New Systemic Fungicides for the Control of Cotton Seedling Disease

G. C. Papavizas, J. A. Lewis, E. B. Minton, and N. R. O'Neill

First and second authors, Soilborne Diseases Laboratory, Plant Protection Institute, Beltsville, MD 20705; third author, Cotton Research Laboratory, Lubbock, TX 79401; fourth author, Field Crops Laboratory, Plant Genetics and Germplasm Institute, Beltsville, MD; all, Agricultural Research, Science and Education Administration, U.S. Department of Agriculture.

Accepted for publication 13 August 1979.

ABSTRACT

PAPAVIZAS, G. C., J. A. LEWIS, E. B. MINTON, and N. R. O'NEILL. 1980. New systemic fungicides for the control of cotton seedling disease. Phytopathology 70:113-118.

The new systemic fungicide *N*-cyclohexyl-*N*-methoxy-2,5-dimethyl-3-furancarboxamide (BAS 389) was combined in acetone with one of the two other new systemic fungicides *N*-(2,6-dimethylphenyl)-*N*-(methoxyacetyl) alanine methylester (CGA-48988) and propyl [3-(dimethylamino)propyl] carbamate HCl (SN66752) and infused into Stoneville 213 and Acala SJ-2 acid-delinted seed of cotton (*Gossypium hirsutum*). The treatments appreciably reduced seedling disease in soil artificially infested with *Rhizoctonia solani* or *Thielaviopsis basicola* alone, in soil infested with *R. solani* and *Fusarium* spp., and in soil infested with a mixture of *Pythium* spp., *R. solani,* and *T. basicola.* None of the fungicides used alone consistently reduced seedling disease. With a few exceptions, methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (benomyl) and methyl benzimidazolecarbamate HCl (MBC-HCl) did not enhance the efficacy of the three new systemic fungicides in reducing seedling damping-off, but their use reduced hypocotyl rot to some extent in the *T. basicola*-infested soil. The BAS 389 + CGA-48988 mixture in acetone was effective at 19 and 27 C and when plants were incubated at 27 C for 1 wk and then at 19 C for 4 wk. Application of BAS 389 in acetone mixtures with CGA-48988 or SN66752 tripled a stand of cotton (Acala SJ-2) in an artificially infested field plot at Beltsville and in a naturally infested plot in Louisiana. Application of BAS 389 alone with acetone was effective in the Beltsville plot, but not in the Louisiana field plot. Differences in stand among seed treatments in the field were less pronounced in naturally infested soil in Texas than in the other two locations. Benomyl and MBC-HCl did not improve seedling stand in the field. Phytotoxicity symptoms were not evident in the field tests.

Additional key words: seed treatment, organic solvent infusion.

Seedling disease (damping-off, seedling blight, seed rot, hypocotyl rot) of cotton (*Gossypium hirsutum* L.) is important in the cotton-producing areas of the USA (1,6,24). The disease can be induced either by a single fungus species or by a complex of soilborne fungi including *Fusarium* spp. (1,5,6,25), *Pythium* spp. (1,4,6,7,25), *Rhizoctonia solani* Kuehn (1,2,5,6,24,25), and *Thielaviopsis basicola* (Berk. & Br.) Ferr. (5,8,10).

Numerous papers on cotton seedling disease control by use of fungicide seed dressings have appeared during the last two decades (3,12,13,17,22–24,26). Some of these papers have been summarized (11,24,27). Most of the research on cotton seed treatments is summarized each year by the National Cotton Council and published in the *Proceedings of the Beltwide Cotton Production Research Conferences.* Very little work has been done, however, with new systemic fungicides for control of cotton seedling disease.

