Published May, 1972

Multiple Cottonseed Treatments: Effects on Germination, Seedling Growth, and Survival[1]

C. D. Ranney[2]

ABSTRACT

This study evaluated the direct effect of, and interactions between, pesticides used as seed treatments on germination, seedling growth, and field survival of cotton (*Gossypium hirsutum* L.). Six nonmercurial protectant fungicides, *N*-[(trichloromethyl)thio]-4-cyclohexene-1,2-dicarboximide (captan), bis(dimethylthiocarbamoyl)disulfide (thiram), 2-(thiocyanomethylthio)benzothiazole (Busan 72), combinations of pentachloronitrobenzene + 5-ethoxy-3-trichloromethyl-1,2,4-thiadiazole (Terracoat L21), tetrachloroisophthalonitrile + sodium-*p*-(dimethylamino) benzene diazosulfonate (chlorothalonil + Dexon), and pentachloronitrobenzene + sodium-*p*-(dimethylamino) benzene diazosulfonate (PCNB + Dexon); two systemic fungicides, 1,4-dichloro-2,5-dimethoxybenzene (chloroneb) and 5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxanilide (carboxin); and the systemic insecticide, *0,0*-diethyl S-[2-(ethylthio)ethyl]phosphorodithioate (disulfoton), were used alone and in all combinations of the pesticide types. When used in a treatment, the protectant fungicide was applied first, followed by the systemic fungicide and the systemic insecticide. Evaluations included germination tests at standard conditions, at constant 20 C, and constant 30 C. Dry weight transfer (DWT) determinations were also made at 20 and 30 C. Percent seedling survival in the field 42 days after planting was determined.

Use of a protectant fungicide either significantly improved germination and seedling growth or did not affect these factors. A significant increase in seedling survival, 22 to 42%, resulted from the use of the various protectant fungicides. The inclusion of a systemic fungicide in the treatment combinations tended to reduce germination and DWT values but improved stands by 40%. Inclusion of the systemic insecticide in the treatment combinations resulted in reduced germination, DWT, and seedling survival (13%). Where the systemic insecticide was used, the inclusion of a systemic fungicide further reduced germination values but often resulted in significant increases in seedling survival. Significant interactions among the different types of chemical treatments and suggestions that temperature affected the treatment response indicate the need to identify combinations of chemicals for seed treatment that are safe and effective under various environmental conditions.

Additional index words: **Fungicides, Systemic insecticides, Chemical interactions, *Gossypium hirsutum* L.**

TREATMENT of cottonseed (*Gossypium hirsutum* L.) with a protectant fungicide is a standard practice throughout the Cotton Belt (4, 7). In many areas systemic fungicides and systemic insecticides are also applied as seed treatments (4, 6, 7). In the development of these multipesticide treatments organic mercury compounds were the materials commonly used as the seed protectant fungicide. There are several nonmercurial seed protectants that are as good or better than the organic Hg compounds (4, 7). However, only a few of these materials have been evaluated in multiple pesticide treatments (6, 8). The purpose of the investigations reported here was to evaluate the direct effect of six nonmercurial seed protectants and possible interactions of these materials with other pesticides used in seed treatment on germination, seedling emergence, and growth of seedling cotton plants.

MATERIALS AND METHODS

Seeds used in these studies were acid-delinted 'Stoneville 213' (84% germination), heavily infested with fungi. Chemicals were applied with a nasal-atomizer onto seeds tumbling in a rotating drum-mixer. In all treatments where multiple materials were used the protectant fungicides were applied first, followed by the systemic fungicides. Seeds were then air-dried in the laboratory for 3 days to equalize seed moisture. Then seed samples were treated with the systemic insecticide and were packaged immediately after treatment in tightly closed glass jars to avoid chemical loss. Comparative treatments not receiving the systemic insecticide were packaged at the same time and in the same manner. Seeds were stored in the laboratory for 14 days before testing was started and the jars were opened only to withdraw samples.

The following chemicals and rates were used:

Seed Protectant Fungicides:

Single fungicides:[3]

Busan 72 — 60% 2-(thiocyanomethylthio)benzothiazole, 1.96 ml/kg (3 fl oz/cwt).

Captan — 75% *N*-[(trichloromethyl)thio]-4-cyclohexene-1,2-dicarboximide, 1.25 g/kg (2 oz/cwt).

