using the Least Significant Difference (LSD) at the 0.05 level of probability.

Before harvest parameters gathered included TN, PH, NFFB, HNR and basal stalk diameter. At harvest evaluations included root and shoot biomass and nematode extraction (eggs and juveniles). At harvest, shoot was removed from root by cutting shoot at ground level using hand pruners and shoot was weighed. Roots were extracted from soil in a bucket and soil-free roots soaked in a 10% Chlorox solution for three minutes and weighed. The remaining solution was poured through a 200 over 500 mesh screen. The remaining soil was processed through a 60 over 325 mesh screen and centrifuged for six minutes. Excess water was next removed and mixed with a sucrose mixture (454 g sucrose per 1,000 ml of water) followed by a one-minute centrifuge process. Liquid was next poured through a 500 mesh screen and sample refrigerated in a 250 ml beaker until counted. Nematode numbers were surveyed via stereo-scope for *R. reniformis* juveniles and eggs by pipetting 20 mls of liquid into a quadrated petri dish.

Results and Discussion

Field experiment. *R. renifor*mis population progression across time aids in determining impact on growth and development of cotton at each growth stage. Final nematode populations increased relative to root development (Lawrence and McClean, 1995; 1996). At location one and two (Table 3 and Figure 1), *R. reniformis* population began low during May and remained unchanged until June when the population began a steady increase. The largest population increase occurred between July and September at this location (Table 3). At location two, initial population development followed a similar pattern between May and June, but from June to September began a slow and steady increase. Major population increases began one month earlier at location one.

Plant population: Plant population was not greatly affected at location one and two (Table 4&5). At both locations, plant populations differed between treated and untreated varieties except untreated FM 1740 had lower population but was greater than treated comparison. Stv 5458 had the greatest population whether treated or untreated. Basically, seed treatment had a lower plant population than untreated plants indicating seed treatment could have a restrictive bearing on movement through the planter making increases in seeding rate possible.

Vigor evaluation: Seedling vigor at location one (Table 4) was not improved when using a nematicide except in Phy 499. Seedling vigor of varieties at location two (Table 5) was improved with addition of a nematicide except for Stv 5458. Differences in variety seedling vigor between treated and untreated were primarily observed at location two.

Hypocotyl length: At both locations, hypocotyl lengths were improved overall with a nematicide. Hypocotyl length of cotton varieties was improved at location one in presence of a nematicide except for Stv 5458 that had greater growth in both soil types despite nematicide treatment (Tables 4&5). Stv 5288 and Phy 499 had less hypocotyl growth with NST at location two while other varieties were the same or improved.

Node of First Fruiting Branch: Nematicide treatments lowered initiation of NFFB in Phy 499 and Stv 5458 at location one and Phy 375, Phy 499 and Stv 5458 at location two. Later maturing varieties Stv 5458 and Phy 499 also had reduced NFFB when treated with a nematicide in both locations. Untreated and treated early maturing cotton varieties, Stv 5288, FM 1740 and Phy 375, at location one did not differ between treated and untreated plants (Table 4). This was also observed at location two with exception of Phy 375, which improved with a nematicide. (Table 5).

Square growth period: All varieties treated with NST had increased plant height during square at location one (Table 6) with exception of Phy 499. Phy 499 lack of growth differences between treated and untreated could be due its late maturing nature. Varieties growing taller at square whether treated or untreated were Phy 375 and Stv 5458. Stv 5458 had reduced node number with NST while Phy 499 had an increased node number with an NST while there was no difference between NST and untreated in the remaining varieties. The NST had little effect on internode length at square as indicated by HNR. At location two (Table 7), all varieties were taller as result of NST with exception of Phy 499 which did not differ from the untreated. In addition, there was no difference between variety (NST vs. untrerated) in plant height or on total nodes. HNR was greatest in Phy 499, which was also the tallest variety (Table 4.6). Since there was no difference in total node, HNR decreased as plant height increased. Phy 499 at both locations showed the smallest differences between treated and untreated. Phy 375 had the greatest height difference between the treated and untreated in both soils. Stv 5458 and FM 1740 showed good nematode tolerance in both soil types possessing smaller differences in growth between the NST and untreated.

Bloom growth period: Plant height of all treated varieties was improved at location one (Table 6). Differences between NST and untreated within variety were greater at location one during bloom than square with Phy 375, Stv 5288 and Phy 499 possessing greatest differences. HNR increased at bloom in all varieties, except Stv 5458, indicating greater internode elongation with NST. With no restriction to internode elongation between NST and untreated, Stv 5458 showed greater nematode tolerance than other varieties at location one. At location two, plant height increased in all varieties with NST (Table 7). There were few differences between NST and untreated variety. However, HNR increased between untreated and NST in all varieties except Phy 375 which had no difference. At location two, NST plants had longer internodes indicating *R. reniformis* restricted growth in all varieties except Phy 375.

Open boll growth stage: Final plant height at location one (Table 6) was increased by NST. Stv 5458 with NST was tallest as well as Stv 5458 with no NST compared to other varieties indicating some tolerance. With exception of Stv 5458, all varieties had more total nodes with NST. HNR increased with NST in all varieties, except FM 1740 and

Phy 499 where nematode infestation limited growth except in these two varieties. Similar results were measured at location two except Phy 499 had no difference in height between NST and untreated (Table 7). At location two, Phy 499 was the tallest variety. Total nodes decreased with NST in Phy 375 and Phy 499, increased with NST in FM 1740 and Stv 5458 and remained same in Stv 5288. However, HNR increased with NST for all varieties tested indicating NST resulted in increased internode elongation in all varieties.

Square growth phase: Evaluation of plant height by node provides a method by which variety performance relative to stress t can be quantified via internode elongation (Kerby et al., 2003). With this method each internode is measured in cumulative fashion completing with total plant height. At location one (Table 8) no differences existed between varieties with NST and untreated at main-stem node one or three. Internode length at main-stem node five and seven indicated few differences between treated or untreated Phy 375, Stv 5458 and Stv 5288 while NST did improve growth of Phy 499 and FM 1740 at these nodes. Average plant height at main-stem node nine indicated a breaking point for untreated treatments with exception of Phy 375, which did not differ from NST Phy 375. Untreated variety height at main-stem node nine was shorter than NST cotton plants of the same variety. At main-stem node eleven, all varieties were taller than untreated plants compared to varieties treated with an NST. This remained true through main-stem node thirteen except for Phy 499 where height was same for NST and untreated. By main-stem node fifteen, all varieties were taller when they received a NST. Phy 375 was as much as one inch taller when treated compared to only about one-half of an inch increase in other varieties indicating greater tolerance from the other varieties during square. Unlike location one, Stv 5288 and FM 1740 at node one at location two (Table 9) were taller in NST than untreated plants. Average plant height at main-stem node three showed no differences between NST or untreated plants within variety except NST Stv 5458 was taller than untreated plants. At main-stem node five and seven, only FM 1740 and Stv 5458 had increased plant height when treated with NST. All other varieties were as tall in the untreated as with the NST. Average plant height at main-stem node nine followed a similar pattern as in previous nodes, except Stv 5288 and Stv 5458 along with FM 1740 increased in plant height with NST. This indicates variety tolerance through node nine. Average plant height at main-stem node eleven at location two is where nematodes appear to affect growth with all varieties increasing in height with NST treatment differing from location one where this break occurred at node nine. This pattern held true through node 15. Nematicides improved growth in *R. reniformis* infested soils during square production period, but response is variety driven. Overall effects of nematodes on plant height occurred earlier at location one than location two.

