The *Journal of Cotton Science 29:172–179* (*2025*)
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PLANT PATHOLOGY & NEMATOLOGY

Evaluation of Cotton Lint Yield and Root-Knot Nematode Density on Commercial Varieties with Nematode Resistance

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ABSTRACT

Root-knot nematode (*Meloidogyne incognita*) (RK) causes yield losses in cotton. Small-plot variety trials were conducted in the southern High Plains of Texas to evaluate RK density (2nd-stage juveniles + eggs/500 cm³ soil) and cotton (*Gossypium hirsutum*) lint yield across commercially identified RK-resistant varieties. These varieties were compared to susceptible varieties (SUS) in nine trials over two years. Only a subset of resistant and SUS varieties was included in each location. Varieties that had consistently lower ($p = 0.05$) transformed RK densities (LRK) compared to SUS were DP 2143NR B3XF (6 of 9 trials), DP 2141NR B3XF (3 of 6 trials), DP 2436NR B3TXF (2 of 5 trials), PHY 205 W3FE (2 of 4 trials), PHY 332 W3FE (3 of 4 trials), PHY 411 W3FE (2 of 3 trials), PHY 415 W3FE (2 of 3 trials), PHY 443 W3FE (3 of 4 trials), PHY 475 W3FE (3 of 4 trials), and PHY 480 W3FE (2 of 2 trials). In contrast, FM 765AX, FM 823AXTP, FM 868AXTP, and ST 6000AXTP did not exhibit reduced LRK densities relative to SUS in any trial. Varieties that had consistently higher ($p = 0.05$) yield than SUS included FM 765AX (2 of 3 trials), PHY 475 W3FE (2 of 4 trials), and PHY 480 W3FE (1 of 2 trials). Cotton producers should consider both the level of resistance of a variety as well as yielding ability in a region when making variety choices for planting cotton in RK fields.

The southern root-knot nematode (*Meloidogyne incognita* [Kofoid & White, 1919]) (RK) can cause significant losses to cotton production. The nematode hatches from an egg to a second-stage juvenile (J2), which is infective to roots. The J2s establish a specialized feeding site in roots that leads to the formation of root galls where the nematodes undergo subsequent molts to third (J3) and fourth (J4) stages, ultimately developing into adult females that produce eggs without fertilization. These galls can result in smaller root size (Ma et al., 2014) and reduced efficiency in water and nutrient uptake (Kirkpatrick et al., 1991, 1995; Wallace, 1974). Additionally, these galls act as sinks for photosynthates (McClure, 1977), resulting in stunted plant growth with substantial yield reduction.

RK is broadly distributed across cotton-growing regions in the U.S. (Faske et al., 2023). In the southern High Plains of Texas, approximately 40% of cotton fields are infested with this nematode (Starr et al., 1993; Wheeler et al., 2000). Orr and Robinson (1984) conducted fumigation trials in 80 RK-infested fields over a 16-year period, and found that on average, cotton yield increased by 26% for varied soil fumigation (nematicide) treatments, compared to non-treated plots.

A high level of resistance to RK in cotton was first developed in the 1970s (Shepherd, 1974a) as Auburn cultivars, including Auburn 623 RNR (Shepherd, 1974b). Two key resistance genes have since been identified on Shepherd's material: one on chromosome 11 and the other on chromosome 14 (Kumar et al., 2016; Shen et al., 2010). Molecular markers have been identified in proximity to these genes (Gutierrez et al., 2010), which facilitate rapid development of RK-resistant commercial varieties. These genes are associated with quantitative trait loci (QTL) that reduce nematode reproduction. The QTL on chromosome 11 reduces the number of root galls, whereas the QTL on chromosome 14 affects later stages of the nematode lifecycle (beyond J2), including egg production (Da Silva et al., 2019; Wubben et al., 2020). When combined, these QTL act additively to further suppress RK reproduction (Wubben et al., 2020).

Historically, in the southern High Plains of Texas, comparisons between RK-resistant commercial varieties and susceptible varieties revealed signifi-

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cant improvement in yields with certain commercial varieties (Wheeler et al., 2009, 2014, 2020). With the continued introduction of new commercial varieties, including some with company-labeled resistance to RK (Table 1), it is important to evaluate the ability of RK populations to reproduce on these varieties under field conditions, and the ability of these varieties to yield competitively (i.e., better than RK-susceptible varieties). The exact number of RK-resistance genes and genetic homogeneity/heterogeneity are generally not available for commercial varieties. Hence, it is important to evaluate commercial RK-resistant varieties (based on company literature), to determine whether resistance appears to be consistently more or less effective based on field RK populations.

