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Effect of Irrigation Rates on Three Cotton (*Gossypium hirsutum* L.) Cultivars in a Root-knot Nematode (*Meloidogyne incognita*) Infested Field

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ABSTRACT

A large-plot study was conducted for five years to determine the effect of irrigation rate and fertigated nitrogen on the performance of Fibermax (FM) 989BR, Stoneville (ST) 5599BR, and Paymaster (PM) 2280 BG/RR in a field infested with the root-knot nematode (*Meloidogyne incognita*). The objective was to determine if irrigation rate would effect the relative ability of susceptible and root-knot nematode tolerant cultivars to perform in a root-knot nematode infested field. The split-plot design included irrigation and nitrogen rates as the whole plots (base irrigation rate = B, 75% of base rate [75%B], and 125% of base rate [125%B], with nitrogen applied through the center pivot system and being proportional to irrigation rate) and cultivars as the sub-plot with three replications. The B and 125%B rates had higher lint yield and gross loan value ha^{-1} ($P \leq 0.05$) than the 75%B rate when averaged across the three cultivars. The root-knot nematode tolerant cultivar ST 5599BR, averaged equal or higher lint yields than FM 989BR at all irrigation rates when averaged over five years. ST 5599BR and FM 989BR had similar gross loan values ha^{-1} at all three irrigation rates. ST 5599BR had higher lint yields and gross loan values ha^{-1} than PM 2280 BG/RR (2003 – 2006) at the B and 125%B rates. The Paymaster cultivar is susceptible to root-knot nematode. Increasing irrigation rate did not improve the profitability of susceptible cultivars in a root-knot infested field, compared to the response of a tolerant cultivar.

Cotton (*Gossypium hirsutum* L.) production in the semi-arid Texas Southern High Plains presents numerous challenges. Water availability is of concern since pumping capacities from the Ogallala aquifer are generally limited and cotton is mostly produced under various levels of deficit irrigation. The low energy precision application (LEPA) irrigation concept was developed to maximize the use of seasonal rainfall and increase irrigation efficiencies in arid and semi-arid areas (Bordovsky, et al., 1992). Cultivar choice is also an important factor that affects cotton yield and quality.

Irrigation recommendations with LEPA are based on the needs of the crop for water at any given time. Reference evapotranspiration (ET_r) is a calculated estimate of potential water loss from a well-watered turf area and is based on environmental conditions. Crop evapotranspiration (ET) which is equal to ET_r x a crop-specific coefficient is based on both environmental conditions and the model used to predict the amount of water that a crop needs as it grows and develops. Cotton is particularly sensitive to the cumulative water availability during flowering (Guinn and Mauney, 1984). In the Southern High Plains of Texas, deficit irrigation is most likely to occur during the flowering period, when crop coefficients are near 1.0.

Nitrogen is the second most limiting factor for semiarid cotton production, following water when considering the three factors of water, nitrogen, and heat units (Morrow and Krieg, 1990). Nitrogen fertilizer response is positively related to irrigation well capacity and irrigation rate (Bronson et al., 2001). Much of the N fertilizer in center-pivot-irrigated cotton produced in the Southern High Plains is injected through the irrigation water (i.e. fertigation).

The performance of different cultivars may be affected by water availability. However, diseases can also affect cultivar performance. Cotton is a host for the southern root-knot nematode (*Meloidogyne incognita* (Kofoid & White) Chitwood). Approximately 40% of the area planted in irrigated cotton in the Southern High Plains, is infested with *M. incognita* (Robinson et al., 1987; Wheeler et al., 2000). There are no commercial upland cultivars available with high levels of resistance to *M. incognita*. Resistance is defined as a reduction in the ability of the

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nematode to reproduce on a given cultivar compared with susceptible cultivars, but does not include any assumptions of yield performance. Tolerance implies the ability of the cultivar to yield well in the presence of the nematode, but does not assume any reduction in the reproduction of the nematode. However, tolerance may be dependent on the nematode density present. A susceptible cultivar implies that the nematode reproduces well on that cultivar and that yield is reduced in the presence of the nematode. Stoneville (ST) 5599BR (Bayer CropScience; Lubbock, TX) was developed from the partially resistant ST LA887 and is considered tolerant (Barfield, 2003) and partially resistant (Phipps and Eisenback, 2005) to *M. incognita*. Partial resistance would indicate some reduction in nematode reproduction on a cultivar. There is limited information available on the tolerance of cotton cultivars to *M. incognita*. Davis and May (2003) used greenhouse assays to evaluate resistance of cotton cultivars, and then field trials to evaluate tolerance of these cultivars. They found that yield depression decreased linearly as nematode resistance increased. Additional studies were conducted with susceptible cultivars, and tolerance was not consistently expressed (Davis and May, 2005). Their conclusion was that susceptible cultivars would not perform well consistently in *M. incognita* infested fields.