Average plant heights by node during bloom growth phase: Since by second evaluation internode growth had ceased in this region, second evaluation continued from node eleven. Average plant height by node at node eleven during bloom obtained growth advantages from NST. All treated varieties at this node had taller growth compared to untreated partners at both locations with exception of treated STV 5458 at location one which did not differ from untreated plants (Table 10). Untreated Stv 5458 was only variety at location one that did not differ from remaining treated varieties indicating its ability to overcome *R. reniformis* negative impacts on growth at this location (Table 10). At this node of location two, untreated Stv 5458 was restricted in growth in presence of *R. reniformis*. Untreated Phy 375 was negatively impacted at node eleven more than other treatments at both locations as was Stv 5288 at location two. However, untreated Stv 5288 showed acceptable growth at location one compared to treated plants indicating some tolerance. It was further observed that at main-stem node eleven at both locations nematicide treatment benefited Phy 375 the greatest. Average plant height at main-stem node thirteen at location one benefitted from nematicide treatment across all varieties except Stv 5288 and Stv5458 which did not differ from untreated plants. However, at location two, all nematicide treated varieties were taller than untreated plants. At both locations, FM 1740 and Phy 375 benefited from nematicide and was taller than remaining treatments with exception of treated Phy 499 that was taller than treated FM 1740 at location two. Further analysis of internode growth at location one (Table 10) indicates all nematicide treated plants were taller in average plant height by node than untreated plants at main-stem node fifteen with exception of Phy 499 and Stv 5458 which did not differ from untreated plants plants. However, at location two (Table 11) all varieties at node fifteen improved elongation in presence of nematicide with exception of Stv 5288 which did not differ from untreated plants. At both locations, FM 1740 and Phy 375 grew taller with a nematicide. All varieties at node seventeen benefited from use of nematicide treatment with exception of Stv 5458 at location one and Phy 499 at location two which were not different from untreated plants. This indicates Stv 5458 provides good tolerance in *R. reniformis* infested soils at location one while Phy 499 provides tolerance at location two. This pattern continued through main-stem node 21 for both locations. Regardless, varieties make a contribution to growth in *R. reniformis* infested soils despite a nematicide.

Square fruiting period: Main stem fruit retention at fruiting position one indicated no differences between treated or untreated varieties at both locations (Tables 12&13). Retention at sympodial position two at location one for Phy 375, Stv 5458 and Phy 499 were lower than treated plants. Unlike location one (Table 12), no difference between treated and untreated varieties existed at sympodial position two for location two. Fruit retention along sympodial fruiting branch at fruiting position >2 at location one resulted in few differences with untreated FM 1740, Phy 499 and Phy 375 not differing from treated plants. However, treated STV 5288 and 5458 B2RF had lower retention at this position. Within location two, (Table 13) at main-stem fruiting position > 2, Phy 375, Phy 499 and FM 1740 had greater retention with a nematicide. Few differences existed during square because of lower internal stress that results during bloom and boll development periods.

Bloom growth stage: Treated varieties at location one (Table 12) had improved retention at fruiting position one compared to untreated plants with exception of Stv 5288 and FM 1740 not differing from untreated plants. However, Phy 375, Phy 499 and Stv 5458 were improved with nematicide. At location two (Table 13) treated varieties had improved retention compared to untreated plants with exception of Stv 5288 that had no differences. Evaluation at position two at location one (Table 12) resulted in few differences between treated and untreated varieties except Stv 5458 had increased retention with a nematicide. At location two (Table 13) all treated varieties had improved retention at fruiting position two compared to untreated plants except with Stv 5288 which did not did not differ from untreated plants. Fruit retention at position > 2 of treated plants was improved at location one (Table 12) by nematicide compared to untreated plants except in FM 1740 which did not differ from untreated plants. At location two (Table 12) few differences existed between nematicide treated and untreated varieties except for Stv 5288 and FM 1740 having greater retention with the nematicide compared to untreated plants.

Open boll growth stage: At location one (Table 12), retention at position one was improved in treated varieties compared to untreated plants with exception of FM 1740 which did not differ from untreated plants. At location two, all varieties had increased retention at position one with nematicide treatment compared to untreated plants. Percent retention at fruiting position two at location one (Table 11) improved with the nematicide compared to untreated varieties with exception of FM 1740 which did not differ from untreated plants. Treated Phy 375 benefited greatest from nematicide at this location. However, as at position one, no differences existed between treated and untreated FM 1740 in retention at position two. Percent retention of all cotton varieties at position two at location two (Table 13) increased with nematicide treatment compared to untreated plants except for Stv 5288. Position > 2 retention at both locations (Table 13) illustrated higher retention levels resulting from lower retention at position one and two increasing fruit compensation farther out the fruiting branch. All varieties were improved in fruit retention with a nematicide but some varieties did display tolerance across fruiting positions like FM 1740. Fruit loss during square was not observed since little internal demand for carbohydrates was on-going during this growth stage. However, fruit loss in untreated plants began to manifest itself during bloom but some untreated varieties had improved retention at fruiting positions one and two. All untreated varieties did show an increased retention at position > 2 which leads to loss of harvest maturity.

NAWF between treated and untreated varieties: Node above white flower (NAWF) at location one (Table 14) was reduced in all treated varieties due to increased boll retention and carbohydrate partitioning with exception of Phy 499 that did not differ from untreated plants. However, untreated plants did maintain adequate NAWF (a measure of plant energy). No difference in NAWF was also found at location two (Table 14). Limited difference between treated and untreated varieties during bloom indicate a high degree of growth in untreated varieties comparable to treated varieties and does verify gained tolerance.

NACB and percent open between treated and untreated varieties: All treated varieties possessed lower NACB at both locations (Table 14) with exception of FM 1740 which did not differ from untreated plants at location one. Treated varieties benefiting the greatest in harvest maturity included Phy 499, Phy 375 and Stv 5288. Further, percent open boll (Table 14) followed the same pattern as NACB with all nematicide treatments having greater open boll compared to untreated plants. NACB and percent open boll had direct correlation with fruit retention. NACB and percent open boll at location two (Tables 14) followed a similar pattern as location one where all treated varieties were lower in NACB and greater in open boll than untreated plants. Untreated Phy 375 had higher NACB than other treatments indicating lack of tolerance.

Comparison of variety effects on boll diameters as expression of maturity: Boll diameter measurements at 12 nodes below terminal at location one (Table 15) illustrated few differences between treated and untreated varieties. However, Phy 375 and Stv 5288 boll diameter was increased by nematicide treatment compared to untreated plants. Boll diameter at 12 nodes below the terminal at location two (Table 15) had increased boll size with nematicide treatment compared to untreated plants with exception of FM 1740 which did not differ from untreated plants. At nine nodes below terminal at location one, nematicides improved boll diameter growth in all varieties as occurred at location two with exception of Phy 375, which did not differ from untreated plants. Evaluation of boll diameter differences indicated all varieties benefitted from nematicide treatment with exception Phy 499 where boll difference were greater than untreated plants at location two. This indicates by closeness of boll size between node nine and twelve below the terminal that despite benefits from nematicide there was a level of tolerance provided by variety in improving harvest maturity.

Basal stalk diameter evaluation: Basal stalk diameter was primarily improved with use of NST across both locations. At location one, all treated varieties had improved basal stalk diameter and differed from untreated plants with exception of FM 1740 and Phy 499. Further investigation showed treated FM 1740 and Phy 375 did not differ from the untreated plants. In general all varieties were greatly improved with a nematicide relative to basal stalk diameter with exception of FM 1740 (Table 15).

