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Effects of 1,3-Dichloropropene for *Meloidogyne incognita* Management on Cotton Produced under Furrow Irrigation

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Abstract: Field trials were conducted during 1990 to evaluate the effects of preplant soil fumigation with 1,3-dichloropropene (1,3-D) on yield and fiber quality of furrow-irrigated cotton cultivars subjected to high population densities of *Meloidogyne incognita.* We measured the responses of eight upland cotton cultivars with different levels of root-knot nematode resistance and compared the responses of upland and Pima cottons. Reductions in lint weight ranged from 10 to 52% among cultivars grown in soil without 1,3-D fumigation compared with those grown in treated soil. *Meloidogyne incognita* reduced yields primarily by reducing the number of bolls on each plant, rather than by decreasing boll size. Cotton fiber quality varied among cultivars but was unaffected by *M. incognita* in either study. Upland cotton cultivar Acala 1517-88 and M-315/240 sustained less than half the yield reductions observed with *M. incognita*-susceptible cultivars Deltapine 41 and Paymaster 145. Sixty days after cotton emergence, fewer *M. incognita* second-stage juveniles were recovered from M-315/240 than all other cultivars.

Key words: cotton, 1,3-dichloropropene, fiber quality, fumigation, furrow irrigation, *Gossypium barbadense, Gossypium hirsutum, Meloidogyne incognita,* nematode, root-knot nematode, yield.

Revenue from upland (*Gossypium hirsutum*) and Pima cotton (*G. barbadense*) ranks second among cash crops in New Mexico. Over one-third of the cotton acreage, most of which is furrow irrigated, is infested with *Meloidogyne incognita* race 3. This nematode has been associated with substantial cotton yield reductions in adjacent regions of Texas (9,14) and in California (6) but has not been studied in the high Chihuahuan desert climate of southern New Mexico. Moderate levels of resistance to *M. incognita* were identified in the Acala 1517-types of cotton grown in New Mexico (7), but yield reductions under field conditions were not measured.

Cotton fiber quality is an important characteristic of lint production that influences price received and usage of the crop. Jones et al. (5) reported no changes in fiber length, strength, or micronaire associated with *Rotylenchulus reniformis* injury to upland cotton, and Veech (16) reported similar findings in microplot studies with *M. incognita* in east-central Texas. In contrast, Smith et al. found decreases in fiber length and increases in micronaire and percentage of mature fibers in plots where *M. incognita* infestations were not controlled in the Texas High Plains (14). Our objective was to determine the effects of 1,3-D and *M. incognita* on yield and fiber quality of cotton cultivars with various levels of resistance to the nematodes.

Materials and Methods

Two experiments were established during 1990 at the New Mexico State University Leyendecker Plant Science Research Center in Dona Ana County, New Mexico. Experiment 1 was located in a Brazito very fine sandy loam (72% sand, 15% silt, 13% clay; 0.7% organic matter; pH 7.8) and experiment 2 in an Anthony-Vinton fine sandy loam (76% sand, 11% silt, 13% clay; 0.8% organic matter; pH 7.9). In 1989, fields were planted to chile pepper (*Capsicum annuum*), an excellent host of *M. incognita* (8). Cotton (*G. hirsutum* or *G. barbadense*) was grown on raised plant beds with furrow irrigation.

Experiment 1 was designed as a split-plot within a balanced incomplete block (2). The whole plots each consisted of seven of the eight cultivars assigned arbi-

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trarily to seven plots within a block. Each cultivar whole plot was split into two subplots. Individual subplots consisted of two rows spaced 1 m apart and 12 m long with 3-m alleys between blocks. The subplot received either no treatment or a preplant fumigation with 56 liters/ha 1,3-dichloropropene (1,3-D) applied with a single shank 30 cm deep in the center of the bed. *Meloidogyne incognita*-resistant or susceptible cotton cultivars were compared with four regionally important cottons. The resistant cultivars were M-315/240, a blend of two resistant lines produced by crossing Auburn 634 (12,13) with Deltapine 61 and released by USDA-ARS Crop Science Research Unit, Mississippi State and Mississippi State University in 1989, and CA-32, also known as Acala Preema. Susceptible cultivars were Deltapine 41 and Paymaster 145. Acala 1517-88, Deltapine 90, McNair 220 and hybrid NX-1 are important regionally.