The Common Credit Corporation (CCC) loan value of a cultivar-fiber can play an important role in the gross loan value that a producer receives. Both ST 5599BR and Fibermax (FM) 989BR (Bayer CropScience; Lubbock, TX) are considered high yielding picker type cultivars (Barfield, 2003; www.cotton-experts.com/seeds/variety/bollgardWithRR.html). However, Fibermax cultivars are generally recognized for their superior fiber properties. FM 989BR was developed from FM 989, which shows significantly less resistance than ST LA887 (Wheeler and Gannaway, 2001). The short season stripper-type cultivar Paymaster (PM) 2280 BG/RR (Monsanto; St. Louis, MO) was developed for irrigated conditions in the High Plains of Texas (Sheetz, 2000). PM 2280 BG/RR also allowed significantly higher reproduction of *M. incognita* and had lower lint yields than ST 5599BR (labeled as STX 9905 in the citation) (Wheeler and Gannaway, 1998). The objective of this study was to determine how irrigation rates (plus fertigated nitrogen) and *M. incognita* susceptible and tolerant cultivars affected lint yield, loan value, and gross loan value ha^{-1} in a field infested with *M. incognita*.

MATERIALS AND METHODS

Large plot field trials were conducted from 2003 to 2007 to compare lint yield and lint value from three irrigation rates (with fertigated N being proportional to irrigation rate) and three cultivars across the irrigation rates using center pivot LEPA irrigation. The study was conducted near Lamesa, TX in a field where the soil series was an Amarillo sandy loam (fine-loamy, mixed, superactive, thermic, Aridic Paleustalf, 81% sand, 8% silt, 11% clay, 0.4% organic matter, pH 8). The rows were circular, and the test area in 2003 and 2004 had individual plot areas ranging from 0.083 ha to 0.174 ha. In 2005 and 2006, the plot areas ranged from 0.286 to 0.800 ha. In 2007, plot areas ranged from 0.137 to 0.378 ha.

The whole plots were the irrigation rates which included a base irrigation rate, 75% of the base and 125% of the base rates. Each irrigation rate within the whole plots was 24 rows wide (1 m centers) arranged in a randomized complete block design with three replications (one replication of three irrigation rates equaled 72 rows). There were no border rows between irrigation rate changes. The base rate represented the optimal irrigation recommendation, targeted at 0.75 ET replacement (Bordovsky et al., 1992; Bordovsky and Lyle, 1999; Bronson et al., 2001; and Bronson et al., 2006). The base irrigation rate was limited by the irrigation capacity of the wells at the research site, therefore, in periods of low rain and high crop ET, available irrigation could not meet the 75% ET target. Nitrogen was applied with the center pivot system, so the plots with 125% of the base rate received approximately 25% more N through the pivot than did plots with the base rate. The subplot (cultivar) was eight rows wide per cultivar, randomized within each whole plot (three cultivars = 24 rows wide, which equaled the width of each whole plot irrigation rate). The cultivars were FM 989BR and ST 5599BR in all years of the test, PM 2280 BG/RR from 2003 to 2006, and Deltapine (DP) 515BR in 2007. DP 515BR replaced PM 2280 BG/RR in 2007. DP 515BR represented a high yielding, but susceptible cultivar. PM 2280BG/RR had lower yield potential than the picker type cultivars. The cultivars remained within the same plot location in 2003 to 2004, and then were relocated to another part of the circle in 2005, and remained in the same locations from 2005 to 2007, except that DP 515BR replaced the rows that PM 2280 BG/RR had been in prior to 2007. The row length was shortened in 2007 from the previous two years.

Early-season irrigation for crop establishment was applied using low-elevation spray sprinklers, with an equal rate applied across all treatments and plot areas. Different seasonal irrigation amounts were accomplished by using LEPA applicators with combinations of appropriate sized orifices. The varying rate LEPA irrigation treatments were initiated on 14 July, 8 July, 17 June, 3 July, and 18 July for 2003, 2004, 2005, 2006, and 2007, respectively. From that time until irrigation termination, the three irrigation rates were applied. This resulted in 15, 9, 19, 28, and 10 irrigation applications for each rate for 2003, 2004, 2005, 2006 and 2007, respectively. The in-season irrigation and rainfall amounts for each year are provided in Table 1.

Table 1. Irrigation amounts, nitrogen fertilizer inputs, rainfall and potential evapotranspiration near Lamesa, TX 2003 – 2007.

Water	2003	2004	2005	2006	2007
	(water in mm)				
Initial[z]	71	210	41	36	0
75% of Base rate	168	183	191	203	76
Base rate	224	244	254	320	102
125% of Base rate	279	305	305	427	127
Rainfall[y]	261	316	116	183	280
Cumulative PET[x]	737	730	664	705	573
	kg N ha^{-1}				
75% of Base rate	75	114	120	120	120
Base rate	101	140	146	146	146
125% of Base rate	125	165	171	171	171

[z] Irrigation from planting until when differential treatments began.

[y] Measured from planting date through 15 September.

[x] Cumulative potential evapotranspiration was measured from planting until 30 September.

Plots were planted on 7, 3, 9, 3, and 16 May in 2003, 2004, 2005, 2006 and 2007, respectively. A John Deere Max Emerge eight row vacuum planter calibrated at 13.3 seed/m row was used to plant the test. Aldicarb (Temik® 15G; Bayer CropScience, Research Triangle Park) was applied in the furrow at planting (0.59 kg a.i. ha^{-1}). Aldicarb, which is a nematicide, was applied because management recommendations for producers will be designed to integrate partial chemical control (i.e. aldicarb or a nematicide seed treatment) with cultivars that perform well in root-knot nematode fields. The rate of aldicarb used in the study is considered low for nematode control, but after a decade of aldicarb rate work at this specific field, the rate of 0.59 kg a.i. ha^{-1} always resulted in yields similar to "nematicidal" rates. Weed control was achieved with pendimethalin (Prowl 3.3 EC; BASF; Research Triangle Park, NC) applied preplant at 1.4 kg ha^{-1} and glyphosate isopropylamine salt (Roundup WeatherMax; Monsanto Co.; St. Louis, MO) post-emergence at 0.87 kg ha^{-1} before the 5th leaf stage, and glyphosate postemergence directed.

