Importance of Fungicide Seed Treatment and Environment on Seedling Diseases of Cotton

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Abstract

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The importance of fungicide seed treatments on cotton was examined using a series of standardized fungicide trials from 1993 to 2004. Fungicide seed treatments increased stands over those from seed not treated with fungicides in 119 of 211 trials. Metalaxyl increased stands compared to nontreated seed in 40 of 119 trials having significant fungicide responses, demonstrating the importance of *Pythium* spp. on stand establishment. Similarly, PCNB seed treatment increased stands compared to nontreated seed for 44 of 119 trials with a significant response, indicating the importance of *Rhizoctonia solani* in stand losses. Benefits from the use of newer seed treatment chemistries, azoxystrobin and triazoles, were demonstrated by comparison with a

historic standard seed treatment, carboxin + PCNB + metalaxyl. Little to no stand improvement was found when minimal soil temperatures averaged 25°C the first 3 days after planting. Stand losses due to seedling pathogens increased dramatically as minimal soil temperatures decreased to 12°C and rainfall increased. The importance of *Pythium* increased dramatically as minimal soil temperature decreased and rainfall increased, while the importance of *R. solani* was not affected greatly by planting environment. These multi-year data support the widespread use of seed treatment fungicides for the control of the seedling disease complex on cotton.

Seedling diseases of cotton (*Gossypium hirsutum* L.) collectively refer to a group of diseases that affect the germination of cottonseed and emergence, survival, and development of seedlings. Cotton seedling diseases are a major factor affecting cotton production worldwide (13,20,36,38). Cotton disease loss estimates for the United States from 1952 to 2009 averaged 2.8%, with loss estimates for seedling diseases accounting for 23% of the total estimated losses in lint production over these years (Disease data-

base, <http://www.cotton.org/tech/pest/seedling/index.cfm>). In the field, the most obvious symptoms of cotton seedling diseases are skips in the planting row resulting from rotted seed or dead seedlings. In addition to stand losses, seedling diseases may delay crop growth, resulting in additional management problems, such as timing of pesticide applications and harvest. In severe disease situations, replanting may be required.

The most important pathogens in the cotton seedling disease complex are *Rhizoctonia solani* Kühn, teleomorph *Thanatephorus cucumeris* (A.B. Frank) Donk, *Pythium* spp., *Fusarium* spp., and *Thielaviopsis basicola* (Berk. & Broome) Ferraris (syn. *Chalara elegans* Nag Raj & Kendrick) (10,11,13,17,24,36,59,60). These pathogens act either alone or in combination to cause a range of symptoms on roots and hypocotyls (13,17,24,59).

Pythium spp. can cause severe stand loss in cotton (14,17, 21,24,38). Johnson et al. (24) found that *Pythium* spp. were the

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most frequently isolated pathogen from diseased cotton seedlings. Many species of *Pythium* contribute to the cotton seedling disease complex (14,21,24,25). The most common symptoms associated with *Pythium* spp. are seed rot and preemergence damping-off (3,21). In Tennessee, a significant negative correlation was obtained between percentage of seedlings from which *Pythium* spp. was isolated and percent emergence (27).

Ranney (40) and Davis (11) in Mississippi and Ray and McLaughlin in Oklahoma (41) reported *R. solani* to be the most important pathogen associated with diseased cotton seedlings. *R. solani* has been consistently associated with all stages of seedling disease. Fulton and Bollenbacher (17) and Ogle et al. (38) reported preemergence death of cotton due to *R. solani*, but damage caused by *R. solani* is most often associated with postemergence damping-off (47,60).

Fusarium spp. are often the most frequently isolated fungal genus from cotton roots (8,17,24,27,36,41,59). A number *Fusarium* spp. are isolated from cotton seedlings (1,8,39,59). Results from pathogenicity tests of *Fusarium* spp. indicated that most species are of minor significance in the etiology of cotton seedling disease (17,24,36). Johnson and Doyle (27) found a negative correlation between disease severity and isolation frequency of *Fusarium* spp., while Roy and Bourland (59) found a positive correlation between incidence of *Fusarium oxysporum* Schlechtend.:Fr. and disease severity on seedlings. Pathogenicity for isolates of several species, most frequently *F. oxysporum* and *F. solani* (Mart.) Sacc., have been demonstrated (1,8,9,36,59).

Black root rot caused by *T. basicola* is considered part of the cotton seedling disease complex (2,27,33,59). Symptoms associated with *T. basicola* include blackening of the roots and the belowground portion of the hypocotyls and stunting of cotton seedlings (2,36,44). In a Mississippi survey, *T. basicola* was detected in 18 of 36 locations and observed on 100% of cotton seedlings for four locations (59). *T. basicola* was found in over 70% of cotton fields surveyed in Arkansas and Texas (49,66). For surveys in Mississippi, incidence of *T. basicola* was negatively correlated with cotton stand and positively correlated with root and hypocotyl disease indices (59).

Growers often plant cotton early to maximize the growing season and to avoid losses from insect damage or rain late in the sea-

son. Soil temperatures, as well as soil moisture, during the first few weeks after planting are important in stand establishment, because of effects on both the host and the pathogens (26,29,37,42). Cotton seedling disease control relies on avoidance, delaying planting until soil temperatures become favorable for cotton germination and growth with a favorable weather forecast, along with planting high-quality seed, proper planting depth, and planting on a well-prepared raised seedbed in well-drained soils (15,20,29,37,60). In addition, cottonseed in the United States is universally treated with combinations of fungicides prior to sale to protect the crop from a range of seedling disease pathogens, but also as a result of centralized seed production and sales due to the delinting process and the use of transgenic cultivars (12,20,37). The National Cottonseed Treatment Program has evaluated cotton seedling survival for commercial fungicide seed treatment combinations over diverse environmental conditions as part of the activities of the Cotton Disease Council. Since 1993, a historic standard fungicide treatment, carboxin + PCNB + metalaxyl, and a nontreated control were included to assess improvements in the efficacy of seed treatment fungicides and document the importance of seedling diseases. In addition, selective fungicide treatments were used to aid in determining the importance of *Pythium* spp. or *R. solani*. The objectives of this report were to examine the importance of seedling diseases on cotton, the role of specific pathogens, and the role of environment on stand establishment on cotton. Annual results of these trials have been published previously (45,46,48,50–58).

Materials and Methods

Fungicide treatment. Acid-delinted neutralized seed of *Gossypium hirsutum* L. were provided by Stoneville Pedigreed Seed Company, Stoneville, MS, in 1993 and 1994, and Delta and Pine Land Company, Scott, MS, from 1995 to 2004. Cultivars were Stoneville 453 (PVP 88001730) in 1993 and 1994, Deltapine 50 (PVP 8400154) in 1995 to 2000, Sure-Grow 747 (PVP 9800118) in 2001, and Deltapine DP 451 B/RR (PVP 9900294) in 2002 to 2004, except for locations in Oklahoma and the Lubbock and College Station locations in Texas in 1995 to 2004, where the cultivars were Paymaster HS26 (PVP 8600087) in 1995 to 2000 and Paymaster PM 2326 RR (PVP 9900191) in 2001 to 2004. A rotat-

Table 1. Active ingredients and products included in analyses of the 1993-2004 National Cottonseed Treatment Program

Common name	Product	Active ingredient
Azoxystrobin	Protégé FL or 70WP Dynasty CST Azoxystrobin 100FS	Methyl (E)-2-{2-[6-(2-cyanophenoxy)pyrimidin-4-yloxy]phenyl}-3-methoxyacrylate
Captan	Captan 4000 Nu-Gro	N-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide
Carboxin	Vitavax-PCNB Vitavax 200	5,6-dihydro-2-methyl-N-phenyl-1,4-oxathiin-3-carboxamide
Chloroneb	Nu-Flow AD, D, or ND	1,4-dichloro-2,5-dimethoxy-benzene
Fludioxonil	Maxim 4FS Dynasty CST	4-(2,2-difluoro-1,3-benzodioxol-4-yl)-1H-pyrrole-3-carbonitrile,
Mefenoxam	Apron XL Dynasty CST	(R)-2-[(2,6-dimethylphenyl)-methoxyacetyl-amino]-propionic acid methyl ester
Metalaxyl	Allegiance FL or LS Apron FL, 3FS, or TL Nu-Flow AD	N-(2,6-dimethylphenyl)-N-(methoxyacetyl) alanine methyl ester
Myclobutanil	Nu-Flow M Systane WP	(alpha-n-butyl-alpha-(4-chlorophenyl)-1H-1,2,4-triazole-1-propanenitrile
PCNB	RTU-PCNB Vitavax 200 Vitavax-PCNB	Pentachloronitrobenzene
TCMTB	Argent 30 Ascend Nu-Flow T or ND Nusan 30 Busan 30AU	2-(thiocyanomethylthio)benzothiazole
Thiram	Thiram 42-S or 75WDG RTU-Baytan-Thiram	Tetramethylthiuram disulfide
Triadimenol	Baytan 30 RTU-Baytan-Thiram	Beta-(4-chlorophenoxy)-alpha-(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol

ing drum seed treater was used from 1993 to 2002, and a Hege 11 liquid seed treater (Hege Maschinen GmbH, Waldenburg, Germany) was used in 2003 and 2004. Fungicides were applied as 2% liquid in water (vol/wt) from 1993 to 2000, 2.5% in 2001, 2.6% in 2002, and 2.5% in 2003 (PCNB was applied at 2.6% vol/wt). Colorant dye was added to seed starting in 1999; Pro-Ized or Day-Glo EPX seed colorant dye was added in 1999 or 2000 to 2002, respectively (Gustafson LLC), and Color Coat Red (Syngenta Inc.) in 2003. In 2004, fungicide treatments were mixed with CaCO₃ (437 g/100 kg seed), polymer (Secure 65 ml/100 kg seed, Syngenta Inc.), and dye (Color Coat Red 65 ml/100 kg seed, Syngenta Inc.) in water at a rate of 2.5% water to seed weight (wt/wt) (PCNB was applied at 2.62% wt/wt). Seed not receiving a fungicide treatment were treated in the same manner as fungicide-treated seed. When two or more fungicides were applied, the fungicides were mixed and applied in a single application, except in 1993 and 1994 when some fungicides were added sequentially. The common seed treatments across all years were no fungicide seed treatment, metalaxyl, PCNB (carboxin + PCNB in 1993), and carboxin + PCNB + metalaxyl. All other fungicide combinations were nominated by industry representatives and ranged from 12 to 16 fungicide treatment combinations for the 1993 to 2004 evaluations (Table 1).