The new systemic fungicide *N*-cyclohexyl-*N*-methoxy-2,5-dimethyl-3-furancarboxamide (BAS 389 05 F; BASF Wyandotte Corp., Parsippany, NJ 07054) has been used sparingly for experimental control of *R. solani* on cotton (13,20,28). The experimental fungicide *N*-(2,6-dimethylphenyl)-*N*-(methoxyacetyl) alanine methyl ester (CGA-48988, Ridomil®, CIBA-Geigy Corp., Greensboro, NC 27409) also has been used with considerable success for experimental control of cotton seedling disease caused by *Pythium* spp. (22). A third experimental fungicide, *S*-ethyl[3-(dimethylamino) propyl]carbamothioate monohydrochloride (SN41703, Previcur®, NOR-AM Agricultural Products, Inc., Woodstock, IL 60098 also has been used experimentally for cotton seed dressings (3). However, SN41703 is no longer available for experimental purposes in the United States. Instead, the oxygen analog propyl [3-(dimethylamino)propyl] carbamate HCl propamocarb, proposed) has become available for experiments on pythiaceous fungi (19,21).

In this paper we report on the efficacy of BAS 389, CGA-48988, SN66752, and other systemic fungicides, used singly or in combination, against cotton seedling disease caused by *Pythium* spp., *R. solani, T. basicola,* and *Fusarium* spp.

MATERIALS AND METHODS

Fungicides and methods of application. The new systemic fungicides used and their sources were: BAS 389 (500 g/liter EC); CGA-48988 (technical, 50 W or 2E); and SN66752 (70% aqueous solution). In addition, benomyl [methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate, Benlate®, E. I. duPont de Nemours & Co., Wilmington, DE 19898] and MBC-HCl (methyl benzimidazolecarbamate HCl) were used. The MBC-HCl was prepared by dissolving 25 g of active benomyl in 500 ml acetone at 24 C, warming the solution to 70 C for 30 min, and mixing it with 400 ml of hot (70 C) 0.35 N HCl (29).

The fungicides were applied to acid-delinted cottonseed either directly or with acetone. With direct application, the liquid fungicides BAS 389 and MBC-HCl were added to batches of seed [BAS 389 at 2.0 and MBC-HCl at 0.75 g of active ingredient (a.i.) per kilogram of seed] and these were shaken thoroughly for 5 min and allowed to dry before being planted. Benomyl 50 W was mixed with graphite and applied to slightly moist seed (1 kg of seed: 2 g of graphite: 1.3 g of benomyl [a.i.]).

The fungicides BAS 389, CGA-48988 technical or 2E, and SN66752, all soluble in several organic solvents, also were applied to cottonseed with acetone by a method described previously (16,17,19). Unless otherwise stated, the fungicides were dissolved in acetone at 2.5% a.i. and the seeds were immersed in the solutions for 45 min. The acetone was evaporated in a hood and the seeds

were stored dry until planting. In some experiments, BAS 389 was combined with CGA-48988 or SN66752 in acetone, the seed was treated as before, and benomyl or MBC-HCl was subsequently added to the seed directly at 1.3 and 0.75 g a.i./kg of seed, respectively.

Greenhouse experiments at Beltsville. All tests in the greenhouse were performed with a sandy loam soil (pH 6.2) brought to the greenhouse from a nearby field that had been kept fallow for at least 10 yr. Emergence in this soil from untreated cottonseed was >80% before soil infestation with the pathogens.

Large batches of soil were placed in greenhouse benches and infested separately with *R. solani* (isolates R-5, R-35, R-85, anastomosis group 4), *T. basicola* (isolates Tb3 and Tb20), and *Pythium* spp. (*P. aphanidermatum* [Edson] Fitzp., *P. myriotylum* Drechs., and *P. ultimum* Trow). The *R. solani* inoculum was grown for 3 wk on sand-cornmeal mixture (97% sand and 3% cornmeal by weight, water to 20% moisture, v/w). The *T. basicola* inoculum was prepared as described previously (18). *Pythium* spp. were grown for 2 wk on autoclaved oats-dilute V8 juice (100 g of oats, 20 ml of V8 juice, 80 ml of water). Inocula were added separately to soil at 2% of the soil weight and the infested soils were planted several times with cottonseed (cultivars Stoneville 213 or Acala SJ-2) to maintain high soil infestation. For each experiment, soils were air-dried and mixed thoroughly in a cement mixer. One-kilogram portions were placed in 12.5-cm-diameter plastic pots and these were planted with 10 acid-delinted cottonseed per pot. For mixtures of pathogens, soils infested with the three pathogens individually were mixed in equal amounts.

