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Peanut Leafspot Research in Alabama 1970 - 1976

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Peanut Leafspot Research in Alabama 1970-1976[1]

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INTRODUCTION

HISTORICALLY, PEANUT PRODUCTION in Alabama began as the boll weevil wiped out the cotton crop in the early part of this century. Almost from the outset the peanut was afflicted with spotted leaves that were often accepted as the nature of the plant. By the late 1930's experiments were begun using sulfur dust for leafspot control, and later copper-sulfur dusts were used. Leafspot was not effectively controlled, but these dusts delayed severe phases of the disease, which resulted in increased yields. More effective control was achieved in the early 1960's following the introduction of organic fungicides and more sophisticated spray equipment. It was not until the introduction of Benlate[3] and Bravo in 1970 that leafspot was controlled to a point where little yield loss occurred as a result of leafspot infection.

[1] This bulletin summarizes 7 years of research on the control of peanut leafspot, under a project supported by Auburn University Agricultural Experiment Station, the Alabama Peanut Producer's Association, and grants from chemical companies. The primary project, begun in 1972, had major objectives of (1) determination of chemicals most effective in control of the leafspot complex; (2) evaluation of the effects of leafspot fungicides on non-target organisms, particularly white mold (*Sclerotium rolfsii* Sacc.); and (3) development of systems for reducing the number of spray applications necessary for leafspot control.

Trade names for chemicals are used for clarity; however, mention of a trademark or proprietary product neither constitutes a guarantee or warranty of the product nor implies its approval to the exclusion of other products that may also be available.

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[3] Common and chemical names of all chemicals referred to in this bulletin can be found in Appendix 1.

The Nature of Peanut Leafspot Disease

An understanding of peanut leafspot is necessary to understand disease research findings. Peanut leafspot may be caused by either of two fungi that occur wherever peanuts are grown. The most common of the two in the Southeastern United States is *Cercospora arachidicola* Hori, which causes early leafspot. Symptoms of this fungus are brown to dark brown circular spots usually surrounded by a yellow halo (see cover photo). Spore production typically occurs on the upper surface.

Late leafspot, caused by *Cercosporidium personatum* (Berk. & Curt.) Deight., occurs later in the season and is usually darker on the lower surface of the leaflet than early leafspot. The lesion typically has a pimply lower surface with a less distinct halo than early leafspot.

The disease cycle of *Cercospora* leafspot in the field is not completely understood, but typically follows this pattern: (1) spores are produced during periods of moisture (dew) on mature lesions; (2) the spores are released when the lesion dries and are windborne to young peanut leaflets; (3) during the next period of moisture the spores are activated, requiring 14-16 hours at 72°F to germinate and complete the infection process (if this time period is interrupted by a period of dryness the spores are killed; (4) 10-14 days after infection the first symptoms of infection are visible; and (5) the mature sporulating lesion develops 16-20 days after infection. Late leafspot seems to follow the same sequence, but is somewhat slower in developing.

Disease Control

The disease cycle can greatly influence short-term results with field-applied fungicides. For example, if a 100 percent effective contact fungicide existed, and it was applied after infection had occurred, a period of 10-12 days would elapse before any disease reduction could be visible. This time lapse between treatment and response occurs because contact fungicides are effective only on spores or germination tubes on the leaf surface; they have no activity on established infections beneath the leaf cuticle. The establishment of control, therefore, must be developed on a preventative basis. The most desirable fungicides are those that possess both contact and systemic activity *(15)*. Systemic fungicides not only kill fungal spores on the leaf surface, but can eradicate already established infections within the leaf. Unfortunately, none of these fungicides is presently available to peanut farmers for leafspot control.

Understanding the disease cycle can allow flexibility in establishing spray intervals. During dry periods (when moisture periods do not exceed 12-14 hours), spray intervals can be extended. Conversely, intervals should be shortened during periods of extended moisture that frequently occur with rain or ground fog.

The data presented in this bulletin deal primarily with the effect of the new high-performance fungicides, not only on leafspot but also on the quality of yield, insects, other diseases, and general plant health. In addition, attempts have been made to achieve control with reduced numbers of applications or reduced quantities of fungicide per acre.

THE EFFECTS OF FUNGICIDES

From 1971 through 1975 the primary fungicides recommended for leafspot disease control were: Benlate 50WP, 6 ounces per acre (through 1973); Bravo 75WP or 6F, 1½ pounds per acre or 1½ pints per acre; Kocide 404S F, 2 quarts per acre; and Duter 47WP, 6 ounces per acre. Peanuts were grown in a Dothan sandy loam soil in a 1-year rotation with corn (*Zea mays* L.). Plot size was either 150 × 24 feet (1971-72) or 50 × 24 feet. Fungicides were applied every 14 days beginning 40-50 days after planting and ending 14-20 days before harvest. All fungicides were applied by a conventional ground sprayer calibrated to deliver 15 gallons per acre at 80 pounds per square inch. Peanuts were harvested three

TABLE 1. PERCENT INFECTION OF FLORUNNER PEANUTS BY *Cercospora* AND *Cercosporidium* FOLLOWING TREATMENT WITH FOLIAR FUNGICIDES

Treatment	Percent infection				
	1971	1972	1973	1974	Mean[1]
Control	97.2 a	85.7 a	64.8 a	92.9 a	87.0 a
Bravo 6F	56.1 c	8.8 c	16.1 c	24.7 c	36.0 c
Benlate 50WP	40.5 d	7.4 c	20.9 c	88.6[2]a	25.8 d
Duter 47WP	60.7 c	29.4 b	26.5 b	51.7 b	45.4 b
Kocide 404S F[3]	75.9 b	25.4 b	12.2 c	55.9 b	40.2 bc

Values within columns followed by the same letter are not significantly different at the 5 percent level using Duncan's Multiple Range Test.

[1] Mean weighted for number of replications in each year's test.

[2] Resistance to Benlate developed in *Cercospora* during the 1973-74 seasons.

[3] $Cu[OH]_2$ only, no sulfur in 1971.

times between 140 and 160 days after planting; optimal harvest date is reported here.

Leafspot incidence (*Cercospora* + *Cercosporidium*) was determined 14 days before harvest by removing 10 non-bearing vertical runners at random from each plot and measuring infection using the following criteria: (i) total leaflets = number of leaf nodes × 4; (ii) percent defoliated = number of leaflets lost ÷ total leaflets × 100; (iii) total leaflets infected = number of leaflets lost + number of leaflets infected; and (iv) percent infection = leaflets infected ÷ total leaflets × 100. This method assumes that defoliation occurred because of previous leafspot infection.

Summary data for fungicides, presented in tables 1-3, indicate that all performed adequately in controlling leafspot. However, there were significant differences in the means. The high figure for disease in Benlate-treated plots in 1974 reflects the occurrence of a Benlate-resistant race of *Cercospora* that caused severe infec-

TABLE 2. PERCENT DEFOLIATION OF FLORUNNER PEANUTS BY *Cercospora* AND *Cercosporidium* FOLLOWING TREATMENT WITH FOLIAR FUNGICIDES

Treatment	Percent defoliation				
	1971	1972	1973	1974	Mean[1]
Control	79.9 a	53.0 a	44.0 a	64.4 a	59.3 a
Bravo 6F	43.4 c	6.4 d	5.8 bc	15.0 c	22.7 c
Benlate 50WP	24.8 d	5.3 d	6.1 bc	55.1[2]b	17.5 d
Duter 47WP	50.2 bc	18.5 b	12.4 b	33.1 c	30.3 b
Kocide 404S F[3]	56.3 b	12.1 c	2.6 c	18.7 c	20.7 cd

Values within columns followed by the same letter are not significantly different at the 5 percent level using Duncan's Multiple Range Test.

[1] Mean weighted for number of replications in each year's test.

[2] Resistance to Benlate developed in *Cercospora* during the 1973-74 seasons.

[3] $Cu[OH]_2$ only, no sulfur in 1971.

