Influence of Nematicide Application on the Severity of the Root-Knot Nematode–Fusarium Wilt Disease Complex in Cotton

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ABSTRACT

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Eight cotton cultivars, with and without aldicarb treatment, were evaluated for their effect on the severity of the root-knot nematode–Fusarium wilt disease complex in cotton. A randomized complete block design with a split-plot arrangement of treatments was used with cotton cultivars as the main plots and nematicide treatments as the subplots. Results in 1994 and 1995 were similar. Yield of lint, boll weight, and wilt and root-gall ratings were different among cultivars and between nematicide treatments both years. Increased lint yield and boll weight, and reduced root-gall and wilt ratings were associated with application of aldicarb. Increased lint percentage was associated with application of aldicarb in 1994, but not in 1995. Fiber micronaire, elongation, uniformity, and strength were different among cultivars, but not between nematicide treatments. Fiber length (UHM; Upper-Half Mean) was different among cultivars and was higher in the aldicarb-treated plots in both years. Numbers of *Meloidogyne incognita* second stage juveniles and eggs extracted from soil samples were lower in the aldicarb-treated plots in July, but not at harvest, both years. Population densities of *M. incognita* were not different among cultivars, except the mid-season sample in 1995.

Additional keywords: disulfoton, *Fusarium oxysporum* f. sp. *vasinfectum*

The root-knot nematode–Fusarium wilt disease complex in cotton (*Gossypium hirsutum* L.) is a serious disease that can result in plant mortality and reduced cotton yields. Both pathogens can damage plants independently, but losses are more severe when they occur together (2,12,16,17). Management strategies for this disease complex include rotations with crops that are poor hosts for the nematode, planting cotton cultivars that are resistant to either the nematode or the fungus, and soil fumigation (5,7,13). Use of rotations to reduce the complex has been of limited value because *Fusarium oxysporum* Schlechtend.: Fr. f. sp. *vasinfectum* (Atk.) W. C. Snyder & H. N. Hans. is a good saprophyte, and also is able to survive in soils for several years on the roots of nonhost plants (20). In addition, the root-knot nematode (*Meloidogyne incognita* (Kofoid & White)

Chitwood) has a broad host range and there are few economically viable alternative crops for use by cotton producers in a rotation program.

The effectiveness of planting resistant cultivars to control the disease complex has been diminished by the lack of high levels of resistance to both the fungus and the nematode in available cultivars. Although some cultivars have resistance to Fusarium wilt (6,10,19,22), none are immune to the pathogen (7). There also is little resistance to the root-knot nematode in commercial cotton cultivars (3,18,22). Furthermore, because root-knot nematodes can induce susceptibility to wilt in normally resistant cultivars (15,16), cotton cultivars with resistance to Fusarium wilt may not be adequate to reduce losses when the complex is present.

Soil fumigation has been successful in reducing nematode populations, resulting in a decrease in wilt incidence (9,11); however, fumigant nematicides are expensive and not always economical for cotton production (7), and their availability in the future is uncertain. Nonfumigant nematicides can be applied in the planting furrow, but the activity of nematicides is limited to a few weeks after planting. There is little information on the efficacy of applying nematicides at planting on the severity of the root-knot nematode–Fusarium wilt disease complex in cotton.

The objective of this study was to evaluate the effectiveness of applying an in-furrow nematicide at planting on the development of the root-knot nematode–Fusarium wilt disease complex in cotton.

MATERIALS AND METHODS

The experiments were conducted at the Red River Research Station in Bossier City, LA, in 1994 and 1995. The soil was a Norwood very fine sandy loam (Typic Udi-fluvent: fine-silty, mixed, calcareous, thermic) with a pH of 6.8, and 0.2% organic matter. The average particle size distribution was 58% sand, 37% silt, and 5% clay. Historically, cotton planted at this location has experienced a high frequency of Fusarium wilt associated with root-knot nematode infection. Prior to the initiation of this study, the population density of *M. incognita* was increased through a series of rotations with kenaf (*Hibiscus cannabinus* L.), an excellent host for the root-knot nematode. Experimental design was a randomized complete block with a split-plot arrangement of treatments with four replications. Main plots, which were eight rows (101 cm spacing) by 13.7 m in length, were cotton cultivars and subplots, which were 4 rows (101 cm spacing) by 13.7 m in length, were in-furrow treatments.