Field experiments. Field experiments were conducted across the Cotton Belt as part of cooperative efforts of members of the Cotton Disease Council to evaluate the efficacy of seed treatment combinations used by the cottonseed industry and experimental compounds (Table 2). The number of trials where data were recorded ranged from 15 trials in 2001 to 20 trials in 1996 for a total of 211 trials. Each trial utilized a randomized complete block experimental design, with the number of replications ranging from

4 to 10. For each trial, stand counts used in the analyses were taken at approximately 31 days after planting depending on the location and year. The mean date for taking stand counts from trials for each year varied from 29 to 35 days after planting over the 12 years. Seedlings were dug from the plots not receiving a fungicide treatment by arbitrarily selecting 0.3-m sections of row and digging up approximately 50 seedlings per site, 100 seedlings per site from 2001 to 2004. A composite soil sample from the top 15 cm of soil was also obtained for each site starting in 1994. Soil and seedlings were placed in insulated packages with refrigerated cool packs and mailed overnight to the University of Arkansas for processing. Soil temperature and moisture was monitored by burying a temperature sensor and a Watermark soil moisture sensor connected to a data logger (Spectrum Technologies, Inc., Plainfield, IL) 10 cm deep at planting starting in 1999. Rainfall data were obtained from the test site or the nearest NOAA site for each trial (<http://www.ncdc.noaa.gov/oa/ncdc.html>).

Seedlings were evaluated for growth by recording the number of nodes from five arbitrarily selected seedlings, and then the above-ground portions of all seedlings were removed and discarded. Seedlings for a location were then rinsed for at least 20 min in running tap water and rated for disease symptoms. The hypocotyl disease severity index was 1 = no symptoms, 2 = few pinpoint lesions or diffuse discolored areas, 3 = distinct necrotic lesion, 4 = girdling lesion, and 5 = seedling dead. The root disease index was 1 = no symptoms, 2 = 1–10% of the root system discolored, 3 = 11–25% of the root system discolored, 4 = 26–50% of the root system discolored, and 5 > 50% of the root system discolored. Seedlings were surface disinfested by immersion for 1.5 min in 0.5% NaClO, blotted dry in a paper towel, and plated on water agar (0.8%) amended with 10 and 250 mg of the antibiotics rifampicin

Table 2. Fungicide seed treatment trials conducted as part of the National Cottonseed Treatment Program from 1993 to 2004

Year	Cooperator	Location	Site	Rep.	Row length (m)	Seed/m	Soil type
1993-2004	Gazaway, Lawrence	Auburn, AL	AL	4-6	3-8	16-23	Decatur silt loam or Lucedale fine sandy loam
1993-2004	Kirkpatrick, Barham	Hope, AR	AR1	5	8-18	12-20	Various
1993-2004	Rothrock, Bourland	Keiser, AR	AR2	4-9	6-24	12-25	Sharkey silty clay
1994-2004	Rothrock	Clarkedale, AR	AR3	6-8	15	16	Dundee silt loam
1993-2004	Hutmacher, Davis, Garber	Shafter, CA	CA	5-8	6-8	16-20	...
1994-1998	Shokes	Quincy, FL	FL	5-6	7-8	14-23	Norfolk loamy fine sand
1997	Shokes	Marianna, FL	FL2	6	7	14	Chipola fine sandy loam
1993-2004	Sumner, Seebold, Kemerait	Tifton, GA	GA	4-5	6-12	8-16	Tifton loamy sand
1993-2004	Colyer	Bossier City, LA	LA1a	5-6	8	13	Norwood very fine sandy loam
1998	Colyer	St. Joseph, LA	LA1b	4	8	13	Bruin and Commerce sandy loam
1993-1998	Lawrence	Monroe, LA	LA2	5	12	17-20	Rilla-Hebert silt loam
1999-2004	Padgett	Winnsboro, LA	LA2	4-5	6-8	13-15	Gigger silt loam
1993-2004	Batson	Mississippi State, MS	MS1	4-5	12-49	10-25	Marietta loam or Brooksville silty loam
1993-2004	Sciombato	Stoneville, MS	MS2	4-5	12-14	16-20	Bosket fine sandy loam
1993-2004	Verhalen, Littlefield, Greenhagan (VLG)	Tipton, OK	OK1	4	6-7	15-16	Tipton silt loam
1993-2004	VLG	Altus, OK	OK2	4	6-7	15-16	Hollister clay loam
1993-2004	VLG	Perkins, OK	OK3	4	6-7	15-16	Teller loam
1993-1996	Mueller	Edisto, SC	SC	4-5	8-12	13	...
1993-2004	Chambers, Newman	Jackson, TN	TN	8-10	5-8	13-22	Dexter loam
1993-2001	Thaxton, Isakeit	College Station, TX	TX1	4-8	6-12	10-16	Lufkin fine sandy loam
1993-2000	Kaufman, Wheeler	Lubbock, TX	TX2	4-6	4-11	16-20	Acuff sandy clay loam
2001-2004	Kaufman, Wheeler	Halfway, TX	TX2	4	11	16	Pullman clay loam
1995-1998	Isakeit	Weslaco, TX	TX3	4	6	16	Raymondville clay loam or Hidalgo sandy clay loam
2002-2003	Isakeit	Victoria, TX	TX3	4	5	19	Lake Charles clay
1996-1997	Isakeit	Edroy, TX	TX3b	4	6	16	Victory clay
2002	Isakeit	Brazos, TX	TX4	4	5	19	...
2003-2004	Isakeit	Beaumont, TX	TX4	4	5-6	16	Morey silt loam
1999-2001	Isakeit	Burleson Co., TX	TX3	4	5-6	16-19	Westwood silt loam
2002-2004			TX5	4	5	18-19	Miller-Norwood Pledger clay loam
1998-2004	P. M. Phipps	Suffolk, VA	VA	4	18	10-13	Kenansville loamy sand or Nansemond fine sandy loam

^z Soil type not reported.

and ampicillin, respectively, and the miticide fenpropathrin (0.14 mg a.i./liter, Danitol 2.4 EC, Valent Chemical Co.). Resulting colonies were transferred to potato dextrose agar (PDA) and identified to genus. After 5 days, the seedlings on water agar were transferred to the Thielaviopsis selective medium TB-CEN (62), which was modified by adding penicillin G (60 mg/liter), to determine isolation frequency of *T. basicola* for the same seedlings as evaluated for other pathogens. A separate evaluation of isolation frequency

for *Pythium* was conducted using an additional set of seedlings for sites, up to 50 seedlings, starting in 2001. Isolation was done by plating seedlings, following a 20-min water rinse, on the selective medium P₅ARP (23). This allowed a different assessment of incidence of *Pythium* spp. from the surface disinfection technique with NaOCl and isolation on water agar.

Soil samples were assayed for populations of *Rhizoctonia* spp. by using the multiple-pellet soil method (19) on a modified Ko and

Table 3. Plant stands for fungicide seed treatment combinations used for analyses from trials with a significant treatment response from the National Cottonseed Treatment Program from 1993 to 1998[†]