Nitrogen fertilizer was applied via fertigation as urea-ammonium nitrate (32-0-0) between first square and mid bloom. Nitrogen amounts varied with corresponding irrigation treatments and are shown in Table 1. Fertilizer P (ammonium polyphosphate 10-34-0) was banded in the soil at 24, 24, 17, 17, and 17 kg ha^{-1} during 2003, 2004, 2005, 2006, and 2007, respectively.

Due to the above average rainfall in 2005, mepiquat pentaborate (Pentia; BASF) was applied at 115 g ha^{-1} at first bloom on the plots with the 125% of base irrigation rate for plant height control. For all other years and irrigation rates, plant height control was not necessary.

Soil samples were obtained during the fall on 20 October, 31 August, and 28 August for 2005, 2006, and 2007, respectively. Samples consisted of five spots that were dug to approximately a 30 cm depth with a narrow bladed shovel within a two-row, 20.8 m long area, and approximately 200-cm^3 soil was removed from the lower 15 cm depth and placed in a bucket. All soil from a sample was mixed in the bucket and placed in a plastic bag for nematode assays. Samples were taken at three locations per plot in 2005, six locations per plot in 2006, and two composite samples consisting of 20 spots were taken throughout the entire plot (per sample) in 2007. Root-knot nematode eggs/500 cm^3 soil were averaged across plot subsamples for each plot. No nematode sampling was conducted in 2003 and 2004. Second-stage juveniles of *M. incognita* were extracted from 200 cm^3 soil using the pie-pan procedure (Thislethwayte, 1970). Eggs were extracted by adding 2 liters of water to 500 cm^3 of soil and root fragments, stirring for 15 seconds, and allowing 15 seconds for settling before pouring the water and organic matter over a sieve with a 0.23-mm-pore opening. The eggs were extracted with NaOCl (0.5%) for 5 min. from the residue collected on the sieve (Hussey and Barker, 1973).

Harvest aids typically consisted of an initial application of a boll opener (ethephon at 1.12 kg ha^{-1}) plus defoliant (tribufos at 0.84 kg ha^{-1}) and then when it was time, a sequential application of a dessicant (paraquat at 0.55 kg ha^{-1}). The first application was made on 17 Oct., 8 Oct., 12 Oct., 29 Sept., and 20 Oct. in 2003 to 2007. The sequential application was made on 31 Oct., 1 Nov., 12 Oct., 13 Oct., and 30 Oct. in 2003 to 2007.

Plots were stripper harvested on 14, 19, 17, 30, and 28 Oct. for 2003, 2004, 2005, 2006 and 2007, respectively using a commercial four row John Deere 7445 with field cleaner. Harvested material was transferred into a weigh wagon with integral electronic scales to determine individual plot weights. Plot lint yields were adjusted to kg ha^{-1}. Grab samples were taken by plot and ginned at the Texas AgriLife Research and Extension Center at Lubbock to determine gin turnouts. Lint samples were submitted to the Fiber and Biopolymer Research Institute at Texas Tech University for high volume (HVI) analysis, and CCC loan values were determined for each cultivar by plot. All cultivars were ready for harvest by these dates, without the need to harvest separately. Cotton seed was delinted with HCL, dried at 100°C, ground and analyzed for N concentration with a Leco FP528 N analyzer (Leco Corp., St. Joseph, MN).

Lint yield, HVI fiber quality factors (length, strength, micronaire, leaf grade), CCC loan value, gross loan value ha^{-1} (lint yield x loan value), *M. incognita* second-stage juveniles (J2) and *M. incognita* eggs, $Log_{10}(J2 + 1)$, and $Log_{10}(eggs + 1)$ were analyzed as a split-plot design for treatment effects using PROC MIXED in SAS (version 9.1, Cary, NC). Within the combined analysis for all years, the random factors were year, block(year), year x irrigation rate (I), block x I(year), year x cultivar, and year x I x cultivar, where nested effects are described with parentheses. Within the individual year analysis, random factors were replicate and replicate x I rate. Fixed effects were I, cultivar, and their interaction. When interactions between irrigation rate and cultivar were significant at $P \leq 0.05$, treatment combination differences were determined by the LSMEANS / PDIFF statement for irrigation rate, cultivar and their interaction. Only differences in treatment combinations that were significant at $P \leq 0.05$ were accepted.

A weather station was maintained at this site to measure environmental parameters in order to calculate estimated evaporative demands. Measurements were recorded and a database maintained at this web site: http://txhighplainset.tamu.edu/. This web site provides evapotranspiration models for cotton water use that are based on different planting dates. For this work, the model for South Plains cotton, planted either 1 or 15 May (depending on the planting date for that year) was used to describe the water needs for that season.