Thiram — 70% bis(dimethylthiocarbamoyl) disulfide, 1.88 g/kg (3 oz/cwt).

[1] Received for publication Nov. 5, 1971.

[2] Research Plant Pathologist, Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, Plant Industry Station, Beltsville, Md. 20705.

[3] Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture, and does not imply its approval to the exclusion of other products that may also be suitable.

Combinations of fungicides:

Chlorothalonil + Dexon — 40% tetrachloroisophthalonitrile + 32% sodium-*p*-(dimethylamino)benzenediazo sulfonate, 1.25 g/kg (2 oz/cwt).

PCNB + Dexon — 50% pentachloronitrobenzene + 23.3% sodium-*p*-(dimethylamino)benzenediazo sulfonate, 4.38 g/kg (7 oz/cwt).

Terracoat L21 — 22.9% pentachloronitrobenzene + 11.4% 5-ethoxy-3-trichloromethyl-1,2,4-thiadiazole, 7.8 ml/kg (12 fl oz/cwt).

Systemic fungicides:

Carboxin — 75% 5,6-dihydro-2-methyl-1,4-oxathiin-3-carboxanilide, 5.00 g/kg (8 oz/cwt).

Chloroneb — 65% 1,4-dichloro-2,5-dimethoxybenzene, 6.25 g/kg (10 oz/cwt).

Systemic Insecticide:

Disulfoton — 96% *0,0*-diethyl S-[2-(ethylthio)ethyl] phosphorodithioate, 4.5 ml/kg (6.9 fl oz/cwt).

Germination studies were conducted by placing 50 seeds between two 30.5- by 45.7-cm (12- by 18-inch) germination papers that were wet with distilled water, made into a roll, covered with wax paper, and held in a vertical position. Each treatment was replicated eight times. Treatments were arranged in a split-split plot design in the germinators. Main plots were treated with protectant fungicides, subplots were treated with systemic fungicides, and split plots were treated with systemic insecticides. Three different temperature regimes were used to evaluate effects on germination: (i) Standard germination test (9), 16 hours at 20 C and 8 hours at 30 C for 12 days. After 4 days germinated seed were counted and removed from the seed-rolls and the rolls were returned to the germinator for final evaluation at 12 days; (ii) Continuous 20 C, germination was evaluated after 7 days; (iii) Continuous 30 C, germination was evaluated after 4 days. Percent germination was recorded for each seed-roll. A seed was considered to have germinated if the emerging radicle was at least 8 mm long.

The effect of the various treatments on seedling growth was assayed by a modification of the DWT method of Christiansen (1). Twenty-five seeds were placed in seed rolls as above; at the end of the respective growth periods the most uniform 20 seedlings were selected from each seed-roll. The cotyledons were separated from the plant axis. The tissues were ovendried at 65 C for 24 hours, were cooled in a desiccator, and were weighed. The DWT method yields a measure of seedling growth in terms of the amount of cotyledon reserves transferred to the axial parts of the developing plant. It is expressed as:

$$\text{DWT} = (\text{Dry wt of axial plant tissue}/\text{Dry wt of total plant}) \times 100$$

DWT determinations were made at two temperature-time regimes, 20 C for 7 days and 30 C for 4 days. Each treatment was replicated eight times, with treatments arranged in a split-split plot design in the germinators.

A field evaluation of these treatments was possible through the cooperation of Dr. Robert G. Davis at the Delta Branch Station of the Mississippi Agricultural Experiment Station at Stoneville, Miss. A split-split plot design was used with eight replications. A single plot consisted of 150 seeds planted 3.8 cm deep in a 9-m row with a belt planter. Stand counts were made 42 days after planting on April 27, 1971.

RESULTS

In several cases, higher germination, due to control of external and internal seedborne disease organisms, was obtained with the use of the protectant fungicides (Table 1). Species of *Fusarium, Aspergillus, Alternaria, Rhizopus, Penicillium,* and various bacteria constituted 86% of the organisms responsible for seed rot or seedling decay. *Xanthomonas malvacearum* (E.F. Sm.) Dows. accounted for less than 1% of the infections and *Glomerella gossypii* Edg. was not detected. There was considerable variation in response to treatment with the systemic fungicides. In the standard germination test treatment with either systemic fungicide resulted in a statistically significant reduction in

Table 1. Effects of seed treatment with protectant fungicides, systemic fungicides, and a systemic insecticide on percent germination at three temperature regimes and dry weight transfer at two temperature regimes, percent seedling survival in the field, and a summary of interactions among different chemical treatments.