Year	Rate	Plant stand (%)											
Treatment ^u	(g a.i./100 kg seed) ^v												
1993		AL	AR1	LA2	MS1	MS2	OK1	TN	TX1a ^w	TX1b ^w			
Triadimenol+metalaxyl+thiram	20.7+15.2+62.5	34	49	62	74	26	74	33	48	85			
Metalaxyl+myclobutanil+captan	16.2+43.5+94.5	32	44	48	72	32	85	42	47	84			
Metalaxyl+myclobutanil+TCMTB	16.2+43.5+45.7	33	46	24	74	36	81	40	45	84			
Triadimenol+metalaxyl+thiram	10.4+15.2+62.5	35	42	44	70	18	76	27	46	88			
Metalaxyl+myclobutanil	16.2+43.5	24	48	24	67	38	79	49	46	87			
Chloroneb-metalaxyl+myclobutanil	130.3+5.2+43.5	29	46	29	69	20	82	43	41	80			
Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	39	44	40	64	18	76	36	48	86			
Carboxin-PCNB	77.1+77.1	28	34	24	59	28	74	24	25	68			
Metalaxyl	15.2	34	40	32	66	6	73	24	47	80			
None		19	31	33	62	10	70	16	26	60			
Location average		32	43	40	67	23	77	34	42	81			
LSD (<i>P</i> = 0.05) ^x		11.1	7.0	13.7	10.2	17.2	8.6	18.0	11.1	8.4			
1994		AR1	AR2	GA	LA1	LA2	MS1	MS2	TN	TX1	TX2		
Triadimenol+metalaxyl+thiram	20.7+15.2+62.5	66	61	43	50	97	76	50	83	73	26		
Triadimenol+metalaxyl+thiram	10.4+15.2+62.5	64	66	54	40	92	74	42	82	69	27		
Captan+metalaxyl+myclobutanil	78.8+16.2+43.5	65	63	49	44	94	76	42	79	68	34		
Chloroneb-metalaxyl+myclobutanil	130.3+15.2+43.5+3.6	65	64	39	41	87	69	45	77	67	24		
+ <i>Trichoderma harzianum</i>													
Captan+metalaxyl+myclobutanil	78.8+16.2+21.8	62	67	41	37	88	74	38	78	70	23		
Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	64	61	31	40	81	71	36	74	63	24		
PCNB	252.8	65	47	29	39	70	74	46	64	60	17		
Metalaxyl	30.4	55	73	19	19	84	71	38	77	62	33		
None		51	50	29	21	66	69	33	64	52	15		
Location average		62	63	38	37	84	73	42	75	65	26		
LSD (<i>P</i> = 0.05)		6.9	13.4	20.0	10.2	16.1	5.2	8.1	7.0	6.8	10.6		
1995		AR1	AR2	AR3	CA	GA	LA1	OK1	OK3	TN	TX1	TX2	
TCMTB+triadimenol+metalaxyl	101.6+10.4+20.2	58	44	63	83	70	81	82	68	67	83	59	
TCMTB+myclobutanil+metalaxyl	40.6+21.8+16.2	58	42	52	81	68	78	78	70	69	79	62	
Triadimenol+metalaxyl+thiram	20.7+15.2+62.5	61	40	61	80	73	76	74	65	72	82	51	
Triadimenol+metalaxyl+thiram	10.4+15.2+62.5	46	38	58	76	66	75	77	63	71	84	55	
Triadimenol-thiram+metalaxyl	10.6+32.0+15.2	64	40	59	76	70	81	71	62	66	82	47	
Thiram+myclobutanil+metalaxyl	63.2+30.5+16.2	64	43	54	78	67	72	71	61	70	83	53	
Thiram+myclobutanil+metalaxyl	63.2+21.8+16.2	54	42	57	80	70	74	74	66	67	80	56	
TCMTB+myclobutanil+metalaxyl	40.6+43.5+16.2	57	34	60	80	71	72	73	68	69	85	53	
Chloroneb-metalaxyl+myclobutanil	130.3+15.2+43.5+ 40.6	61	42	54	84	64	72	75	58	69	83	55	
+TCMTB													
TCMTB+myclobutanil+metalaxyl	50.8+30.5+16.2	63	36	50	72	66	74	70	64	70	83	61	
Thiram-triadimenol+PCNB+metalaxyl	21.3+7.1+52.3+15.2	62	35	52	82	76	72	74	58	72	78	56	
Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	58	40	52	82	51	73	76	64	66	80	53	
PCNB	252.8	59	12	55	69	54	71	74	49	50	71	42	
Metalaxyl	30.4	47	46	40	76	65	59	66	51	63	67	44	
None		41	15	42	76	61	61	58	32	41	52	34	
Location average		57	37	55	78	68	73	74	61	65	79	54	
LSD (<i>P</i> = 0.05)		4.9	10.7	10.6	9.9	14.1	10.2	10.5	7.7	8.6	5.6	12.2	
1996		AR2	AR3	CA	FL	GA	LA1	OK1	OK2	OK3	TN	TX1	TX2
Triadimenol+FB23 ^y +metalaxyl	10.4+NA+15.2	70	76	90	61	72	68	76	67	89	90	53	47
Triadimenol-thiram+metalaxyl+thiram	10.7+32.6+15.2+31.2	77	78	88	70	76	71	63	68	79	86	47	40
Triadimenol+thiram+metalaxyl	20.7+62.5+15.2	74	79	86	62	65	62	68	71	89	85	52	51
Chloroneb-TCMTB+myclobutanil+metalaxyl	134.3+51.4+30.5+16.2	68	76	84	60	65	66	74	66	84	89	53	46

(continued on next page)

[†] Numbers of trials conducted per year were: 17 in 1993, 18 in 1994, 17 in 1995, 20 in 1996, 18 in 1997, 19 in 1998.

[‡] A plus (+) between the fungicides indicates fungicides were separate formulations; a hyphen (-) between fungicides indicates one formulation.

[‡] NA = a.i. rate not available.

^w TX1 = College Station; TX1a, 2 April planting date; TX1b, 27 April planting date.

^x Least significant difference to compare among treatments within a column and year for a trial with a significant *F* test.

^y Experimental products.

^z Treatment not evaluated.

Hora medium (30). Populations were corrected using a multiple-infection correction prior to calculating propagules per 100 g of soil. Soil populations of *Pythium* spp. and *T. basicola* were detected by diluting 25 g of soil, oven-dry weight equivalent, in 0.2% water agar to a total volume of 250 ml and placing on a wrist action shaker for 20 min. *Pythium* spp. were quantified by the spread-plate method on the selective medium P₅ARP, and *T. basicola* populations were quantified using the pour-plate method with the modified TB-CEN selective medium.

Statistics. Data were analyzed by the GLM procedure using SAS (SAS Institute Inc., Cary, NC). Percent stand was analyzed by location, because of a significant location by treatment interaction for all years, except 1999. Treatment means for trials having a significant *F* test were separated by using a protected LSD at *P* = 0.05. For each trial with differences in percent stand, the difference between the percent stand for the seed treatment and nontreated seed was modeled nonparametrically using bivariate smoothing splines (35) as a function of minimal soil temperature and rainfall

Table 3. (continued from preceding page)

Year	Treatment ^a	Rate (g a.i./100 kg seed) ^b	Plant stand (%)											
	Triadimenol-thiram+metalaxyl+thiram	10.7+32.6+20.2+31.2	71	77	89	58	80	66	51	65	88	88	47	42
	Triadimenol+FB23 ^y +metalaxyl	20.7+NA+15.2	76	79	92	60	72	71	72	68	81	88	40	47
	Captan+myclobutanil+metalaxyl	78.4+21.8+16.2	68	79	87	60	74	68	77	72	75	87	46	37
	Thiram+myclobutanil+metalaxyl	126.4+21.8+16.2	70	74	86	51	77	70	65	73	85	88	49	40
	WE120C ^y +myclobutanil+metalaxyl	NA+30.5+16.2	63	75	84	67	71	71	75	64	73	89	50	47
	Metalaxyl+myclobutanil+fludioxonil	21.1+26.1+2.7	69	78	87	63	73	63	72	63	75	84	55	42
	Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	72	70	78	58	77	67	60	66	72	90	48	44
	PCNB	252.8	59	67	79	56	70	59	62	65	74	82	42	45
	Metalaxyl	30.4	66	66	82	51	71	50	47	69	57	82	43	31
	None		57	63	80	56	65	49	42	35	57	70	38	28
	Location average		68	74	84	59	72	64	66	65	76	85	46	41
	LSD (<i>P</i> = 0.05)		7.8	6.6	10.4	10.2	9.7	12.8	16.5	11.1	10.5	4.0	6.5	9.1
1997			AR3	FL2	LA1	LA2	MS1	OK1	OK2	OK3	TN	TX1	TX2	TX3b
	Triadimenol+TCMTB+metalaxyl	10.4+42.6+15.2	71	61	46	70	80	70	54	60	29	70	73	83
	TCMTB+fludioxonil+myclobutanil+mefenoxam	40.6+2.7+30.5+7.5	71	72	50	70	80	58	62	62	31	65	68	82
	Chloroneb-TCMTB+myclobutanil+mefenoxam	134.3+51.4+30.5+7.5	72	64	49	69	74	64	55	70	33	68	67	... ^z
	Captan+myclobutanil+mefenoxam	78.8+21.8+7.5	67	58	47	71	80	64	54	66	25	67	69	82
	Triadimenol-thiram+metalaxyl+thiram	10.6+32.6+15.2+31.2	72	61	45	64	68	54	65	65	25	69	68	79
	Triadimenol+thiram+metalaxyl	20.7+62.5+15.2	67	66	46	71	79	60	66	64	28	64	71	84
	WE120C ^y +myclobutanil+mefenoxam	NA+21.8+7.5	68	64	50	72	75	60	54	55	25	70	64	...
	TCMTB+myclobutanil+mefenoxam	81.3+30.5+7.5	68	63	47	76	77	56	54	33	27	56	62	81
	Mefenoxam+fludioxonil+myclobutanil	10.0+2.7+22.8	66	67	52	62	79	58	62	40	26	60	61	84
	Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	60	56	48	54	72	52	48	56	19	62	66	72
	PCNB	252.8	62	69	30	46	74	49	49	44	22	30	34	49
	Metalaxyl	30.3	63	47	39	56	58	60	59	64	17	66	65	68
	None		60	38	23	45	59	17	36	14	10	19	31	42
	Location average		66	49	44	65	74	56	56	55	24	61	62	75
	LSD (<i>P</i> = 0.05)		7.3	8.7	9.8	12.1	8.6	12.7	15.3	14.0	7.2	13.3	11.5	11.2
1998			AR1	AR3	GA	LA2	MS1	MS2	OK1	OK3	TN	TX1	VA	
	Chloroneb-TCMTB+myclobutanil+mefenoxam	134.3+51.4+29.2+7.7	64	81	86	60	91	83	80	75	55	78	35	
	TCMTB+myclobutanil+mefenoxam	45.7+20.8+7.7	56	84	85	59	92	75	75	80	60	77	38	
	Triadimenol-thiram+metalaxyl+thiram+LS151 ^y	10.7+32.6+15.2+31.2+NA	60	81	82	54	92	79	79	82	53	80	38	
	Mefenoxam+fludioxonil+myclobutanil	10.1+2.7+29.2	57	78	85	61	93	80	74	77	57	77	34	
	Carboxin-PCNB+triadimenol+metalaxyl+thiram	89.9+89.9+5.2+15.2+78.1	56	84	83	62	93	73	77	80	55	77	42	
	Triadimenol-thiram+metalaxyl+thiram	10.7+32.6+15.2+31.2	54	82	75	60	96	72	72	77	60	81	38	
	WE120C ^y +myclobutanil+mefenoxam	NA+29.2+7.7	50	81	79	60	95	76	72	70	61	83	36	
	TCMTB+triadimenol+metalaxyl	42.6+10.4+15.2	58	81	83	61	93	81	76	72	56	73	39	
	TCMTB+fludioxonil+myclobutanil+mefenoxam	45.7+2.7+29.2+7.7	53	81	88	57	94	77	79	79	51	74	38	
	Thiram-carboxin+triadimenol+metalaxyl	76.4+76.4+5.2+15.2	60	76	82	56	91	76	58	75	55	78	37	
	Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	50	80	84	57	90	79	69	75	49	81	34	
	PCNB	252.8	55	77	84	48	83	75	64	71	49	60	31	
	Metalaxyl	30.3	40	70	79	48	89	66	53	60	50	76	32	
	None		33	67	75	49	82	65	59	60	44	69	24	
	Location average		53	80	83	57	92	76	71	74	54	77	36	
	LSD (<i>P</i> = 0.05)		13.6	6.1	8.0	7.3	4.4	8.7	12.7	12.7	8.7	9.3	5.6	