Yield response: Yield was increased at location one (Table 16) with addition of nematicide treatment with exception of treated FM 1740 and Stv 5458 which did not differ from untreated plants. Phy 375 had greatest yield improvement where nematicide was used. Treated Stv 5288 and Phy 499 did not differ from each other but were greater in yield than remaining treatments. This indicates untreated varieties are providing some tolerance in *R. reniformis* infested soils. Yield differences between treated and untreated plants are as follows from greatest to lowest; Phy 375, Stv 5288, Phy 499, Stv 5458 and FM 1740 at 430, 203, 177, 60 and 28 Lbs lint/ac respectively. This validates Phy 375 insensitivity to *R. reniformis* followed by Stv 5288, which was proven by plant mapping. Phy 499, Stv 5458 and FM 1740 are moderately tolerant at tested *R. reniformis* populations. At location two of higher CEC (Table 16) yields indicate that all treated varieties were greater than untreated plants. Treated Phy 499, FM 1740 and Stv 5458 did not differ from each other but yielded greater than the remaining treatments. Yield differences between treated and untreated are as follows from greatest to lowest; Phy 375, Phy 499, FM 1740, Stv 5288 and Stv 5458 at 173, 167, 121, 94 and 90 Lbs lint cotton/ac respectively. As at location one, Phy 375 shows intolerance to *R. reniformis* while FM 1740 and Stv 5458 have acceptable tolerance at location two.

Greenhouse experiment: As *R. reniformis* populations began to increase, root volumes declined across all varieties but at differing degrees (Table 17). Even though root growth declined with Phy 499 as *R. reniformis* populations increased, it displayed greater root development when compared to other treatments. In absence of nematicide, Phy 499 root development was reduced especially at *Pi* 7,500 which did not occur at lower populations indicating tolerance at low to moderate nematode levels. Remaining treated varieties indicated positive root growth but did not differ from each other at *R. reniformis Pi* 2,500. As population increased to *Pi* 5,000, root growth differences among varieties containing nematicides began differing from each other with Stv 5458, FM 1740 and Stv 5288 having greater root volume. At *P*i 5,000 population, treated FM 1740 and Stv 5288 did not differ from each other but were lower than Stv 5458 and Phy 499. As *R. reniformis* population, increased to *Pi*, 7,500, only treated FM 1740 produced greater root volumes with exception of treated Phy 499. Untreated plants began decline of root volumes at lower *R. reniformis* populations. Untreated Phy 375 and Stv 5288 produced lower root volumes at *R. reniformis Pi* of 2,500 compared to remaining treatments (Table 17). As *Pi* increased to 5,000, no difference in root growth among untreated Stv 5288, Stv 5458 or FM 1740 existed. As *R. reniformis* population increased to *Pi* 7,500, no untreated variety produced adequate root mass. This indicates that nematicides do improve performance in *R. reniformis* populations but root biomass reduction still occurs as nematode population increases. In addition, there was observed tolerance by variety until *R. reniformis* population reached *Pi* of 7,500 level.

Effect of R. reniformis at different populations on shoot biomass development: Shoot biomass production across treated varieties declined at varying degrees as *R. reniformis* populations increased. Treated Phy 375 had lower shoot biomass compared to other treatments at *Pi* 2,500 and this reduction continued as nematode population increased indicating intolerance to *R. renifromis* despite nematicide presence. At *Pi* 2,500, treated Stv 5288, Phy 499, Stv 5458 and FM 1740 had greater biomass while not differing from each other. Further separation continued at *Pi* 5,000 with treated Stv 5458, FM 1740 and Phy 499 differing from remaining treatments. Within *Pi* 7,500, treated Phy 499 maintained increases in shoot biomass over remaining varieties followed by FM 1740, Stv 5458 and Stv 5288 (Table

17) indicating Phy 499 and FM 1740 were enhanced in shoot development with nematicide as *R. reniformis* numbers increased (Table 17). Shoot biomass across untreated varieties was reduced as *Pi* increased. At *Pi* 2,500, Phy 499, Stv 5288 B2RF, Stv 5458 had greater shoot biomass. Untreated Phy 499 continued producing acceptable biomass at *Pi* 5,000 not differing greatly from *Pi* 2,500 but underwent large reduction between *Pi* 5,000 to 7,500. Untreated Stv 5288 and Stv 5458 despite reductions in shoot biomass did not illustrate changes between *Pi* 2,500 to 5,000. Untreated Phy 375 possessed greatest reduction. Despite sizeable reductions in shoot biomass, Phy 499 and FM 1740 produced greatest biomass levels at *Pi* 7,500.

Recovered R. reniformis juvenile numbers by variety: Juvenile population numbers under greenhouse environments possessed direct relation to root growth. As root biomass increased so did population of *R. reniformis* as shown by Lawrence and McClean (1995; 1996). As with root growth and development, Phy 499 possessed highest *R. reniformis* juveniles recovered as observed in untreated plants across lower *R. reniformis* populations. Treated Phy 375 (Table 18) provided least tolerance at higher *Pi* as observed with lower root volumes. Within treated varieties at *Pi* 2,500, numbers recovered were higher in Phy 499 indicating benefits from nematicide treatment. Untreated Phy 499 also showed high juvenile numbers recovered followed by Stv 5458 and Stv 5288. Sizeable decline in juveniles recovered occurred at *Pi* 5,000 with Phy 499 possessing greatest recovery decline in nematicide treatment. However, this variety illustrated high numbers recovered in untreated state indicating tolerance to *R. reniformis*. Treated Stv 5458 showed higher juvenile recovery level indicating benefit of nematicide but also possessed a small difference indicating tolerance at this population. At this population, Stv 5288 began to cease tolerance in absence of nematicide. Treated FM 1740, despite being different from treated Phy 499 and Stv 5458, remained consistent as *R. reniformis* population increased which aligned itself with root biomass as observed with untreated plants. All varieties benefited from nematicide at *Pi* 7,500. Within this population treated and untreated FM 1740 became comparable to Phy 499 while 5458 began to decline. Stv 5288 began its decline in recovered *R. reniformis* at the *Pi* 5,000 while Stv 5458, Phy 499 and FM 1740 began their decline at *Pi* 7,500 (Table 18).

Recovered R. reniformis egg numbers by variety: Nematode reproduction was altered early in the Phy 375 treatment possessing low egg numbers at *Pi* 2,500. Untreated FM 1740 and Stv 5288 followed this reproduction format but were greater in recovery compared to Phy 375. Untreated Phy 499 and Stv 5458 provided the greatest egg recovery. As population increased to *Pi* 5,000, all varieties benefitted from nematicide treatment with exception of FM 1740 which did not differ from untreated plants. Remaining untreated varieties illustrated root growth development facilitating continued nematode reproduction as they did not differ from each other but had greater recovery than Phy 375. As with juvenile recovery and root biomass assessments, STV 5288 illustrated egg recovery decline while FM 1740 stabilized across populations. At *Pi* 7500 all varieties suffered great loss as egg recovery declined. However, treated FM 1740, Phy 499 and Stv 5458 still had adequate reproduction on going signifying better root development and how tolerance and nematicide can function synergistically.

Effect of R. reniformis on cotton plant height at varying populations: Plant height of treated varieties at *Pi* 2,500 was greater than untreated plants for all varieties. Of treated varieties, Phy 499, Stv 5458 and Stv 5288 were taller (Table 19). All varieties treated with nematicide at *Pi* 5,000 and 7,500 population were taller than untreated plants. However, plant height did decline as inoculation population increased. Untreated Phy 499 and Stv 5458 at *Pi* 5,000 did not differ from each other but had greater plant height than remaining treatments. At *Pi* 5,000, treated and untreated FM 1740 illustrated smallest change compared to plant height at *Pi* 2,500 indicating ability not to deviate greatly from genetically governed plant height in presence of *R. reniformis*. Treated and untreated Stv 5288 showed plant height reduction at *Pi* 5,000. All varieties reduced in plant height at *Pi* 7,500 and benefited from nematicide application (Table 19). Treated FM 1740 and Stv 5458 demonstrated no differences when compared to untreated plants. As mentioned, FM 1740 and Stv 5458 demonstrated small differences between treated and untreated as population increased. Seemingly, STV 5288 provides tolerance at low to moderate *R. reniformis* populations while Phy 375 is intolerant at very low populations (Table 19).