TABLE 3. YIELDS OBTAINED FROM PEANUT LEAFSPOT CONTROL TESTS, 1971-74

Treatment	Pounds per acre				
	1971	1972	1973	1974	Mean[1]
Control	1,851	3,176	2,389	2,817	2,558 d
Bravo 6F	3,589	3,283	3,531	4,653	3,889 a
Benlate 50WP	3,792	3,594	2,926	2,834[2]	3,286 c
Duter 47WP	3,136	3,533	2,743	4,319	3,433 bc
Kocide 404S F	3,176[3]	3,390	3,277	4,523	3,591 b

Values within columns followed by the same letter are not significantly different at the 5 percent level using Duncan's Multiple Range Test.

[1] Mean weighted for number of replications in each year's test.

[2] Resistance to Benlate developed in *Cercospora* during the 1973-74 seasons.

[3] $Cu[OH]_2$ only, no sulfur in 1971.

TABLE 4. RESULTS OF FUNGICIDE TRIALS FOR PEANUT LEAFSPOT CONTROL, 1975-76

Fungicide, rate[1] per acre	Infection			Defoliation			Yield (137 days)			Yield (147 days)		
	1975	1976	Av.	1975	1976	Av.	1975	1976	Av.	1975	1976	Av.
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
1 Nontreated control	79.2	72.4	75.8	58.9	48.4	53.6	2,984	3,521	3,253	2,403	2,192	2,298
2 Benlate, 6 oz.	73.8	68.8	71.3	50.0	43.7	46.8	3,056	3,325	3,190	3,035	2,265	2,650
3 Benlate-Manzate-Oil, 4 oz.-1.5 lb. + 1 qt.	65.9	55.0	60.4	39.7	35.1	37.4	3,427	3,688	3,557	3,557	2,817	3,187
4 Dithane + Oil, 2 lb. + 1 qt.	67.8	55.3	61.5	43.9	33.6	38.7	3,389	3,877	3,633	3,035	3,078	3,056
5 Kocide 404-S, 2 qt.	67.1	46.0	56.5	37.8	26.3	32.0	3,615	3,674	3,644	2,976	3,165	3,070
6 Super-6 (S-6), 2 qt.	68.7	52.6	60.6	43.3	29.3	36.3	3,601	3,732	3,666	3,296	3,078	3,187
7 Difolatan, 3 pt.	51.7	33.0	42.3	25.2	16.8	21.0	4,095	3,514	3,804	4,037	3,107	3,572
8 Duter, 6 oz.	65.1	56.8	60.9	40.0	32.5	36.2	3,671	4,022	3,846	3,572	3,209	3,390
9 Bay Meb, 8 oz.	61.6	45.8	53.7	40.8	30.3	35.5	4,028	3,877	3,952	3,717	2,962	3,339
10 SN-513 30% L, 3 pt.	53.4	36.0	44.7	26.5	24.1	25.3	3,812	3,237	3,524	3,804	2,541	3,172
11 Bravo, 1.5 pt.	65.4	41.5	53.4	37.6	25.0	31.3	3,981	3,761	3,871	3,862	3,499	3,680
12 Duter + T-H Sulfur, 6 oz. + 1 qt.	61.2	48.6	54.9	39.4	27.3	33.3	3,639	3,804	3,721	3,528	2,875	3,201
13 Manzate-Oil, 1.5 lb. + 1 qt.	69.3	—	—	41.7	—	—	3,578	—	—	2,933	—	—
14 Manzate 200, 1.5 lb.	65.7	64.4	65.1	46.1	41.7	43.9	3,464	3,876	3,670	3,078	2,555	2,817
15 Benlate + Manzate 200, 6 oz. + 2 lb.	68.4	—	—	43.8	—	—	3,331	—	—	3,310	—	—
16 DPX-112 + Oil, 2 lb. + 1 qt.	69.4	—	—	42.1	—	—	3,052	—	—	3,412	—	—
17 DPX-112, 2 lb.	72.2	—	—	45.9	—	—	3,395	—	—	2,904	—	—
18 Dithane + Super-6, 1.5 lb. + 2 qt.	73.2	—	—	42.9	—	—	3,589	—	—	3,238	—	—
19 Kocide 101-S, 2 lb.	67.3	—	—	38.9	—	—	3,572	—	—	2,802	—	—
20 Fungisperse, 2 gal.	66.8	—	—	39.0	—	—	3,499	—	—	3,600	—	—
21 Difolatan, 6 pt. (2) 3 pt. (5)	49.0	—	—	23.6	—	—	4,074	—	—	4,080	—	—
22 Difolatan, 2 pt. (3) 3 pt. (4)	58.1	—	—	31.8	—	—	4,056	—	—	3,877	—	—

Continued

TABLE 4 (CONTINUED). RESULTS OF FUNGICIDE TRIALS FOR LEAFSPOT CONTROL, 1975-76

Fungicide, rate[1] per acre	Infection			Defoliation			Yield (137 days)			Yield (147 days)		
	1975	1976	Av.	1975	1976	Av.	1975	1976	Av.	1975	1976	Av.
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
23 Duter + Kocide, 3 oz. + 1 qt.	71.6	—	—	46.1	—	—	3,488	—	—	3,325	—	—
24 Kocide 404 + Super-6, 2 qt. + 2 qt.	60.1	—	—	30.3	—	—	3,726	—	—	3,717	—	—
25 Bravo + Super-6, 1.5 pt. + 2 qt.	58.9	—	—	35.1	—	—	3,874	—	—	3,674	—	—
26 SN-513 30% L, 6 pt.	49.2	—	—	25.0	—	—	3,842	—	—	3,949	—	—
27 Oxycop LS, 3 qt.	60.2	—	—	36.9	—	—	3,891	—	—	3,600	—	—
28 Benlate + Oil, 6 oz. + 1 qt.	71.5	—	—	45.8	—	—	3,389	—	—	3,049	—	—
29 Bravo, 1.5 pt. (5)	—	53.8	—	—	29.4	—	—	3,659	—	—	2,628	—
30 Bravo, 1.0 pt.	—	58.6	—	—	36.4	—	—	3,485	—	—	3,107	—
31 Bravo-Manzate, 1.5 pt. (4) 1.5 lb. (3)	—	58.4	—	—	38.8	—	—	3,688	—	—	2,788	—
32 Bravo/Duter (alternate), 1.5 pt./6 oz.	—	56.2	—	—	33.6	—	—	3,819	—	—	3,020	—
33 Difolatan, 3 pt. (5)	—	35.4	—	—	18.3	—	—	3,732	—	—	3,006	—
34 Difolatan, 3 pt. (3); 2 pt. (4)	—	36.4	—	—	18.5	—	—	3,630	—	—	3,049	—
35 Dithane M-45, 3 lb.	—	58.8	—	—	37.5	—	—	3,949	—	—	3,034	—
36 R-H 5532, 1.5 lb.	—	67.2	—	—	42.0	—	—	3,630	—	—	2,759	—
37 EL-222, 40 g ai	—	48.4	—	—	30.2	—	—	4,385	—	—	3,470	—
38 EL-222, 60 g ai	—	41.1	—	—	31.4	—	—	3,978	—	—	2,802	—
39 EL-228, 40 g ai	—	46.7	—	—	27.4	—	—	3,920	—	—	3,165	—
40 EL-228, 60 g ai	—	34.6	—	—	26.3	—	—	4,501	—	—	3,543	—
41 DPX-110, 3 lb.	—	50.7	—	—	39.4	—	—	3,819	—	—	2,817	—
42 DPX-110, 4.5 lb.	—	54.5	—	—	34.5	—	—	3,804	—	—	3,093	—
43 Benlate + Duter (mix), 4 oz. + 5 oz.	—	49.1	—	—	32.1	—	—	3,906	—	—	3,180	—

[1] Brackets ( ) indicate number of sprays at a particular rate. All treatments received seven applications except treatments 29 and 33 which received only the first five applications.

tion and defoliation. Data on the newly recommended fungicides Difolatan 4F (3 pints per acre) and Duter plus sulfur (6 ounces + 1½ pounds per acre) are given in Table 4. This table, which lists all fungicides tested during 1975 and 1976, indicates the number of fungicides tested and discarded each year. Table 3 gives annual and multi-year yield averages for peanuts sprayed with the major fungicides. These figures reveal important differences in yield and generally show that although yield is usually an indicator of disease control, for some fungicides yields lower than expected are obtained. These deviations from expected yields will be covered in depth in the following sections.

Appendix 3 lists the 1977 recommended fungicides for peanut leafspot control based on these and other data and gives suggested operational procedures for best results.