Experiment 2 was designed as a split plot within a randomized complete block. Each of the six blocks contained a total of two whole plots, with one of the whole plots in each block planted with Acala 1517-75 (*G. hirsutum*) and the other whole plot planted with Pima S-6 (*G. barbadense*). The cultivars were assigned at random to the whole plots. Each whole plot was split into three subplots to which one of three fumigation rates (0, 38, or 56 liters/ha 1,3-D) was arbitrarily assigned. Plots were the same size as in Experiment 1.

Both sites were fertilized with 225 kg/ha of 18-40-6 (N-P-K) on 29 March 1990, followed immediately by application and incorporation of 1.12 kg a.i./ha trifluralin + 1.4 kg a.i./ha prometryn for early season weed control. Telone II (94% 1,3-D) was applied on 11 April 1990, through a single shank 30 cm deep with a two-row Reddick Flo-Meter (Reddick Fumigants, Williamston, NC). Plant beds were formed immediately afterward, producing a final fumigant depth of 40 cm in the row. Soil temperature was 20 C at 30 cm at the time of 1,3-D application. Plots were irrigated on 12 April, and seeds were planted on 3 May 1990 with a four-row John Deer Flex-Planter (John Deere Inc., Moline, IL) at 17 seeds/m. Seed beds were capped with 10 cm soil to preserve residual moisture and aid germination. Five days after planting, the cap was removed with a harrow, allowing seedlings to emerge. Plants were side-dressed with an additional 48 kg/ha N on 18 June 1990. Plots were cultivated and furrow irrigated every 14–21 days between emergence and 15 September 1990.

Preplant populations of *M. incognita* second-stage juveniles (J2) were determined from 10 soil cores 2.5-cm-d × 30 cm deep collected from all untreated plots on 17 April 1990. All plots in both experiments were sampled for J2 from within the root zone of the cotton plants 60 days after seedling emergence 12 July 1990. Nematodes were extracted from 500-cm^3 subsamples with a semi-automatic elutriator (1) and sugar flotation (4).

Plant height data were collected from Experiment 2 approximately 60 days after emergence. Numbers of bolls and plants and seed cotton weights from 4 m of each row were recorded in all plots. Cotton from both studies was hand harvested at maturity. Lint weights were obtained by hand-ginning 500-g samples of the seed cotton, and fiber quality data were determined using high-volume instrument (HVI) analysis (Textile Research Center, Lubbock, TX). Cotton lint weights, numbers of bolls per plant and per 7.9 m row, cotton fiber length, strength, micronaire, uniformity ratios, and numbers of *M. incognita* J2 in both experiments and plant height in experiment 2 were analyzed with a general linear model (10). Means of significant ($P = 0.05$) cultivar and treatment effects were separated by Fisher's protected least significant difference test (FLSD), $P = 0.05$.

Results

Experiment 1: The experimental site contained 33 *M. incognita* J2/100 cm^3 soil at planting. *Criconemella* spp. and *Pratylenchus* spp. were also detected in less than 10% of these samples and were less common in samples collected 60 days after seedling emergence. Plants in 1,3-D-treated plots produced significantly higher cotton yields, produced more bolls per plant, and showed decreased numbers of *M. incognita* juveniles at midseason, compared with untreated plots (Table 1). Fiber length, strength, micronaire, and uniformity ratio, which are components of lint quality, were not affected by 1,3-D treatment. There were no significant fumigation by cultivar interactions for any of the parameters examined; thus differences in response among cultivars are given without reference to 1,3-D treatment.

Cotton yields and midseason numbers of *M. incognita* J2 varied among cultivars (Table 2). M-315/240 produced more lint than NX-1 or Paymaster 145 and supported fewer J2 than all other cultivars at midseason. NX-1 produced the largest number of bolls per plant. The cultivars differed in fiber quality (Table 3), with NX-1 producing the longest and most uniform fibers. Fiber quality differences among cultivars are not given because they were unaffected by soil fumigation, and these inherent differences are often the basis for cultivar uniqueness.

Experiment 2: At planting, the mean *M. incognita* abundance was 90 J2/100 cm^3 soil. *Criconemella* spp. were also recovered in small numbers (10 to 20/100 cm^3 soil) from nearly half the plots at planting, but were not detected at midseason. No other plant-parasitic nematodes were recovered at this site. Plots treated with 1,3-D prior to planting showed increased plant heights ($P = 0.0023$) 60 days after emergence and greater lint yields ($P = 0.0101$) compared with untreated plots (Table 4). Number of bolls per plant ($P = 0.0725$) and bolls per 7.9 m of row ($P = 0.0651$) also responded to soil treatment. There was an interaction ($P = 0.0760$) between lint yields and soil fumigation. Acala 1517-75 produced more lint following soil treatment with 1,3-D, but lint yields did not differ between rates, while Pima S-6 yields were not affected by soil fumigation. No other cultivar-by-treatment interactions were detected.