for the first 3 days after planting. Trials with less than a mean stand of 30% were eliminated for these models. These 12 of the 102 total trials with environmental data were considered as outliers and eliminated from the statistical analyses because stands were limited for agronomic reasons not related to the objectives of this study (e.g., soil crusting, heavy rainfall, or cold temperatures). When

included, these results distorted the graphical presentation of the relationship between stand percentage, rainfall, and soil temperature after planting.

Mixed model analyses were used to compare stands for treatments. Product combinations used for comparisons included the fungicides azoxystrobin, myclobutanil, triadimenol, or PCNB each

Table 4. Plant stands for fungicide seed treatment combinations used for analyses from trials with a significant treatment response from the National Cottonseed Treatment Program for years with environmental data, 1999 to 2004^v

Year	Treatment ^w	Rate (g a.i./100 kg seed) ^x	Plant stand (%)											
1999			AR3	CA	LA2	MS1	OK2	TN	TX1	TX2	TX3	VA		
	WE120C ^y +myclobutanil+metalaxyl	NA+29.2+16.3	72	75	70	70	82	59	79	35	72	45		
	Mefenoxam+fludioxonil+azoxystrobin	7.7+2.7+4.9	67	75	63	65	80	59	78	32	79	49		
	Chloroneb-TCMTB+myclobutanil+metalaxyl	89.5+34.3+29.2+16.3	64	76	82	64	81	47	78	32	78	48		
	Mefenoxam+fludioxonil+myclobutanil	7.7+2.7+20.8	73	77	72	63	78	57	80	34	72	40		
	Triadimenol+TCMTB+metalaxyl	10.4+32.0+15.2	72	72	72	67	84	56	79	46	74	44		
	Azoxystrobin+metalaxyl+TCMTB	1.6+15.2+32.0	68	75	76	68	74	45	81	38	75	50		
	Triadimenol-thiram+metalaxyl	10.7+32.6+15.2	74	73	82	70	80	56	80	38	73	42		
	TCMTB+myclobutanil+metalaxyl	45.7+20.8+16.3	66	77	78	62	75	50	78	51	78	43		
	Chloroneb+metalaxyl+myclobutanil+TCMTB	270.9+15.2+20.8+45.7	72	74	78	62	76	53	79	45	73	50		
	Carboxin-PCNB+metalaxyl+triadimenol	77.1+77.1+15.2+5.2	68	75	69	65	82	54	81	37	73	49		
	Chloroneb+metalaxyl+myclobutanil	270.9+15.2+20.8	68	70	60	68	83	56	72	36	77	47		
	Mefenoxam+fludioxonil+myclobutanil	7.7+2.7+29.2	68	76	63	69	78	50	76	29	65	43		
	Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	72	72	72	58	73	44	78	35	74	46		
	PCNB	252.8	67	60	72	61	76	55	70	26	75	33		
	Metalaxyl	30.5	62	68	67	52	73	38	73	27	68	34		
	None		56	66	62	56	65	37	68	23	70	30		
	Location average		68	72	72	64	78	51	77	35	73	44		
	LSD (<i>P</i> = 0.05) ^z		7.6	6.2	13.3	9.6	9.2	13.8	7.8	11.1	8.0	7.7		
2000			AL	AR2	AR3	CA	LA1	LA2	MS1	OK2	OK3	TN	TX1	VA
	Triadimenol+TCMTB+metalaxyl	10.4+32.0+15.2	60	67	74	81	62	30	71	74	71	88	71	66
	Triadimenol-thiram+metalaxyl+TCMTB+ <i>Bacillus subtilis</i> +carboxin-PCNB	10.7+32.6+20.3+32.0+ 0.4+89.9+89.9	63	79	68	72	66	28	72	78	72	86	74	66
	Mefenoxam+fludioxonil+azoxystrobin	7.7+2.7+19.7	58	66	68	78	63	38	74	74	61	89	65	65
	TCMTB+myclobutanil+mefenoxam	45.7+19.7+24.1	52	68	70	75	59	34	64	80	70	86	68	69
	Azoxystrobin-triadimenol-metalaxyl+ TCMTB	3.0+5.0+15.0+32.0	53	74	73	76	60	28	71	66	64	88	66	70
	TCMTB+myclobutanil+mefenoxam+ WE-143 ^y + WE-144 ^y	45.7+19.7+24.1 NA+NA	60	75	69	76	55	36	70	75	72	86	64	63
	Triadimenol-thiram+metalaxyl	10.7+32.6+15.2	58	70	73	78	56	29	67	73	65	85	74	69
	Mefenoxam+fludioxonil+myclobutanil	7.7+2.7+20.8	46	71	68	72	60	34	67	69	56	86	70	66
	Mefenoxam+fludioxonil+myclobutanil	7.7+2.7+29.2	54	70	71	71	58	30	68	74	40	88	71	71
	Chloroneb-TCMTB+myclobutanil+ mefenoxam	134.3+51.4+19.7+24.1	55	70	60	71	62	24	71	72	61	87	66	62
	Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	45	65	66	75	52	25	66	72	61	84	65	58
	PCNB	252.8	49	58	63	74	44	15	65	73	53	82	57	60
	Metalaxyl	30.5	45	54	62	71	52	14	53	58	51	80	67	63
	None		51	42	63	68	36	12	51	47	42	81	56	53
	Location average		54	68	68	74	57	27	67	71	60	86	67	64
	LSD (<i>P</i> = 0.05)		11.5	8.3	8.2	7.1	9.8	14.0	8.8	12.5	15.8	3.5	9.6	9.3
2001			AR3	CA	GA	LA1	LA2	MS2	TN	VA				
	Chloroneb-TCMTB+mefenoxam+ myclobutanil	134.4+51.4+24.1+21.0	77	65	56	66	27	56	86	73				
	Triadimenol+TCMTB+metalaxyl	10.4+32.0+15.2	75	69	69	61	24	44	77	72				
	Triadimenol-thiram+metalaxyl	10.7+33.0+15.2	72	64	65	65	18	44	78	70				
	Azoxystrobin+TCMTB+metalaxyl+ triadimenol	3.1+32.0+15.2+5.2	76	61	62	59	8	56	82	65				
	Mefenoxam+WECO01B50 ^y +myclobutanil	24.1+NA+21.0	72	66	62	59	20	44	81	66				
	Mefenoxam+fludioxonil+myclobutanil	7.7+2.7+21.0	76	61	68	60	18	47	83	67				
	Triadimenol-thiram+metalaxyl+ <i>Bacillus subtilis</i> +carboxin-TCMTB-metalaxyl	10.7+33.0+15.2+0.5+ 91.0+190.3+15.2	74	63	38	57	30	52	78	70				
	Azoxystrobin+TCMTB+metalaxyl	3.1+32.0+15.2	72	47	58	64	13	43	81	71				
	Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	70	50	64	65	11	56	78	68				
	PCNB	252.8	61	38	61	12	6	30	72	40				
	Metalaxyl	30.5	60	46	43	40	8	48	66	65				
	None		55	27	43	12	2	34	66	47				
	Location average		69	51	59	49	15	44	75	63				
	LSD (<i>P</i> = 0.05)		8.3	9.2	15.9	13.3	12.7	11.6	7.3	8.7				

(continued on next page)

^v Number of trials conducted per year were: 17 in 1999, 17 in 2000, 15 in 2001, 18 in 2002, 17 in 2003, and 18 in 2004.

^w A plus (+) between the fungicides indicates fungicides were separate formulations; a hyphen (-) between fungicides indicates one formulation.

^x NA = a.i. rate not available.

^y Experimental products.

^z Least significant difference to compare among treatments within a column and year for a trial with a significant *F* test.

with mefenoxam or metalaxyl. Pearson product-moment correlation was used to determine correlation coefficients among percent stand, disease, pathogen isolation frequency, and soil populations over locations. As a result of data for variables not being collected in some years or missing data, the number of observations for correlations is limited by the lowest number of observations for one of the variables (n).