MATERIALS AND METHODS

Plots for trials were two rows wide, 10.7 m long on 1-m centers, and entries were typically arranged in a randomized complete block design with four replications (Table 2). Trials contained both commercial varieties and commercial experimental lines; all experimental lines were removed from the data sets before analyses. Each trial included a minimum of two RK-susceptible varieties, with some trials containing more than half of the entries as susceptible varieties (Table 2). Trials were conducted on irrigated fields and planted with a cone planter using 13 seeds per meter row. Trials were conducted in Dawson (4), Lubbock (1), Cochran (3), and Terry (1) counties, Texas.

Soil samples were taken in August or September in each plot and assayed for plant-parasitic nematodes. A narrow-bladed shovel was used to sample four to five locations per plot, taking soil 10 to 14 cm from the plant stalk to a depth of approximately 15 to 20 cm. Soil was then collected from the 8 to 20 cm depth, mixed in a bucket, and approximately 1 L of soil was placed in a plastic bag. Samples were stored in a refrigerator until nematode extraction, which was within 2 wk of sampling. Two assays were conducted on each sample, the first was a modified Baermann funnel (termed pie-pan, Thistlethwayte, 1970), designed to recover mobile nematodes and the second was to extract RK eggs from root fragments in the soil (Byrd et al., 1983; Hussey and Barker, 1973).

Table 1. Root-knot nematode (RK)-resistant cotton varieties included in the trials

Variety[z]	Evidence of RK resistance
DP 2141NR B3XF	Tested as 19R238NRB3XF, patent 11317592-B1. Resistant to RK and reniform nematode
DP 2143NR B3XF	Tested as 19R242NRB3XF, patent 11432521-B2. Resistant to RK and reniform nematode.
DP 2349NR B3XF	Tested as 21R649NRB3XF, patent pending
DP 2436NR B3XF	Tested as 22R1136NRB3TXF, patent pending
FM 765AX	No patent or PVP currently available.
FM 823AXTP	PVP 202400386. Rated as 3 on a scale of 1 to 4 (susceptible).
FM 868AXTP	PVP 202400385. Rated as 3 on scale of 1 to 4 (susceptible).
PHY 205 W3FE	No patent or PVP found; experimental number unknown.
PHY 332 W3FE	PVP 202000220. Rated as resistant to RK and reniform nematodes; two native RK resistant genes.
PHY 400 W3FE	Patent 11166432. Tested as PX3B07W3FE. Rated as moderately resistant to RK.
PHY 411 W3FE	Tested as PX4B08W3FE, patent or PVP unknown.
PHY 415 W3FE	Tested as PX1140Z383-04W3FE, patent or PVP unknown.
PHY 443 W3FE	PVP 202000221. Rated as resistant to RK and reniform nematodes; contains two native RK resistance genes.
PHY 475 W3FE	Tested as PX1150B437-04W3FE, patent or PVP unknown.
PHY 480 W3FE	Patent 11013202. Tested as PX4A52W3FE. Rated as RK resistant (highest category of resistance).
ST 6000AXTP	No PVP currently available.

[z]The transgenic traits abbreviations associated with these varieties are as follows: 'B3' is Bollgard 3 (Bayer CropScience: 3-gene Lepidoptera resistance), 'TP' is Twinlink Plus (BASF: 3-gene Lepidoptera resistance), 'W3' is Widestrike 3 (Corteva: 3-gene Lepidoptera resistance), 'T' is Thryvon (Bayer CropScience: tarnished plant bug and thrips resistance), 'XF' is Xtend Flex (Bayer CropScience: glyphosate, glufosinate, dicamba herbicide tolerance), 'FE' is Enlist (Corteva: glyphosate, glufosinate, 2, 4-D herbicide tolerance), and 'AX' is Axant Flex (BASF: glyphosate, glufosinate, dicamba-HPPD herbicide tolerance). 'NR' is native nematode resistance.