Tolerance of Leafspot Fungi to Benlate

Two fungi, *Cercospora arachidicola* and *Cercosporidium personatum*, cause leafspot of peanuts; both were controlled effectively with Benlate 50WP until 1973. Tolerance to Benlate has been reported in *Cercospora apii* Fries *(3,4)* and *C. beticola* Sacc. *(13)*. In 1973, inadequate leafspot control was observed in several fields in southern Alabama which were being sprayed with the recommended Benlate program of 6 ounces per acre applied at 14-day intervals. Tests were conducted to determine: (1) if *C. arachidicola* and *C. personatum* had developed tolerance to benomyl (the active ingredient in Benlate), (2) if the proportion of Benlate-tolerant biotypes of *Cercospora* in problem areas differed from that in other areas, and (3) if the tolerance detected also applied to fungicide chemicals related to Benlate.

Leaves infected with *Cercospora* and *Cercosporidium* spp. were obtained from fields with three different leafspot control histories. Field 1 was an isolated peanut field in an area where peanuts were not grown and which had never received Benlate; field 2 received Benlate and other fungicides in previous years and Benlate exclusively in 1973 with good results; field 3 received Benlate in 1973 but not in 1971-72 (area surrounding field 3 had extensive use of Benlate in 1971 and 1972), with adequate control. Leaves from each field were washed, placed on moistened filter paper in petri dishes, and incubated at 28°C for 4-6 days under constant illumination by white fluorescent tubes. Sporulating lesions were either sampled immediately or were air-dried for subsequent use. Single spores removed from the lesions were placed on PDA-tetracycline-streptomycin agar (PDATS) and subsequently examined at weekly intervals for 6 weeks *(18)*. Mycelial fragments from colonies which developed on the original fungicide-amended media were transferred to media containing different fungicides and rated to observe the effect on colony growth. Fungicides and rates tested were Benlate at 5 and 50 p.p.m., thiophanate methyl (Topsin M 70WP) at 5 and 50 p.p.m., and Chemagro's Bay Dam 18654 at 5 p.p.m. All fungicides for these tests and also for the spore germination tests were added to the PDATS after autoclaving.

Spores of *C. arachidicola* and *C. personatum* germinated on PDATS plates containing 5 p.p.m. benomyl. However, marked differences in development after germination were noted. Some germ tubes ceased development early and were assumed to be susceptible, while others showed tolerance by continuing to grow and producing viable colonies in the presence of the fungicide. An intermediate response was also noted, in which the spores germinated and showed some growth, but failed to develop into viable colonies. Growth on PDATS amended with 5 p.p.m. benomyl was considered indicative of tolerance, since 0.5 p.p.m. was adequate to inhibit development of *C. arachidicola* when Benlate first became available (unpublished data from the authors). Other investigators *(3)* showed earlier that, prior to the development of tolerance to Benlate by *C. apii*, less than 1.0 p.p.m. of benomyl was sufficient to completely inhibit growth of that species. Spores of *C. arachidicola* from field 1 showed little tolerance, Table 5, since only 1.0 percent of the spores exhibited short-term growth.

TABLE 5. GERMINATION AND GROWTH OF *Cercospora arachidicola* SPORES ON CONTROL AND BENOMYL-AMENDED MEDIA

Field[1]	Medium[2]	Total spores	Germination	Short-term growth	Continued growth[3]
		No.	*Pct.*	*Pct.*	*Pct.*
1	PDA	40	78	0	100
	PDA + 5 p.p.m.	105	89	1	0
2	PDA	112	95	0	100
	PDA + 5 p.p.m.	107	96	82	1
3	PDA	28	79	0	100
	PDA + 5 p.p.m.	41	78	56	44

[1] Field 1, no present or past leafspot control with Benlate; field 2, good leafspot control with Benlate in 1973; and field 3, poor leafspot control with Benlate in 1973.

[2] Concentration expressed as p.p.m. of active ingredient of formulated product: Benomyl 50% W.P.

[3] Calculated on basis of spores that germinated.

An intermediate level of tolerance probably existed in field 2, where 82 percent of the isolated spores showed short-term growth and 1.0 percent produced viable cultures on the PDATS amended with 5 p.p.m. benomyl. Forty-four percent of the spores from field 3 developed and formed typical colonies on the fungicide-amended medium, indicating a level of tolerance sufficiently high to cause inadequate control by Benlate of leafspot in the field.

Cercosporidium personatum occurred at a low frequency in the three test fields; however, development of germ tubes from spores plated on fungicide-amended medium was similar to that obtained with *C. arachidicola.* Cultures tolerant to 5 p.p.m. benomyl were obtained. Transfer of cultures of *C. arachidicola* resistant to 5 p.p.m. benomyl indicated that these cultures could tolerate 50 p.p.m. benomyl, 50 p.p.m. thiophanate methyl (Topsin-M), and 5 p.p.m. Bay Dam 18654. Growth at 50 p.p.m. benomyl and thiophanate methyl was much slower than at the lower concentrations. Since Benlate and Topsin-M have a common fungitoxic breakdown product, MBC (methyl 2-benzimidizolecarbamate) *(5,8)*, it is probable that the tolerance observed in these biotypes was to MBC.

Because of the data obtained in this study, Benlate was removed from the list of recommended fungicides for the 1974 season. A conservative estimate made in 1974 indicated that at least 30 percent of Alabama's peanut acreage was infested with *Cercospora* strains resistant to Benlate. If growers farming these acres had not followed Auburn's new recommendations, losses of 40 percent would have resulted. Thus, a potential loss of $7 million to Alabama peanut production was averted, and a new average yield record was established.

Effects on Kernel Quality and Crop Value

Throughout the studies on leafspot control, samples of harvested pods were obtained and graded according to standards set by the Federal-State Inspection Service *(20)*. Value per harvested ton and value per acre (yield × value) were computed.

Multi-year analyses of kernel quality, Table 6, indicated a significant ($p < 0.05$) decrease in value per ton for peanuts from fungicide treated plots in comparison with control plots. Grade data indicated that the inferior quality was due to damage to the mature kernels and that this damage was caused by fungi. Kernels

TABLE 6. KERNEL QUALITY VALUES OBTAINED FROM PEANUT LEAFSPOT CONTROL TESTS, 1971-74

Treatment	Value per ton				
	1971	1972	1973	1974	Mean[1]
	$	$	$	$	$
Control	304.46	296.38	298.25	408.95	327.03 a
Bravo 6F	301.04	290.57	276.89	397.98	316.56 b
Benlate 50WP	296.97	281.32	268.23	395.21	310.64 b
Duter 47WP	298.53	284.45	239.39	367.41	298.33 c
Kocide 404S F	300.79[2]	298.91	291.29	385.92	312.94 b

Values within columns followed by the same letter are not significant at the 5 percent level of probability using Duncan's Multiple Range Test.
[1] Mean weighted for number of replications in each year's test.
[2] $Cu[OH]_2$ only, no sulfur in 1971.

from the control plots were significantly better in quality than the fungicide plots. Kernel quality of peanuts from plots treated with Bravo was slightly better than that from other fungicide treatments, but was inferior to the quality of kernels from control plots. Peanuts from plots treated with Duter were significantly ($p < 0.05$) lower in quality than any of the other fungicide treatments or the control. In comparisons of yield, quality, and value per acre, Bravo returned more money than any other fungicide tested or the control, Table 7.