Results

For the 211 replicated trials between 1993 and 2004 conducted by cooperators of the National Cottonseed Treatment Program, a significant F test was found for 125 trials. However, a significant fungicide response was found for one or more treatments com-

pared to no fungicide treatment in only 119 of these trials, or 56% of trials (Tables 3 to 5). Metalaxyl gave a significant stand response in 40 of the 119 trials. The selective activity of metalaxyl indicates the role of *Pythium* spp. in cotton stand establishment for these trials. A metalaxyl response was found at 18 of the 29 sites used in the evaluations, suggesting the widespread importance of this group of pathogens. PCNB gave a significant stand response in 44 of the 119 trials. The selectivity of PCNB, carboxin + PCNB in 1993, indicated a role for *R. solani* in stand establishment for these trials. The PCNB response was found for 19 of the 29 sites, suggesting the widespread importance of *R. solani* on cotton stand establishment. For PCNB and metalaxyl, a response for either fungicide was found in less than half of the evaluations, suggesting

Table 4. (continued from preceding page)

Year Treatment ^w	Rate (g a.i./100 kg seed) ^x	Plant stand (%)									
2002		AR1	AR2	AR3	CA	GA	LA2	OK2	TN	VA	
Azoxystrobin-fludioxonil-mefenoxam+myclobutanil	14.6+2.4+7.3+21.0	74	64	37	73	38	39	92	68	69	
Mefenoxam+chloroneb-TCMTB+myclobutanil	24.1+134.3+51.4+25.0	72	59	43	70	41	31	91	70	63	
Triadimenol-thiram+metalaxyl+azoxystrobin-triadimenol-metalaxyl+Bacillus subtilis	10.7+32.6+15.2+3.0+5.0+15.0+0.5	72	54	53	72	36	30	89	69	65	
Azoxystrobin-fludioxonil-mefenoxam	14.6+2.4+7.3	75	52	41	71	38	32	89	66	67	
Azoxystrobin+TCMTB+metalaxyl	3.0+21.3+15.2	73	61	29	73	40	18	87	62	74	
Triadimenol+TCMTB+metalaxyl	10.4+21.3+15.2	68	60	27	70	37	25	91	72	67	
Azoxystrobin-fludioxonil-mefenoxam	14.6+2.4+7.3	69	51	43	68	35	30	90	67	70	
Triadimenol-thiram+metalaxyl	10.7+32.6+15.2	66	55	46	66	35	32	90	71	66	
Azoxystrobin-fludioxonil-mefenoxam	14.6+2.4+7.3	70	57	32	68	40	31	88	69	65	
Triadimenol-thiram+metalaxyl+Bacillus subtilis+carboxin-TCMTB-metalaxyl	10.7+32.6+15.2+0.5+91.0+190.3+15.2	70	44	32	65	36	29	88	67	71	
Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	76	56	37	69	38	30	84	57	67	
PCNB	252.8	68	49	21	68	34	25	84	48	67	
Metalaxyl	30.5	60	46	23	57	15	14	82	39	56	
None	...	62	47	13	58	10	14	75	41	61	
Location average		69	55	34	68	34	27	87	62	66	
LSD (P = 0.05)		8.6	9.1	13.0	6.0	11.9	12.2	5.1	8.0	6.4	
2003		AR1	CA	GA	LA1	LA2	TN	TX2	TX4		
Mefenoxam+myclobutanil+chloroneb-TCMTB	24.1+43.5+259.7+99.5	84	84	87	60	81	77	85	37		
Azoxystrobin-fludioxonil-mefenoxam+myclobutanil	14.7+2.5+7.4+21.0	76	78	87	65	82	72	81	41		
Triadimenol+TCMTB+metalaxyl	10.4+32.0+15.2	79	80	84	50	83	82	83	39		
Azoxystrobin-fludioxonil-mefenoxam	14.7+2.5+7.4	72	75	86	64	80	74	87	41		
Mefenoxam+myclobutanil+TCMTB	24.1+43.5+40.6	73	82	86	67	85	71	79	25		
Triadimenol-thiram+metalaxyl	10.7+32.6+15.2	79	80	85	56	80	76	85	33		
Mefenoxam+myclobutanil+TCMTB+WECO 0257 ^y	24.1+43.5+40.6+NA	78	80	85	52	82	74	82	39		
Azoxystrobin-fludioxonil-mefenoxam	18.6+3.1+9.3	79	80	85	49	74	75	79	40		
Metalaxyl+L0288 ^y +triadimenol-thiram	15.2+NA+10.7+32.6	79	79	83	68	78	80	81	34		
Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	80	82	86	60	80	73	82	20		
PCNB	252.8	66	69	88	66	77	53	79	12		
Metalaxyl	30.5	66	67	75	36	74	68	78	26		
None		63	66	82	23	67	55	74	7		
Location average		75	77	84	54	79	70	81	28		
LSD (P = 0.05)		10.0	11.1	7.0	15.7	9.0	7.8	6.4	13.2		
2004		AR3	CA	LA1	OK3	TX2	TX4	TX5			
Azoxystrobin-fludioxonil-mefenoxam	18.6+3.1+9.3	70	73	74	82	63	91	64			
Azoxystrobin-fludioxonil-mefenoxam+myclobutanil	14.7+2.5+7.4+21.0	73	75	78	72	64	88	63			
Triadimenol+TCMTB+metalaxyl	10.4+32.0+15.2	68	74	80	78	66	96	51			
Azoxystrobin-fludioxonil-mefenoxam	14.7+2.5+7.4	64	73	79	68	60	86	49			
L1226 ^y +metalaxyl+triadimenol	NA+20.3+6.6	68	72	80	76	63	93	50			
Metalaxyl+L0288 ^y +triadimenol-thiram	15.2+NA+10.7+32.6	66	75	81	78	57	91	59			
Mefenoxam+WECO 0257 ^y +myclobutanil+chloroneb-TCMTB	23.4+NA+43.5+134.3+51.4	71	76	79	78	60	90	44			
Triadimenol-thiram+metalaxyl	10.7+32.6+15.2	67	75	77	80	61	89	47			
Mefenoxam+WECO 0257 ^y +myclobutanil	23.4+NA+43.5	73	73	77	78	61	92	38			
Carboxin-PCNB+metalaxyl	77.1+77.1+15.2	62	70	75	73	59	88	57			
PCNB	252.8	64	69	66	68	57	90	48			
Metalaxyl	30.5	62	69	60	57	50	82	49			
None		60	64	44	65	48	80	43			
Location average		66	72	72	74	59	89	47			
LSD (P = 0.05)		6.7	4.1	9.5	14.7	8.6	6.1	20.4			

a role for other pathogens or a complex of pathogens in disease development. Carboxin + PCNB + metalaxyl, the historic standard fungicide treatment, improved stands for 78 of the 119 trials where a response was observed compared to no fungicide treatment (Tables 3 to 5). In 38% of the trials where a response was observed (45 trials), one or more of the nominated fungicide combinations increased stand compared to the historic standard fungicide treatment. In all years except 1999, the best fungicide combination or combinations improved stand for all trials or all but one trial.

From the nominations across years, selected treatments were used to compare specific changes in chemistries used as seed treatments by the industry. These new chemistries, triazoles (myclobutanil or triadimenol) and azoxystrobin, were compared to carboxin + PCNB, with all products being used in combination with either metalaxyl or mefenoxam. For 390 observations, the mean stands for azoxystrobin, 63.1%, or triazoles, 63.0%, were greater than the historic combination, carboxin + PCNB, 61.2% ($P = 0.0036$). Comparison of these same chemistries for trials (95 observations) with 20% or more isolation frequency of *T. basicola* found stands of 65.8, 64.2, and

Table 5. Ratio of significant responses over seed without fungicides to total number of trials for a site^v (significant response over the historic standard^w) for fungicide seed treatment combinations used for analyses from trials for the National Cottonseed Treatment Program, 1993 to 2004^x