Seed treatments		% seed germination*			Dry weight transfer*		% seedling survival in the field*
Material	Dosage g-ml/kg	Std. test	20°	30°	20°	30°	
Protectant fungicides							
None	-0-	87.5 b	83.9 bc	84.9 b	27.9 c	32.7 a	36.3 d
Captan	1.25	89.7 a	84.5 b	86.5 ab	28.0 c	33.0 a	46.3 bc
Thiram	1.88	89.9 a	85.4 b	87.0 ab	27.9 c	32.9 a	44.6 c
Terracoat L21	7.80	87.2 b	82.2 c	85.1 b	28.3 c	32.4 a	50.4 ab
Busan 72	1.96	88.1 ab	88.7 a	87.7 a	32.6 a	31.5 a	46.2 bc
Chlorothalonil + Dexon	1.25	88.7 ab	87.5 a	86.8 ab	31.1 b	32.6 a	46.8 bc
PCNB + Dexon	4.38	88.2 ab	84.2 b	84.6 b	30.4 b	31.6 a	51.9 a
Coeff. of variation		5.1	5.3	6.5	11.6	10.1	22.9
Systemic fungicides							
None	-0-	89.6 a	85.7 a	86.1 a	29.8 a	32.6 a	36.2 b
Chloroneb	6.25	88.2 b	85.9 a	86.2 a	29.3 b	32.4 a	50.3 a
Carboxin	5.00	87.6 b	83.9 b	86.0 a	29.2 b	32.2 a	51.6 a
Coeff. of variation		5.6	5.0	5.9	5.0	4.8	17.4
Systemic insecticide							
None	-0-	90.3 a	85.9 a	87.2 a	30.1 a	33.3 a	49.0 a
Disulfoton	4.5	86.7 b	84.4 b	84.9 b	28.9 b	31.5 b	43.1 b
Coeff. of variation		4.7	6.0	5.4	7.3	4.9	16.1
Interactions							
PF × SF		ns	ns	ns	1%	5%	1%
PF × SI		1%	ns	1%	1%	1%	ns
SF × SI		5%	ns	ns	ns	ns	ns
PF × SF × SI		5%	ns	ns	ns	ns	ns

* Means not followed by the same letter are significantly different at the 5% level as measured by Duncan's New Multiple Range Test.

germination. This was also true of carboxin in the 20-C test. However, the magnitude of these reductions in germination are relatively small; the maximum difference was only 2%. In the case of the use of a systemic insecticide, a statistically significant reduction in germination was associated with the use of this material in all the germination tests; again the magnitude of this reduction was relatively small.

Results from the DWT studies were similar to the results of the germination studies. Control of damage, caused by seedborne disease organisms, through the use of any protectant fungicide, resulted in an improved DWT in the 20-C test and in no differences in the 30-C test. At the lower temperature conditions the use of systemic fungicides resulted in a statistically significant reduction in DWT. When seeds were treated with disulfoton, significant reductions in DWT, at twice the magnitude of that associated with the use of systemic fungicides, were evident in both DWT tests.

Results from the field test indicate that the use of any seed protectant fungicide resulted in a significant increase in seedling survival. Under field conditions the inclusion of either of the systemic fungicides increased seedling survival by 40%, compared with stands where the systemic fungicides were not used. When disulfoton was included in the treatment combinations, seedling survival was reduced 13%.

Interactions between protectant fungicides and systemic fungicides were significant in three evaluations; seedling survival in the field and DWT at 20 and 30-C. Any protectant-systemic fungicide treatment, even treatment with a systemic fungicide alone, resulted in better seedling survival in the field than no seed treatment (Table 2). While this difference can contribute to the significant interaction the major causes were the different responses associated with the use of the systemic fungicides in the presence of the various protectant fungicides. When captan, Ter-

Table 2. Effects of protectant fungicides and systemic fungicides on cotton seedling dry weight transfer measurements at 20 and 30 C and seedling survival in the field.