RESULTS

Within the five years of the study, many different environments were encountered. The cumulative ET replacement for the growing season was > 1 for all years during May (Fig. 1). ET replacement $< 75\%$ occurred in the month of June only during 2006. During July, ET replacement was near (2004) or less than 75% for all irrigation treatments in all years, with the exception of 2007 when timely rains complemented irrigations during the month (Fig. 1). In August of 2003, 2005, and 2006, ET replacement in all irrigation treatments was less than 75% due to limited irrigation capacity. Cumulative ET replacement was close to 0.75 during August in 2004 and 2007.

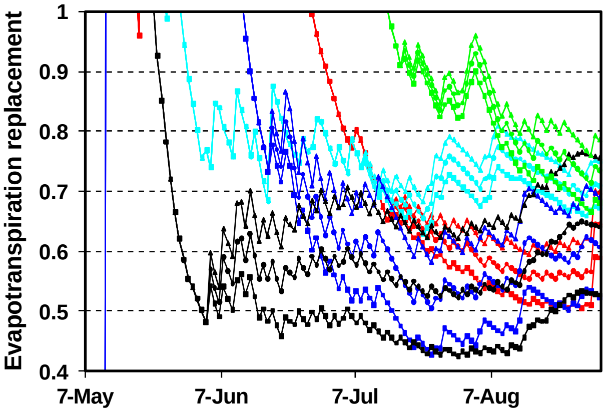

Figure 1. Evapotranspiration replacement of cotton during 2003 (—), 2004 (—), 2005 (—), 2006 (—), and 2007 (—). There were three irrigation treatments, a base rate (○), a rate approximately 25% higher than the base rate (△) and a rate approximately 25% lower than the base rate (□).

Lint yield was effected by the interaction between irrigation rate and cultivars during 2003, 2004, and when combining 2003 - 2006. In the combined analysis, ST 5599BR had significantly higher yields than PM 2280 BG/RR at the base and 125% of the base irrigation rates (Table 2). At 125% of the base rate, ST 5599BR had significantly higher lint yield than FM 989BR, and the two cultivars had similar yields at the base and 75% of base rates (Table 2). FM 989BR had similar yields to PM 2280 BG/RR at both the base and 75% of the base irrigation rates (Table 2).

Table 2. Effect of the whole plot treatments (irrigation rate and fertigated nitrogen) and subplot cultivars averaged over four years (2003 – 2006) on cotton lint yield and gross loan value ha-1, in a field infested with Meloidogyne incognita.

Cultivar	Whole plot Treatments[z]		
	75% of Base	Base	125% of Base
	Lint Yield (kg ha^{-1})		
Stoneville 5599BR	1100 ay^{y}	1441 az^{x}	1584 az
Fibermax 989BR	955 ay	1345 abz	1345 bz
Paymaster 2280 BG/RR	900 ay	1140 bz	1113 cz
	Gross loan value (\$ ha^{-1})		
Stoneville 5599BR	1190 ay	1568 az	1752 az
Fibermax 989BR	1105 ay	1581 az	1606 az
Paymaster 2280 BG/RR	1011 ay	1297 bz	1282 bz

[z] Base irrigation rate was estimated to replace 75% of the evaporative demands of the crop. 75% Base represented a 25 % reduction of the base irrigation rate and 125% Base represented a 25% increase of the base irrigation rate. Nitrogen was applied through the center pivot system, so rates applied were proportional to irrigation.

[y] Different letters (y, z) indicate that yield is significantly different ($P \leq 0.05$) between irrigation rates (within a row).

[x] Different letters (a, b, c) indicate that yield was significantly different ($P \leq 0.05$) between cultivars (with a column).

The results differed in 2003 in that ST 5599BR had higher yields than FM 989BR and PM 2280 BG/RR at all three irrigation rates and FM 989BR had higher yields than PM 2280 BG/RR at all three irrigation rates (Table 3). The results in 2004 were unusual with respect to the other years. In 2004, ST 5599BR had similar lint yields to both FM 989BR and PM 2280 BG/RR at the base and 125% of the base irrigation rates, but had significantly lower lint yields than PM 2280 BG/RR at 75% of the base irrigation rate (Table 4). Otherwise, the yearly results were similar to the overall results, where in 2003, 2005, 2006, and 2007 ST 5599BR had higher lint yields when averaged over all irrigation rates than the other two cultivars. FM 989BR had higher lint yields than PM 2280 BG/RR, when averaged over all irrigation rates in 2003 and 2005, and yielded similarly to DP 515BR in 2007. For all three cultivars, lint yield was significantly lower at 75% of the base irrigation rate than the base or 125% of the base irrigation rate in the overall analysis (Table 2). The base and 125% of base irrigation rate resulted in similar lint yields in the overall analysis (Table 2).

Table 3. Effect of the whole plot treatments (irrigation rate and fertigated nitrogen) and subplot cultivars in 2003 on cotton lint yield and gross loan value ha^{-1}, in a field infested with *Meloidogyne incognita*.

Cultivar	Whole plot Treatments[z]		
	75% of Base	Base	125% of Base
	Lint Yield (kg ha^{-1})		
Stoneville 5599BR	1206 ax^{y}	1424 ay^{x}	1665 az
Fibermax 989BR	962 by	1225 bz	1164 bz
Paymaster 2280 BG/RR	731 cx	916 cy	1046 cz
	Gross loan value (\$ ha^{-1})		
Stoneville 5599BR	1324 ax	1460 ay	1877 az
Fibermax 989BR	1056 by	1361 bz	1387 bz
Paymaster 2280 BG/RR	798 cx	1000 cy	1170 cz

[z] Base irrigation rate was estimated to replace 75% of the evaporative demands of the crop. 75% Base represented a 25 % reduction of the base irrigation rate and 125% Base represented a 25% increase of the base irrigation rate. Nitrogen was applied through the center pivot system, so rates applied were proportional to irrigation.