Seed treatment	AL	AR1	AR2	AR3	CA	FL1	FL2	GA
Metalaxyl+thiram+triadimenol	2/19(1)	9/15(1)	8/19(0)	13/17(4)	6/16(2)	1/11(0)	2/2(1)	5/19(4)
Metalaxyl+myclobutanil+captan	1/4(0)	3/4(0)	2/4(0)	1/3(0)	0/4(0)	0/3(0)		0/4(0)
Metalaxyl+myclobutanil+TCMTB	1/5(0)	4/5(1)	3/5(0)	2/4(0)	1/5(0)	0/3(0)		0/5(3)
Metalaxyl+myclobutanil	0/1(0)	1/1(0)	0/1(0)		0/1(0)			0/1(0)
Chloroneb+metalaxyl+myclobutanil ^y	0/3(0)	2/3(0)	1/3(0)	1/2(0)	0/3(0)	0/1(0)		0/3(0)
Metalaxyl+TCMTB+triadimenol	0/9(1)	3/6(0)	3/9(0)	8/9(2)	5/7(1)	0/3(0)	1/1(0)	2/9(1)
Metalaxyl+myclobutanil+thiram	0/3(0)	2/3(1)	3/3(0)	3/3(0)	0/3(0)	0/3(0)		1/3(2)
Chloroneb+metalaxyl+myclobutanil+TCMTB	0/4(0)	1/4(0)	2/4(0)	4/4(0)	2/4(0)	0/2(0)		0/4(0)
Metalaxyl+PCNB+thiram+triadimenol	0/1(0)	1/1(0)	1/1(0)	0/1(0)	0/1(0)	0/1(0)		1/1(1)
Metalaxyl+myclobutanil+exp. ^z	0/2(0)	0/2(0)	0/2(0)	2/2(0)	1/2(0)	1/1(0)		0/2(0)
Fludioxonil+metalaxyl+myclobutanil	0/1(0)	0/1(0)	1/1(0)	1/1(0)	0/1(0)	0/1(0)		0/1(0)
Metalaxyl+triadimenol+exp. ^z	0/3(0)	0/3(0)	2/3(0)	3/3(0)	2/3(0)	0/2(0)		0/3(0)
Fludioxonil+mefenoxam+myclobutanil+TCMTB	0/2(0)	1/1(0)	0/2(0)	2/2(1)		0/2(0)	1/1(1)	1/2(1)
Chloroneb+mefenoxam+myclobutanil+TCMTB	0/6(0)	3/3(1)	2/6(0)	4/6(1)	3/4(1)	0/2(0)	1/1(0)	2/6(0)
Captan+myclobutanil+mefenoxam	0/1(0)		0/1(0)	0/1(0)		0/1(0)	1/1(0)	0/1(0)
Mefenoxam+myclobutanil+exp. ^z	0/4(0)	1/2(0)	0/4(0)	4/4(2)	2/2(1)	0/2(0)	1/1(0)	1/4(0)
Mefenoxam+myclobutanil+TCMTB	0/4(0)	2/2(0)	1/4(0)	2/4(1)	1/2(0)	0/2(0)	1/1(0)	1/4(0)
Fludioxonil+mefenoxam+myclobutanil	0/7(0)	1/3(0)	2/7(0)	4/7(0)	3/5(0)	0/2(0)	1/1(1)	2/7(0)
Metalaxyl+thiram+triadimenol+exp. ^z	0/3(0)	2/3(0)	0/3(0)	1/3(0)	2/2(1)	0/1(0)		0/3(0)
Carboxin+metalaxyl+PCNB+thiram+triadimenol	0/1(0)	1/1(0)	0/1(0)	1/1(0)		0/1(0)		0/1(0)
Carboxin+metalaxyl+thiram+triadimenol	0/1(0)	1/1(0)	0/1(0)	1/1(0)		0/1(0)		0/1(0)
Carboxin+metalaxyl+PCNB+triadimenol	0/1(0)	0/1(0)	0/1(0)	1/1(0)	1/1(0)			0/1(0)
Azoxystrobin+fludioxonil+mefenoxam	0/9(1)	2/8(0)	2/9(0)	5/9(0)	8/9(0)			3/9(0)
Azoxystrobin+metalaxyl+TCMTB	0/3(0)	1/2(0)	1/3(0)	3/3(0)	3/3(0)			1/3(0)
Carboxin+metalaxyl+PCNB+TCMTB+thiram+triadimenol+ <i>Bacillus subtilis</i>	1/1(1)		1/1(1)	0/1(0)	0/1(0)			0/1(0)
Mefenoxam+myclobutanil+TCMTB+exp. ^z	0/2(1)	1/1(0)	1/2(1)	0/2(0)	2/2(0)			0/2(0)
Azoxystrobin+metalaxyl+TCMTB+triadimenol	0/2(1)		1/2(1)	2/2(0)	2/2(1)			1/2(0)
Carboxin+metalaxyl+TCMTB+thiram+triadimenol+ <i>Bacillus subtilis</i>	0/2(0)	0/1(0)	0/2(0)	2/2(0)	2/2(1)			1/2(0)
Azoxystrobin+fludioxonil+mefenoxam+myclobutanil	0/3(0)	2/3(0)	1/3(0)	2/3(1)	3/3(1)			1/3(0)
Azoxystrobin+metalaxyl+thiram+triadimenol+ <i>Bacillus subtilis</i>	0/1(0)	1/1(0)	0/1(0)	1/1(0)	1/1(0)			1/1(0)
Chloroneb+mefenoxam+myclobutanil+TCMTB+exp. ^z	0/1(0)	0/1(0)	0/1(0)	1/1(1)	1/1(1)			0/1(0)
Carboxin-PCNB+metalaxyl	1/12	6/9	3/12	5/11	4/10	0/5	1/1	4/12
PCNB	0/12(0)	3/9(0)	1/12(0)	3/11(0)	3/10(0)	0/5(0)	1/1(1)	3/12(0)
Metalaxyl	1/12(0)	2/9(0)	4/12(0)	0/11(0)	2/10(0)	0/5(0)	1/1(0)	0/12(0)
	LA1	LA2	MS1	MS2	OK1	OK2	OK3	SC
Metalaxyl+thiram+triadimenol	14/19(0)	11/19(1)	7/19(2)	2/19(1)	8/18(0)	8/14(3)	11/17(0)	0/7(0)
Metalaxyl+myclobutanil+captan	3/4(0)	3/4(0)	1/4(0)	2/4(0)	2/4(1)	1/4(0)	1/4(0)	0/3(0)
Metalaxyl+myclobutanil+TCMTB	3/5(0)	1/5(0)	1/5(0)	1/5(1)	4/4(0)	1/2(0)	3/5(0)	0/4(0)
Metalaxyl+myclobutanil	0/1(0)	0/1(0)	0/1(0)	1/1(1)	1/1(0)	0/1(0)	0/1(0)	0/1(0)
Chloroneb+metalaxyl+myclobutanil	1/3(0)	1/3(0)	1/3(1)	1/3(1)	1/2(0)	1/3(1)	0/3(0)	0/2(0)
Metalaxyl+TCMTB+triadimenol	6/9(1)	5/9(2)	4/9(0)	1/9(0)	3/8(1)	4/6(2)	3/7(0)	0/1(0)
Metalaxyl+myclobutanil+thiram	3/3(0)	0/3(0)	0/3(0)	0/3(0)	3/3(0)	1/1(0)	3/3(0)	0/2(0)
Chloroneb+metalaxyl+myclobutanil+TCMTB	2/4(0)	2/4(0)	0/4(0)	0/4(0)	2/2(0)	3/3(0)	2/4(0)	0/1(0)
Metalaxyl+PCNB+thiram+triadimenol	1/1(0)	0/1(0)	0/1(0)	0/1(0)	1/1(0)		1/1(0)	0/1(0)
Metalaxyl+myclobutanil+exp. ^z	1/2(0)	0/2(0)	1/2(1)	0/2(0)	1/1(0)	2/2(0)	1/2(0)	
Fludioxonil+metalaxyl+myclobutanil	1/1(0)	0/1(0)	0/1(0)	0/1(0)	1/1(0)	1/1(0)	1/1(0)	
Metalaxyl+triadimenol+exp. ^z	2/3(0)	0/3(0)	0/3(0)	0/3(0)	2/3(0)	2/3(0)	2/3(0)	
Fludioxonil+mefenoxam+myclobutanil+TCMTB	1/3(0)	2/2(1)	2/2(0)	1/2(0)	2/2(0)	1/2(0)		
Chloroneb+mefenoxam+myclobutanil+TCMTB	4/6(1)	5/6(2)	3/6(0)	2/6(0)	2/6(0)	3/4(1)	3/4(0)	
Captan+myclobutanil+mefenoxam	1/1(0)	1/1(1)	1/1(0)	0/1(0)	1/1(0)	1/1(0)	1/1(0)	
Mefenoxam+myclobutanil+exp. ^z	3/5(0)	3/4(1)	2/4(1)	1/4(0)	2/4(0)	1/3(0)	1/3(0)	

(continued on next page)

^v Fisher's protected least significant difference, $P = 0.05$.

^w Historic fungicide standard carboxin+PCNB+metalaxyl.

^x Fungicide combinations are listed in the chronological order (year) they first appeared.

^y In 1994, fungicide combination included *Trichoderma harzianum*.

^z Treatments included one or more experimental products.

62.1% for triazoles (triadimenol or myclobutanil), azoxystrobin, and carboxin + PCNB, respectively. For these trials, triazoles were greater than carboxin + PCNB, but azoxystrobin was not significantly different from either chemistry ($P = 0.0009$).

Correlations were examined for the association of disease symptoms, isolation frequency, and soil populations of selected pathogen groups to plant stand. Percent stand was negatively correlated with the hypocotyl ($r = -0.28$, $P < 0.0001$, $n = 204$) and root disease indices ($r = -0.20$, $P = 0.0038$, $n = 204$), respectively. Mean plant stands for trials also were negatively correlated with soil populations of *Pythium* spp. ($r = -0.32$, $P < 0.0001$, $n = 179$), with a weak association with isolation of *Pythium* spp. on P₅ARP ($r = -0.23$, $P = 0.0617$, $n = 67$) and *R. solani* ($r = -0.12$, $P = 0.0843$, n

$= 202$), respectively. The hypocotyl disease index was positively correlated with isolation frequency of *R. solani* ($r = 0.37$, $P < 0.0001$, $n = 201$) and *T. basicola*, ($r = 0.28$, $P < 0.0001$, $n = 202$). The root disease index was positively correlated with isolation frequency of *T. basicola* ($r = 0.26$, $P = 0.0002$, $n = 202$). In addition, isolation frequency was positively correlated with soil populations for *R. solani* ($r = 0.32$, $P < 0.0001$, $n = 183$) and *T. basicola* ($r = 0.54$, $P < 0.0001$, $n = 183$). Isolation frequency of *Pythium* was associated with soil population counts of *Pythium* on water agar ($r = 0.14$, $P = 0.06$, $n = 176$) or P₅ARP ($r = 0.41$, $P = 0.0009$, $n = 64$). Isolation of *Fusarium* spp. was negatively correlated with isolation of *R. solani* ($r = -0.34$, $P < 0.0001$, $n = 202$) and *T. basicola* ($r = -0.26$, $P = 0.0002$, $n = 202$).