Seed treatment		Dry weight transfer at:*		% seedling survival in the field*
Protectant fungicide ×	Systemic fungicide	20°	30°	
None	None	27.3 h	32.5 abcdefg	16.0 e
	Chloroneb	28.0 efgh	33.2 abc	43.9 c
	Carboxin	28.4 efgh	32.4 abcdefg	49.2 abc
Captan	None	28.7 ef	33.3 ab	34.8 d
	Chloroneb	27.4 gh	32.5 abcdefg	51.3 ab
	Carboxin	27.9 efgh	33.1 abc	52.7 ab
Thiram	None	27.8 efgh	32.9 abcd	34.7 d
	Chloroneb	28.2 efgh	32.9 abcd	46.7 bc
	Carboxin	27.6 fgh	32.8 abcde	52.4 ab
Terracoat L21	None	28.6 efg	32.7 abcdef	47.6 abc
	Chloroneb	27.4 gh	32.0 abcdefgh	52.2 ab
	Carboxin	28.8 e	32.6 abcdefg	51.2 ab
Busan 72	None	34.1 a	31.0 h	36.5 d
	Chloroneb	32.0 b	31.9 cdefgh	53.0 ab
	Carboxin	31.8 b	31.7 defgh	49.0 abc
Chlorothalonil + Dexon	None	31.2 bc	33.6 a	33.3 d
	Chloroneb	31.7 b	32.7 abcdef	53.6 a
	Carboxin	30.9 cd	31.6 efgh	53.4 ab
PCNB + Dexon	None	31.0 bc	32.1 bcdefgh	50.9 ab
	Chloroneb	30.4 cd	31.3 gh	51.8 ab
	Carboxin	29.8 d	31.5 fgh	53.2 ab
Coefficient of variation		5.0	4.8	17.4

* Means not followed by the same letter are significantly different at the 5% level as measured by Duncan's New Multiple Range Test.

racoat L21, chlorothalonil + Dexon, or PCNB + Dexon was used no differences occurred between chloroneb or carboxin treatments. In the absence of a protectant fungicide, or where thiram was used, the use of carboxin resulted in higher seedling survival than when chloroneb was used in the treatment combination. In the case of Busan 72 the opposite was evident. Furthermore, when either Terracoat L21 or PCNB + Dexon was used there were no differences in response associated with the inclusion of either chloroneb or carboxin in the treatment combination. In all other cases, the inclusion of the systemic fungicides increased seedling survival.

At 20 C no reduction in DWT was associated with the use of any of the protectant fungicides. There were three instances where DWT was significantly increased. In four combinations, captan-chloroneb, Busan 72-chloroneb, Busan 72-carboxin, and PCNB + Dexon-carboxin, the inclusion of the systemic fungicide resulted in significant reductions in DWT in comparison to use of the seed protectant alone; in the other comparisons there were no significant differences in DWT. With the exception of thiram, the use of any of the protectant fungicides resulted in a higher DWT than that of seedlings not receiving any treatment.

In the 30-C study, responses in DWT to treatment combinations involving Busan 72 or PCNB + Dexon were quite different from those associated with other protectant fungicides. Use of Busan 72 alone resulted in a significantly lower seedling DWT than that of the untreated seeds. With this exception, DWT was higher where only the protectant fungicides were used. The differences in DWT associated with use of seed protectants, and especially Busan 72, in the 20- and the 30-C DWT tests, suggest a probable protectant fungicide × temperature interaction.

Significant interactions resulted from the use of protectant fungicides and systemic insecticides (Table 3). In the standard germination test inclusion of disulfoton in the treatment combination with either Terracoat L21, Busan 72, chlorothalonil + Dexon, or

Table 3. Effects of protectant fungicides and systemic insecticides on cottonseed germination and dry weight transfer measurements at 20 and 30 C.

Seed treatment		% seed germination at:*		Dry wt transfer at:*	
Protectant fungicide ×	Systemic insecticide	Standard test	30°	20°	30°
None	None	88.2 cd	84.8 de	28.6 e	33.9 a
	Disulfoton	86.9 de	85.0 de	27.2 f	31.5 cde
Captan	None	91.0 ab	88.5 ab	29.0 de	34.1 a
	Disulfoton	88.5 bcd	84.5 de	27.1 f	31.9 cd
Thiram	None	90.6 abc	88.2 abc	29.5 de	34.0 a
	Disulfoton	89.2 bcd	85.7 bcd	26.2 f	31.8 cd
Terracoat L21	None	88.8 bcd	85.6 bcd	29.3 de	33.9 a
	Disulfoton	85.6 e	84.6 de	27.2 f	31.1 de
Busan 72	None	91.1 ab	90.2 a	33.2 a	32.5 bc
	Disulfoton	85.1 e	85.3 cd	32.1 ab	30.6 e
Chlorothalonil + Dexon	None	91.8 a	86.2 bcd	30.9 bc	33.2 ab
	Disulfoton	85.7 e	87.3 abcd	31.3 bc	32.0 cd
PCNB + Dexon	None	90.8 ab	87.0 bcd	30.0 cd	31.7 cd
	Disulfoton	85.7 e	82.2 e	30.8 bc	31.5 cde
Coefficient of variation		4.7	5.4	7.3	4.9