The level of disease control achieved with all test fungicides was significantly better than the untreated control, tables 1 and 2, yet kernel quality of peanuts from all fungicide-treated plots was inferior to that of the non-treated control plots, Table 6. Data from this study, and from one covered in the following section, indicated that maintenance of a complete foliar canopy alters the subcanopy environment with a resulting deterioration of kernel quality (2). These data also indicate another possible mechanism

TABLE 7. YIELD, QUALITY, AND VALUE PER ACRE OBTAINED FROM PEANUT LEAFSPOT CONTROL TESTS, 1971-74

Treatment	Yield/acre	Value/ton	Value/acre
	Lb.	$	$
Control	2,558 d	327.03 a	418.27 d
Bravo 6F	3,889 a	316.56 b	615.55 a
Benlate 50WP	3,286 c	310.64 b	510.38 c
Duter 47WP	3,433 bc	298.33 c	512.08 bc
Kocide 404S F	3,591 b	312.94 b	561.88 b

Values within columns followed by the same letter are not significantly different at the 5 percent level of probability using Duncan's New Multiple Range Test.

for kernel quality effects: direct toxic effects of the foliar fungicides on soil-borne pathogens or their natural antagonists may occur. Thus, kernels of superior quality would be expected from plots where the fungicide exhibited toxicity to the pathogen(s), but where little or no effect on the antagonist(s) occurred. Inferior-quality kernels would occur in plots where fungicides exhibited toxicity to the antagonist(s), but with little or no effect on the quality-deteriorating pathogens. Several observations support this hypothesis. First, similar levels of defoliation were obtained when Benlate, Duter, or Kocide were used to control leafspot. However, use of Duter resulted in significantly inferior kernels when compared to the other two fungicides. Secondly, when values for kernel quality were examined, peanuts from the control plot had a significantly higher dollar value per ton than those from any of the fungicide treatments. If a true inverse relationship exists between leaf maintenance and kernel quality, then Benlate or Kocide-treated plots (which had the least defoliation) should have had the poorest kernel quality of any fungicide-treated plots; however, they were not significantly lower in quality than those from the Bravo-treated plots. A third indication that toxic action by the fungicides altered the ecology of the geocarposphere (soil immediately surrounding the pod) was observed with Benlate. Benlate was extremely effective as a leafspot control fungicide in 1971 and 1972. However, during 1973 *Cercospora* developed resistance to this fungicide *(7)*, and in 1974 defoliation in Benlate-treated plots was nearly equal to that of the control. Data for Benlate-treated plots over the 4-year period showed no improvement in kernel quality as defoliation levels increased. While not conclusive, these observations indicate that the toxic effects of fungicides on natural antagonists or pathogens are more important to kernel quality than the degree of leaf maintenance and the resulting canopy. Additional research is necessary to determine: (1) the extent to which each mechanism affects kernel quality, and (2) whether any interactions exist *(14)*.

Fungicide Effects on White Mold (Sclerotium rolfsii)

After 1970 peanut farmers in the Southeast became increasingly aware of losses to white mold (southern stem blight) caused by *Sclerotium rolfsii*. Effective leafspot control procedures adopted during this period made at least three major changes to the ecology of soil-borne fungi: (1) few leaves were lost to the soil surface to serve as organic food sources for the white mold fungus; (2) fungicides were prevented from reaching the soil by the "umbrella effect" of the intact canopy; and (3) an altered sub-canopy environment was created which may be stimulatory to soil-borne fungi. Previous workers *(10,11)* indicated that *S. rolfsii* is more severe when defoliation provides an organic food base. Those studies were made when effective fungicides for leafspot control were not available, and were of necessity performed under high levels of defoliation. Increased levels of *S. rolfsii* damage in fields with excellent leafspot control indicated that something other than a food base of leaf litter was involved in white mold severity.

A study was made during the 1972 and 1973 seasons to determine: (1) the significance of defoliation on severity of white mold; (2) the importance of canopy in shielding the soil from foliar fungicides and the contribution of sub-canopy environment to disease severity; and (3) the relationship between the incidence of *S. rolfsii* and the toxicity of leafspot fungicides to this pathogen and the natural antagonist *Trichoderma viride* (Pers. ex. Fr.).

Spraying operations and leafspot evaluations were conducted as described previously. White mold damage was determined by counting the number of dead areas showing signs of the fungus in the center two rows of each plot *(17)*. Two tests were conducted in 1973.

In a laboratory test, Benlate, Bravo, and Topsin M were incorporated into potato dextrose agar (PDA, Difco) at concentrations of 0.5 and 5.0 p.p.m., and Kocide was used at 50 and 250 p.p.m. (based on $Cu[OH]_2$). Twenty ml of each medium and a no-fungicide control were poured into 90-mm diameter petri dishes. Each

TABLE 8. OCCURRENCE OF WHITE MOLD *(S. rolfsii)* IN PEANUT FIELD PLOTS FOLLOWING APPLICATION OF LEAFSPOT FUNGICIDES

Treatment	Dead sites/100 ft. row			
	1972	1973A	1973B	Mean[1]
Untreated control	2.17	1.88	1.80	1.92
Benlate 50WP	3.75	6.12	4.00	4.94
Bravo 6F	2.83	3.88	3.40	3.49
Kocide 404S F	3.17	2.00	2.60	2.45
Topsin 70WP	1.50	5.12	1.80	3.29
LSD ($P = 0.05$)	*2.68*	*3.23*	*2.10*	*1.46*
LSD ($P = 0.01$)	*3.76*	*3.47*	*2.90*	*1.94*

[1] Mean weighted for number of replications in each experiment.

treatment was replicated 10 times, five of which were inoculated with one disc (7 mm diameter) of *T. viride* and five with *S. rolfsii*. Inoculum discs were removed from the periphery of 48-hour-old cultures growing on PDA. Radial growth of each fungus was measured 36 hours after inoculation.

Field tests revealed only minor differences in peanut leafspot control among fungicide treatments, tables 1 and 2. However, multi-year analysis indicated that these small differences in leafspot control reflected disproportionate differences in peanut yield and quality, tables 3 and 6. Numbers of plants killed by *S. rolfsii* were significantly different ($P = 0.01$) among treatments, Table 8.

Laboratory studies showed that the various foliar fungicides differed greatly in effects on *S. rolfsii* and its antagonist *T. viride*, Table 9. In agar medium, Benlate was the only fungicide displaying little or no effect on the pathogen but toxicity to the antagonist. The fungi showed intermediate responses to the other fungicides.

TABLE 9. COMPARISON OF DISEASE OCCURRENCE IN PEANUT FIELD PLOTS WITH GROWTH OF *Sclerotium rolfsii* AND *Trichoderma viride* ON FUNGICIDE-AMENDED POTATO DEXTROSE AGAR (PDA)

Fungicide treatment	Rate p.p.m.	No. dead sites	Radial growth[1] (mm)	
			S. rolfsii	Trichoderma
PDA control	—	1.92	15.3	20.5
Benlate	0.5	4.94	16.2	4.5
Benlate	5.0	—	14.8	0
Bravo	0.5	3.49	9.0	12.0
Bravo	5.0	—	4.0	4.8
Kocide 404S F	50.0	2.45	15.8	11.8
Kocide 404S F	250.0	—	13.0	3.8
Topsin M	0.5	3.29	16.2	20.0
Topsin M	5.0	—	16.8	5.5

[1] Radial growth in mm (longest axis + shortest axis) ÷ 2 on PDA culture plate; average of five replications.

The importance of leaf retention in increasing white mold damage can be determined by comparing the untreated control plot to those receiving fungicide treatments. In all cases the control, with a high level of leafspot infection (and defoliation), had the least white mold damage. This observation was confirmed by comparing Benlate-treated plots to Benlate-treated plots that had been clipped (mechanically defoliated) or hormone-treated (plant size reduced without defoliation). Clipped plots treated with Benlate had significantly less ($P = 0.01$) white mold damage than non-clipped plots treated with Benlate, Table 10. Clipping fungicide-treated plots reduced white mold damage to a level similar to the unsprayed control plots.

All experiments reported in this section were conducted during dry growing conditions (30 days or more of drought after blooming). In the authors' opinion, under dry conditions an intact canopy creates and maintains a humid atmosphere that is conducive to fungal growth and disease development; the more defoliated control plots would be subject to greater fluctuations in soil moisture, since they would not have sufficient leaves to maintain a humid atmosphere. This would be obviated in peanuts grown under irrigation or during wet seasons.