Effect of R. reniformis on total node production at varying populations: Total node production in *Pi* 2,500, was increased with nematicide over untreated plants. However, treated Phy 499 did not differ from untreated plants indicating tolerance at this population. As *Pi* increased to 5,000, node number continued declining at varying rates among varieties with treated Stv 5458, Stv 5288, FM 1740 and Phy 499 being affected least. Untreated varieties at this population maintained adequate node number despite differing from treated plants but not themselves. At *Pi*

7,500 all nematicide treated varieties increased node production compared to untreated except FM 1740 and Stv 5288, which did not differ from each other. Nematicide treatment did improve total node production compared to untreated plants. (Table 19).

Effect of R. reniformis on HNR at varying populations: All treated varieties had greater HNR than Phy 375 at *Pi* 2,500 and did not differ from each other (Table 19) nor untreated plants. At *Pi* 5,000, treatments not differing from untreated plants included Stv 5458, FM 1740 and Phy 499. Treated varieties Stv 5288, Stv 5458, Phy 375 and FM 1740, produced lower HNRs within *Pi* 7,500 compared to Phy 499 and Stv 5458. However, no treated variety differed from untreated plants indicating NST efficacy loss at higher nematode populations but variety tolerance existed. Phy 375 began diminishing tolerance at *Pi* 2,500. Another variety possessing low tolerance was Stv 5288, which declined at *Pi* 5,000. Phy 499, Stv 5458 and FM 1740 continued providing tolerance to *R. reniformis* at *Pi* 5,000 based on HNR.

Effect of R. reniformis on NFFB at varying populations: Treated varieties at *Pi* 2,500 demonstrated lower NFFB across all untreated varieties with exception of Phy 499 and Stv 5288 which did not differ from untreated plants (Table 20). Fruit initiation increased despite presence of nematicide up main stem as *Pi* increased and was accentuated where nematicide was not used especially at higher *R. ren*iformis populations. Treated varieties within *Pi* 5,000 initiated fruit higher compared to 2,500 population but did not differ from comparable treatments in *Pi* 2,500. All untreated varieties in *Pi* 5,000 initiated fruiting higher than treated plants with the exception of Stv 5458 (Table 20). Treated varieties at *Pi* 7,500 increased fruit initiation compared to *Pi* 5,000 with FM 1740 being only treated variety to increase in NFFB. However, FM 1740 was the only untreated variety not differing from treated plants. In summary initiation of fruiting is hastened in *R. reniformis* infested soils when a nematicide was used indicating value in early fruit initiation and cotton development. However, tolerance was observed relative to initiation of fruiting in some varieties. Untreated Phy 375 began being affected at *Pi* of 2,500 where *R. reniformis* promoted sizeable delay in fruiting. Fuller season varieties, Stv 5458, FM 1740 and Phy 499 respectively offered tolerance until *Pi* 7,500.

Effect of R. reniformis on basal stalk development at varying populations: Basal stalk diameter did not show great degrees of change as *R. reniformis* populations increased with greatest reduction occurring at *Pi* 2,500. In untreated varieties the only variety not differing from the treated plants was Stv 5458 at *Pi* 2,500 and 5,000 (Table 20).

Conclusion

In conclusion some commercial varieties do provide tolerance in *R. reniformis* infested soils due. Differences are not observed in early growth stages but are manifested later especially during bloom as cotton physiology shifts carbohydrate flow into boll development. Granted, nematicide treatments did improve performance of varieties and growth parameters in presence of *R. reniformis* influencing variety performance in combination with varietal characteristics. Many differences laid in loss of harvest maturity resulting from lower retention at fruiting position one and two in the untreated varieties. However, low to moderate tolerance could be assessed. Ranking of varieties based on tolerance are as follows from high to low; FM 1740, Stv 5458, Phy 499, Stv 5288 and Phy 375. Phy 375 is very sensitive to *R. reniformis* requiring special attention while FM 1740 and Stv 5458 showed the least amount of differences between treated and untreated plants. Understanding intrinsic variety characteristics allows for accurate positioning and management of varieties not gathered from just yields. In many instances the differences or benefits are subtle but can lead to certain management decisions around characteristics of a variety and many some varieties due to tolerance can enhance a nematicide.

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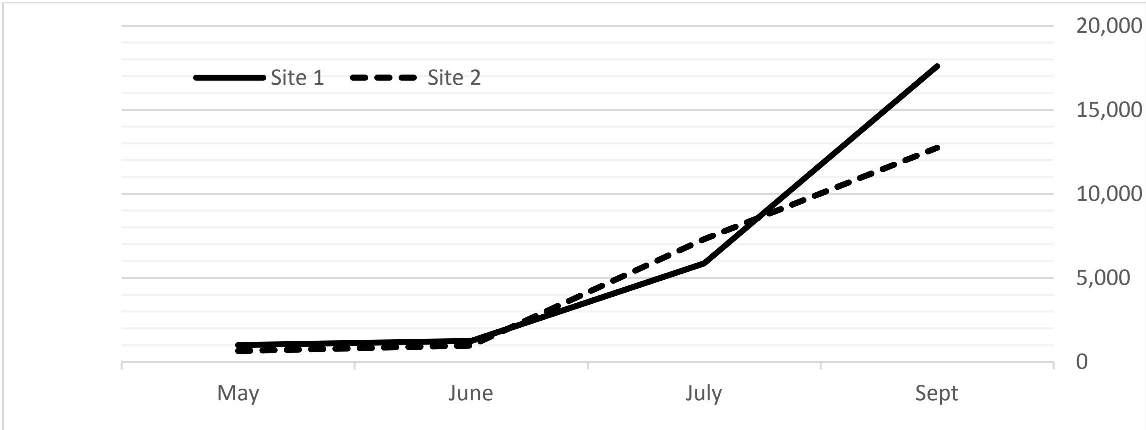

Figure 1. Seasonal population progression of *R. reniformis*/500cc across cotton varieties and soil types during four growth stages at Mississippi State University.

Table 1. In-the field treatments relative to contributions from five commercial cotton varieties (Phy 375 WRF, Phy 499 WRF, Stv 5458 B2RF, Stv 5288 B2RF, FM 1740 B2RF) treated and untreated with Aeris® seed treatment in *R. reniformis* infested soils

Variety	Treatment	Variety Maturity
PHY 375 WRF	Aeris® @ 0.075 mg ai/seed rate	Early
	Untreated	
PHY 499 WRF	Aeris® @ 0.075 mg ai/seed rate	Full
	Untreated	
STV 5458 B2RF	Aeris® @ 0.075 mg ai/seed rate	Mid
	Untreated	
STV 5288 B2RF	Aeris® @ 0.075 mg ai/seed rate	Early
	Untreated	
FM 1740 B2RF	Aeris® @ 0.075 mg ai/seed rate	Mid
	Untreated	

Table 2. Treatments of five commercial cotton varieties grown in varying populations of *R. reniformis* in greenhouse

Variety	Initial Nematode Population	Treatment	
PHY 375 WRF	0		
PHY 499 WRF	2,500		
STV 5458 B2RF	5,000	Aeris® @ 0.075 mg ai/seed rate	Untreated
STV 5288 B2RF	7,500		
FM 1740 B2RF			

z Variety derivations: Phytogen (PHY) a subsidiary of Dupont. Stoneville (STV) and Fibermax (FM) subsidiaries of Bayer Crop Sciences (Raleigh, North Carolina).
y Aeris® was applied to the seed prior to planting by Bayer Crop Science (Raleigh, North Carolina).