Table 2. Site details for trials

Trial	Latitude	Longitude	Planted	Harvest	Water[z]	R/S[y]	Reps	Soil[x] Series
1	33.5101	-101.5856	5/14/24	10/22/24	Drip/B	7/5	4	Am
2	32.7777	-101.9418	5/31/23	11/02/23	Pivot	13/10	4	Am
3	33.7199	-102.7206	5/18/23	11/17/23	Drip/F	6/23	4	Md/Ar
4	33.7191	-102.7211	5/23/23	11/14/24	Drip/F	7/18	4	Md/Ar
5	33.1900	-102.1849	5/20/24	10/25/24	Drip/B	7/18	4	Am
6	33.7867	-102.6607	6/06/23	11/21/23	Drip/B	5/3	10	Md
7	32.7763	-101.9453	5/17/23	11/07/23	Pivot	13/5	4	Am
8	32.7783	-101.9415	5/09/24	10/15/24	Pivot	15/2	4	Am
9	32.7771	-101.9422	5/09/24	10/31/24	Pivot	12/2	3	Am

[z]Drip refers to subsurface drip irrigation (1-m centers under each bed [B] or 2-m centers every other furrow [F]).

[y]R is the number of resistant varieties and S is the number of susceptible varieties.

[x]Am is Amarillo fine sandy loam; Md is Midessa fine sandy loam; Ar is Arch loam.

A pie-pan assay with 200 cm^3 soil plus root fragments was used to extract J2 over 48 h. The circular pie-pans were made of glass, and a wire mesh (0.64 cm diameter) was placed in the pie-pan. Two pieces of facial tissue (2-ply) were laid on top of the mesh and the soil sample placed on the facial tissue. Tap water (250 ml) was gently added to the pie-pan without disturbing the soil, and then the wet facial tissues were arranged around the soil to keep it from floating into the water. A cover was placed over the pie-pan to eliminate evaporation. The extracted J2 were counted by concentrating the extracted liquid to 100 ml and then counting the J2 in a 5-ml aliquot, or if J2 densities were low by concentrating to 50 ml and counting a 10-ml aliquot.

A second assay with 500 cm^3 soil was used to extract RK eggs. The soil sample with root fragments was mixed with 3 L of water in a bucket and stirred for 10 sec. After settling for 15 sec, the suspension was poured over a 230-µm sieve and root fragments were collected and washed into a beaker in 100 ml of tap water. Samples were stirred on a plate for 5 min in NaOCl (0.525%), poured through stacked 230-µm and 25-µm sieves, and rinsed. The contents from the bottom sieve were rinsed with tap water, washed into a beaker, dyed with acid fuchsin (Byrd et al., 1983), and the eggs were counted from a 5- or 10-ml aliquot taken out of the 150 ml total volume. The density of RK was calculated by the eggs plus J2 in 500 cm^3 soil. Analyses were conducted based on a $LOG_{10}(RK+1)$ transformation.

Plots were mechanically harvested with a cotton stripper (John Deere model 484, Moline, IL) modified to weigh plot yields using load cells. Harvested plot weights included lint, seed, and plant debris. A 1,000-g sample was collected from each plot, and two replicate samples were ginned from each entry to determine lint proportion (turnout). The research gin was equipped with a 10-saw gin stand, stick machine, feeder extractor, and saw lint cleaner. Gin components have been modified for research scale and are not commercially manufactured. Lint samples were sent to the Texas Tech University Biopolymer Research Institute (Lubbock, TX) for HVI analysis.

All susceptible varieties (excluding experimental lines) were labeled as susceptible. Varieties labeled as RK-resistant/tolerant by BASF FiberMax/Stoneville (FM/ST), Bayer CropScience Deltapine (DP), and Corteva Phytogen (PHY) were included in the trials.

All trial locations were sprayed by the producer or farm manager with glyphosate and glufosinate as well as various herbicides that can be sprayed on all cotton varieties (e.g., S-metolachlor). Trials 1, 3, 4, 5, and 6 were also treated with dicamba as needed. Trials 2, 7, 8, and 9 had some varieties that could not tolerate dicamba, so only glyphosate and glufosinate were used over the top of plants. Hoeing was used to control weeds that escaped herbicide applications. Dicamba was used outside of the test area at trials 2, 7, 8, and 9, which caused light foliar symptoms of dicamba injury to PHY varieties. Susceptible varieties in the trials may have differed in Bt protection (i.e. some were XF and some were B3XF or W3FE types). There were no signs of worm type feeding on the leaves. Some thrips damage occurred at some test sites, but varieties with the ThryvOn® technology did not demonstrate any yield advantage over those without this technology.

Each trial was analyzed separately (total of nine trials), comparing resistant varieties with susceptible varieties. Susceptible varieties included those under the brand names Armor, DP, FM, NexGen, and ST, with no known RK resistance. Least squares analysis was conducted using PROC GLIMMIX in SAS version 9.4 (SAS Institute, Cary, NC), with replication as a random factor (variety was the independent variable) and least square mean separations were performed using the conservative T group at alpha = 0.05. The dependent variables of interest were LOG_{10}(RK+1) density / 500 cm^3 soil (RK = J2 + eggs) and lint yield. RK density was presented in the results, but the least square mean separations were based on the individual transformed plot values. Average values for cotton fiber length and strength are presented, but no statistical analysis was conducted. One susceptible variety per trial was included along with the resistant varieties for fiber properties.