[y] Different letters (x, y, z) indicate that yield or gross loan value is significantly different ($P \leq 0.05$) between irrigation rates (within a row).

[x] Different letters (a, b, c) indicate that yield or gross loan value was significantly different ($P \leq 0.05$) between cultivars (with a column).

Table 4. Effect of the whole plot treatments (irrigation rate and fertigated nitrogen) and subplot cultivars in 2004 on cotton lint yield, in a field infested with *Meloidogyne incognita*.

Cultivar	Whole plot Treatments[z]		
	75% of Base	Base	125% of Base
	Lint Yield (kg ha^{-1})		
Stoneville 5599BR	964 by^{y}	1385 az^{x}	1409 az
Fibermax 989BR	981 aby	1510 az	1425 az
Paymaster 2280 BG/RR	1202 az	1384 az	1195 az

[z] B = Base irrigation rate estimated to replace 75% of the evaporative demands of the crop. 75% of Base was a 25 % reduction of this irrigation rate and 125% of Base was a 25% increase of the irrigation rate. Nitrogen was applied through the center pivot system, so rates applied were proportional to irrigation.

[y] Different letters (x, y, z) indicate that yield is significantly different ($P \leq 0.05$) between irrigation rates (within a row).

[x] Different letters (a, b, c) indicate that yield is significantly different ($P \leq 0.05$) between cultivars (within a column).

Seed N uptake, which was obtained in 2005 to 2007, was higher in 2005 and 2006 with ST 5599BR than for PM 2280 BG/RR (Table 5). In 2007, seed N uptake was similar across all cultivars. Nitrogen uptake reflected the irrigation rates in 2005 and 2006. The increase in seed N uptake was lowest at 75% of the base irrigation rate compared to the larger seed N uptake at the base and 125% of base irrigation rates in 2005 and 2006. In the wetter than average 2007 season, there was no cultivar or irrigation rate effect on seed N uptake (Table 5). Seed N uptake is a valuable data set that reveals the N requirements by the plant (Bronson et al., 2008). In general, greater lint and seed yields equate with greater N removal in seed. Theoretically, N in other plant parts such as leaves and stems stay in the field and are recycled.

Gross loan value ha^{-1} was effected by an interaction between irrigation rate and cultivar in 2003 and in the overall analysis (2003 to 2006). In the overall analysis, ST 5599BR and FM 989BR had higher gross loan values ha^{-1}, than PM 2280 BG/RR at the base and 125% of base irrigation rates (Table 2). In 2003, cultivar results at each irrigation rate were similar to yield differences, with ST 5599BR having the highest gross loan value ha^{-1}, followed by FM 989BR, followed by PM 2280 BG/RR (Table 3). In 2003, 2006, and 2007, ST 5599BR had a higher gross loan value ha^{-1} than the other cultivars (Table 6). In 2004, all cultivars had similar gross loan value ha^{-1}, while in 2005, FM 989BR had a higher gross loan value ha^{-1} than the other cultivars, averaged across all irrigation rates (TabIrrigation and fertigation rate had a significant effect on gross loan value ha^{-1} in all individual years and the overall analysis. In the overall analysis, the gross loan value ha^{-1} at the base (\$1,574 ha^{-1}) and 125% of base irrigation rates (\$1,611 ha^{-1}) were significantly higher than 75% of the base irrigation rate (\$1,173 ha^{-1}). A similar relationship between the base and 125% of the base irrigation rate was seen in 2006 and 2007, while in 2003 and 2005, higher rates of irrigation and fertigated nitrogen meant higher gross loan value ha^{-1} (Table 7). In 2004, the gross loan value ha-1 was higher for the base irrigation rate than the 125% of the base irrigation rate (Table 7).

Table 5. Seed nitrogen uptake as affected by whole plot treatments (irrigation rate and fertigated nitrogen) and subplot cultivars, in a field infested with *Meloidogyne incognita*, during 2005 – 2007.

Cultivar	Year	Whole plot Treatments^{z}			Mean
		75% of Base	Base	125% of Base	
			(kg ha^{-1})		
Stoneville 5599BR	2005	92 ay^{yx}	104 az	107 az	101 a
Fibermax 989BR	2005	90 ay	96 by	108 az	98 a
Paymaster 2280 BG/RR	2005	79 by	94 bz	95 bz	89 b
Means for 2005	2005	87 y	98 z	103 z	
Stoneville 5599BR	2006	69 ax	88 ay	106 az	88 a
Fibermax 989BR	2006	59 by	89 az	87 bz	78 ab
Paymaster 2280 BG/RR	2006	52 by	82 az	85 bz	73 b
Means for 2006	2006	60 y	87 z	93 z	
Stoneville 5599BR	2007	72	82	79	77
Fibermax 989BR	2007	62	68	89	73
DP 515BR	2007	63	72	72	71
Means for 2007	2007	65	74	82	

[z] Base irrigation rate estimated to replace 75% of the evaporative demands of the crop. 75% of base was a 25 % reduction of this irrigation rate and 125% of base was a 25% increase of the irrigation rate. Nitrogen was applied through the center pivot system, so rates applied were proportional to irrigation.