Eight cotton cultivars (Chembred 333, Deltapine 20, Deltapine 51, Deltapine 5690, DES 119, Hyperformer HS-46, Stoneville LA887, and Suregrow 501) with different levels of susceptibility to Fusarium wilt and the root-knot nematode were evaluated. The nematicide aldicarb (Temik 15G, Rhone-Poulenc Ag Co., Research Triangle Park, NC) was applied at planting in the seed furrow at 1.18 kg a.i. per hectare. Plots that did not receive aldicarb were treated with disulfoton (Di-Syston 15G, Miles, Inc., Kansas City, MO) at 1.11 kg a.i. per hectare. Disulfoton, which has little efficacy against nematodes, was applied to control thrips and other early season insect pests that are also controlled by aldicarb. All cotton seed was commercially treated with carboxin-pentachloronitrobenzene-metalaxyl.

Cotton was planted on 20 May 1994 and 11 May 1995 at 200 seeds per 13.7-m row. Weed and insect control was according to Louisiana Cooperative Extension Service guidelines. Seed cotton was harvested from the two center rows of each plot with a

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spindle picker on 31 October 1994 and 5 October 1995. Boll samples of 50 arbitrarily selected, hand-harvested bolls from each plot were used to determine boll size, and then ginned on a 10-saw laboratory gin to determine lint percentage ([weight of lint/weight of lint plus seed] $\times$ 100) and provide lint samples for fiber quality analysis. Fiber qualities (micronaire, length, uniformity, strength, and elongation) were determined from boll samples submitted to the Department of Agronomy, Cotton Fiber Testing Laboratory, Louisiana State University, with high volume instrumentation. Lint yield was calculated as the yield of unclean seed cotton from each plot multiplied by its lint percentage (mean of three replications), converted to weight per hectare.

Nematode populations (second-stage juveniles [J2] and eggs) were determined from a composite of 20 soil cores collected from the two center rows of each plot to a depth of 20 cm with a 2.5-cm-diameter sampling tube. Soil samples were collected on 25 May, 20 July, and 1 November 1994, and 25 May, 21 July, and 3 November 1995. Nematodes were extracted from a 500 cm³ subsample by wet sieving and sugar flotation, and J2 of *M. incognita* were counted under a dissecting microscope (1). All root fragments in the subsample were collected and shaken for 4 min in 0.05% NaOCl to free the eggs from the egg masses (8). The total number of J2 and eggs in each plot was recorded, and transformed [$\log(J2+eggs+1)$] for statistical analysis.

Severity of Fusarium wilt and root-knot nematode infection was rated following inspection of 10 plants per plot after harvest. Fusarium wilt severity was based on vascular stem discoloration as follows: 0 = no vascular discoloration; 1 = <10%; 2 = 1 to 25%; 3 = 26 to 50%; 4 = 51 to 75%; and 5 = >75% of the vascular tissue discolored. Root-knot severity was assessed as root galling as follows: 0 = no galls; 1 = 1 to 2 galls; 2 = 3 to 10 galls; 3 = 11 to 30 galls; 4 = 31 to 100 galls; and 5 = >100 galls per root system. Arbitrarily selected samples of stems displaying vascular discoloration were incubated on potato-carrot agar to verify the presence of *Fusarium oxysporum*.

Data were subjected to analysis of variance with PC/SAS software (SAS Institute, Cary, NC). Means were separated with Duncan's new multiple range test ($P = 0.05$).

RESULTS

In 1994, lint yield was 30% greater and percentage of lint recovered after ginning was 1.5% greater across all cultivars following treatment with aldicarb than following treatment with disulfoton (Table 1). Lint yield and lint percentage were also different among cotton cultivars ($P = 0.01$), but the interaction between cultivars

and in-furrow treatments was not significant ($P = 0.05$). Chembred 333 produced significantly lower lint percentage than the other cultivars. Boll weights differed among cultivars ($P = 0.01$), and in-furrow treatment with aldicarb resulted in 4% larger bolls across all cultivars (Table 2). Stoneville LA887 produced larger bolls than the other cultivars. Fiber qualities were different among cultivars (data not shown), but only length was different between in-furrow treatments (Table 2). The

interaction between cultivars and in-furrow treatments was not significant for any of the fiber qualities measured or for boll weight ($P = 0.05$).