Plant height 60 days after emergence was greater in treated Acala 1517-75 plots and in Pima S-6 plots treated with 56 liters/ha 1,3-D than in untreated plots (Table 4). Abundance of *M. incognita* J2 increased in all plots after planting and was not significantly lower in treated plots at midseason than in untreated plots. Fiber quality parameters were not affected by soil fumigation. Fiber length and strength were greater for Pima S-6 than Acala 1517-75, but the latter cultivar produced larger plants and more than twice the amount of lint.

TABLE 1. Effect of soil fumigation on cotton yield, fiber quality, and abundance of *Meloidogyne incognita* race 3 in a field trial in Dona Ana County, New Mexico, in 1990.

Response	T†	NT†
M. incognita juveniles/ 100 cm^3 soil‡	16	68
Lint weight (kg/ha)	1,286	1,044
No. bolls/plant	10.6	9.0
No. bolls/7.9 m row	543	452
Fiber quality		
Length (mm)	29.62	29.64
Strength ($kgNmkg^{-1}$)	272	276
Micronaire§	3.82	3.79
Uniformity ratio‖	84.25	84.16

Data are means of eight replications of seven cultivars each.
† T = treated with 56 liters/ha 1,3-dichloropropene, NT = not treated.
‡ Sampled 60 days after cotton emergence.
§ Micronaire is a unitless measure.
‖ Ratio of long fibers to short fibers.

DISCUSSION

Sixty days following seedling emergence, *M. incognita*-resistant M-315/240 was the only cultivar showing reduced soil populations of *M. incognita* juveniles compared with those at planting. Despite this, M-315/240 and all other cultivars examined in Experiment 1 exhibited a positive yield response to preplant application of 1,3-D. Under conditions similar to those encountered in Experiment 1, moderately resistant Acala 1517-88 (7) and M-315/240 could be expected to maintain 25% more yield than highly susceptible cultivars Pay-

TABLE 2. Influence of cultivar on cotton yield parameters and development of *Meloidogyne incognita* race 3 in a field trial in Dona Ana County, New Mexico, in 1990.

	Yield			
Cultivar	Lint weight (kg/ha)	No. bolls per plant	No. bolls per 7.9 m row	*M. incognita* juveniles per 100 cm^3 soil†
M-315/240	1,300	8.2	557	6
CA-32	1,239	7.7	419	36
NX-1	1,054	17.6	565	40
McNair 220	1,198	9.8	473	47
Acala 1517-88	1,138	7.6	480	47
Deltapine 41	1,193	10.3	536	59
Deltapine 90	1,140	9.5	515	43
Paymaster 145	1,053	7.7	434	59
LSD (P = 0.05)	157	2.2	73	10

Data are means of eight replications with two observations (+ and − fumigation) per replication.
† Numbers of juveniles recovered 60 days after cotton emerged.

master 145 and Deltapine 41 (13) in the absence of nematicide treatment.

Meloidogyne incognita-induced yield losses in both experiments were due to reduction in the number of bolls per plant rather than reductions in boll size. Veech (16,17) and Smith et al. (14) reported similar reductions in numbers of bolls on cotton plants infected with *M. incognita.* The shedding of flower primordia and bolls is common in cotton stressed by insufficient moisture or low carbohydrate levels. Such stresses have also been associated with changes in fiber quality (3,11,15). Smith et

TABLE 3. Effect of cultivar and fumigation on fiber quality of cotton produced in *Meloidogyne incognita* race 3-infested soil in a field trial in Dona Ana County, New Mexico, in 1990.