* Means not followed by the same letter are significantly different at the 5% level as measured by Duncan's New Multiple Range Test.

PCNB + Dexon resulted in significant reductions in germination. In combination with other protectant fungicides, or where protectant fungicides were not used, the germination reduction was not significant. Four treatment combinations resulted in lower germination than the untreated seeds. A similar situation exists in the 30-C germination test; in three of the seven possible comparisons there was a significant germination reduction associated with the inclusion of disulfoton in the treatment combination. In two cases there was a slight nonsignificant reduction, and in two cases, seeds without a protectant fungicide treatment and chlorothalonil + Dexon treated seeds, there were nonsignificant increases in germination associated with the use of disulfoton.

The data on DWT at 20 C indicate that seeds treated with either Busan 72, chlorothalonil + Dexon, or PCNB + Dexon were more effective in transferring food reserves into axial growth than untreated seeds. Also with these three protectant fungicides, the inclusion of disulfoton in the treatment combinations did not cause significant reductions in DWT. In contrast, where the seeds were not treated with a protectant fungicide or with one of the other protectants the inclusion of disulfoton in the combinations resulted in significant reductions in DWT. During evaluation of the seed-rolls, the presence of fungal growth radiating from one or more diseased seeds was recorded. The frequency of occurrence for this event was as follows: seeds not receiving a protectant fungicide, 61%; captan, 22%; thiram, 15%; Terracoat L21, 13%; Busan 72, 9%; chlorothalonil + Dexon, 8%; and PCNB + Dexon, 8%. The lower incidence of fungal growth and possible affect on adjacent seedlings associated with the latter three treatments may be a factor affecting DWT and germination values. In DWT studies at 30 C the inclusion of disulfoton in the treatment combination resulted in significant reductions in DWT in all instances except when used with PCNB + Dexon. Where significant reductions did occur, the magnitude of the differences was higher at 30 than at 20 C. Again the DWT data indicate the probability of a significant interaction between the use of protectant fungicides and temperature.

The significant interaction between systemic fungicides and systemic insecticides on germination under standard test conditions is also of interest:

	None	*Disulfoton*
None	90.6a	88.6 b
chloroneb	90.2ab	86.3 c
carboxin	90.2ab	85.1 c

In the absence of disulfoton the inclusion of the systemic fungicides did not significantly alter germination. In the presence of disulfoton germination was reduced in all cases, but the magnitude of the reduction was higher in the presence of the systemic fungicides.

The significant protectant fungicide × systemic fungicide × systemic insecticide interaction on germination at standard test conditions and a summary of performance of the various treatments on seedling survival in the field are presented in Table 4. When a seed protectant was not used, the inclusion of a systemic fungicide and/or a systemic insecticide or both resulted in improved germination compared to untreated seeds. When either captan, thiram, or Terracoat L21 was used, the inclusion of a systemic fungicide and/or a systemic insecticide or both resulted in a reduction in germination, compared to seeds receiving only the protectant fungicide. With the other three protectant fungicides one or more of the multiple treatments were better than, and others were not as good as, the germination record of the seeds treated with only the protectant fungicide. The main effect of inclusion of the systemic fungicides in the treatment complex was to reduce germination (Table 1). In the germination data (Table 4) it is apparent that the germination values for protectant fungicide + systemic fungicide + disulfoton are lower than where disulfoton is omitted from the treatment complex, except in the case of thiram + chloroneb, where they are equal. In the treatment complexes of Busan 72 and chloroneb, chlorothalonil + Dexon with either chloroneb or carboxin, and PCNB + Dexon and chloroneb, the inclusion of the systemic insecticide gave higher germination values than those with only the respective protectant fungicides alone.