In 1995, seed cotton and lint yields were lower than in 1994. Otherwise, the relative effects of in-furrow treatments and cultivars on lint yield (Table 3), boll weight, and fiber length (Table 4) were similar to 1994, when treatment with aldicarb resulted in increases in these parameters. Lint percentage was different among culti-

Table 1. Effect of cotton cultivars and in-furrow chemicals on lint yield and lint percentage, 1994

Cultivar	Lint (kg/ha)			Lint (%)		
	Aldicarb ^w	Disulfoton ^x	Mean ^y	Aldicarb ^w	Disulfoton ^x	Mean ^y
Chembred 333	892	653	773 bc	39.8	39.1	39.5 c
Deltapine 20	1,191	740	965 a	41.3	40.7	41.0 b
Deltapine 51	1,175	853	1,015 a	41.1	40.9	41.0 b
Deltapine 5690	877	615	746 c	41.0	40.6	40.8 b
DES 119	1,092	885	989 a	41.4	41.1	41.2 b
Hyperformer HS-46	949	607	778 bc	41.2	41.0	41.1 b
Stoneville LA-887	1,240	790	1,015 a	42.6	41.4	42.0 a
Suregrow 501	1,066	760	914 ab	41.7	41.3	41.5 ab
Mean	1,058 ^z	738		41.3 ^z	40.7	

^w Temik 15G applied at 1.18 kg a.i./ha in-furrow at planting.

^x DiSyston 15G applied at 1.11 kg a.i./ha in-furrow at planting.

^y Means within a column followed by the same letter are not significantly different according to Duncan's new multiple range test ($P = 0.05$).

^z Means significantly different at $P = 0.01$.

Table 2. Effect of cotton cultivars and in-furrow chemicals on boll weight and fiber length, 1994

Cultivar	Boll weight (g)			Length (Upper-Half Mean)		
	Aldicarb ^w	Disulfoton ^x	Mean ^y	Aldicarb ^w	Disulfoton ^x	Mean ^y
Chembred 333	5.6	5.1	5.3 b	1.13	1.11	1.13 ab
Deltapine 20	5.5	5.1	5.3 b	1.12	1.11	1.12 b
Deltapine 51	5.1	4.9	5.0 bc	1.17	1.13	1.15 a
Deltapine 5690	4.8	4.6	4.7 cd	1.13	1.10	1.12 b
DES 119	4.5	4.7	4.6 d	1.14	1.13	1.14 ab
Hyperformer HS-46	4.8	4.8	4.8 cd	1.14	1.12	1.13 ab
Stoneville LA-887	6.2	5.7	6.0 a	1.17	1.11	1.14 ab
Suregrow 501	5.0	4.8	4.9 cd	1.12	1.11	1.12 b
Mean	5.2 ^z	5.0		1.14 ^z	1.12	

^w Temik 15G applied at 1.18 kg a.i./ha in-furrow at planting.

^x DiSyston 15G applied at 1.11 kg a.i./ha in-furrow at planting.

^y Means within a column followed by the same letter are not significantly different according to Duncan's new multiple range test ($P = 0.05$).

^z Means significantly different at $P = 0.01$.

Table 3. Effect of cotton cultivars and in-furrow chemicals on lint yield and lint percentage, 1995

Cultivar	Lint (kg/ha)			Lint (%)		
	Aldicarb ^v	Disulfoton ^w	Mean ^x	Aldicarb ^v	Disulfoton ^w	Mean ^x
Chembred 333	304	277	290 b	35.3	36.1	35.7 e
Deltapine 20	439	347	393 a	37.5	37.6	37.6 bcd
Deltapine 51	417	286	351 ab	37.2	36.9	37.1 d
Deltapine 5690	431	312	372 ab	37.6	38.3	38.0 bcd
DES 119	423	385	404 a	38.7	37.9	38.3 ab
Hyperformer HS-46	309	236	273 b	37.8	37.0	37.4 cd
Stoneville LA-887	475	370	422 a	39.2	39.0	39.1 a
Suregrow 501	367	220	344 ab	38.4	38.9	38.7 ab
Mean	395 ^y	317		37.7 ^z	37.7	

^v Temik 15G applied at 1.18 kg a.i./ha in-furrow at planting.