		Fiber quality			
Cultivar	Rate of fumigation (liters/ha)†	Length (mm)	Strength ($kNmkg^{-1}$)	Micronaire‡	Uniformity ratio§
M-315/240	56	27.5	237	3.89	83.3
	0	27.4	249	3.93	83.3
CA-32	56	30.3	335	3.97	86.1
	0	30.0	328	3.86	85.7
NX-1	56	33.9	293	3.73	87.3
	0	34.5	297	3.70	87.1
McNair 220	56	29.2	298	3.67	84.1
	0	29.1	300	3.70	84.1
Acala 1517-88	56	30.5	261	3.90	84.3
	0	30.5	258	3.84	84.4
Deltapine 41	56	28.9	269	3.80	82.0
	0	29.4	275	3.91	82.9
Deltapine 90	56	29.2	238	3.61	83.4
	0	28.7	242	3.66	82.9
Paymaster 145	56	27.4	245	4.00	83.4
	0	27.7	258	3.73	82.9
LSD (P = 0.05)		0.7	11	0.21	0.7

Data are means of eight replications of two HVI analyses for each fiber sample.
† Application rate of 1,3-dichloropropene at 40 cm depth.
‡ Micronaire is a unitless measure.
§ Ratio of long fibers to short fibers.

TABLE 4. Effect of fumigation on cotton yield, fiber quality, and abundance of *Meloidogyne incognita* race 3 in a field trial in Dona Ana County, New Mexico, in 1990.

Cultivar	Treatment (liters/ha)†	Yield: Lint weight (kg/ha)	Yield: No. bolls per plant	Yield: No. bolls per 7.9 m row	Fiber quality: Length (mm)	Fiber quality: Strength ($kNmkg^{-1}$)	Fiber quality: Micronaire‡	Fiber quality: Uniformity ratio§	Juveniles per 100 cm^3 soil‖	Plant height (cm)¶
Acala 1517-75	0	605	9.1	242	30.0	293	3.73	84.8	277	22.1
	38	899	8.0	344	30.0	291	3.80	84.7	200	26.4
	56	917	10.2	357	30.2	284	3.65	84.7	207	25.1
Pima S-6	0	332	8.5	257	32.8	335	3.77	86.3	303	16.6
	38	339	13.3	269	33.5	335	3.77	86.2	433	18.3
	56	356	13.9	318	33.3	320	3.82	86.2	308	20.6

Data are means of six replications.
† Rate of 1,3-dichloropropene applied at 40 cm depth.
‡ Micronaire is a unitless measure.
§ Ratio of long fibers to short fibers.
‖ Numbers of *M. incognita* juveniles recovered 60 days after cotton emergence.
¶ Plant height 60 days after emergence.

al. (14) observed a decrease in fiber length and increases in micronaire and percentage of mature fibers (uniformity ratio) in cotton produced on *M. incognita*-infested soil. None of these anticipated differences were observed in our experiments despite the close relationships among boll retention, nematode control, and yield. Veech (16) and Veech and Smith (17) also failed to detect significant fiber differences associated with *M. incognita* injury. These apparent contradictions may be explained in part by differences in the intensity of moisture stress among the study locations. Cotton in the Texas High Plains was subjected not only to nematode-related stress but also environmental stress because there were only three post-plant irrigations (Smith, pers. comm.) compared with seven in New Mexico, despite similar temperature regimes and lengths of growing season between the two locations.

In both of our studies, the yield increases among upland cotton cultivars treated with 1,3-D ranged from approximately 20 to 50%. These yield responses are consistent with those reported elsewhere in the Southwest under similar *M. incognita* pressure and rates of 1,3-D (6,14). The poor response of Pima S-6 to treatment was not anticipated. Pima cultivars are grown primarily in New Mexico and Arizona and are recognized as highly susceptible to *M. incognita*. For this reason, we expected yield responses in the range of 45 to 50%, similar to those observed with the susceptible upland cultivars Paymaster 145 and Deltapine 41. Instead, the 38 liters/ha 1,3-D treatment resulted in yields essentially the same as the untreated control, while the higher rate increased Pima S-6 yield by only 7%. In Experiment 1 cultivar NX-1, which normally yields well in southern New Mexico, produced lint weights similar to the poorest yielding *M. incognita*-susceptible cultivar Paymaster 145. NX-1 is an interspecific hybrid produced from a male sterile upland cotton parent and a Pima pollinator. It possesses intermediate qualities between the two *Gossypium* species. The low yields and poor response to soil fumigation may also reflect high susceptibility of the *G. barbadense* germplasm. Further research is needed to ascertain the nature of these poor yield responses in Pima S-6 and hybrid cultivars. For upland cotton cultivars, on the other hand, it may be more economical to reduce rates of 1,3-D from 56 to 38 liters/ha for *M. incognita* control.

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