Table 3. Seasonal population progression of *R. reniformis* across cotton varieties during four growth stages at Mississippi State University

Treatment	Location 1				Location 2			
	Reniform Nematode Numbers/500cc				Reniform Nematode Numbers/500cc			
	May (At Plant)	June (Square)	July (Bloom)	Sept (Harvest)	May (At Plant)	June (Square)	July (Bloom)	Sept (Harvest)
Phy 375 UT	516b	516c	1,548d	26,402ab	482ab	849cd	4,289de	11,030c
Phy 375 Trt	1,032ab	2,365a	1,3352a	46,762a	447ab	505de	9,108c	21,575a
Stv 5288 UT	581b	548c	1,150d	11,813b	826ab	1339b	2,808ef	6,493d
Stv 5288 Trt	681b	1,580b	4,913c	36,787ab	482ab	559de	5,074de	9,546c
FM 1740 UT	517b	516c	2,217d	16,899b	1032a	2075a	1,298f	5,676d
FM 1740 Trt	580b	2,483a	6,375c	22,349ab	482ab	344e	12,338b	9,925c
Phy 499 UT	548b	516c	559d	17,834b	619ab	1032c	5,504d	7,256d
Phy 499 Trt	1,330a	548c	1,3964a	47,838a	344b	519de	14,674a	18,330b
Stv 5458 Trt	548b	516c	1,368d	29,082ab	757ab	1419b	4,451de	3,752e
Stv 5458 UT	516b	1,967ab	8,127b	37,378ab	413b	591de	13,591a	22,462a
LSD(0.05)	360	637	1,726	17,057	368	250	1,893	1,756

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 4. Variety effect in *R. reniformis* soils on plant population, node of first fruiting branch, vigor and hypocotyl length at location 1

Treatment	Plants/acre	Node of First Fruiting Branch	Vigor (1-5)	Hypocotyl Length (inches)
Phy 375 Trt	42,783bc	6.6c	1.0c	4.3ab
Phy 375 UT	44,979b	6.8c	1.4bc	3.8c
Stv 5288 Trt	43,781b	6.2c	1.0c	4.5a
Stv 5288 UT	44,230b	6.4c	1.4bc	4.1b
FM 1740 Trt	41,657c	6.2c	1.3bc	4.1b
FM 1740 UT	43,945b	6.4c	1.5b	3.7c
Phy 499 Trt	44,435b	7.9b	1.3bc	4.2ab
Phy 499 UT	45,088b	8.8a	2.3a	3.7c
Stv 5458 Trt	47,212a	6.8c	1.1bc	4.2ab
Stv 5458 UT	47,266a	7.9b	1.1bc	4.2ab
LSD(0.05)	1799	0.80	0.33	0.20

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 5. Effects of variety with and without Aeris® nematicide in *R. reniformis* soils on plant population, node of first fruiting branch, vigor and hypocotyl length at location 2

Treatment	Plants/ac	Node of First Fruiting Branch	Vigor (1-5)	Hypocotyl Length (inches)
Phy 375 UT	32,346d	8.3b	3.1a	3.70b
Phy 375 Trt	29,823ef	7.4c	1.2cd	4.40a
Stv 5288 UT	31,184de	7.5c	3.0a	4.60a
Stv 5288 Trt	28,207f	7.4c	1.2cd	3.80b
FM 1740 UT	29,133ef	6.4d	2.9a	3.70b
FM 1740 Trt	28,371f	6.4d	1.4c	4.30a
Phy 499 UT	41,331a	10.0a	2.2b	4.50a
Phy 499 Trt	34,905c	8.4b	1.4c	3.70b
Stv 5458 UT	38,535b	10.1a	1.1cd	4.20a
Stv 5458 Trt	38,336b	8.5b	1.0d	4.40a
LSD(0.05)	1973	0.7	0.3	0.30

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 6. Effect of variety growth regarding growth parameters, total nodes, plant height, height to node ratio during square, bloom and open boll, in *R. reniformis* infested soils at location 1

Treatment	Square (June)			Bloom (July)			Open Boll (September)		
	TN	Plant Ht (“)	HNR (“)	TN	Plant Ht (“)	HNR (“)	TN	Plant Ht (“)	HNR (“)
Phy 375 UT	14.0b	14.9b	1.10b	20.8ab	28.6e	1.4e	19.1e	32.6e	1.7c
Phy 375 Trt	14.0b	16.0a	1.10a	20.0abc	34.4a	1.7a	21.2c	39.3c	1.9b
Stv 5288 UT	14.0b	13.7d	0.98cd	19.8bc	28.8e	1.45d	20.4d	34.3e	1.7c
Stv 5288 Trt	13.0c	14.2c	1.10b	20.6ab	31.6c	1.5c	21.5bc	39.6c	1.8b
FM 1740 UT	15.0a	13.4d	0.89e	19.2c	30.3d	1.5c	20.0d	34.4e	1.7c
FM 1740 Trt	14.8a	14.1c	0.95d	19.8bc	32.1c	1.7b	21.7bc	36.1d	1.7c
Phy 499 UT	13.2c	13.2d	1.00c	20.8ab	31.8c	1.5c	18.7e	34.5e	1.8b
Phy 499 Trt	13.8b	13.5d	0.98cd	21.0a	34.5a	1.7b	22.0bc	39.5c	1.8b
Stv 5458 UT	15.0a	15.2b	1.00c	19.0c	31.8c	1.67b	22.3ab	41.5b	1.9b
Stv 5458 Trt	15.0a	15.8a	1.10b	20.0abc	33.0b	1.65b	23.1a	47.1a	2.0a
LSD(0.05)	0.31	0.5	0.04	0.70	0.60	0.04	0.64	0.84	0.04

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 7. Cotton growth parameters (total nodes, plant height, height to node ratio) during square, bloom and open boll, in *R. reniformis* infested soils at location 2

Treatment	Square			Bloom			Open Boll		
	TN	Plant Ht (“)	HNR (“)	TN	Plant Ht (“)	HNR (“)	TN	Plant Ht (“)	HNR (“)
Phy 375 UT	13.3a	14.1de	1.00cd	17.9bc	30.6e	1.70cd	24.8a	40.7c	1.60de
Phy 375 Trt	13.3a	14.8b	1.10b	18.8a	33.0c	1.76c	23.5b	43.7a	1.90a
Stv 5288 UT	13.2a	13.4fg	1.00de	17.8c	27.5g	1.54f	22.5cd	38.5d	1.70cd
Stv 5288 Trt	12.9a	14.6bc	1.10b	18.4abc	32.2d	1.70c	22.7cd	42.5b	1.90a
FM 1740 UT	13.2a	13.2g	0.99e	18.2abc	26.5h	1.50g	22.1d	35.7e	1.50e
FM 1740 Trt	13.3a	13.5f	1.09de	18.8a	28.7f	1.53f	23.10bc	42.8ab	1.70cd
Phy 499 UT	13.3a	16.4a	1.20a	18.5ab	34.1b	1.80b	24.6a	44.0a	1.80b
Phy 499 Trt	13.5a	16.4a	1.20a	18.3abc	34.8a	1.90a	23.0bc	44.1a	1.90a
Stv 5458 UT	13.6a	13.9e	1.00de	18.5ab	30.5e	1.65e	23.5b	40.6c	1.60
Stv 5458 Trt	13.3a	14.3cd	1.10c	18.8a	31.7d	1.69d	25.0a	42.1b	1.70cd
LSD(0.05)	0.40	0.30	0.04	0.50	0.80	0.04	0.64	0.84	0.04

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 8. Average plant height (inches) at each node cumulating in total height (inches) measured during square in *R. reniformis* infested soils at location 1