For *Rhizoctonia* and *Pythium* infection the pots were incubated for 4–5 wk in a growth chamber at a constant temperature (27 ± 0.3 C with a 14-hr photoperiod, about 3,600 lux). When *T. basicola* was present in the soil, the pots were incubated for 1 wk at 27 C and then the temperature was lowered to 19 ± 0.3 C to facilitate *T. basicola* infection. Cotton seedlings were removed after 4 or 5 wk and percent plant stand was determined from the final plant counts. Hypocotyl rot was also evaluated on a scale of 0 = no disease to 4 = plants dead. Each treatment was replicated six times and all experiments were repeated at least twice.

Populations of *T. basicola* in soils were estimated with the dilution-plate method on a selective medium developed for this pathogen (14). Saprophytic activity of *R. solani* was assayed by means of the tablebeet (*Beta vulgaris* L.) seed colonization method (15). Populations of *Pythium* spp. were estimated with the use of a most probable number technique and differentially selective media (9).

Greenhouse experiments at Lubbock. All greenhouse tests at Lubbock, Texas were performed in two soils infested with *R. solani* and *Fusarium* spp. The soils were planted several times with high rates of low quality Acala SJ-2 cottonseed to increase infestation. The soil used for the April and November 1978 plantings consisted of field (Amarillo loam) soil, builder's sand, and peat moss (3:1:1, v/v). Crusting was not a problem in this mixture. The Amarillo loam soil used for the May and July plantings was not mixed with sand or peat moss. Treated and untreated cottonseed were planted in soil on greenhouse benches at 50 seeds per row and the final stand counts were recorded ~30 days after planting. A disease severity index was determined by the formula:

$$\frac{0(X) + 1(X) + 2(X) + 3(X) + 4(X)}{\text{total number of plants}}$$

in which X = number of plants, 0 = no lesions, 1 = lesions extending one-third of the way around the root, 2 = lesions extending two-thirds of the way around the root, 3 = lesions extending all the way around the root, and 4 = all plants dead. The average data for the four experiments are presented in this paper.

Field experiments. Treated and untreated Acala SJ-2 cottonseed was planted in three field plots in various parts of the country. The same treatments were included in each experiment. The field plot (18 × 20 m) at Beltsville, Maryland was artificially infested on 22 May 1978 with *R. solani* and *T. basicola* (0.4 kg of sand-cornmeal inoculum of *R. solani* and 0.1 kg of oats-V8 juice inoculum of *T. basicola* per square meter). Inocula were applied to the surface of the soil and rototilled into the soil to a depth of 10–12 cm. Cottonseed was planted the same day in 8-m rows (150 seeds per row, five replications), 62 cm apart, in a randomized block design. Since no herbicides were used, weeds were removed manually. Plant stand was recorded 1, 21, 31, and 36 days after planting. Treated and untreated seeds of this experiment also were planted in the greenhouse in soil infested with a mixture of *Pythium* spp., *R. solani,* and *T. basicola* (1:1:1, v/v).

The other two field plots were naturally infested with fungi causing cotton seedling disease. At St. Joseph, LA the prevalent cotton seedling pathogens were *Pythium* spp. and *R. solani.* The experiment was established on 10 April 1978 in six 11-m rows (one row = one replication), 200 seeds per row, in a randomized block design. Stand counts were recorded 8 wk after planting. At Lubbock, TX the prevalent seedling pathogens were *R. solani, T. basicola, Fusarium* spp., and nematodes (*Meloidogyne incognita acrita* (Kofoid & White) Chitwood). Treated and untreated cottonseed from the Beltsville experiment was planted 10 May 1978 in six 16-m rows, 400 seeds per row. The experimental design was a randomized block with six replications and two rows per plot. Stand counts were recorded 4 wk after planting. Cotton lint yield was also recorded at harvest.