^w DiSyston 15G applied at 1.11 kg a.i./ha in-furrow at planting.

^x Means within a column followed by the same letter are not significantly different according to Duncan's new multiple range test ($P = 0.05$).

^y Means significantly different at $P = 0.01$.

^z Means not significantly different.

vars ($P = 0.01$), but not between in-furrow treatments in 1995 ($P = 0.05$). The interaction between cultivars and in-furrow treatments was not significant for any of these parameters in 1995 ($P = 0.05$).

Root-knot nematode J2 population densities were low or undetectable in all plots

at the beginning of the season in May of both years (data not shown). J2+egg population densities in July and November were similar for 1994 and 1995. Numbers of *M. incognita* J2 and eggs were lower following application of aldicarb than following disulfoton at mid-season, but not at

harvest (Tables 5 and 6). No differences in numbers of J2+eggs were found among cultivars either at mid-season or at the end of the season except in July of 1995. The interaction between cultivars and in-furrow treatments was not significant for J2+egg populations at any sampling period in either year ($P = 0.05$).

Root gall ratings among cultivars and between in-furrow treatments were similar in 1994 and 1995, but mean ratings were higher in 1995 (Table 7). In both years, root gall ratings were 23% lower across cultivars in the aldicarb-treated plots. Gall ratings were different among cultivars both years ($P = 0.01$). The cultivar $\times$ in-furrow treatment interaction was significant in 1994 ($P = 0.05$), but not in 1995 ($P = 0.05$). Stoneville LA887 had the lowest root gall ratings among cultivars in both years.

Although mean wilt ratings were lower in 1994 than 1995, the results were similar (Table 8). The highest wilt ratings were 1.2 and 3.5 in 1994 and 1995, respectively. In 1994 and 1995, wilt ratings were 37.5 and 30.4% lower, respectively, in the aldicarb plots. Wilt ratings were different among cultivars both years ($P = 0.01$), but the interaction between cultivars and in-furrow treatments was not significant either year ($P = 0.05$). In 1995, Stoneville LA887 had significantly lower wilt ratings, whereas Hyperformer HS-46 had higher wilt ratings than the other cultivars. *Fusarium oxysporum* was consistently recovered from stem sections displaying vascular discoloration.

DISCUSSION

The relative effects of in-furrow treatments and cultivars on lint yields were similar both years, but seed cotton and lint yields were lower in 1995 than in 1994 due to extremely dry conditions. Total rainfall from planting to harvest for 1994 and 1995 was 66.07 and 30.61 cm, respectively. During May and June, total rainfall in 1994 was 11.02 cm compared with only 3.81 cm in 1995. July rainfall was similar in 1994 and 1995 (11.71 versus 11.07 cm), but in August 8.36 cm was reported in 1994 compared with 4.06 cm in 1995.

The application of aldicarb improved lint yield both years and lint percentage in 1994, and reduced the severity of the root-knot nematode–*Fusarium* wilt disease complex both years. Other researchers have improved cotton yields and reduced root galling caused by the root-knot nematode with the application of in-furrow nematicides (14), but the effect of these pesticides on the root-knot nematode–*Fusarium* wilt disease complex has not been evaluated. The severity of the root-knot nematode–*Fusarium* wilt complex in cotton has been reduced with the use of soil fumigants (9,11). In addition to reducing nematode populations in the soil, some fumigants may affect survival of the wilt

Table 4. Effect of cotton cultivars and in-furrow chemicals on boll weight and fiber length, 1995

Cultivar	Boll weight (g)			Length (Upper-Half Mean)		
	Aldicarb ^w	Disulfoton ^x	Mean ^y	Aldicarb ^w	Disulfoton ^x	Mean ^y
Chembred 333	4.8	4.5	4.7 b	1.10	1.08	1.09 b
Deltapine 20	4.3	4.1	4.2 c	1.10	1.08	1.09 b
Deltapine 51	4.3	4.1	4.2 c	1.13	1.12	1.12 a
Deltapine 5690	4.1	4.2	4.2 c	1.12	1.10	1.11 ab
DES 119	3.9	3.8	3.9 d	1.13	1.13	1.13 a
Hyperformer HS-46	4.2	3.8	4.0 cd	1.13	1.12	1.12 a
Stoneville LA-887	5.2	5.0	5.1 a	1.16	1.12	1.14 a
Suregrow 501	4.2	3.8	4.0 cd	1.12	1.11	1.12 ab
Mean	4.4 ^z	4.2		1.12 ^z	1.11	

^w Temik 15G applied at 1.18 kg a.i./ha in-furrow at planting.