Treatment	Plant height at each node (inches) Node Number							
	1	3	5	7	9	11	13	15
Phy 375 UT	1.5b	4.5ab	6.5a	9.1a	12.5a	14.4b	14.7c	14.9c
Phy 375 Trt	1.7b	4.4abc	6.5a	9.2a	12.5a	15.1a	15.9a	16.0a
Stv 5288 UT	2.1a	4.5ab	6.1ab	8.3c	10.8d	12.5e	13.5ef	13.7d
Stv 5288 Trt	2.2a	4.6a	6.2ab	8.5c	11.5bc	13.5d	14.2d	14.2c
FM 1740 UT	1.6b	3.8d	5.5c	7.6d	10.5de	12.4e	13.2f	13.6f
FM 1740 Trt	1.7b	3.7d	6.0b	8.4c	11.3bc	13.3d	13.8de	14.1c
Phy 499 UT	1.8b	4.1c	5.6c	7.5d	10.4e	12.0f	13.1f	13.2f
Phy 499 Trt	1.7b	4.2bc	6.5a	9.0ab	11.4bc	12.7e	13.4ef	13.5d
Stv 5458 UT	1.7b	4.4abc	6.5a	8.5c	11.2c	14.0c	14.9c	15.2b
Stv 5458 Trt	1.8b	4.2bc	6.3ab	8.8bc	11.7b	14.4b	15.4b	15.8a
LSD(0.05)	0.20	0.30	0.30	0.40	0.30	0.30	0.50	0.50

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 9. Average plant height (inches) at each node culminating in total height (inches) during square in *R. reniformis* infested soils at location 2

Treatment	Plant height at each node (inches) Node Number							
	1	3	5	7	9	11	13	15
Phy 375 UT	1.7cd	4.3ab	6.6b	8.7b	11.5b	13.4c	13.9b	14.1c
Phy 375 Trt	1.7cd	4.4ab	6.5b	8.5b	11.2b	13.8b	14.7a	15.1a
Stv 5288 UT	2.0bc	4.4a	6.5b	8.3b	10.7c	12.3e	12.8d	12.8e
Stv 5288 Trt	2.3a	4.4ab	6.5b	8.6b	11.5b	12.9d	13.4c	13.4d
FM 1740 UT	2.0b	4.1b	5.9c	7.6c	10.5d	12.5e	13.4c	13.7d
FM 1740 Trt	2.4a	4.3ab	6.3b	8.4b	11.2b	13.3c	14.2b	14.4b
Phy 499 UT	1.6c	3.7c	5.7c	7.8c	10.4d	11.8f	12.1e	12.1f
Phy 499 Trt	1.8bc	3.6c	5.7c	7.7c	10.2d	12.3e	13.2c	13.4d
Stv 5458 UT	1.9bc	4.2bc	6.2b	8.6b	11.4b	12.7de	13.3c	13.5d
Stv 5458 Trt	2.0b	4.6a	7.2a	9.4a	12.2a	14.4a	15.0a	15.2a
LSD(0.05)	0.30	0.30	0.30	0.40	0.30	0.40	0.30	0.30

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 10. Average plant height (inches) at each node culminating in total height (inches) measured during bloom in *R. reniformis* infested soils at location 1

Treatment	Plant height at each node (inches) Node Number							
	7	9	11	13	15	17	19	21
Phy 375 UT	7.5f	10.5f	14.5e	19.4	24.8g	27.9e	28.8e	29.1d
Phy 375 Trt	9.7b	14.3b	20.5b	27.2a	31.5a	33.3a	34.3a	34.1a
Stv 5288 UT	9.6b	13.4c	17.3d	22.6de	25.6f	28.1e	28.7e	28.7d
Stv 5288 Trt	8.8d	12.5d	18.6c	22.6de	26.6e	29.9d	31.4c	31.9b
FM 1740 UT	7.9e	11.7e	16.8d	22.6de	26.8e	29.9d	30.4d	30.5c
FM 1740 Trt	10.6a	15.8a	21.3a	26.4b	30.4b	31.9b	32.3bc	32.3b
Phy 499 UT	7.4f	10.6f	16.9d	22.2e	28.3d	30.9c	32.1bc	32.2b
Phy 499 Trt	10.4a	14.6b	18.3c	23.2d	28.6d	32.4b	33.8a	34.1a
Stv 5458 UT	9.2c	13.3c	18.6c	24.0c	29.5c	31.8b	32.3bc	32.3b
Stv 5458 Trt	9.5be	13.2c	18.3c	24.4c	29.3c	32.1b	32.8b	33.0b
LSD(0.05)	0.40	0.40	0.50	0.70	0.50	0.70	0.90	0.90

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 11. Average plant height at each node cumulating in total height (inches) during bloom in *R. reniformis* infested soils at location 2

Treatment	Plant height at each node (inches) Node Number							
	7	9	11	13	15	17	19	21
Phy 375 UT	7.6d	10.6f	14.4f	19.1h	24.6g	26.4g	28.8d	30.2bc
Phy 375 Trt	9.7a	14.3a	21.4a	28.1a	32.4a	33.5a	33.7a	33.7a
Stv 5288 UT	8.5c	11.1e	14.7f	20.1g	25.2g	26.9g	27.5e	27.7e
Stv 5288 Trt	9.5ab	13.6b	18.5c	21.7f	25.3g	28.5c	29.6d	29.9cd
FM 1740 UT	7.8d	11.4e	17.0f	21.7g	26.3e	29.1d	30.3c	31.9b
FM 1740 Trt	8.7c	12.5c	18.9c	25.0c	29.60b	32.2b	33.1ab	33.3a
Phy 499 UT	7.7d	11.5e	16.4e	22.2e	28.2d	30.1d	30.6c	30.7c
Phy 499 Trt	9.2b	14.2a	20.5b	25.6b	28.8c	30.5d	30.9c	31.2bc
Stv 5458 UT	8.7c	12.1d	16.9d	21.1f	26.0f	27.9f	29.0d	29.4d
Stv 5458 Trt	9.3b	13.5b	18.5c	24.1d	29.6b	32.0b	32.7b	32.9a
LSD(0.05)	0.30	0.37	0.50	0.40	0.30	0.60	0.70	0.80

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 12. Fruit retention at sympodial positions 1, 2 and > 2 during square, bloom and open boll at location 1 infested with *R. reniformis*

Treatment	Square % Retention			Bloom % Retention			Open Boll % Retention		
	Pos 1	Pos 2	Pos >2	Pos 1	Pos 2	Pos >2	Pos 1	Pos 2	Pos >2
Phy 375 UT	97.5a	59.2c	24.1c	81.6b	52.9a	23.1d	33.9c	13.2c	10.0a
Phy 375 Trt	100.0a	70.7ab	30.6c	88.7a	51.9a	42.1b	41.7b	20.4a	2.7c
Stv 5288 UT	98.9a	76.6a	52.7a	80.0bc	55.3a	52.2a	36.6c	9.2d	4.6b
Stv 5288 Trt	100.0a	71.3ab	42.8b	81.2b	51.1a	32.7c	42.4b	13.3c	4.6b
FM 1740 UT	99.2a	75.9a	52.9a	73.8cd	44.8c	22.9d	35.0c	15.0bc	0.42d
FM 1740 Trt	100.0a	75.1a	53.9a	77.6bc	45.8bc	24.6d	37.1c	16.4b	1.5cd
Phy 499 UT	95.9a	45.0d	30.2c	72.3d	45.9bc	19.9d	38.7bc	13.1c	2.5c
Phy 499 Trt	100.0a	69.7ab	29.7c	88.5a	50.1ab	30.6c	47.3a	16.5b	2.2c
Stv 5458 UT	95.9a	66.7b	51.3a	74.7cd	44.2c	19.5d	37.1c	8.7d	1.7cd
Stv 5458 Trt	98.6a	74.0a	42.1b	81.3b	55.7a	51.3a	46.9a	12.5c	2.2c
LSD(0.05)	3.20	5.60	6.50	3.70	4.30	5.50	3.70	2.30	1.30

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test $P\alpha$=0.05.