RESULTS

Greenhouse experiments at Beltsville. In the first experiment with Stoneville 213 cottonseed planted in soil infested with *R. solani* alone (saprophytic activity of *R. solani* was 86%), BAS 389

TABLE 1. Effect of fungicides applied to Stoneville 213 cottonseed directly or with acetone infusion on seedling disease caused by *Rhizoctonia solani*

Fungicide[x]	Plant stand[y] (%)	
	1 wk	5 wk
None (control)	55 def[z]	54 def
Acetone (control)	56 def	55 def
BAS 389, 2.5% in acetone		
No benomyl	65 cdef	65 cdef
Benomyl	52 efg	52 efg
MBC-HCl	48 fg	40 g
BAS 389 + SN66752, each 2.5% in acetone		
No benomyl	67 bcde	70 bcde
Benomyl	67 bcde	75 abcd
MBC-HCl	70 bcde	73 abcd
BAS 389 + CGA-48988, each 2.5% in acetone		
No benomyl	77 abc	87 ab
Benomyl	80 abc	93 a
MBC-HCl	82 abc	83 abc

[x]Cottonseed was immersed in the acetone-fungicide solutions for 45 min. Rates used (grams a.i./kg seed): benomyl, 1.3; MBC-HCl, 0.75.
[y]Plants kept continuously at 27 C.
[z]Values followed by the same letters do not differ significantly ($P = 0.05$) according to Duncan's multiple range test. Averages are based on six replications.

did not provide any control of seedling disease (Table 1). Addition of benomyl or MBC-HCl to the BAS 389-acetone did not improve the efficacy of BAS 389. In fact, plant stand at 5 wk from seed treated with MBC-HCl was lower than that of the untreated control or the acetone control.

All seed treatments with BAS 389 + CGA-48988 in acetone, with or without benomyl or MBC-HCl, decreased seedling disease considerably at 1 and 5 wk. The combination BAS 389 + SN66752 was less effective.

The treated and untreated Stoneville 213 seed of the first experiment also was planted in soil infested with *T. basicola* alone (800 propagules per gram soil). All fungicide-solvent treatments containing BAS 389 with CGA-48988 or SN66752 reduced hypocotyl rot and seedling disease significantly more compared with the control treatments and considerably more than did BAS 389 alone in the soil containing *T. basicola* (Table 2). Benomyl or MBC-HCl did not enhance the efficacy of the infused fungicides in reducing damping-off, but they reduced somewhat the severity of hypocotyl and root rot. The BAS 389-acetone treatment alone or with benomyl or MBC-HCl was not as effective as the combinations of infused fungicides.

Soil containing all three pathogens (*Pythium* spp., *R. solani,* and *T. basicola*) also was planted with treated and untreated cottonseed. The soil infested with the three pathogens contained 285 and 450 propagules of *Pythium* spp. and *T. basicola* per gram of soil, respectively, and had a 60% saprophytic activity of *R. solani.* All seed treatments containing BAS 389 plus CGA-48988 or SN66752 in acetone (with or without benomyl or MBC-HCl) reduced disease considerably in soil infested with *Pythium* spp., *R. solani,* and *T. basicola* (Table 3). For instance, more than 80% of the seedlings from cottonseed treated with BAS 389 + CGA-48988 in acetone, with or without benomyl or MBC-HCl, survived after exposure to 27 C for 1 wk and then to 19 C for 4 wk, whereas only 15% of the seedlings from untreated or acetone-treated seed survived under the same conditions. In this experiment, BAS 389 alone reduced seedling disease at 5 wk to some extent, but it was not as effective as the above combinations.