RESULTS AND DISCUSSION

Significant differences ($p = 0.05$) in transformed RK densities (LRK) were observed among cotton varieties in trials 4, 5, 6, 7, 8, and 9 (Table 3). In trial 4, DP 2143NR B3XF, DP 2349NR B3XF, and DP 2436NR B3TXF exhibited significantly lower LRK values than the susceptible group, whereas FM 765AX, FM 823AXTP, FM 868AXTP, and ST 6000AXTP were not different from the susceptible group (Table 3). In trial 5, DP 2143NR B3XF and DP 2436NR B3TXF had reduced LRK densities compared to the susceptible group. In trial 6, LRK densities were generally low across the site. DP 2141NR B3XF and DP 2143NR B3XF demonstrated significantly lower LRK densities than the susceptible group. In trial 7, DP 2141NR B3XF, DP 2143NR B3XF, PHY 205 W3FE, PHY 332 W3FE, PHY 411 W3FE, PHY 415 W3FE, PHY 443 W3FE, PHY 475 W3FE, and PHY 480 W3FE all had re-

Table 3. Least square means of root-knot nematode (RK) density across test locations

Variety	1[z]	2	3	4	5	6	7	8	9
	RK/500 cm^3 soil (J2 + Eggs)								
Susceptible[y]	1655	5940	1625	6822 a[x]	6084 ab	457 a	3983 a	7245 ab	11534 a
DP 2141NR B3XF	25	746	66			62 bc	0 d		40 cd
DP 2143NR B3XF	38	123	90	300 d	1673 d	7 c	13 d	0 f	0 d
DP 2349NR B3XF	30	1611	1270	8005 bc	1473 bc	313 ab		673 a-d	280 cd
DP 2436NR B3TXF	470			1165 cd	615 c			2540 ab	156 abc
FM 765AX				3220 ab	7258 ab			3910 a	
FM 823AXTP	493	3206	831	2668 abc	2563 abc	575 a	2283 a	4215 a	
FM 868AXTP	30	5274	485	943 abc	2835 abc	246 a	825 ab	385 bcd	1427 ab
ST 6000AXTP	303	410	630	2625 ab	7588 a		3413 a	4105 a	2661 ab
PHY 205 W3FE		2321					613 bc	483 abc	600 bc
PHY 332 W3FE		7305					58 cd	175 cde	17 cd
PHY 400 W3FE		4223					2090 ab	1540 ab	313 bc
PHY 411 W3FE		1480					18 d	25 ef	
PHY 415 W3FE		1405					80 cd		680 cd
PHY443 W3FE		3997					84 cd	68 def	17 cd
PHY 475 W3FE		1650					1505 cd	0 f	0 d
PHY 480 W3FE							30 d	73 def	
Prob>F	0.124	0.252	0.086	0.001	0.001	0.001	0.001	0.001	0.001

[z]The numbers refer to different trials. 1 was a drip field in Lubbock County, 2, 7, 8, and 9 were under a center pivot in Dawson County, 3 and 4 were a subsurface drip field in Cochran County, 5 was a subsurface drip field in Terry County, and 6 was a different subsurface drip field in Cochran County.

[y]The susceptible varieties changed from test to test and were tested as a composite group.

[x]A conservative T grouping for least squares means, with alpha = 0.05. Least squares mean with the same letters are not significantly different, based on a LOG_{10}(RK+1) transformation.

duced LRK densities compared to the susceptible group. In site 8, DP 2143NR B3XF, PHY 332 W3FE, PHY 443 W3FE, PHY 475 W3FE, and PHY 480 W3FE demonstrated lower LRK densities than the susceptible group. In trial 9, DP 2141NR B3XF, DP 2143NR B3XF, DP 2349NR B3XF, PHY 205 W3FE, PHY 332 W3FE, PHY 400 W3FE, PHY 415 W3FE, PHY 443 W3FE, and PHY 475 W3FE had lower LRK densities than the susceptible group. The LRK densities in trial 1 were not significantly different between entries and were generally low. However, this subsurface drip-irrigated location had dry soil in the sampling zone at the time of sampling. It is likely that the actual nematode counts were underestimated, as the dry conditions limited the ability to penetrate the soil adequately when sampling. Otherwise, sampling conditions for all other sites were adequate.