The data for seedling survival in the field are included in Table 4 for two reasons. The most important reason is to indicate the value of the systemic fungicide in improving seedling survival under field conditions. This is particularly evident in the treatments not receiving a protectant fungicide or with seeds receiving either captan, thiram, Busan 72, or chlorothalonil + Dexon. The second reason is to show the lack of a significant relationship between germination values and field performance. The following seed treatments were associated with excellent germination values, but rather poor field survival values: disulfoton alone, chloroneb and disulfoton, captan alone, thiram alone, thiram and disulfoton, Busan 72 alone, Busan 72 and disulfoton, chlorothalonil + Dexon alone, and chlorothalonil + Dexon and disulfoton. On the other hand, the following treatment combinations were responsible for lower values in the standard germination test, but resulted in field survival values exceeding 50%: Terracoat L21 and chloroneb, Terracoat L21 and chloroneb and disulfoton, chlorothalonil + Dexon and chloroneb and disulfoton, and PCNB + Dexon and carboxin and disulfoton. Most of this difference in response is due to soilborne organisms attacking the seeds and seedlings. Previous information on pathogens involved in the seedling disease complex (5 and C.D. Ranney, unpublished data) indicated that *Rhizoctonia solani* Kuehn is the predominate pathogen responsible for seedling disease loss in field plantings at Stoneville. Treatments containing either PCNB, carboxin, or chloroneb, which are effective in reducing disease loss due to *R. solani,* were consistently associated with better stands in the field plantings.

Table 4. Effects of protectant fungicides, systemic fungicides, and systemic insecticides on percent germination under standard test conditions, and summary of seedling survival in the field.

Multiple seed treatment			% germination standard test*	% seedling survival in the field*
Protectant fungicide ×	Systemic fungicide ×	Systemic insecticide		
None	None	None	84.8 h-l	15.2 k
	None	Disulfoton	88.8 a-i	16.8 k
	Chloroneb	None	90.2 a-f	49.3 b-f
	Chloroneb	Disulfoton	85.5 f-l	38.3 g-i
	Carboxin	None	89.5 a-h	53.4 a-d
	Carboxin	Disulfoton	86.5 c-k	44.9 d-g
Captan	None	None	92.2 ab	38.8 g-i
	None	Disulfoton	86.8 c-k	30.8 ij
	Chloroneb	None	90.0 a-g	52.3 a-e
	Chloroneb	Disulfoton	90.0 a-g	50.3 a-e
	Carboxin	None	90.7 a-c	52.2 a-e
	Carboxin	Disulfoton	88.7 a-i	53.2 a-d
Thiram	None	None	92.0 ab	38.8 g-i
	None	Disulfoton	89.2 a-h	30.5 ij
	Chloroneb	None	89.0 a-h	52.0 a-e
	Chloroneb	Disulfoton	87.8 b-j	41.4 f-h
	Carboxin	None	90.8 a-e	56.1 abc
	Carboxin	Disulfoton	90.5 a-f	48.7 b-f
Terracoat L21	None	None	92.8 ab	51.7 a-e
	None	Disulfoton	88.0 a-j	43.5 e-h
	Chloroneb	None	86.0 d-k	51.8 a-e
	Chloroneb	Disulfoton	85.0 g-l	52.7 a-d
	Carboxin	None	87.8 b-j	53.2 a-d
	Carboxin	Disulfoton	83.8 i-l	49.3 b-f
Busan 72	None	None	91.0 a-d	36.2 h-j
	None	Disulfoton	88.5 a-i	36.8 g-j
	Chloroneb	None	92.5 ab	58.7 a
	Chloroneb	Disulfoton	85.8 e-l	47.2 c-f
	Carboxin	None	89.7 a-h	53.5 a-d
	Carboxin	Disulfoton	81.0 l	44.6 d-h
Chlorothalonil + Dexon	None	None	91.0 a-d	37.6 g-i
	None	Disulfoton	89.0 a-h	29.1 j
	Chloroneb	None	91.5 a-d	57.4 ab
	Chloroneb	Disulfoton	84.8 h-l	49.7 a-f
	Carboxin	None	93.0 a	58.4 a
	Carboxin	Disulfoton	83.3 j-l	48.4 b-f
PCNB + Dexon	None	None	90.8 a-e	52.6 a-d
	None	Disulfoton	90.0 a-g	49.2 b-f
	Chloroneb	None	92.0 ab	54.8 abc
	Chloroneb	Disulfoton	85.0 g-l	48.7 b-f
	Carboxin	None	89.7 a-h	54.5 abc
	Carboxin	Disulfoton	82.0 kl	51.8 a-e
Coefficient of variation			4.7	16.1

* Means not followed by the same letter are significantly different at the 5% level as measured by Duncan's New Multiple Range Test.