^x DiSyston 15G applied at 1.11 kg a.i./ha in-furrow at planting.

^y Means within a column followed by the same letter are not significantly different according to Duncan's new multiple range test ($P = 0.05$).

^z Means significantly different at $P = 0.01$.

Table 5. Effect of cotton cultivars and in-furrow chemicals on number of *Meloidogyne incognita* second-stage juveniles and eggs per 500 cm³ soil, 1994^u

Cultivar	20 July			1 November		
	Aldicarb ^v	Disulfoton ^w	Mean ^x	Aldicarb ^v	Disulfoton ^w	Mean ^x
Chembred 333	0.50	1.73	1.11 a	1.46	1.61	1.54 a
Deltapine 20	1.17	1.84	1.50 a	1.45	1.42	1.44 a
Deltapine 51	0.25	2.22	1.23 a	1.04	1.63	1.33 a
Deltapine 5690	0.81	1.38	1.10 a	2.03	1.58	1.80 a
DES 119	0.61	1.72	1.16 a	1.56	0.84	1.20 a
Hyperformer HS-46	0.89	1.84	1.37 a	1.44	1.57	1.51 a
Stoneville LA-887	0.25	1.38	0.82 a	1.57	1.52	1.55 a
Suregrow 501	1.29	1.95	1.62 a	1.64	1.73	1.69 a
Mean	0.72 ^y	1.76		1.49 ^z	1.52	

^u Actual populations transformed for statistical analysis; $\log(\text{juveniles} + \text{eggs} + 1)$.

^v Temik 15G applied at 1.18 kg a.i./ha in-furrow at planting.

^w DiSyston 15G applied at 1.11 kg a.i./ha in-furrow at planting.

^x Means within a column followed by the same letter are not significantly different according to Duncan's new multiple range test ($P = 0.05$).

^y Means significantly different at $P = 0.01$.

^z Means not significantly different.

Table 6. Effect of cotton cultivars and in-furrow chemicals on number of *Meloidogyne incognita* second-stage juveniles and eggs per 500 cm³ soil, 1995^u

Cultivar	21 July			3 November		
	Aldicarb ^v	Disulfoton ^w	Mean ^x	Aldicarb ^v	Disulfoton ^w	Mean ^x
Chembred 333	1.15	1.47	1.31 ab	2.67	2.12	2.39 a
Deltapine 20	0.89	2.19	1.54 a	2.15	2.43	2.29 a
Deltapine 51	1.22	1.98	1.60 a	2.29	2.14	2.21 a
Deltapine 5690	1.27	1.82	1.55 a	2.37	2.51	2.44 a
DES 119	1.81	1.94	1.88 a	2.52	2.47	2.49 a
Hyperformer HS-46	1.65	1.87	1.76 a	2.44	2.41	2.42 a
Stoneville LA-887	0.44	0.68	0.56 b	2.01	2.28	2.15 a
Suregrow 501	0.78	1.79	1.29 ab	2.41	2.45	2.43 a
Mean	1.15 ^y	1.72		2.35 ^z	2.35	

^u Actual populations transformed for statistical analysis; $\log(\text{juveniles} + \text{eggs} + 1)$.

^v Temik 15G applied at 1.18 kg a.i./ha in-furrow at planting.

^w DiSyston 15G applied at 1.11 kg a.i./ha in-furrow at planting.

^x Means within a column followed by the same letter are not significantly different according to Duncan's new multiple range test ($P = 0.05$).

^y Means significantly different at $P = 0.01$.

^z Means not significantly different.

fungus in the soil (7). The ability of aldicarb to reduce the severity of the root-knot nematode–Fusarium wilt disease complex in this study is probably related to its impact on numbers of *M. incognita*, which were reduced in July both years. It has been demonstrated previously that management of root-knot nematodes reduces the severity of Fusarium wilt (12,16,17).