Across trials, the data confirmed that DP 2141NR B3XF and DP 2143NR B3XF exhibited strong resistance to RK. Trials 7, 8, and 9 were particularly useful for comparing resistant DP to resistant PHY varieties. In general, PHY 205 W3FE and PHY 400 W3FE were less resistant to RK than DP 2141NR B3XF and DP 2143NR B3XF. However, PHY 411 W3FE, PHY 415 W3FE, PHY 443 W3FE, PHY 475 W3FE, and PHY 480 W3FE appeared to have similar resistance or at least similar densities of RK as the two DP varieties. DP 2349NR B3XF and DP 2436NR B3TXF often had higher LRK densities than DP 2141NR B3XF or DP 2143NR B3XF, though usually LRK were numerically less than the susceptible group (and significantly less in some trials). The BASF varieties with claimed nematode resistance (FM 765AX, FM 823AXTP, FM 868AXTP, and ST 6000AXTP) did not perform as well in reducing LRK as DP resistant varieties (DP 2141NR B3XF and DP 2143NR B3XF).

Significant differences ($p = 0.05$) in lint yield among varieties were observed in trials 2, 5, 6, and 8 (Table 4). In trial 2, PHY 415 W3FE and PHY 475 W3FE outperformed the susceptible group, with yield increases of 55.5 and 34.7%, respectively. In

Table 4. Least square means of cotton lint yield across test locations

Variety	1[z]	2	3	4	5	6	7	8	9
	kg/ha								
Susceptible[y]	1653	759 cd[x]	891	706	792 b	1636 a	714	805 ef	646
DP 2141NR B3XF	1807	778 bcd	893			1650 a	783		647
DP 2143NR B3XF	1818	628 d	847	725	993 a	1600 a	720	848 de	559
DP 2349NR B3XF	1733	861 bcd	927	775	700 b	1648 a		729 ghi	591
DP 2436NR B3TXF	1910			710	780 b			773 e-h	636
FM 765AX				794	995 a			1059 a	
FM 823AXTP	1849	693 cd	830	708	712 b	1474 b	658	796 efg	
FM 868AXTP	1816	832 bcd	888	859	814 ab	1696 a	628	703 hi	709
ST 6000AXTP	1693	673 cd	1070	720	661 b		688	767 f-i	640
PHY 205 W3FE		779 bcd					655	691 i	656
PHY 332 W3FE		835 bcd					643	774 e-h	663
PHY 400 W3FE		805 bcd					744	922 cd	770
PHY 411 W3FE		866 bcd					801	933 bc	
PHY 415 W3FE		1180 a					703		796
PHY443 W3FE		925 abc					702	902 cd	758
PHY 475 W3FE		1022 ab					618	882 cd	725
PHY 480 W3FE							713	1010 ab	
Prob>F	0.096	0.011	0.330	0.641	0.005	0.006	0.806	0.001	0.123

[z]The numbers refer to different trials. 1 was a drip field in Lubbock County, 2, 7, 8, and 9 were under a center pivot in Dawson County, 3 and 4 were a subsurface drip field in Cochran County, 5 was a subsurface drip field in Terry County, and 6 was a different subsurface drip field in Cochran County.

[y]The susceptible varieties changed from test to test and were tested as a composite group.

[x]A conservative T grouping for least squares means, with alpha = 0.05. Least squares mean with the same letters are not significantly different.

trial 5, FM 765AX and DP 2143NR B3XF yielded 25.6 and 25.3% higher than the susceptible group. In trial 6, most varieties performed similarly, except FM 823AXTP, which had a 10% reduction in yield compared with the susceptible group. This trial had the lowest RK densities, and it is unlikely RK had much impact on yield. In trial 8, FM 765AX, PHY 480 W3FE, PHY 411 W3FE, PHY 400 W3FE, PHY 443 W3FE, and PHY 475 W3FE exhibited significantly higher yields than the susceptible group. DP 2349NR B3XF and PHY 205 W3FE yielded lower than the susceptible group.

Fiber length and strength differences between resistant varieties varied by trial and were influenced by specific field conditions. In trial 5, irrigation was lost during a critical stage of crop development and was not restored for approximately 3 wk. This stress resulted in reduced yields and generally shorter and weaker fiber (Tables 5 and 6). Varieties that consistently produced the shortest and weakest fiber included DP 2349NR B3XF, PHY 205 W3FE, and PHY 411 W3FE. In contrast, FM 823AXTP and ST 6000AXTP consistently produced longer fibers, and ST 6000AXTP also produced the strongest fiber in multiple trials.