Differences in levels of damage from white mold among fungicide plots can be related to fungicide effects on the pathogen and/or its natural antagonist *Trichoderma* spp, Table 9. Benlate-treated plots had the highest incidence of white mold. Benlate exhibited no in vitro effect on *S. rolfsii,* while exhibiting a toxic effect on *Trichoderma.* The related benzimidazole, Topsin-M, was equally innocuous to *S. rolfsii* but displayed only mild toxicity to *Trichoderma.* The significant difference ($P = 0.05$) in field levels of white mold between these two treatments indicates a probable role for *Trichoderma* in reducing *S. rolfsii* damage under natural conditions. Fungicides having a direct toxic effect to *S. rolfsii* in the laboratory (e.g. Bravo) did not show the field reduction of incidence in *S. rolfsii* that might have been inferred from laboratory data. Bravo should have had the lowest damage because it was the most toxic fungicide to *S. rolfsii* and least toxic to *Trichoderma.* The fact that it did not perform as expected may indicate the importance of a complete canopy as well as point to other soil ecological factors that may play a role in *S. rolfsii* severity. In addition, data not presented here indicate that Bravo is an excellent contact fungicide but is inactive once it contacts the soil.

TABLE 10. THE EFFECT OF FOLIAGE CLIPPING AND A GROWTH REGULATING HORMONE ON WHITE MOLD AND YIELD IN PEANUT FIELD PLOTS

Treatment	Dead sites/ 100 ft. of row	Yield/acre
	No.	*Lb.*
Benlate	7.2	2,266
Benlate + hormone	5.7	2,003
Benlate (clipped)	3.8	2,175
LSD ($P = 0.05$)	*3.23*	*NS*
LSD ($P = 0.01$)	*3.47*	*NS*

These data indicate that researchers should be aware of and observe non-target effects of leafspot fungicides. Both yield and crop quality can be severely affected. The farmer, on the other hand, should be aware that control of peanut leafspot may lead to changes in the severity of other diseases. For white mold, the old theory of leaf defoliation causing increased severity has been disproved; good leafspot control will cause greater white mold damage. The following section will relate leaf loss and white mold damage to yield.

The Relationship between Leaf Loss and Yield

For the past 4 years Auburn research has sought to define the relationship between leaf loss and yield. Statistical evaluation of more than a thousand research plots revealed that a farmer with a projected yield of 3,000 pounds per acre using recommended leafspot fungicides will lose 14 pounds per acre for every 1 percent increase in leafspot. The best fungicides usually reduce infection to 10-15 percent, while poorer products allow 40-60 percent infection. This means at least 400 additional pounds are lost if 40 percent of the leaves have spots or have fallen off just because a poor fungicide was chosen instead of an effective one, or the spray interval was too long. Even the best fungicides presently recommended still allow yield reductions of 150 pounds per acre due to leafspot.

When rates of leafspot infection higher than 40 percent occur, leaf loss is even more important, resulting in yield reductions greater than 14 pounds per percent. In 1974 a 1,300-pound difference in yield occurred between plots with 25 percent infection and those with 90 percent infection.

These data emphasize the advantages of adequate leafspot control. In addition, they serve to illustrate why peanut farmers should continue their leafspot programs despite increased white mold losses. Farmers should, however, use recommended soil fungicides on land where white mold has been severe.

Fungicide Effects on Foliar-feeding Insects[4]

Observations of soybeans treated with fungicides indicate that some fungicides reduce insect damage to leaves, while others ac-

[4] In cooperation with Dr. James D. Harper, Department of Zoology-Entomology.

tually increase insect damage. A field test was conducted in 1975 to determine if insect populations were affected by leafspot fungicides.

Plots of peanuts were sprayed with fungicides and evaluated for incidence of leafspot, stem rot, and insect feeding damage. Standard recommended fungicides and rates, applied on a 14-day schedule, were: Difolatan 4F, 3 pints per acre; Kocide 404-S, 2 quarts per acre; Bravo 6F, 1.5 pints per acre; and Duter 47WP, 6 ounces per acre. GTA (guazatine triacetate, SN-513) 30% L was compared on the same schedule to these fungicides and a non-treated control at rates of 3 and 6 pints per acre. Plots were 24 × 50 feet with eight rows per plot. Treatments were replicated six times. All fungicides were applied with a conventional ground sprayer delivering 14 gallons per acre at an operating pressure of 60 p.s.i.

Leafspot incidence (*Cercospora* + *Cercosporidium*) was evaluated 14 days before harvest using criteria discussed previously. Stem rot was determined 10 days before harvest by counting the number of disease loci in the two center rows of each plot showing signs of white mold infection *(17)*. Insect defoliation was evaluated the day before harvest by visual estimate using a linear scale of 1-5 (1 = no evidence of insect feeding, 5 = totally defoliated).

After digging and air-drying, peanuts were harvested with a Lilliston 1500 combine with sacking attachment. Only the two center rows of each plot were harvested.

Soybean looper, *Pseudoplusia includens* Walker, and soybean, *Glycine max* L., were chosen as a model host-insect system for laboratory tests to verify field observations of repellency and anti-feeding effects. Fully expanded soybean leaves (trifoliates) were excised from greenhouse-grown plants, placed on a laboratory belt sprayer, and treated with GTA at rates of 0, 1.5, 3.0, and 6.0 pints per acre. All treatments were applied using a carrier volume of 30 gallons per acre and a pressure of 60 p.s.i. Sprayed leaves were maintained by wrapping the petiole in cotton which was then used to stopper water-filled shell vials. Two vials with leaves were placed in each petri dish. Three 5th-instar soybean looper larvae were then placed in each dish, and leaf area consumed was recorded after 24 and 48 hours. All rates were replicated four times.

In a similar study, the 0 and 1.5 pints per acre rates of GTA were compared in a feeding preference test. Two vials, one containing a treated leaf and the other containing an untreated leaf, were placed in each of five dishes. Three soybean looper larvae were added to each dish and percentage leaf area consumed was determined for each leaf.

Contact toxicity of GTA at rates from 1.5 to 6.0 pints per acre was rated by spraying 5th-instar soybean looper larvae directly on the belt sprayer. Insects were placed on rearing medium and observed at intervals until pupation.

Repellency of GTA to soybean looper moths was tested by releasing 10 moths in a cage containing one peanut plant for each of the following fungicides and rates per acre: (1) non-sprayed control; (2) GTA, 1.5 pints; (3) GTA, 3.0 pints; and (4) Cyprex (a fungicide related to GTA), 1.5 pounds. Treatments were replicated in a randomized complete block design. Plants were maintained in a greenhouse at 82° ± 5°F with 16 hours of daylight. Egg deposition was observed 2 days after moth release and feeding damage by hatched larvae was assessed at 7 and 12 days after release.

Oral toxicity of GTA to 5th-instar soybean looper larvae was also determined. GTA solutions ranging in concentration from 0.0001-0.24 mg per μl were delivered in volumes of 4 or 8 μl into the foreguts of 10 larvae by means of a microsyringe *(16)*. Larval mortality was recorded 24 hours after forced feeding.

Control of peanut leafspot with 3.0 and 6.0 pints per acre of GTA equalled that with recommended fungicides, Table 11. GTA demonstrated a slight burn of peanut foliage when leaves were inspected for leafspot control. Phytotoxicity was evidenced by brown to dark brown spotting of the leaf; its effect on yield

TABLE 11. EFFECT OF PEANUT LEAFSPOT FUNGICIDES ON TARGET PESTS, NON-TARGET PESTS, AND CROP YIELD, 1975

Fungicide rate/acre	Leafspot control		Insect	Stem rot	Yield/acre
	Infection	Defoliation	damage[1]	sites/30 m	
	Pct.	*Pct.*		*No.*	*Lb.*
Control	79.3	61.2	2.8	3.0	2,985
GTA 30% L, 3.0 pints	53.4	26.5	1.8	5.2	3,811
GTA 30% L, 6.0 pints	49.2	25.0	1.4	4.8	3,847
Duter 47 WP, 6.0 ounces	61.2	39.4	3.4	3.6	3,638
Difolatan, 3 pints	51.7	25.2	3.3	4.8	4,094
Bravo 6F, 1.5 pints	63.4	37.6	3.4	5.2	3,981
Kocide 404S, 2 quarts	67.1	37.8	3.5	5.8	3,653

[1] Insect damage rated on a 1-5 scale, where 1 = no damage, 2 = 25 percent, 3 = 50 percent, 4 = 75 percent, and 5 = 100 percent of leaf area lost. Control insect damage is artificially low due to severe defoliation from leafspot infections.

could not be determined. GTA showed no improvement in stem rot control over the recommended leafspot fungicides. However, GTA-treated plots showed reductions in defoliation by lepidopterous larvae, Table 11. Insects found in the peanut plots included the corn earworm, *Heliothis zea* (Boddie), velvetbean caterpillar, *Anticarsia gemmatalis* Hübner, and beet armyworm, *Spodoptera exigua* (Hübner). Visual estimates of damage showed GTA-treated plots to have only 10-20 percent average defoliation. Most of this damage occurred on new, untreated foliage. Peanut leaves treated with all other fungicides sustained 60-65 percent average defoliation. The untreated control plots had an intermediate insect damage rating (about 40 percent) because many of the insect damaged leaves abscissed prior to rating of leaves for leafspot damage.