In another experiment involving soil infested with the three

TABLE 2. Effect of fungicides applied to Stoneville 213 cottonseed directly or with acetone infusion on seedling disease caused by *Thielaviopsis basicola*

Fungicide[x]	Plant stand (%) After 1 wk at 27 C	Plant stand (%) After 1 wk at 27 C and then 4 wk at 19 C	Disease severity index[y] at 5 wk
None (control)	18 ghi[z]	5 i	3.6 d
Acetone (control)	20 ghi	6 i	3.5 d
BAS 389, 2.5% in acetone			
No benomyl	53 de	27 fgh	3.0 cd
Benomyl	38 ef	12 hi	3.5 d
MBC-HCl	35 gh	8 i	3.0 cd
BAS 389 + SN66752, each 2.5% in acetone			
No benomyl	87 a	65 bcd	2.5 bc
Benomyl	75 abc	73 abc	2.5 bc
MBC-HCl	68 bcd	60 cd	2.0 ab
BAS 389 + CGA-48988, each 2.5% in acetone			
No benomyl	82 ab	75 abc	2.5 bc
Benomyl	82 ab	80 ab	2.0 ab
MBC-HCl	80 ab	90 a	1.8 a

[x]Cottonseed was immersed in the acetone-fungicide solutions for 45 min. Rates used (grams a.i./kg seed): benomyl, 1.3; MBC-HCl, 0.75.
[y]Scale: 0 = no visible disease to 4 = plants dead.
[z]For plant stand and disease index separately, values followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test. Averages are based on six replications.

TABLE 3. Effect of fungicides applied to Stoneville 213 cottonseed directly or with acetone infusion on seedling disease caused by a mixture of *Pythium*[w] spp., *Rhizoctonia solani,* and *Thielaviopsis basicola*

Fungicide[x]	Plant stand (%) After 1 wk at 27 C	Plant stand (%) After 1 wk at 27 C and then 4 wk at 19 C	Disease severity index[y] at 5 wk
None (control)	58 cde[z]	15 g	3.5 d
Acetone (control)	56 cde	15 g	3.5 d
BAS 389, 2.5% in acetone			
No benomyl	53 de	45 ef	3.0 cd
Benomyl	45 e f	28 fg	3.2 cd
MBC-HCl	43 e f	15 g	3.5 d
BAS 389 + SN66752, each 2.5% in acetone			
No benomyl	73 abc	72 abc	2.5 bc
Benomyl	73 abc	83 ab	1.6 a
MBC-HCl	72 abc	82 ab	1.5 a
BAS 389 + CGA-48988, each 2.5% in acetone			
No benomyl	75 ab	88 a	2.0 ab
Benomyl	70 abcd	83 ab	1.5 a
MBC-HCl	68 bcd	87 ab	1.5 a

[w]*Pythium aphanidermatum, P. myriotylum,* and *P. ultimum.*
[x]Cottonseed was immersed in the acetone-fungicide solutions for 45 min. Rates used (grams a.i./kg seed): benomyl, 1.3; MBC-HCl, 0.75.
[y]Scale: 0 = no visible disease to 4 = plants dead.
[z]For plant stand and and disease index separately, values followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test. Averages are based on six replications.

pathogens at the same inoculum densities as before, Acala SJ-2 cottonseed was treated with BAS 389 applied directly and with BAS 389, CGA-48988, or SN66752 applied to the seed individually with acetone infusion at lower rates than those used in the previous experiments (1.5 and 2.0% in acetone for CGA-48988 and SN66752, respectively). The BAS 389 also was applied to the seed in acetone mixtures with CGA-48988 or SN66752 supplemented or not with benomyl or MBC-HCl. The pots were incubated for 4 wk continuously at 19 and 27 C. At both temperatures, all BAS 389 + CGA-48988 treatments, with or without benomyl or MBC-HCl, significantly increased plant stand in this heavily infested soil (Table 4). The BAS 389 + SN66752 combination increased plant stand only when it was combined with MBC-HCl. None of the three new systemic fungicides increased plant stand when used alone either directly or with acetone.