Historically (2003-2017), Texas cotton producers have used RK-resistant varieties (ST 5599BR, DP 174 RF, ST 5458B2F, ST 4288B2F, PHY 367 WRF, ST 4946GLB2, PHY 417 WRF, DP 1558NR B2RF, DP 1747NR B2XF, and PHY 427 WRF) in sufficient acreage to be recorded in the annual *Cotton Varieties Planted*, previously published by the USDA Agricultural Marketing Service (Memphis, TN) (Wheeler et al., 2018). However, these older varieties are no longer commercially available, and resistance traits have been incorporated into new varieties with updated transgenic packages. It is important to understand the level of resistance in these new varieties. Strong RK-resistance was demonstrated for dicamba-tolerant DP 2141NR B3XF and DP 2143NR B3XF, along with 2,4-D tolerant PHY 332 W3FE, PHY 411 W3FE, PHY 415 W3FE, PHY 443 W3FE, PHY 475 W3FE, and PHY 480 W3FE. These PHY varieties had high RK-resistance but could be tested only at one location with four trials (due to blanket dicamba applications at other sites). Therefore, they

Table 5. Cotton fiber length (inches) of root-knot nematode resistant varieties at nine test locations.

Variety	1[z]	2	3	4	5	6	7	8	9
Susceptible[y]	1.03	1.10	1.05	1.11	1.01	1.12	1.04	1.05	0.98
DP 2141NR B3XF	1.10	1.09	1.08			1.10	1.07		1.03
DP 2143NR B3XF	1.10	1.11	1.09	1.11	1.03	1.09	1.05	1.09	1.08
DP 2349NR B3XF	1.08	1.06	1.08	1.05	0.98	1.13		0.99	1.02
DP 2436NR B3TXF	1.08			1.12	1.02		1.10	1.09	1.07
FM 765AX				1.07	1.01			1.07	
FM 823AXTP	1.11	1.10	1.11	1.08	1.03	1.16	1.05	1.07	
FM 868AXTP	1.09	1.07	1.05	1.09	1.01	1.11	1.06	1.07	1.08
ST 6000AXTP	1.10	1.12	1.10	1.10	1.02		1.07	1.06	1.10
PHY 205 W3FE		1.02					0.99	1.00	1.02
PHY 332 W3FE		1.10					1.06	1.01	1.07
PHY 400 W3FE		1.06					1.01	1.01	1.00
PHY 411 W3FE		1.03					0.97	0.97	
PHY 415 W3FE		1.11					1.06		1.05
PHY443 W3FE		1.07					1.02	1.02	0.99
PHY 475 W3FE		1.04					1.00	1.02	1.02
PHY 480 W3FE							1.03	1.03	

[z]The numbers refer to different trials. 1 was a drip field in Lubbock County, 2, 7, 8, and 9 were under a center pivot in Dawson County, 3 and 4 were a subsurface drip field in Cochran County, 5 was a subsurface drip field in Terry County, and 6 was a different subsurface drip field in Cochran County.

[y]The susceptible variety used for comparison purposes was different depending on trial. Trial 1 and 9 used DP 2127 B3XF; trial 6 used DP 2317 B3TXF; trial 7 used FM 2334GLT; and trial 2, 3, 4, 5 and 8 used DP 2335 B3XF.

Table 6. Cotton fiber strength (grams/tex) of root-knot nematode resistant varieties at nine test locations.

Variety	1[z]	2	3	4	5	6	7	8	9
Susceptible[y]	25.8	30.4	27.4	31.2	24.2	26.5	27.4	24.0	23.8
DP 2141NR B3XF	29.2	31.3	28.4			26.6	29.8		27.2
DP 2143NR B3XF	29.8	31.6	28.2	31.6	26.7	26.3	29.4	27.0	28.9
DP 2349NR B3XF	27.9	28.3	27.5	28.0	24.8	26.1		22.9	26.1
DP 2436NR B3TXF	28.1			31.7	25.7		31.8	27.2	29.3
FM 765AX				30.4	26.2			28.0	
FM 823AXTP	29.8	30.6	28.7	31.4	27.5	27.5	29.7	27.4	
FM 868AXTP	30.0	29.9	27.5	31.5	26.1	27.2	30.3	27.5	29.5
ST 6000AXTP	29.2	32.6	29.9	32.3	26.9		31.2	28.8	30.6
PHY 205 W3FE		27.9					27.6	24.2	28.1
PHY 332 W3FE		29.1					29.4	22.6	27.4
PHY 400 W3FE		30.3					28.0	23.7	26.1
PHY 411 W3FE		29.3					28.0	24.0	
PHY 415 W3FE		30.9					30.7		27.9
PHY443 W3FE		30.0					29.7	27.2	26.2
PHY 475 W3FE		29.6					28.2	25.9	27.7
PHY 480 W3FE							29.2	25.8	

[z]The numbers refer to different trials. 1 was a drip field in Lubbock County, 2, 7, 8, and 9 were under a center pivot in Dawson County, 3 and 4 were a subsurface drip field in Cochran County, 5 was a subsurface drip field in Terry County, and 6 was a different subsurface drip field in Cochran County.