Table 5. (continued from preceding page)

Seed treatment								
Mefenoxam+myclobutanil+TCMTB	3/5(0)	4/4(1)	3/4(0)	1/4(0)	2/4(0)	2/3(0)	3/3(0)	
Fludioxonil+mefenoxam+myclobutanil	4/8(0)	5/7(0)	5/7(1)	2/7(0)	2/5(0)	5/6(0)	2/6(0)	
Metalaxyl+thiram+triadimenol+exp. ^z	2/4(0)	1/3(0)	1/3(0)	1/3(0)	1/3(0)	0/2(0)	1/2(0)	
Carboxin+metalaxyl+PCNB+thiram+triadimenol	0/2(0)	1/1(0)	1/1(0)	0/1(0)	1/1(0)	0/1(0)	1/1(0)	
Carboxin+metalaxyl+thiram+triadimenol	0/2(0)	0/1(0)	1/1(0)	1/1(0)	0/1(0)	0/1(0)	1/1(0)	
Carboxin+metalaxyl+PCNB+triadimenol	0/1(0)	0/1(0)	0/1(0)	0/1(0)		1/1(0)	0/1(0)	
Azoxystrobin+fludioxonil+mefenoxam	5/6(1)	5/9(0)	1/9(0)	0/9(0)	0/8(0)	5/7(1)	2/7(0)	
Azoxystrobin+metalaxyl+TCMTB	1/2(0)	1/3(0)	1/3(1)	0/3(0)	0/2(0)	1/2(0)	0/2(0)	
Carboxin+metalaxyl+PCNB+TCMTB+thiram+triadimenol+ <i>Bacillus subtilis</i>	1/1(1)	1/1(0)	1/1(0)	0/1(0)	0/1(0)	1/1(0)	1/1(0)	
Mefenoxam+myclobutanil+TCMTB+exp. ^z	2/2(0)	2/2(0)	1/2(0)	0/2(0)	0/2(0)	1/1(0)	1/1(0)	
Azoxystrobin+metalaxyl+TCMTB+triadimenol	2/2(0)	1/2(0)	1/2(0)	1/2(0)	0/2(0)	1/1(0)	1/1(0)	
Carboxin+metalaxyl+TCMTB+thiram+triadimenol+ <i>Bacillus subtilis</i>	1/1(0)	2/2(0)	0/2(0)	1/2(0)	0/2(0)	1/1(0)	0/1(0)	
Azoxystrobin+fludioxonil+mefenoxam+myclobutanil	2/2(0)	2/3(0)	0/3(0)	0/3(0)	0/3(0)	1/2(1)	0/2(0)	
Azoxystrobin+metalaxyl+thiram+triadimenol+ <i>Bacillus subtilis</i>		1/1(0)	0/1(0)	0/1(0)	0/1(0)	1/1(0)	0/1(0)	
Chloroneb+mefenoxam+myclobutanil+TCMTB+exp. ^z	1/1(0)	0/1(0)	0/1(0)	0/1(0)				
Carboxin-PCNB+metalaxyl	8/12	3/12	3/12	2/12	3/11	3/9	5/10	0/3
PCNB	3/12(0)	1/12(0)	2/12(0)	3/12(1)	3/11(0)	4/9(0)	3/10(0)	0/3(0)
Metalaxyl	4/12(0)	1/12(0)	1/12(0)	1/12(0)	1/11(0)	3/9(0)	2/10(0)	0/3(0)
	TN	TX1	TX2	TX3	TX4	TX5	VA	
Metalaxyl+thiram+triadimenol	16/19(5)	17/18(1)	13/19(0)	2/18(1)	2/3(0)	0/3(0)	4/7(1)	
Metalaxyl+myclobutanil+captan	4/4(0)	5/5(1)	1/4(0)	0/2(0)				
Metalaxyl+myclobutanil+TCMTB	4/5(0)	6/6(0)	4/5(1)	0/4(0)			1/1(0)	
Metalaxyl+myclobutanil	1/1(0)	2/2(0)	0/1(0)					
Chloroneb+metalaxyl+myclobutanil	3/3(0)	3/4(0)	1/3(0)	0/1(0)			1/1(0)	
Metalaxyl+TCMTB+triadimenol	8/9(3)	4/6(0)	5/9(0)	1/9(0)	2/3(2)	0/3(0)	4/7(0)	
Metalaxyl+myclobutanil+thiram	3/3(0)	3/3(0)	3/3(0)	0/4(0)				
Chloroneb+metalaxyl+myclobutanil+TCMTB	3/4(0)	4/4(0)	3/4(0)	0/5(0)			2/2(0)	
Metalaxyl+PCNB+thiram+triadimenol	1/1(0)	1/1(0)	1/1(0)	0/1(0)				
Metalaxyl+myclobutanil+exp. ^z	2/2(1)	2/2(0)	2/2(0)	0/39(0)			1/1(0)	
Fludioxonil+metalaxyl+myclobutanil	1/1(0)	1/1(0)	1/1(0)	0/2(0)				
Metalaxyl+triadimenol+ exp. ^z	2/3(0)	1/2(0)	3/3(0)	0/4(0)	1/1(0)	0/1(0)	0/1(0)	
Fludioxonil+mefenoxam+myclobutanil+TCMTB	1/2(1)	1/2(0)	1/2(0)	1/3(0)			1/1(0)	
Chloroneb+mefenoxam+myclobutanil+TCMTB	6/6(3)	2/4(0)	2/6(0)	0/7(0)	1/2(1)	0/2(0)	2/5(0)	
Captan+myclobutanil+mefenoxam	1/1(0)	1/1(0)	1/1(0)	1/2(0)				
Mefenoxam+myclobutanil+exp. ^z	3/4(1)	2/3(0)	2/4(0)	0/3(0)	1/1(0)	0/1(0)	2/3(0)	
Mefenoxam+myclobutanil+TCMTB	4/4(2)	2/3(0)	1/4(0)	1/5(0)	1/1(0)	0/1(0)	2/3(1)	
Fludioxonil+mefenoxam+myclobutanil	6/7(1)	5/7(0)	1/7(0)	1/8(0)			6/6(1)	
Metalaxyl+thiram+triadimenol+exp. ^z	2/3(0)	1/1(0)	2/3(0)	0/2(0)	2/2(1)	0/2(0)	1/3(0)	
Carboxin+metalaxyl+PCNB+thiram+triadimenol	1/1(0)	0/1(0)	0/1(0)	0/1(0)			1/1(1)	
Carboxin+metalaxyl+thiram+triadimenol	1/1(0)	0/1(0)	0/1(0)	0/1(0)			1/1(0)	
Carboxin+metalaxyl+PCNB+triadimenol	1/1(0)	1/1(0)	1/1(0)	0/1(0)			1/1(0)	
Azoxystrobin+fludioxonil+mefenoxam	7/9(5)	1/2(0)	3/9(0)	1/7(0)	3/7(2)	1/7(0)	4/9(0)	
Azoxystrobin+metalaxyl+TCMTB	2/3(0)	1/2(0)	1/3(0)	0/3(0)	0/1(0)	0/1(0)	3/3(1)	
Carboxin+metalaxyl+PCNB+TCMTB+thiram+triadimenol+ <i>Bacillus subtilis</i>	1/1(0)	1/1(0)	0/1(0)	0/1(0)			1/1(0)	
Mefenoxam+myclobutanil+TCMTB+exp. ^z	2/2(0)	0/1(0)	1/2(0)	0/2(0)	1/1(1)	0/1(0)	1/2(0)	
Azoxystrobin+metalaxyl+TCMTB+triadimenol	2/2(1)	1/2(0)	0/2(0)	0/2(0)			2/2(1)	
Carboxin+metalaxyl+TCMTB+thiram+triadimenol+ <i>Bacillus subtilis</i>	2/2(1)	0/1(0)	0/2(0)	0/2(0)	0/1(0)	0/1(0)	2/2(0)	
Azoxystrobin+fludioxonil+mefenoxam+myclobutanil	2/3(1)		2/3(0)	0/2(0)	2/3(1)	0/3(0)	1/3(0)	
Azoxystrobin+metalaxyl+thiram+triadimenol+ <i>Bacillus subtilis</i>	1/1(1)		0/1(0)	0/1(0)	0/1(0)	0/1(0)	0/1(0)	
Chloroneb+mefenoxam+myclobutanil+TCMTB+ exp. ^z	0/1(0)		1/1(0)		1/1(0)	0/1(0)	0/1(0)	
Carboxin+PCNB+metalaxyl	8/12	8/10	6/12	1/11	1/3	0/3	3/7	
PCNB	4/12(0)	2/10(0)	2/12(0)	0/11(0)	1/3(0)	0/3(0)	2/7(0)	
Metalaxyl	4/12(0)	6/10(0)	2/12(0)	1/11(1)	1/3(0)	0/3(0)	3/7(0)	

Environment had a large impact on stand establishment, with stand being similar at the highest minimal soil temperatures of 25°C across rainfall amounts of no rain to 62 mm the first 3 days after planting (Fig. 1). Mean stand over plotted trials was 55%. As soil temperature the first 3 days after planting decreased among trials to the minimal soil temperature examined of 12°C, stands decreased. In addition, an increase in stand reduction at these lower temperatures was seen as rainfall increased (Fig. 1). The role of environment on seedling disease severity was examined as a change in stand between the standard carboxin + PCNB + metalaxyl treatment and seed not receiving a fungicide treatment for trials (Fig. 2A). The mean stand improvement for carboxin + PCNB + metalaxyl was 10.4. Under all environmental conditions, fungicides improved stand compared to seed not receiving fungicides (Fig. 2A). Lowest stand improvements occurred at a minimal soil temperature of 25°C. As rainfall amounts increased and soil temperatures decreased for trials, seed treatment fungicides increased stands more compared to nontreated seed. The greatest seedling disease pressure or stand increases with fungicides occurred for rainfall at lower soil temperatures compared to higher soil temperatures for the carboxin + PCNB + metalaxyl treatment (Fig. 2A). An additional profile was developed for nominations containing a triazole fungicide and metalaxyl or mefenoxam and nontreated seed to observe the response of newer

chemistries across environments (Fig. 2B). The mean stand improvement for a triazole and metalaxyl or mefenoxam was 13.2. A very similar profile was observed for stand difference over environments as for carboxin + PCNB + metalaxyl. However, increases in stand with these fungicide products at reduced minimal soil temperatures at planting and increasing rainfall were greater than observed with the historic standard fungicide.