Greenhouse experiments at Lubbock. The seed treated with single fungicides and combinations was planted four times in 1978 (April 28, May 25, July 25, and November 3) in the greenhouse at Lubbock in each of the two soils infested with *R. solani* and *Fusarium* spp. The fungicide BAS 389 alone or combined with other fungicides provided excellent control, manifested by plant stands and low disease severity ratings, in both soils (Table 5). Little or no control was observed when BAS 389 was not included in the seed treatment.

Field experiments. The single fungicides and their combinations as shown in Table 4 were applied to large batches of Acala SJ-2 cottonseed and lots of seed treated identically were planted in three field experiments. In the artificially infested field plot at Beltsville, seedling disease was significantly reduced by BAS 389 alone infused into the seed with acetone or by BAS 389 combined with CGA-48988 or SN66752, with or without benomyl or MBC-HCl (Table 6). Differences in stand between the effective treatments and the controls were not as pronounced as those observed in the greenhouse tests (Table 4,5). Application of BAS 389 to the seed directly and applications of CGA-48988 or SN66752 singly with acetone infusion were not effective.

Plant stands at Beltsville recorded at 11, 21, 31, and 36 days showed that seedling disease reduced stand progressively with time up to 21 days with plant populations being stable for the duration of the experiment (6 September 1978). Four of the six treatments that were effective at 11 days remained effective to the end of the experiment (Fig. 1). No phytotoxicity symptoms were observed on any of the treatments in the field.

In the Louisiana field test, BAS 389 + SN66752, and BAS 389 +

TABLE 4. Effect of fungicides applied to Acala SJ-2 cottonseed directly or with acetone infusion on seedling disease caused by a mixture of *Pythium*[x] spp., *Rhizoctonia solani,* and *Thielaviopsis basicola*

Fungicide[y]	Concentration (grams a.i./kg of seed)	Plant stand (%) At 19 C for 4 wk	Plant stand (%) At 27 C for 4 wk
None (control)		0 c[z]	0 d
BAS 389	2.0	0 c	2 d
BAS 389, 2.5% in acetone		0 c	0 d
CGA-48988, 1.5% in acetone		0 c	0 d
SN66752, 2.0% in acetone		0 c	0 d
BAS 389 + SN66752 (2.5 and 2.0%, respectively) in acetone			
No benomyl		10 c	12 cd
Benomyl	1.3	12 c	18 c
MBC-HCl	0.75	32 b	40 b
BAS 389 + CGA-48988 (2.5 and 1.5%, respectively) in acetone			
No benomyl		72 a	42 b
Benomyl	1.3	84 a	64 a
MBC-HCl	0.75	80 a	76 a

[x] *Pythium aphanidermatum, P. myriotylum,* and *P. ultimum.*
[y] Cottonseed was immersed in the acetone-fungicide solutions for 45 min.
[z] In each column, values followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test. Averages are based on six replications.

TABLE 5. Effect of fungicides applied to Acala SJ-2 cottonseed directly or with acetone infusion on seedling disease caused by a mixture of *Rhizoctonia solani* and *Fusarium* spp.[w] in the greenhouse at Lubbock, TX

Fungicide[x]	Concentration (grams a.i./kg of seed)	Total seedling emergence (%)	Plant stand at 30 days (%)	Disease severity index[y]
None (control)		51 b[z]	15 b	2.6 a
BAS 389	2.0	81 a	68 a	1.9 b
BAS 389, 2.5% in acetone		80 a	69 a	2.1 b
CGA-48988, 1.5% in acetone		57 b	28 b	2.5 a
SN66752, 2.0% in acetone		47 b	20 b	2.9 a
BAS 389 + SN66752 (2.5 and 2.0%, respectively) in acetone				
No benomyl		80 a	62 a	2.0 b
Benomyl	1.3	73 a	62 a	1.8 b
MBC-HCl	0.75	74 a	59 a	1.8 b
BAS 389 + CGA-48988 (2.5 and 1.5%, respectively) in acetone				
No benomyl		81 a	69 a	2.0 b
Benomyl	1.3	83 a	73 a	1.9 b
MBC-HCl	0.75	86 a	72 a	1.8 b

[w] Average of 28 April, 25 May, 25 July, and 3 November 1978 data.
[x] Cottonseed was immersed in the acetone-fungicide solutions for 45 min.
[y] Scale: 0 = no visible disease to 4 = plants dead.
[z] In each column, values followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test. Averages based on five replications.