[y]The susceptible variety used for comparison purposes was different depending on trial. Trial 1 and 9 used DP 2127 B3XF; trial 6 used DP 2317 B3TXF; trial 7 used FM 2334GLT; and trial 2, 3, 4, 5 and 8 used DP 2335 B3XF.

were not vigorously tested under different nematode populations and field conditions.

RK-resistant varieties provide producers with opportunities to reduce RK densities in the soil, enabling rotation with susceptible varieties in subsequent years, or require continuous planting of resistant varieties for those with weak resistance. For the newly available BASF partially resistant varieties (i.e., FM 765AX, FM 823AXTP, FM 868AXTP, and ST 6000AXTP), FM 868AXTP was the only one with better resistance than the susceptible varieties, and in general the level of resistance will require planting resistant varieties annually. Varieties with the strongest resistance might reduce RK densities to a point where some incorporation of nematode-susceptible varieties can be used.

Ultimately, for a cotton variety to be adopted by producers, it should demonstrate good yield and fiber quality and possess a desirable transgenic trait package. In addition, certain disease resistance traits, usually native (i.e., not transgenic) can significantly enhance the value of a variety. The ability of resistant varieties to sustain high yields under southern RK pressure provides considerable value to producers farming in infested fields. Overall, these results offer cotton producers valuable new options for managing RK pressure while maintaining high yields, paving the way for more sustainable cotton production practices.

ACKNOWLEDGMENTS

Funding for the research in this manuscript was provided by Texas Cotton State Support and by Plains Cotton Improvement Program. We also appreciate the support of Texas A&M AgriLife Research and Texas A&M AgriLife Extension Service.

REFERENCES

Byrd, D.W., T. Kirkpatrick, and K.R. Barker. 1983. An improved technique for clearing and staining plant tissue for detection of nematodes. J. Nematol. 15:142–143.

Da Silva, M.B., R.F. Davis, P. Kumar, R.L. Nichols, and P.W. Chee. 2019. Resistance quantitative trait loci qMi-C11 and qMi-C14 in cotton have different effects on the development of *Meloidogyne incognita*, the southern root-knot nematode. Plant Dis. 103:853–858. https://doi.org/10.1094/PDIS-06-18-1050-RE

Faske, T.R., J. Mueller, J.O. Becker, E.C. Bernard, C. Bradley, J. Bond, J. Desager, J. Eisenback, Z. Grabau, J. Hu, R. Kemerait, A. Koehler, K. Lawrence, H. Mehl, R.E. Rudolph, E.J. Sikora, S. Thomas, N. Walker, T. Wheeler, A.J. Wrather, W. Ye, and L. Zhang. 2023. Summarized distribution of the southern root-knot nematode, *Meloidogyne incognita*, in field crops in the United States. Plant Health Prog. 24:522–524. https://doi.org/10.1094/PHP-04-23-0031-BR

Gutierrez, O.A., J.N. Jenkins, J.C. McCarty, M.J. Wubben, R.W. Hayes, and F.E. Callahan. 2010. SSR markers closely associated with genes for resistance to root-knot nematode on chromosomes 11 and 14 of upland cotton. Theor. Appl. Genet. 121:1323–1337. https://doi.org/10.1007/s00122-010-1391-9

Hussey, R.S, and K.R. Barker.1973. A comparison of methods of collecting inocula of *Meloidogyne* spp., including a new technique. Plant Dis. Reporter. 57:1025–1028.

Kirkpatrick, T.L., D.M. Oosterhuis, and S.D. Wullschleger. 1991. Interaction of *Meloidogyne incognita* and water stress in two cotton cultivars. J. Nematol. 23:462–467.

Kirkpatrick, T.L., M.W. Van Iersel, and D.M. Oosterhuis. 1995. Influence of *Meloidogyne incognita* on the water relations of cotton grown in microplots. J. Nematol. 27:465–471.