In processing these data correlation analysis between seedling survival in the field and each of the other factors measured were made. Only the correlation between 20 C DWT and field survival was significant, and this at the 1% level. However, the correlation value, .154, was so low that trying to use 20 C DWT as a means of predicting field performance has little value.

DISCUSSION

Treatment with any of the protectant fungicides resulted in improved seedling survival, germination, and increased rate of seedling growth, or did not affect the latter two factors. This benefit on germination and seedling growth was probably due to both control of seedborne disease organisms and inhibition of spread of disease from seed internally infected to adjacent uninfected seedlings. These results are in contrast to those reported for several mercurial seed protectants (2, 3), where a degree of phytoxicity was associated with their use. Treatment with the systemic fungicides either slightly, but significantly, reduced germination and DWT or did not affect these values. Use of the systemic fungicide in a treatment did significantly increase seedling survival in the field. A major cause of the significant interactions involving protectant fungicides and systemic fungicides is that these materials are not additive in that the effect of the combination treatment does not equal the sum of the individual treatments. However, from the practical standpoint, the significant increases in seedling survival resulting from the use of a protectant fungicide and a systemic fungicide together warrants use of the combination treatment.

In all cases the use of the systemic insecticide disulfoton in the treatment complex resulted in a deleterious effect; germination, DWT, and percent seedling survival in the field were reduced. The benefit of early season insect control obtained from the use of the systemic insecticide may offset these deleterious effects. However, seed processors and cotton producers should be aware of the possible deleterious effects associated with the use of this chemical. In general, the combination of a systemic fungicide with a systemic insecticide tended to slightly reduce germination percentages but resulted in significant improvements in plant survival in the field in comparison to treatments where the systemic fungicide was not included.

The results obtained from germination and DWT tests in this study and field data from a previous study (6) indicate that temperature has a definite effect on treatment response. Consequently, extensive testing under various environmental conditions is essential to identify specific combinations of chemicals that consistently give effective pest control and a high level of seedling survival.

ACKNOWLEDGMENT

The aid and assistance of William H. Heartley, Jr., Laboratory Technician, Plant Science Research Division, Agricultural Research Service, USDA, Plant Industry Station, Beltsville, Md., and Dr. Robert G. Davis, Plant Pathologist, Delta Branch of the Mississippi Agricultural Experiment Station, Stoneville, Miss., are gratefully acknowledged.

REFERENCES

1. Christiansen, M. N. 1962. A method of measuring and expressing epigeous seedling growth rate. Crop Sci. 2:487-489.
2. Dransfield, M. 1964. Phytotoxicity of liquid mercurial seed dressings to cotton. Emp. Cot. Gr. Rev. 41:266-272.
3. Leach, L. D., and Paul G. Smith. 1945. Effect of seed treatment on protection, rate of emergence and growth of garden peas. Phytopathology 35:191-206.
4. Pinckard, J. A., and John Ivey. 1971. Chemical treatments for cottonseed. Louisiana Agr. Exp. Sta. Bull. 655. 36 p.
5. Ranney, C. D. 1962 Fungi involved in the seedling disease complex of cotton in the Yazoo-Mississippi Delta. Plant Dis. Rep. 46:122-123.
6. ———. 1970. Multiple chemical treatment of cottonseed, effects on seedling survival. Crop Sci. 10:684-686.
7. ———. 1971. Effective substitutes for alkyl mercury seed treatments for cottonseed. Plant Dis. Rep. 55:285-288.
8. Taylor, E. E., C. D. Ranney, H. R. Carns, and M. N. Christiansen. 1971. Interacting effects of seed applied pesticides on germination. Proc. Beltwide Cotton Prod. Res. Conf. p. 74-75.
9. US Department of Agriculture. 1952. Manual for testing agricultural and vegetable seeds. US Dep. Agr. Handbook 30. 440 p.