TABLE 6. Effect of fungicides applied to Acala SJ-2 cottonseed either directly or with acetone infusion on seedling disease in the field[x]

Fungicide[y]	Concentration (grams a.i./kg of seed)	Plant stand (%) at indicated wk after planting		
		Beltsville, MD (4.5 wk)	St. Joseph, LA (8 wk)	Lubbock, TX (4 wk)
None (control)		16 cd[z]	14 bc	68 abcd
Acetone (control)		14 cd	15 bc	...
BAS 389	2.0	17 cd	35 a	65 bcd
BAS 389, 2.5% in acetone		45 ab	26 abc	63 d
CGA-48988, 1.5% in acetone		12 d	26 abc	64 cd
SN66752, 2.0% in acetone		8 d	12 c	68 abcd
BAS 389 + SN66752 (2.5 and 2.0%, respectively) in acetone				
No benomyl		25 bcd	35 a	71 abc
Benomyl	1.3	34 abc	46 a	64 cd
MBC-HCl	0.75	42 ab	29 abc	68 abcd
BAS 389 + CGA-48988 (2.5 and 1.5%, respectively) in acetone				
No benomyl		39 ab	36 a	72 ab
Benomyl	1.3	49 a	41 a	71 abc
MBC-HCl	0.75	37 abc	31 ab	74 a

[x]The field plot at Beltsville was infested with *Thielaviopsis basicola* and *Rhizoctonia solani* 3 wk before planting; the other two plots were naturally infested.
[y]Cottonseed was immersed in the acetone-fungicide solutions for 45 min.
[z]In each column, values followed by the same letter do not differ significantly ($P = 0.05$), according to Duncan's multiple range test. All averages are based on five replications.

CGA-48988 with or without benomyl were the only cottonseed treatments that significantly reduced seedling disease (Table 6). In general, disease incidence was high in the naturally infested Louisiana plot. Seedling disease of cotton was less severe in the Lubbock plot than in the other two plots (Table 6). Stand counts at Lubbock recorded about 30 days after planting indicated that no treatment differed from the untreated control. The treatments containing BAS 389 + CGA-48988 (with or without an MBC fungicide) and BAS 389 + SN66752 (without an MBC fungicide) resulted in slightly higher stands and lint yields than the untreated control.

DISCUSSION

Our tests with the new systemic fungicides BAS 389, CGA-48988, and SN66752, applied to cottonseed either directly or with acetone infusion, showed the importance of quantitative and qualitative knowledge of the pathogens present in the soil in selecting single fungicides or combinations for seedling disease control. For instance, BAS 389 provided excellent control of cotton seedling disease in soil infested with *R. solani* in the greenhouse experiments at Lubbock (Table 5) but not in similar experiments at Beltsville (Table 1). In the Beltsville soil, BAS 389 was very effective when it was combined with CGA-48988, a fungicide specific for pythiaceous fungi. Further analysis of the Beltsville soil showed that it contained a natural population of *Pythium* spp. (60–80 propagules per gram of soil) capable of causing damping-off. The CGA-48988 was needed, therefore, to suppress *Pythium* spp., for which BAS 389 is not effective.

The importance of knowing the kinds of pathogens in soil before selecting the fungicides is further emphasized by the data in Table 4. The fungicides BAS 389, CGA-48988, and SN66752 used alone were completely ineffective in soil that had been infested with *R. solani, T. basicola,* and *Pythium* spp. The BAS 389 is fungitoxic to *R. solani* and, to some extent, *T. basicola.* Combinations of these fungicides, however, provided excellent control not only at 27, but also at 19 C, a temperature which is conducive to infection by *T. basicola* (17).