Kumar, P., Y. He, R. Singh, R.F. Davis, H. Guo, A.H. Paterson, D.G. Peterson, X. Shen, R.L. Nichols, and P.W. Chee. 2016. Fine mapping and identification of candidate genes for a QTL affecting *Meloidogyne incognita* reproduction in upland cotton. BMC Genomics. 17:567. https://doi.org/10.1186/s12864-016-2954-1

Ma, J., J. Jaraba, T.L. Kirkpatrick, and C.S. Rothrock. 2014. Effects of *Meloidogyne incognita* and *Thielaviopsis basicola* on cotton growth and root morphology. Phytopathology. 104:507–512. https://doi.org/10.1094/PHYTO-06-12-0120-R

McClure, M.A. 1977. *Meloidogyne incognita*: A metabolic sink. J. Nematol. 9:88–90.

Orr, C.C., and A.F. Robinson. 1984. Assessment of losses in western Texas caused by *Meloidogyne incognita*. Plant Dis. 68:284–285. https://doi.org/10.1094/PD-68-284

Shen, X.L., Y.J. He, E.L. Lubbers, R.F. Davis, R.L. Nichols, P.W. Chee. 2010. Fine mapping QMi-C11 a major QTL controlling root-knot nematodes resistance in upland cotton. Theor. Appl. Genet. 121:1623–1631. https://doi.org/10.1007/s00122-010-1415-5

Shepherd, R.L. 1974a. Transgressive segregation for root-knot nematode resistance in cotton. Crop Sci. 14:872–875. https://doi.org/10.2135/cropsci1974.0011183X001400060029x

Shepherd, R.L. 1974b. Registration of Auburn 623 RNR cotton germplasm (Reg. No. GP 20). Crop Sci. 14:911. https://doi.org/10.2135/cropsci1974.0011183X001400060058x

Starr, J.L., C.M. Heald, A.F. Robinson, R.G. Smith, and J.P. Krausz. 1993. *Meloidogyne incognita* and *Rotylenchulus reniformis* and associated soil textures from some cotton production areas of Texas. J. Nematol. 25:895–899.

Thistlethwayte, B. 1970. Reproduction of *Pratylenchus penetrans* (Nematoda: Tylenchida). J. Nematol. 2:101–105.

Wallace, H.R. 1974. The influence of root-knot nematode, *Meloidogyne javanica*, on photosynthesis and on nutrient demand by roots of tomato plants. Nematologica. 20:27–33. https://doi.org/10.1163/187529274X00546

Wheeler, T.A., K.D. Hake, and J.K. Dever. 2000. Survey of *Meloidogyne incognita* and *Thielaviopsis basicola*: their impact on cotton fruiting and producers' management choices in infested fields. J. Nematol. 32:576–583.

Wheeler, T.A., J.E. Woodward, and N.R. Walker. 2018. Plant parasitic nematodes of economic importance in Texas and Oklahoma. pp. 433–451 *In* S.A. Subbotin and J.J. Chitambar (eds.), Plant Parasitic Nematodes in Sustainable Agriculture of North America Vol. 2 Northeastern, Midwestern and Southern USA. Springer Nature Switzerland AG. https://doi.org/10.1007/978-3-319-99588-5

Wheeler, T.A., J.W. Keeling, J.P. Bordovsky, J. Everitt, K.F. Bronson, R.K. Boman, and B.G. Mullinix, Jr. 2009. Effect of irrigation rates on three cotton (*Gossypium hirsutum* L.) cultivars in a root-knot nematode (*Meloidogyne incognita*) infested field. J. Cotton Sci. 13:56–66.

Wheeler, T.A., K.T. Siders, M.G. Anderson, S.A. Russell, J.E. Woodward, and B.G. Mullinix, Jr. 2014. Management of *Meloidogyne incognita* with chemicals and cultivars in cotton in a semi-arid environment. J. Nematol. 46:101–107.

Wheeler, T.A., K. Siders, C. Monclova-Santana, and J.K. Dever. 2020. The relationship between commercial cotton cultivars with varying *Meloidogyne incognita* resistance genes and yield. J. Nematol. 52:e2020-64. https://doi.org/10.21307/jofnem-2020-064

Wubben, M.J., A.G. Gaudin, J.C. McCarty Jr., and J.N. Jenkins. 2020. Analysis of cotton chromosome 11 and 14 root-knot nematode resistance quantitative trait loci effects on root-knot nematode postinfection development, egg mass formation, and fecundity. Phytopathology. 110:927–932. https://doi.org/10.1094/PHYTO-09-19-0370-R