In greenhouse and laboratory studies, GTA was a repellent to soybean looper larvae, Table 12. When treated leaves were the only food available, they were never completely consumed, even after 48 hours; consumption decreased with increasing dosage, Table 12. Larvae feeding on untreated foliage consumed all available leaves within the first 24 hours.

When larvae were given the choice of an untreated leaf and a treated leaf, Table 12, the untreated leaf was always consumed within 24 hours while the treated leaf was not completely consumed even after 48 hours. Direct spraying of larvae at 6.0 pints per acre had no apparent deleterious effect since all sprayed larvae progressed normally to pupation. Larvae that were force-fed GTA solutions tolerated all dosages < 0.24 mg per larvae, Figure 1. Dosages of > 0.71 mg per larvae caused 100 percent mortality within 24 hours.

TABLE 12. PERCENT OF SOYBEAN LEAF AREAS CONSUMED BY SOYBEAN LOOPER LARVAE AFTER TREATMENT WITH GUAZATINE TRIACETATE[1]

Test	Rate, pints/acre			
	0	1.5	3.0	6.0
Repellency				
24 hours	100	52	10	8
48 hours	—[2]	88	23	18
Preference[3]				
24 hours	100	8	—	—
48 hours	—[2]	88	—	—

[1] All values presented are averages from 4 replicates.
[2] Food supply was exhausted in first 24-hour feeding period; further consumption was impossible.
[3] Untreated and treated leaves simultaneously available.

In oviposition tests, moths deposited most of their eggs on cage walls. Those few which were placed on plants were uniformly distributed over all treatments. However, where significant levels of egg-laying occurred on treated peanuts, larvae continued to feed only on check plants or on those treated with Cyprex. On GTA-treated peanuts, feeding was initiated but ceased before significant leaf damage had occurred.

These data indicate that GTA is an effective fungicide for peanut leafspot control when applied at rates of 3 pints per acre or greater. Further, this fungicide significantly reduced feeding damage by lepidopterous larvae *(12)*. No evidence of an antifeeding effect could be found for any other fungicide in the field test.

The laboratory tests with *P. includens* indicated that GTA had an anti-feeding effect based primarily on repellency. Larvae showed a feeding preference for untreated foliage over treated foliage. Observations further indicated that, at least for small larvae, feeding occurred on the surface of the leaf opposite the treated surface. Larvae that did ingest treated foliage showed no ill effects. Forced feeding demonstrated acute toxicity of GTA, but the amounts required to kill larvae are several times higher than individual larvae would normally consume on treated foliage. A spray mix applied uniformly over 1 acre of leaf surface at the rate of 3.0 pints per acre would deposit a maximum 0.008 mg AI per cm^2, assuming total deposit. Fifth-instar soybean looper larvae consume about 10 cm^2 of peanut leaves per 24 hours (J. D. Harper, unpublished data) and would, therefore, require more than 3 days of feeding to accumulate the minimum dose exhibiting toxicity. However, since the conditions described represent assumptions of maximal conditions, including a lack of repellency, it is highly unlikely that a lethal dosage would ever be ingested.

GTA exhibits excellent fungicidal activity against peanut leafspot. In addition, these data indicate a true repellency of lepidopterous larvae. These features suggest that GTA is a likely candidate for inclusion in an integrated pest management system for peanuts. Its spectrum of repellency and use in other crops needs further investigation.

EFFECT OF KYLAR ON PEANUT YIELDS

The hormone Kylar (Succinic acid 2,2-dimethyl-hydrazide) has frequently been promoted for increased peanut yields. The re-

TABLE 13. EFFECT OF KYLAR ON DISEASE AND YIELD OF RUNNER PEANUT, 1973

Treatment	Defoliation	White mold dead sites	Yield/ acre	Value/ton
	Pct.	*No.*	*Lb.*	*$*
Fungicides only	10.0	3.78	2,497	300
Fungicides + Kylar at low rate	11.4	2.84	2,327	291
Fungicides + Kylar at high rate	9.8	4.19	2,232	292
LSD .05	*N.S.*	*1.18*	*145*	*N.S.*

ported reduction in vine growth was thought to reduce disease damage and equipment damage to vines. Experiments were conducted for 2 years at the Wiregrass Substation, Headland, to determine if these claims were accurate for Florunner peanuts grown in the Southeast.

In 1973 Kylar was tested at two rates as a tank mix with various recommended fungicides. The low rate consisted of ½ pound of Kylar 85W applied 55 days after planting with ¼ pound applied four times at 14-day intervals thereafter. The high rate received ½ pound on all five dates. Treatments were replicated eight times with each of four fungicides on 50-foot by four-row plots. Disease and yield were rated as previously described. A similar study was conducted in 1974, except that Kylar was applied three times at ½ pound with each of five fungicides and a control.

Table 13 represents means of the Kylar + fungicide mixtures at each Kylar rate tested. These showed no effect on foliar disease, a slight reduction in white mold damage, and a slight yield reduction. Disease data from 1974 were similar to those presented in 1973, except yields were not depressed, Table 14.

In conclusion, Kylar shows little benefit to overall yield in run-

TABLE 14. YIELDS OF SIX FUNGICIDE PROGRAMS WITH AND WITHOUT KYLAR PROGRAM, 1974

Hormone treatment	Yield, by fungicide treatment						
	No Fungicide	Benlate[1]	Bravo	Benlate-Manzate-oil	Duter	Dithane	Mean
	Lb.	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*	*Lb.*
No Kylar	2,439	3,020	3,862	3,456	3,557	3,528	3,311
Kylar ½ lb. (3 times)	2,512	2,948	3,993	3,441	3,542	3,571	3,340
Mean	2,476	2,984	3,928	3,448	3,550	3,550	

[1] Benlate resistance.

ner peanuts grown in Alabama, and therefore is not recommended by Auburn University.

THE ROLE OF SULFUR IN LEAFSPOT CONTROL

Sulfur was used extensively for peanut leafspot control until the mid-1960's when it was effectively replaced by organic fungicides. Studies have continued through the past several years to determine if the performance of these 'modern' fungicides can benefit from the addition of sulfur to the spray tank.

Data in Table 15 illustrate results obtained with two formulations of Kocide during 1976. Differences between sulfurs in their ability to control peanut leafspot are apparent. Super-6 sulfur is produced by a wet-milling process and appeared to perform better than Stoller sulfur (molten sulfur process) or micronized sulfur (air-milled). These data were consistent over several years. Table 4 contains additional data (1976) in which Super-6 and Stoller sulfur (TH-S) were compared when added to Duter. These data are consistent with those developed when sulfur formulations were added to Kocide.

The addition of sulfur to Duter (1973-76) is summarized in Table 16. On a multi-year basis there is a consistent improvement in disease control (reduced defoliation) and yield. These data in-

TABLE 15. EFFECT OF 3 COMMERCIAL SULFUR FORMULATIONS ON THE CONTROL OF PEANUT LEAFSPOT BY THE FUNGICIDE KOCIDE, 1976

Fungicide	Percent defoliation[1]		
	With Super-6F	With Stoller 6F	With micronized sulfur
Kocide 404F	10.2	10.4	13.7
Kocide 101 WP	12.2	17.5	—
Mean	11.2	14.0	

[1] Yields not reported due to severe drought.

TABLE 16. EFFECT OF THE ADDITION OF SULFUR ON PEANUT LEAFSPOT CONTROL WITH DUTER

Fungicide	Defoliation					Yield, 1973-76 average
	1973	1974	1975	1976	Av.	
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Lb.*
Duter	12.4	33.1	40.0	32.5	29.5	3,466
Duter + sulfur	6.8	24.4	39.4	26.1	24.2	3,629

dicate that sulfur definitely improves peanut leafspot disease control and yield for mid-range performing fungicides. Auburn recommendations for peanut leafspot control therefore suggest that sulfur be used with Kocide and Duter.