The second point shown by the present studies was the failure of benomyl and MBC-HCl to enhance the efficacy of the infused fungicides in suppressing cotton damping-off. Benomyl, however, reduced both root and hypocotyl rots. This finding is in agreement with previous research (17) in which benomyl improved the performance of other fungicides in the suppression of *T. basicola* when root rot rather than damping-off was used as the index of suppression. It is also of interest that the combinations BAS 389 + CGA-48988 and, to a lesser extent, BAS 389 + SN66752 reduced the damping-off phase in a soil containing *T. basicola* together with *R. solani* and *Pythium* spp.

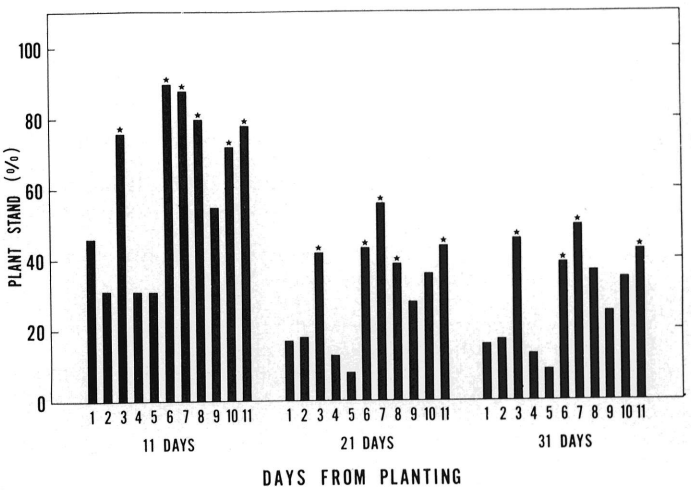

Fig. 1. Effect of fungicides applied to Acala SJ-2 cottonseed directly or with acetone infusion on seedling disease in a Beltsville field infested with *Pythium* spp., *Rhizoctonia solani,* and *Thielaviopsis basicola.* Numbers under columns designate treatments, as follows: 1, control; 2, BAS 389, applied directly at 2.0 g/kg of seed; 3, BAS 389, 2.5% in acetone; 4, CGA-48988, 1.5% in acetone; 5, SN66752, 2.0% in acetone; 6, BAS 389 + CGA-48988, 2.5 and 1.5% in acetone, respectively; 7, as in 6 plus benomyl at 1.3 g/kg of seed; 8, as in 6 plus MBC-HCl at 0.75 g/kg of seed; 9, BAS 389 + SN66752, 2.5 and 2.0% in acetone, respectively; 10, as in 9 plus benomyl; 11, as in 9 plus MBC-HCl. Values for columns with an asterisk differ significantly ($P = 0.05$) from the control value by Duncan's multiple range test. Averages are based on five replications.

The importance of knowing the pathogenic potential of soils also is emphasized by the results of the three field experiments performed in widely separated areas of the USA. Seed treatments, for instance, did not increase stand or yield substantially over the control at Lubbock. Although the soil at Lubbock was naturally infested with several pathogens, cotton seedling disease was very mild in the control in 1978. In contrast, the surviving stand would have been disastrously low at Beltsville and St. Joseph, Louisiana without the seed treatments. The seed treatments with the appropriate fungicides were, therefore, needed as an adequate

guarantee for obtaining a satisfactory stand in the field.

Because of the ability of cotton plants to compensate for stand differences, especially during favorable growing conditions, it is often difficult to obtain significant yield differences among seed treatments. Some fungicide treatments in our study had higher lint yields than the control, but the differences were not significant. One treatment produced 44 kg/ha more lint than the check; thus, the gross returns to the producer were increased $27/ha, while the effective fungicide cost about $2.2/ha. With more severe disease, seed dressings have increased lint yields significantly (E. B. Minton, *unpublished*) at Lubbock. Also, fungicides more effectively increase yields when adverse weather occurs for extended periods during the growing season, which was not the case in 1978.

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