Environment also influenced the importance of pathogen groups in the seedling disease complex. Plotting the stand difference between the metalaxyl seed treatment and no fungicide treatment over environment showed that metalaxyl gave a mean improvement of 5.9 (Fig. 3). Little change in stand response was found for metalaxyl over the minimal soil temperatures of 12 to 25°C in the absence of rainfall the first 3 days after planting. However, as rainfall after planting increased at lower minimal soil temperatures, a metalaxyl response was evident, with stand differences of close to 20 at 62 mm of rainfall and a minimal soil temperature of 12°C. For stand differences between stands for the PCNB seed treatment compared to no fungicide seed treatment, a mean stand change of 3.6% was found over environments (Fig. 4). Few differences were evident over the range of temperatures of 12 to 25°C and rainfall amounts of none to 62 mm, although there was a suggestion of greater response with the combination of low soil temperature and high rainfall amounts.

Discussion

Value of fungicide seed treatments. The National Cottonseed Treatment Trials from 1993 to 2004 documented the importance of seedling diseases in stand establishment problems. Of 212 replicated trials conducted over 12 years and 29 locations, seed treatment fungicides significantly improved stand in 119 trials over a range of soil types and planting environments. This work supports the widespread use of fungicide seed treatments on cotton. It is common to use multiple fungicides to target the range of seedling disease pathogens. Davis et al. (12) over a 3-year period in the San Joaquin Valley observed a response to the fungicides myclobutanil + metalaxyl or myclobutanil in 22 of 25 trials. Metalaxyl alone improved stands only in trials in 1995, but not the 18 trials in 1993 or 1994. Kaufman et al. (28) demonstrated the value of seed treatments in improving cotton stands in Texas. This study also demonstrated reduced root necrosis and yield increases from use of triazole fungicides at a site with a history of black root rot (28). Wheeler et al. (65) also demonstrated yield increases from seed treatment fungicides.

Historically, carboxin + PCNB + metalaxyl were used widely to limit stand reductions from *R. solani* and *Pythium* spp. The availability of new or alternative chemistries for the control of seedling diseases is important as older chemistries, such as PCNB, are not being reregistered for use on cotton. In these studies, newer

Fig. 1. Percent stand for the mean of trials from 1999 to 2004 in relation to rainfall and average minimal soil temperature for the first 3 days after planting.

Fig. 2. Difference in mean stand percentages between seed treated with A, carboxin + PCNB + metalaxyl or B, a triazole and either metalaxyl or mefenoxam and seed with no fungicide treatment for trials from 1999 to 2004 in relation to rainfall and average minimal soil temperature for the first 3 days after planting.

chemistries for the control of *R. solani* and other pathogens, azoxystrobin and triazole fungicides, were shown to significantly improve stands when used in combination with mefenoxam or metalaxyl compared to carboxin + PCNB + metalaxyl. Fichtner et al. (16) also observed that triadimenol with thiram and metalaxyl was more effective in reducing root necrosis and hypocotyl discoloration compared to seed treatment with carboxin + PCNB + mefenoxam. Newer chemistries such as the triazoles are also increasing the spectrum of seedling diseases being controlled, with the triazoles providing some control of *T. basicola* (28,63). This was evident at the sites for these trials having black root rot, with stands for seed treatments containing triazole fungicides being more effective than other fungicide chemistries.

Role of environment. Stand reductions were evident over sites as soil temperatures decreased and rainfall increased the first 3 days after planting. Poor stands and an increase in seedling diseases are often associated with early planting (10,26). Johnson et al. (26) found poor stands at soil temperatures of 10°C or lower, with good stands at minimal soil temperatures of 19°C or higher. In Louisiana, Colyer et al. (10) found plant populations were low in an early April planting, increased in late April and early May plantings, and remained high for a mid-May planting. Planting too early is not recommended, as it is often associated with low temperatures and abundant rainfall that increase abiotic stresses, including soil crusting, soil anoxia, and chilling injury, and increase susceptibility to seedling disease pathogens. However, research has not clearly defined the role of environmental or soil factors on the relative importance of seedling diseases associated with reduced stands for cotton. In these studies, fungicide response compared to seed not receiving a fungicide treatment clearly identified the role of seedling diseases in stand differences across environments. Fungicide stand response increased as stands decreased with decreasing soil temperature and increasing soil water content. Incidence and severity of cotton seedling diseases have been shown previously to be affected by soil temperature and moisture content (6,26,34). However, in these studies stand responses were not associated with chilling injury that may increase seedling diseases caused by *R. solani* or *Pythium* spp., since the soil responses were examined at minimal soil temperatures of 12°C and above (7,31,34,61). Davis et al. (12) found good fungicide response over environments with mean soil temperatures that ranged from 19.7 to 22.2°C for the first 5 days after planting, suggesting that even at favorable soil temperatures seedling diseases can be important in stand establishment.

The use of fungicide treatments with selective spectrums of activity also indicated the importance of stand losses associated with seedling diseases caused by *Pythium* spp. or *R. solani*. Stand losses from *Pythium* spp. clearly increased as soil temperature decreased from a minimal soil temperature of 25 to 12°C and with increasing rainfall the first 3 days after planting. This supports earlier research from Tennessee that found in 7 years of field studies, soil moisture and temperature at planting directly affected isolation frequency of *Pythium*, with isolation being negatively correlated with minimal soil temperature and positively correlated with soil moisture content (26). These observations on the role of soil temperature and moisture on the severity of seedling disease caused by different *Pythium* spp. is supported by controlled studies. Optimal temperature for root rot in cotton caused by *P. irregulare* was 15°C, over a range of temperatures from 15 to 31°C (43). Arndt (3) found *P. ultimum* caused the most damage at 18 and 21°C over a temperature range of 18 to 30°C. Black root rot of cotton caused by *T. basicola* is also more severe under cool wet environments after planting (5,32,44).

Response from the PCNB seed treatment compared to no fungicide treatment varied little with soil environment after planting, suggesting stand losses from *R. solani* were not influenced greatly by soil temperature or rainfall the first 3 days after planting. Previous controlled temperature studies by Arndt (4) found *R. solani* to be most destructive at 18 to 33°C. Similarly, Hunter et al. (22) found activity from 20 to 32°C for three isolates of *R. solani*. Walker (64) found stand losses from *R. solani* over a similar range of temperatures and also found that the pathogen reduced stand over a wide range of soil water contents. Based on isolation frequency from field studies, seedlings were equally susceptible when grown at minimal soil temperatures ranging from 14 to 24°C, and susceptibility was not associated with soil moisture (26).

Relation of pathogen isolation and population to stand establishment. Limited research has tried to examine the importance of soil pathogen populations on disease development. In these trials, a significant negative correlation was found between *Pythium* soil populations and stand, but not other pathogens examined. Isolation frequency was positively correlated with soil populations of *R. solani*, *Pythium* spp., and *T. basicola*. Soil population explained only a small proportion of the variability in stands observed across sites and years. DeVay et al. (14) observed that survival of cotton seedlings from nontreated seeds was negatively correlated with populations of *P. ultimum* in field soils. Other studies in California

Fig. 3. Difference in mean stand percentages between seed with a metalaxyl fungicide treatment and no fungicide treatment for trials from 1999 to 2004 in relation to rainfall and average minimal soil temperature for the first 3 days after planting.

Fig. 4. Difference in mean stand percentages between seed with a PCNB fungicide treatment and no fungicide treatment for trials from 1999 to 2004 in relation to rainfall and average minimal soil temperature for the first three days after planting.

found stands decreased as populations of *R. solani* and *Pythium* increased for 12 trials, and the decrease was related to response of fungicide with activity to specific pathogen groups (18). However, Davis et al. (12) did not find an association between *R. solani* or *Pythium* soil populations and stands. Johnson and Doyle (27) in Tennessee also found no relationship between *Pythium* soil populations and isolation frequency or disease on cotton seedlings. This information along with the environmental response of fungicides suggests soil pathogen populations are not the primary factor in determining seedling disease severity on cotton.

These multi-year data support the widespread use of seed treatment fungicides for cotton. Newer seed treatment fungicides with QoI or triazole chemistries were demonstrated to be superior to older fungicide seed treatment chemistries. Although pathogen populations were shown to be associated with stand establishment or disease severity, environment appeared to be more important in determining stand establishment across sites and years.

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