Cotton cultivars differ in yield potential and fiber qualities. Some of the observed differences in lint yield, lint percentage, boll size, and fiber length among cultivars may have been the result of differences in yield potential among cultivars, whereas others may have been the result of different levels of resistance to the root-knot nematode–Fusarium wilt disease complex. The disease complex often reduces cotton yields (5,7,11,21). Veech (23) reported shorter fiber length, reduced seed cotton yield, and fewer bolls associated with nematode infection. Large bolls, reduced root galling, and wilt-related stem discoloration for Stoneville LA887 were not un-

expected. Upon release, this cultivar was reported to produce large bolls with high yield potential and improved root-knot nematode–Fusarium wilt resistance (10), and it has performed well in statewide evaluations (4).

The application of aldicarb in-furrow at planting reduced the severity of the root-knot nematode–Fusarium wilt complex in cotton and improved lint yield, lint percentage, and boll size. Although some of these improvements may be related to yield potential among cultivars, it is apparent that the reduction in the disease complex was also involved. More thorough investigation of the contribution of reducing nematode population density with nematicides to the overall severity of the root-knot nematode–Fusarium wilt disease complex may allow more cost-effective management strategies to be developed.

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Table 7. Effect of cotton cultivars and in-furrow chemicals on root gall ratings, 1994 and 1995

Cultivar	Root gall rating ^y					
	1994			1995		
	Aldicarb ^w	Disulfoton ^x	Mean ^y	Aldicarb ^w	Disulfoton ^x	Mean ^y
Chembred 333	2.0	3.7	2.8 a	3.1	4.0	3.6 b
Deltapine 20	2.0	2.7	2.4 ab	3.4	4.6	4.0 ab
Deltapine 51	1.6	2.3	2.0 b	3.3	4.5	3.9 ab
Deltapine 5690	2.3	2.5	2.4 ab	3.5	4.9	4.2 ab
DES 119	2.4	3.1	2.7 a	3.7	4.8	4.2 ab
Hyperformer HS-46	2.2	2.9	2.6 a	4.4	4.7	4.6 a
Stoneville LA-887	1.2	1.3	1.2 c	1.5	2.0	1.8 c
Suregrow 501	2.3	2.6	2.5 a	3.2	4.8	4.0 ab
Mean	2.0 ^z	2.6		3.3 ^z	4.3	

^y Root gall rating on a scale of 0 to 5: 0 = no root galling, 5 = severe root galling.

^w Temik 15G applied at 1.18 kg a.i./ha in-furrow at planting.

^x DiSyston 15G applied at 1.11 kg a.i./ha in-furrow at planting.

^y Means within a column followed by the same letter are not significantly different according to Duncan's new multiple range test ($P = 0.05$).

^z Means significantly different at $P = 0.01$.

Table 8. Effect of cotton cultivars and in-furrow chemicals on wilt ratings, 1994 and 1995

Cultivar	Wilt rating ^y					
	1994			1995		
	Aldicarb ^w	Disulfoton ^x	Mean ^y	Aldicarb ^w	Disulfoton ^x	Mean ^y
Chembred 333	0.5	1.1	0.8 ab	1.8	2.2	2.0 bc
Deltapine 20	0.4	0.4	0.4 b	1.6	2.3	1.9 bc
Deltapine 51	0.4	0.7	0.6 ab	1.9	3.0	2.5 b
Deltapine 5690	0.5	0.9	0.7 ab	1.2	2.6	1.9 c
DES 119	0.5	0.7	0.6 ab	1.2	1.7	1.5 c
Hyperformer HS-46	0.8	1.2	1.0 a	3.3	3.5	3.4 a
Stoneville LA-887	0.1	0.5	0.3 b	0.6	0.6	0.6 d
Suregrow 501	0.5	0.9	0.7 ab	1.5	2.6	2.0 bc
Mean	0.5 ^z	0.8		1.6 ^z	2.3	

^y Wilt rating on a scale of 0 to 5: 0 = no vascular discoloration, 5 = entire vascular ring discolored.

^w Temik 15G applied at 1.18 kg a.i./ha in-furrow at planting.

^x DiSyston 15G applied at 1.11 kg a.i./ha in-furrow at planting.

^y Means within a column followed by the same letter are not significantly different according to Duncan's new multiple range test ($P = 0.05$).

^z Means significantly different at $P = 0.01$.

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