Table 4 reflects the performance of Super-6 alone at 2 quarts per acre and Super-6 in combination with Bravo and Difolatan at recommended rates. Super-6 alone was effective as a fungicide, but when mixed with Bravo and Difolatan it did not improve disease control over that from Bravo and Difolatan used alone.

As a nutritional aid sulfur would only help if a sulfur deficiency was present. Since Bravo and Difolatan showed neither an improvement in disease control nor an improvement in yield when sulfur was added, Table 4, it can be assumed that sulfur deficiency was not present in these tests. Tests conducted by the Department of Agronomy and Soils show that sulfur deficiencies are rare in Alabama peanuts (Dr. Fred Adams, personal communication). Sulfur should therefore be used only where a significant improvement in disease control can be expected (i.e. with Kocide and Duter).

SPRAY EQUIPMENT AND DELIVERY RATES

Methods of Application of Leafspot Fungicides

Several types of spray equipment are used by peanut farmers, but no comprehensive comparisons of equipment performance have been made in the past. Beginning in 1970 an equipment comparison test was begun at the Wiregrass Substation. Each year four recommended fungicides were applied in replicated trials through each of three types of spray equipment: (1) a conventional ground sprayer that operated at 60 p.s.i. and 15-20 gallons per acre; (2) a low-volume ground sprayer (Span®) that delivered 4-5 gallons per acre using hydraulic fans for spray propulsion; and (3) an airplane equipped with a boom sprayer, that operated at 3-4 gallons per acre. Plot widths were adjusted for swath width (8 rows for conventional, 12 rows for low-volume, and 16 rows for the airplane). The middle six rows were used for disease samples and yield. Plot lengths were 150 feet and each treatment was replicated five times. Data are reported as the means of all fungicides applied by a given piece of equipment throughout the entire 3-year study, Table 17.

TABLE 17. TYPE OF SPRAY EQUIPMENT AND ITS RELATIONSHIP TO PEANUT LEAFSPOT CONTROL WITH FUNGICIDES, 1970-72

Control measure	Conventional ground sprayer	Low-volume ground sprayer	Low-volume airplane sprayer
Infection, pct.	36.3	36.7	45.1
Defoliation, pct.	19.9	19.2	24.8
Yield/acre, lb.	3,706	3,742	3,609
Dead plants[1] per acre (white mold)	356	487	581

[1] 1972 data only.

These data revealed that conventional ground applications were generally equal to low-volume ground application for yield and disease control. Airplanes were slightly less effective, but as can be seen from Table 18 this was primarily due to the poor performance of Benlate when applied by air. Low-volume and airplane applications usually had higher white mold damage, probably a result of poorer fungicide penetration to the soil surface.

Overall performance did not differ appreciably when the currently recommended contact fungicides were compared. The choice of equipment remains with the farmer. However, several areas of caution should be stressed: (1) never spray with low-volume ground or airplane sprayers when windspeed is greater than 4-5 miles per hour; (2) adjust swath width to compensate for drift (fewer rows upwind, more rows downwind) for low-volume and airplane sprayers; and (3) accurately flag airplane swaths so that some overlap occurs to compensate for reduced spray deposition at the swath edge. The airplane is the sprayer of choice when prolonged wet weather prevents ground application. Severe disease can occur if application is delayed until the soil dries enough to support ground equipment.

TABLE 18. DISEASE CONTROL AND YIELD IN PLOTS SPRAYED WITH BENLATE AND BRAVO (1970-1972) BY TYPES OF SPRAY EQUIPMENT

Fungicide	Conventional ground			Low-volume ground			Low-volume airplane		
	Infection	Defoliation	Yield/acre	Infection	Defoliation	Yield/acre	Infection	Defoliation	Yield/acre
	Pct.	*Pct.*	*Lb.*	*Pct.*	*Pct.*	*Lb.*	*Pct.*	*Pct.*	*Lb.*
Benlate	21.4	10.5	3,882	22.6	19.6	3,813	41.2	22.6	3,696
Bravo	35.2	19.8	3,908	39.3	21.6	3,889	43.1	21.1	3,830

Delivery Rates for Ground Sprayers

In 1971 a study was conducted to determine the optimal rate of water to use in delivery of peanut foliar fungicides by a conventional ground sprayer. The sprayer was adjusted to operate at 60 p.s.i., using three hollow-cone nozzles per row. Four fungicides were applied for each delivery rate. Fungicide × volume combinations were replicated four times each. Means reflect the average of all fungicides at each rate.

Data indicate little difference between any of the delivery rates, Table 19, and suggest that farmers have a great deal of latitude with peanuts when choosing their delivery volume. Auburn currently recommends rates of 10-20 gallons per acre because there is more latitude for such factors as worn nozzles and nozzle height at the slightly higher rates.

TABLE 19. WATER DELIVERY RATE PER ACRE AND ITS EFFECT ON THE PERFORMANCE OF LEAFSPOT FUNGICIDES ON PEANUTS[1]

Gallons of water per acre	Infection	Defoliation	Yield/acre
	Pct.	*Pct.*	*Lb.*
5	60.2	42.2	3,377
10	63.4	44.6	3,338
15	58.6	43.4	3,487
20	59.7	40.5	3,266

[1] Data represent mean of Benlate, Bravo, and Kocide delivered at 60 p.s.i. through hollow cone nozzles, three nozzles per row.

IMPROVEMENT OF BRAVO (CHLOROTHALONIL) PERFORMANCE

Beginning in 1974 efforts were made to find a more effective Bravo fungicide formulation to permit a reduction in the amount of product used per acre. Some success was achieved earlier when the '6F' formulation was found to be more effective than the former Bravo 75WP.

This study was undertaken to determine: (1) is wet-milled Bravo superior to air-milled for achieving a smaller particle size, (2) are wet-milled preparations superior in control of peanut leafspot, and (3) what physical parameters other than particle size affect disease control?

Flowable formulations of chlorothalonil were prepared by wet-mill grinding of technical Bravo in the flowable matrix. Grinding was achieved by the shearing action of metal balls rotating under pressure in a steel chamber (attriter). Samples were removed after 3, 9, and 13 hours, adjusted to 54 percent active ingredient (w/v), and particle size and distribution determined with a Coulter model TA-2 counter equipped with a 30-μm orifice. Median particle size, total surface area per gram, and numbers of particles per gram of active ingredient were estimated assuming a spherical particle shape.

In 1974, wet-milled formulations were compared to commercial air-milled formulation (Bravo 6F) for physical properties and for field performance. The same procedure was used in 1975, but a wet-milled sample was selected that had physical parameters similar to that of the standard air-milled product. A second wet-milled sample that had a mean particle size approaching that found to be most effective in 1974 was also tested in 1975.

Fungicidal performance was evaluated in 1974 and 1975 on peanut field plots for control of early and late leafspot. Experiments were conducted with rates of 0, 0.5, 1.0, and 1.5 pints per acre of formulated ingredient for each formulation, delivered in a spray volume of 14 gallons per acre at a pressure of 60 p.s.i. In addition, a rate of 0.75 pint per acre of each formulation was tested during the 1975 season. Each plot consisted of four 50-foot rows spaced 3 feet apart. The first spray was applied approximately 45 days after planting and was repeated at 14-day intervals for a total of seven applications. Leafspot disease evaluations and yields were obtained by methods described earlier in this bulletin.

Field plots were in a randomized complete block design. The inherent factorial arrangement permitted development of Duncan's multiple range comparisons *(19)* of formulation means, rate means, and treatment means.

Preparations of air-milled and wet-milled chlorothalonil used in 1975 were suspended in water and filtered onto a Millipore filter membrane (0.22-μm pore size), dried at 40°C for 10 hours, shadowed with gold, and viewed and photographed on an AMR model 1000 scanning electron microscope to determine particle surface configuration and size.