Table 13. Fruit retention at sympodial positions 1, 2 and > 2 during (June), bloom (July) and open boll (September) at location 2 soils infested with *R. reniformis*

Treatment	Square % Retention			Bloom % Retention			Open Boll % Retention		
	Pos 1 [x]	Pos 2	Pos >2	Pos 1	Pos 2	Pos> 2	Pos 1	Pos 2	Pos 2
Phy 375 UT	70.3c	41.1c	7.1e	67.0d	39.9d	12.1g	32.4f	18.1c	4.9d
Phy 375 Trt	81.5bc	52.9bc	9.4e	84.2b	48.8bc	15.0f	43.8b	23.2a	3.7e
Stv 5288 UT	90.3ab	62.6ab	19.9bcd	76.8c	47.4c	20.8d	36.7e	17.6c	6.1c
Stv 5288 Trt	100.0a	66.0ab	29.5b	78.1c	49.2bc	50.4a	44.8b	18.9c	5.5d
FM 1740 UT	100.0a	71.3a	14.7de	76.2c	33.7f	24.5c	32.8f	14.1d	3.1f
FM 1740 Trt	100.0a	75.7a	26.4bc	90.3a	59.9a	26.4c	47.7a	18.6c	7.8a
Phy 499 UT	96.5a	69.2a	28.3b	85.5b	37.3e	25.9c	33.7f	14.3d	6.7b
Phy 499 Trt	100.0a	70.7a	37.4a	91.1a	47.2c	38.2b	39.6d	20.9b	4.2e
Stv 5458 UT	73.7c	42.0c	17.6cd	78.7c	40.8d	15.6f	36.7e	14.0d	5.4d
Stv 5458 Trt	77.3bc	47.5c	26.1bc	85.4b	51.5b	17.7e	41.6c	18.4c	4.2e
LSD(0.05)	12.4	13.1	7.7	3.50	3.00	2.40	1.60	1.20	0.60

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test $P\alpha$=0.05.

Table 14. Cotton maturity, nodes above white flower, nodes above cracked boll and percent open boll, as affected by variety treated and untreated in *R. reniformis* infested, location 1 and 2

Treatment	NAWF		NACB		Open Boll	
	Low CEC	High CEC	Low CEC	High CEC	Low CEC	High CEC
Phy 375 UT	8.80abc	8.20ab	9.40b	10.50a	10.40d	12.3d
Phy 375 Trt	8.00g	8.00ab	7.30d	7.30d	28.40a	22.7a
Stv 5288 UT	8.70bcd	8.60ab	10.50a	8.30c	9.30d	7.4f
Stv 5288 Trt	8.50e-f	8.20ab	8.20c	7.50d	17.50c	14.6c
FM 1740 UT	9.10a	8.40ab	9.40b	8.90b	13.50c	8.1e
FM 1740 Trt	8.60cde	7.90b	9.30b	8.30c	22.00b	18.8b
Phy 499 UT	8.40def	8.90a	10.40a	8.50b	14.70c	12.6d
Phy 499 Trt	8.20fg	8.20ab	7.20d	7.50d	24.30b	15.3c
Stv 5458 UT	8.90ab	8.00ab	10.80a	8.30c	6.90c	6.6g
Stv 5458 Trt	8.30efg	7.90ab	8.90b	7.80d	15.10c	14.7c
LSD(0.05)	0.30	0.60	0.80	0.40	3.80	0.80

[z] Means followed by same letter are not different according to Least Significant Difference means separation test $P\alpha$=0.05.

Table 15. Basal stalk and boll diameters (mm) of six plants per plot taken at the ninth and twelfth node below terminal to evaluate variety assistance in *R. reniformis* infested soils at location 1 and 2

Treatment	Low CEC	High CEC	Low CEC			High CEC		
	Basal Stalk Dia	Basal Stalk Dia	Boll Dia Node 9	Boll Dia Node 12	Boll Dia Diff	Boll Dia Node 9	Boll Dia Node12	Boll Dia Diff
Phy 375 UT	9.5e	9.8d	17.1g	31.2bc	14.2a	27.3de	32.5de	6.7c
Phy 375 Trt	10.7bc	10.3cd	28.6a	32.8a	3.6f	28.0de	34.0bc	4.5d
Stv 5288 Trt	10.7bc	11.1bc	21.3e	31.6abc	10.3b	29.8c	33.2cd	4.3d
Stv 5288 UT	9.8de	9.6d	21.3e	28.7d	7.3b	21.2g	31.7e	10.5a
FM 1740 UT	10.4c	11.1bc	17.8g	32.3ab	15.0a	28.4d	34.2bc	6.4c
FM 1740 Trt	10.6bc	11.3b	23.4d	32.3ab	8.9c	30.8bc	34.8b	3.5e
Phy 499 UT	11.2b	10.7bc	20.4e	30.8c	10.8b	31.3b	34.1bc	2.8f
Phy 499 Trt	11.3b	12.1a	26.4b	31.5abc	5.2e	32.9a	36.6a	3.6e
Stv 5458 UT	10.2cd	10.4cd	19.4f	30.7c	11.4b	23.4f	32.5de	9.1b
Stv 5458 Trt	12.3a	12.1a	24.4c	31.3bc	6.3d	26.6e	34.1bc	6.5c
LSD(0.05)	0.60	1.00	1.00	1.01	1.30	1.10	1.10	0.80

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05.

Table 16. Yield of Aeris® seed treatment compared to no nematicide varieties grown in *R. reniformis* infested soils at location 1 and 2

Treatment	Low CEC		High CEC	
	Lbs Lint/Ac	Yield Difference	Lbs Lint/Ac	Yield Difference
Phy 375 UT	1384e	430	1482e	173
Phy 375 Trt	1814a		1538d	
Stv 5288 UT	1482cd	203	15239de	100
Stv 5288 Trt	1685b		16234c	
FM 1740 UT	1508cd	28	1580cd	121
FM 1740 Trt	1536c		1624c	
Phy 499 UT	1457d	177	1719ab	167
Phy 499 Trt	1634b		1768a	
Stv 5458 UT	1435de	60	1624c	90
Stv 5458 Trt	1495cd		1689b	
LSD(0.05)	62		55.2	

[z] Means followed by the same letter are not different according to Least Significant Difference means separation test *P*α=0.05

Table 17. Shoot and root biomass of cotton varieties grown at varying *R. reniformis* populations under greenhouse environments.

Treatment	Inoculated Population[v]	Root Biomass (grams)		Shoot Biomass (grams)	
		Aeris® Treated	Untreated	Aeris® Treated	Untreated
FM 1740	0	55.9bc[z]	44.1fg	77.1ab	45.6i-l
PHY 375	0	64.5a	45.7ef	60.8d-g	53.9g-j
PHY 499	0	64.4a	44.8f	84.7a	53.0g-k
STV 5288	0	53.8bc	35.3ijk	86.3a	64.6c-g
STV 5458	0	56.8b	42.6fgh	70.9b-e	54.3g-j
FM 1740	2,500	51.4bcd	35.1ijk	63.1c-g	45.8i-l
PHY 375	2,500	50.4cde	24.9l	52.4g-k	40.6klm
PHY 499	2,500	56.7b	42.3fgh	72.6bcd	59.1e-h
STV 5288	2,500	53.9bc	24.5l	73.6bc	47.2h-l
STV 5458	2,500	54.1bc	39.4ghi	71.4bcd	52.7g-k
FM 1740	5,000	38.5hij	26.5l	55.7f-j	35.1lm
PHY 375	5,000	25.1l	12.9m	51.6g-k	42.7i-m
PHY 499	5,000	55.0bc	45.8ef	70.0b-e	51.9g-k
STV 5288	5,000	37.6ijk	25.1l	54.5g-j	37.9lm
STV 5458	5,000	46.4def	27.5l	67.7b-f	44.2i-l
FM 1740	7,500	35.8ijk	13.1m	53.4g-j	38.7lm
PHY 375	7,500	14.1m	8.4n	32.6m	23.2n
PHY 499	7,500	43.8fgh	13.9m	66.6b-f	42.6j-m
STV 5288	7,500	25.0l	14.8m	45.3i-l	23.5n
STV 5458	7,500	25.9l	13.4m	46.3i-l	25.8n
LSD(0.05)		4.00		7.70	

[z] Means within columns followed by same letter are not different according to Least Significant Difference means separation test *Pα=0.05*.