[y] Different letters (x, y, z) indicate that seed nitrogen uptake is significantly different ($P \leq 0.05$) between irrigation rates (within a row).

[x] Different letters (a, b, c) indicate that seed nitrogen uptake is significantly different ($P \leq 0.05$) between cultivars (within a year and a column).

Table 6. The effect of cultivar, averaged across three irrigation rates, on gross loan value ha^{-1} ($) in a cotton field infested with *Meloidogyne incognita* from 2003 – 2007.

Cultivar	2003	2004	2005	2006	2007
Stoneville 5599BR	1,553 a[z]	1,398	1,648 b	1,414 a	2,067 a
Fibermax 989BR	1,268 b	1,541	1,717 a	1,197 b	1,694 b
Paymaster 2280 BG/RR	989 c	1,472	1,281 c	1,044 b	-------
Deltapine 515BR	-------	-------	-------	-------	1,716 b

[z] Different letters (a, b, c) indicate that gross loan value ha^{-1} is significantly different ($P \leq 0.05$) between cultivars (within a column).

Table 7. The effect of irrigation rate and fertigated nitrogen, averaged across three cultivars, on gross loan value ha^{-1} ($) in a cotton field infested with *Meloidogyne incognita* from 2003 - 2007.

Irrigation rate[z]	2003	2004	2005	2006	2007
125% of Base	1,478 ay	1,543 b	1,738 a	1,429 a	1,965 a
Base	1,274 b	1,670 a	1,569 b	1,416 a	2,011 a
75% of Base	1,059 c	1,199 c	1,340 c	809 b	1,500 b

[z] Base irrigation rate estimated to replace 75% of the evaporative demands of the crop. 75% of Base was a 25% reduction of this irrigation rate and 125% of Base was a 25% increase of the irrigation rate. Nitrogen was applied through the center pivot system, so rates applied were proportional to irrigation.

[y] Different letters (a, b, c) indicate that gross loan value ha^{-1} is significantly different ($P \leq 0.05$) between irrigation rates (within a row).

Loan value was significantly effected by cultivar in all years and in the overall analysis. Irrigation rate significantly effected loan value in 2003, 2005, 2006, and 2007, but not in the overall analysis, and the irrigation rate with the highest or lowest loan value changed from year to year. Cultivar had the most important overall effect on loan value. Loan value was higher for FM 989BR lint ($1.19 kg^{-1} lint), and PM 2280 BG/RR lint ($1.15 kg^{-1} lint), than for ST 5599BR lint ($1.11 kg^{-1} lint). Irrigation rate effects were inconsistent among cultivars in different years. However in 2005 and 2007, the 75% of base irrigation rate had lower loan values than the base or 125% of base irrigation rates. The interaction between cultivar and irrigation rate was significant in 2003, 2004, and 2006. In all three years, loan value was uneffected by irrigation rate for PM 2280 BG/RR (Table 8). In 2003 for ST 5599BR, the loan value was lower at the base irrigation rate than the lower or higher irrigation rates. For FM 989BR, loan value was higher for the 125% of base irrigation rate compared with the base and 75% of base irrigation rate. In 2004, ST 5599BR again had the lowest loan value at the base irrigation rate. Loan value was not effected by irrigation rate for FM 989BR (Table 8). In 2006 for ST 5599BR and FM 989BR, loan value was lower for the 75% of base irrigation rate compared with the base and 125% base irrigation rate (Table 8).

Table 8. Effect of the whole plot treatments (irrigation rate and fertigated nitrogen) and subplot cultivars in 2003, 2004, and 2006 on loan value, in a field infested with *Meloidogyne incognita*.

Irr[z]	2003			2004			2006		
	Cultivar[w]			Cultivar			Cultivar		
	ST	FM	PM	ST	FM	PM	ST	FM	PM
	Loan value ($ kg^{-1})								
75%B	1.09 a[y]	1.09 b	1.09	1.12 ax	1.20 z[x]	1.17 y	1.00 by	1.06 bz	1.08 z
B	1.01 by	1.10 bz	1.09z	1.07 by	1.20 z	1.19 z	1.04 ax	1.13 az	1.09 y
125%B	1.12 ay	1.19 az	1.12y	1.12 ay	1.19 z	1.19 z	1.06 ay	1.12 az	1.09 z

[z] Base irrigation rate (B) was estimated to replace 75% of the evaporative demands of the crop. 75%B represented a 25 % reduction of the base irrigation rate and 125%B represented a 25% increase of the base irrigation rate. Nitrogen was applied through the center pivot system, so rates applied were proportional to irrigation.

[y] Different letters (a, b, c) indicate that loan value is significantly different ($P \leq 0.05$) between irrigation rates (within a column).

[x] Different letters (x, y, z) indicate that loan value was significantly different ($P \leq 0.05$) between cultivars (with a row for a given year).

[w] ST = Stoneville, FM = Fibermax, PM = Paymaster.

There was a significant effect of cultivar on fiber length during 2004 to 2007 and in the overall analysis. Cotton fiber was longer for FM 989BR (2.72 cm) than for PM 2280 BG/RR (2.65 cm) or ST 5599BR (2.63 cm) when averaged over 5 years (4 years for PM 2280 BG/RR). There was a significant effect of irrigation rate on fiber length in 2003, 2005 to 2007, and in the overall analysis. Cotton fiber was longer for the 125% of base irrigation rate (2.69 cm) and base irrigation rate (2.68 cm) than for the 75% of base irrigation rate (2.62 cm) when averaged over 5 years.

Cotton fiber strength was not effected by irrigation rate in any year, but was effected by cultivar in 2003 to 2007, but not in the overall analysis (Table 9), and by the interaction between irrigation rate and cultivar only in 2003. In every year, ST 5599BR had lower values of fiber strength than FM 989BR, though not always statistically different (Table 9). PM 2280 BG/RR was less consistent, and had stronger fiber in 2003 than the other cultivars, weaker fiber strength in 2004 than FM 989BR, and similar fiber strength in 2005 and 2006 as FM 989BR (Table 9). In 2003, PM 2280 BG/RR had better fiber strength at the 75% of base irrigation rate (31.1 g tex^{-1}) than ST 5599BR (30.1 g tex^{-1}) or FM 989BR (29.4 g tex^{-1}). At the base irrigation rate in 2003, ST 5599BR had weaker fiber strength (29.8 g tex^{-1}) than did FM 989BR (30.8 g tex^{-1}) or PM 2280 BG/RR (31.3 g tex^{-1}). At the 125% of base irrigation rate, fiber strength was similar across all three cultivars.

Micronaire was not significantly effected by irrigation rate or cultivar in the overall analysis. In 2004, 2006, and 2007, the 75% of base irrigation rate had lower micronaire than the base irrigation rate (Table 10). In 2006 and 2007, the 125% of base irrigation rate had lower micronaire than the base irrigation rate. There was an interaction between irrigation rate and cultivar in 2004, where all cultivars had similar micronaire at the highest irrigation rate. ST 5599BR had lower micronaire

Table 9. Effect of cultivar on fiber strength during 2003 - 2007 in a field infested with *Meloidogyne incognita*.

Year	Cultivars			
	ST 5599BR[z]	FM 989BR	PM 2280 BG/RR	DP 515BR
	(g tex^{-1})			
2003	30.2 b[y]	30.5 b	31.2 a	----
2004	28.9 ab	29.9 a	28.0 b	----
2005	28.3 b	29.7 a	29.5 a	----
2006	26.1 b	27.3 a	27.6 a	----
2007	28.0 ab	28.5 a	----	27.5 b
2003 to 2006	28.4	29.4	29.1	----

[z] ST = Stoneville, FM = Fibermax, PM = Paymaster, and DP = Deltapine

[y] Different letters (a, b, c) indicate that strength is significantly different ($P \leq 0.05$) between cultivars (within a row).

Table 10. Effect of cultivar and irrigation and fertigated nitrogen rate on micronaire over five years (2003 – 2007) from cotton grown in a field infested with *Meloidogyne incognita*.

Year	Cultivars[z]				Irrigation rates[y]		
	ST	FM	PM	DP	75% of Base	Base	125% of Base
2003	5.1 a[x]	4.8 b	4.5 c	--	4.8	4.8	4.8
2004	3.7 b	3.8 ab	4.0 a	--	3.6 b	3.9 a	3.9 a
2005	4.1 a	3.8 b	3.8 b	--	3.9	3.9	3.9
2006	5.2 a	5.0 b	4.8 c	--	4.9 b	5.1 a	4.9 b
2007	4.6 a	4.3 b	--	4.4 b	4.4 b	4.6 a	4.4 b
2003 to 2006	4.5	4.3	4.2		4.3	4.4	4.4

[z] ST = Stoneville, FM = Fibermax, PM = Paymaster, and DP = Deltapine.

[y] Base irrigation rate estimated to replace 75% of the evaporative demands of the crop. 75% of Base was a 25 % reduction of this irrigation rate and 125% of Base was a 25% increase of the irrigation rate. Nitrogen was applied through the center pivot system, so rates applied were proportional to irrigation.

[x] Different letters (a, b, c) indicate that micronaire is significantly different ($P \leq 0.05$) between cultivars (within a row).

(3.65) at the base irrigation than the other cultivars (4.05 and 4.1), and FM 989BR had lower micronaire (3.7) than PM 2280 BG/RR (4.05) at the 75% of base irrigation rate. There was a cultivar effect in 2003 to 2007, but not in the overall analysis on micronaire. In 2003, and 2005 – 2007, ST 5599BR had higher micronaire than FM 989BR (Table 10). In 2003, and 2005 to 2006, ST 5599BR had a higher micronaire than PM 2280 BG/RR, and in 2007 ST 5599BR had a higher micronaire than DP 515BR. As was seen with lint yield and other parameters, cultivar response to micronaire was different in 2004 when ST 5599BR had a lower micronaire than PM 2280 BG/RR. The micronaire would have been discounted (micronaire $\geq$ 5.0) for ST 5599BR in 2003 and 2006, and for FM 989BR in 2006.

Leaf grade was significantly effected by cultivar in all years, but not by irrigation rate. Leaf grade was significantly better in fiber from FM 989BR (2.1) than fiber from ST 5599BR (2.9) in each individual year as well as the overall analysis (Table 11). The leaf grade of fiber for FM 989BR (2.1) was better than leaf grade for PM 2280 BG/RR (2.6) in the overall analysis. FM 989BR is considered a normal/smooth leafed cultivar, while PM 2280BG/RR and ST 5599BR are both listed as semi-smooth, based on company descriptions. The higher leaf grades, which are considered lower in quality, were poorer for the semi-smooth leafed cultivars than the normal/smooth leafed cultivar. Generally, a leaf grade of 2 to 3 is not going to result in discounted fiber and for the High Plains region is considered excellent.