Table 18. Reproduction of *R. reniformis* across five cotton varieties treated and untreated

Treatment	Inoculated Population	Juvenile Numbers		Egg Numbers	
		Aeris® Treated	Untreated	Aeris® Treated	Untreated
FM 1740	0	0n	0n	0q	0q
PHY 375	0	0n	0n	0q	0q
PHY 499	0	0n	0n	0q	0q
STV 5288	0	0n	0n	0q	0q
STV 5458	0	0n	0n	0q	0q
FM 1740	2,500	15,991d	12,741efg	9,115.5.0g	5,312k
PHY 375	2,500	13,861e	11,119ghi	7,977.4h	2,284mno
PHY 499	2,500	36,729a	17,484cd	21,521.9b	15,089d
STV 5288	2,500	18,406c	16995cd	13,750.5e	9,924g
STV 5458	2,500	18,728c	17304cd	16,840.5c	14,678d
FM 1740	5,000	10,928ghi	6953k	6,586.9ijk	6,257ijk
PHY 375	5,000	6,046kl	3,651m	3,599.9l	1,437n-q
PHY 499	5,000	14,124e	11,866fgh	13,184.0e	6,849h-k
STV 5288	5,000	9,8056ij	6,033kl	7,192.0hi	5,614jk
STV 5458	5,000	13,596ef	9,167j	11,621.0f	6,201ijk
FM 1740	7,500	8807j	4,069m	5,376.6k	1,411n-q
PHY 375	7,500	3,5145m	77n	875.5opq	258q
PHY 499	7,500	8,652j	4,449lm	5,871.0ijk	2,016nop
STV 5288	7,500	4,759lm	1,494n	2,446.3mn	646.q
STV 5458	7,500	5,253klm	1,622n	3908.9l	1,862nop
LSD (0.05)		1,478		1,099.5	

[z] Means within columns followed by the same letter are not different according to the Least Significant Difference means separation test *Pα=0.05*

Table 19. Growth parameters of five cotton varieties treated and untreated at varying *R. reniformis* populations

Treatment	Inoculated Population[v]	Plant Height (inches)		Total Nodes		HNR (inches)	
		Aeris®	Untreated	Aeris®	Untreated	Aeris®	Untreated
FM 1740	0	24.7d-h	21.6j-o	13.0cde	11.8f-j	2.1b-g	2.0b-j
PHY 375	0	26.1b-e	23.6f-k	13.3bcd	11.8f-j	2.2b-e	2.0b-j
PHY 499	0	28.8a	23.9e-j	13.0cde	12.0e-i	2.2bc	2.1b-f
STV 5288	0	28.0ab	23.1g-l	14.3a	12.5d-g	2.4a	2.0b-i
STV 5458	0	28.7a	23.8e-j	14.0ab	12.3e-h	2.1b-f	2.1b-g
FM 1740	2,500	23.2g-l	20.2m-r	12.3e-h	11.0ijk	2.0b-j	1.8j-p
PHY 375	2,500	23.1g-l	18.9o-r	13.3bcd	11.8f-j	1.7k-p	1.7k-p
PHY 499	2,500	27.1abc	22.5h-m	13.0cde	12.0e-i	2.1b-f	2.0c-k
STV 5288	2,500	26.4bcd	22.5h-m	14.0ab	12.3e-h	2.1b-h	1.9f-m
STV 5458	2,500	26.2bcd	21.2k-p	13.8abc	11.8f-j	2.0b-j	1.9e-k
FM 1740	5,000	23.2g-l	19.8n-r	11.3hij	11.0ijk	1.9e-l	1.8h-n
PHY 375	5,000	20.9l-q	16.7s	12.0e-i	11.0ijk	1.7m-p	1.4q
PHY 499	5,000	26.9a-d	22.0j-n	13.0cde	11.3hij	2.1b-g	1.9f-m
STV 5288	5,000	25.8c-f	19.2pqr	12.5d-g	11.0ijk	2.0b-j	1.6opq
STV 5458	5,000	26.8a-d	21.3j-o	13.0cde	11.8f-j	2.0b-j	1.9f-m
FM 1740	7,500	21.6j-o	19.4o-r	11.3hij	10.8jk	1.8i-o	1.7k-p
PHY 375	7,500	19.8n-r	14.3s	12.0e-i	10.0l	1.6n-q	1.4q
PHY 499	7,500	25.4c-g	21.6j-o	13.0cde	11.3hij	2.0c-k	1.8h-n
STV 5288	7,500	23.9e-j	18.3r	11.0ijk	11.0ijk	1.7l-p	1.5pq
STV 5458	7,500	24.7d-l	20.9l-q	12.3e-h	10.3kl	1.9e-l	1.8g-n
LSD (0.05)		1.50		0.60		0.15	

[z] Means within columns followed by the same letter are not different according to the Least Significant Difference means separation test *Pα=0.05*.

Table 20. Growth parameters of five cotton varieties treated and untreated at varying *R. reniformis*

Treatment	Inoculated Population	NFFB		Basal Stalk Diameter (mm)	
		Aeris®	Untreated	Aeris®	Untreated
FM 1740	0	7.0i-l	8.3fgh	6.5e-i	5.6k-n
PHY 375	0	6.3kl	7.8hij	6.7c-g	5.1no
PHY 499	0	8.0ghi	9.0d-g	7.1bcd	6.5e-i
STV 5288	0	6.0l	7.0i-l	7.7a	6.0h-i
STV 5458	0	6.8jkl	8.8e-h	7.5ab	6.4e-i
FM 1740	2,500	8.0ghi	9.3def	6.4e-i	5.6k-n
PHY 375	2,500	6.8jkl	8.33fgh	6.6d-i	4.7op
PHY 499	2,500	8.0ghi	9.0d-g	7.0b-e	5.9i-l
STV 5288	2,500	6.0l	7.0i-l	7.2bc	5.5mn
STV 5458	2,500	7.0i-l	9.0d-g	6.5e-i	6.2f-j
FM 1740	5,000	8.0ghi	9.5cde	6.4e-i	5.4lmn
PHY 375	5,000	7.0i-l	10.0bcd	6.6d-i	4.6op
PHY 499	5,000	8.3fgh	10.3bc	6.4e-i	5.6k-n
STV 5288	5,000	6.5kl	9.8cde	6.3f-j	5.3mn
STV 5458	5,000	7.3ijk	8.0ghi	6.4e-i	6.1g-k
FM 1740	7,500	9.8cde	10.0bcd	6.0h-l	4.7op
PHY 375	7,500	7.0i-l	11.3a	6.4e-i	4.3p
PHY 499	7,500	8.8e-h	10.0bcd	6.4e-i	5.3mn
STV 5288	7,500	6.8jkl	10.0bcd	6.5e-i	4.4p
STV 5458	7,500	7.8hij	9.3def	6.5e-i	5.4lmn
LSD(0.05)		0.60		0.39	

[z] Means within columns followed by the same letter are not different according to the Least Significant Difference means separation test *Pα*=0.05.