Table 11. Effect of cultivar, averaged over three irrigation rates, on leaf grade over five years (2003 – 2007) from cotton grown in a field infested with *Meloidogyne incognita*.

Year	Cultivars[z]			
	ST 5599BR	FM 989BR	PM 2280 BG/RR	DP 515BR
2003	1.7 a[y]	1.0 b	2.0 a	---
2004	3.7 a	2.8 b	3.0 b	---
2005	2.7 a	1.8 b	2.4 a	---
2006	3.7 a	2.8 b	3.1 b	---
2007	2.1 a	1.2 b	---	1.2 b
2003-2006	2.9 a	2.1 b	2.6 a	---

[z] ST = Stoneville, FM = Fibermax, PM = Paymaster, and DP = Deltapine.

[y] Different letters (a, b) indicate that leaf grade is significantly different ($P \leq 0.05$) between cultivars (within a row).

The effect of irrigation rate on nematode population density was significant only in 2006, where the 75% of base irrigation rate had a lower density of *M. incognita* eggs (2569 eggs/500 cm^3 soil) than the base (8509 eggs/500 cm^3 soil) or 125% of base irrigation (10,016 eggs/500 cm^3 soil) rates. The test was not sampled for nematodes in 2003 and 2004. This difference could have been due to sampling difficulties in hard, dry soil, or could reflect true population density differences. The effect of cultivar was significant in 2007 on the J2 of *M. incognita*, where ST 5599BR had fewer J2 (62 J2/100 cm^3 soil) than FM 989BR (200 J2/100 cm^3 soil) or DP 515BR (147 J2/100 cm^3 soil). The effect of cultivar was also significant in the overall (three year) analysis on the Log10 transformed eggs of *M. incognita*, where ST 5599BR had fewer eggs (5560 eggs/500 cm^3 soil) than FM 989BR (8150 eggs/500 cm^3 soil).

DISCUSSION

Orgaz et al. (1992) found that the lint yield from both short-season and long-season cultivars responded linearly to seasonal ET replacement up to about 700 mm of applied water and rainfall, and the short-season cultivar was capable of higher yields than the longer-season cultivars if sufficient water was applied. The total amount of water in our tests was considerably less than 700 mm except for the highest irrigation rate in 2006 (Table 1). PM 2280 BG/RR (a short-season cultivar) was not capable of yielding as well as the longer season cultivars except at the lowest irrigation rate. In general, as irrigation rate increased, PM 2280 BG/RR was less competitive than the picker-type cotton cultivars. Though, in 2004, which was the season with the highest ET replacement values (when PM 2280 BG/RR was planted), PM 2280 BG/RR was as competitive as the picker type cultivars. The 2007 season had even higher replacement ET for the bulk of the season, but PM 2280 BG/RR was replaced with DP 515BR that season. ST 5599BR and FM 989BR were the most similar in lint yield and gross value ha^{-1} at the base irrigation rate. At higher or lower irrigation rates, ST 5599BR increased its yield advantage over FM 989BR. DP 515BR had a similar lint yield to FM 989BR in its only season (2007). DP 515BR was chosen to replace PM 2280 BG/RR because it had performed very well in small plot trials at that site in the previous year and represented a potentially high yielding, but susceptible cultivar with different genetics than FM 989BR.

It is not possible to separate N and water effects in this study. However, previous N x irrigation rate research at this site indicated the effect of water was much greater than the effect of N fertilizer on lint yields (during typical seasons) (Bronson et al., 2001; Bronson et al., 2006). In wetter than average seasons, N fertilizer effects were similar or less than irrigation effects.

The tolerant and partially resistant cultivar ST 5599BR did have somewhat lower fall population densities of *M. incognita* than the susceptible cultivar FM 989BR. Root-knot nematode damage is related to impairment of water uptake. Root-knot nematode infested cotton had a lower cumulative rate of water uptake than non-infested cotton (Kirkpatrick et al., 1995). Yield losses in tobacco (*Nicotiana tabacum* L.) when soil was infested with different densities of *M. incognita* were higher for a given density of the nematode, when irrigation was limited compared to well watered tobacco (Wheeler et al., 1991). So, the expectation was that as irrigation increased, the susceptible cultivars would be more competitive with a tolerant and partially resistant cultivar. However, the highest irrigation rate did not increase lint yield over the base irrigation rate for the susceptible cultivar FM 989BR (it decreased by an average of 3%). In contrast, the highest irrigation rate increased lint yield by 7% for ST 5599BR over the base rate. Decreasing irrigation by 25% from the base rate decreased lint yield by 23% for ST 5599BR and by 28% for FM 989BR. So, “extra water” cannot be used as a management tool for control of root-knot nematode in cotton, though adequate water is recommended. With adequate water, a high yielding susceptible cultivar with excellent fiber properties could compete with a tolerant and partially resistant, high yielding cultivar with relatively poor fiber properties. While both of these cultivars will be obsolete after 2009, due to the lack of re-registration of the Bollgard (containing Cry1Ac only) trait, the principle could be relevant for other partially resistant and susceptible cultivars.

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