Coulter counter analyses of wet-milled chlorothalonil preparations and the standard air-milled product indicated that wet-milling (WM) produced a more finely divided product than did

TABLE 20. LEAFSPOT INFECTION AND DEFOLIATION OF FLORUNNER PEANUTS TREATED WITH VARIOUS RATES AND FORMULATIONS OF 54 PERCENT FLOWABLE BRAVO, 1974

Formulation	Percent defoliation,[1,2] by formulation rate[3]/acre			
	0.5 pt.	1.0 pt.	1.5 pt.	Formulation mean
Air-milled	59.0 b	42.3 cde	32.2 ghi	44.5 A
Wet-milled				
3 hours	56.0 bc	41.4 def	25.1 hij	40.8 AB
9 hours	50.1 bcd	32.6 gh	21.0 j	34.6 B
13 hours	48.6 cde	34.2 fgh	27.8 ij	35.2 B
Rate mean	53.4 X	37.6 Y	25.3 Z	
	Percent infection,[1,2] by formulation rate[3]/acre			
	0.5 pt.	1.0 pt.	1.5 pt.	Formulation mean
Air-milled	39.2 b	24.5 def	19.0 fgh	27.6 A
Wet-milled				
3 hours	32.9 bc	23.9 ef	15.5 gh	24.1 A
9 hours	31.5 cd	17.2 fgh	14.1 h	20.9 B
13 hours	27.2 cde	22.9 egh	15.4 gh	21.8 B
Rate mean	32.7 X	22.1 Y	16.0 Z	

[1] Control value = 73.8 percent infection and 50.4 percent defoliation.
[2] Values followed by different letters (lower case) are significantly different at the 5 percent level using Duncan's Multiple Range Test; mean values followed by different upper case letters are significantly different.
[3] Active ingredient rate per acre.

air-milling. Near minimal particle size and maximal surface area were achieved after 9 hours.

Results revealed that the 9-WM and 13-WM preparations generally were more effective than the standard product air-milled in reducing peanut leafspot infection and defoliation, Table 20. Furthermore, results indicated that rates of 1 pint per acre of 9-WM were as effective as 1.5 pints of the standard air-milled product. The 3-WM, with a larger median particle size, less total surface area, and fewer particles per gram, consistently controlled disease better than the air-milled formulation *(1,6)*.

Evaluation of 1975 disease control data confirmed results obtained in 1974, Table 21. Again, disease control from the finely ground, wet-milled preparation applied at rates between 0.75 and 1.0 pint per acre was equivalent to the standard product air-milled applied at a rate of 1.5 pints per acre. The wet-milled standard, with particle size and surface area similar to that found for the air-milled, was significantly more effective than the air-milled product in controlling disease. Peanut yield data (not presented) indicated significant differences ($P < 0.05$) and these were inversely related to disease incidence in both 1974 and 1975.

TABLE 21. LEAFSPOT INFECTION AND DEFOLIATION OF FLORUNNER PEANUTS TREATED WITH VARIOUS RATES AND FORMULATIONS OF 54 PERCENT FLOWABLE BRAVO, 1975

Formulation	Percent infection[1], by formulation rate/acre[2]					
	0	0.5 pt.	0.75 pt.	1.0 pt.	1.5 pt.	Formulation mean
Air-milled	61.2 ab	56.5 abc	54.6 bc	50.4 cd	41.6 efg	52.9 A
Wet-milled	62.8 ab	56.2 abc	44.2 def	43.7 def	35.3 gh	48.4 B
Wet-milled (fine)	64.6 a	49.0 cde	45.8 def	37.4 fgh	31.4 h	45.6 B
Rate mean	62.9 W	53.9 X	48.2 Y	43.8 Y	36.1 Z	
	Percent defoliation, by formulation rate/acre[2]					
	0	0.5 pt.	0.75 pt.	1.0 pt.	1.5 pt.	Formulation mean
Air-milled	38.7 a	35.1 abcd	33.4 abcd	33.5 abcd	26.9 d	33.5 X
Wet-milled	39.0 a	35.1 abc	29.7 cd	27.7 d	27.7 d	31.8 X
Wet-milled (fine)	37.0 ab	31.5 bcd	30.6 bcd	29.4 cd	26.6 d	31.0 X
Rate mean	38.2 A	33.9 B	31.3 B	30.2 BC	27.1 C	

[1] Values followed by different letters (lower case) are significantly different at the 5 percent level using Duncan's Multiple Range Test; mean values followed by different upper case letters are significantly different.
[2] Active ingredient rate per acre.

Scanning electron micrographs of air-milled and wet-milled chlorothalonil preparations revealed that the wet-milled sample contained somewhat more fractured, angular, and smaller-sized particles than did the air-milled sample. In addition, major differences in the distribution were apparent. Use of the Coulter counter provides plot data on particle size distribution not available in 1950. The resultant "profiles" developed here demonstrate visually how various particle-size blends may result in improved performance of many water-insoluble fungicides, Figure 1 and Figure 2. The resultant decrease in rates required for disease control could significantly reduce the total pesticide load in agricultural areas.

Whether Bravo activity is most affected by the distribution of particle sizes or surface configuration of particles was not determined. Regardless, formulations should have smaller particles with a reserve of larger particles to weather down continually to the more biologically active small particles.

Three physical factors relating the nature of chlorothalonil particles in the Bravo formulation to fungicidal efficacy were determined in this study: (1) particle size; (2) the distribution of particle sizes, and (3) surface configuration of the individual par-

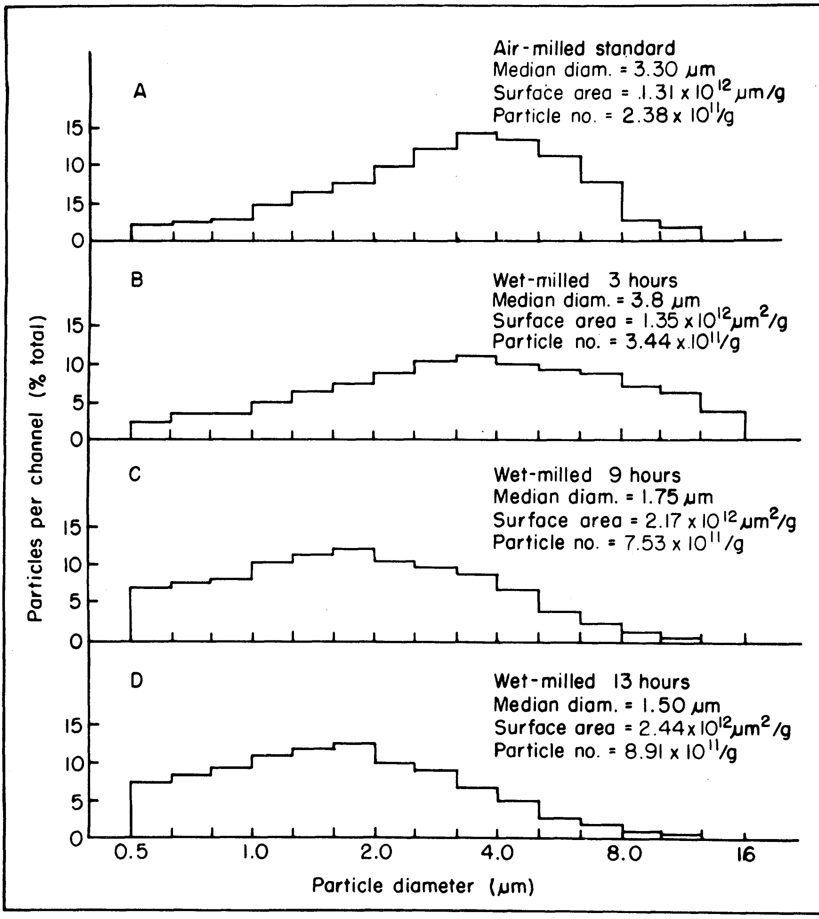

FIG. 1. Effects of air-milling (commercial formulation) and wet-milling of technical chlorothalonil on particle-size distribution of 1974 samples.

ticles. The standard air-milled formulation affects only particle size advantageously, while wet-milling improves chlorothalonil efficacy through all three components.

The results of this study convinced Diamond Shamrock Corporation of the improved performance of wet-milled Bravo 6F. In 1976 all Bravo 6F sold in Alabama was the wet-milled type. Studies will be continued to determine if rates can be reduced from 1976 recommendations. Studies are continuing to evaluate the performance of wet-milled sulfur (Super-6) and other fungicides to further evaluate the potential of this process.

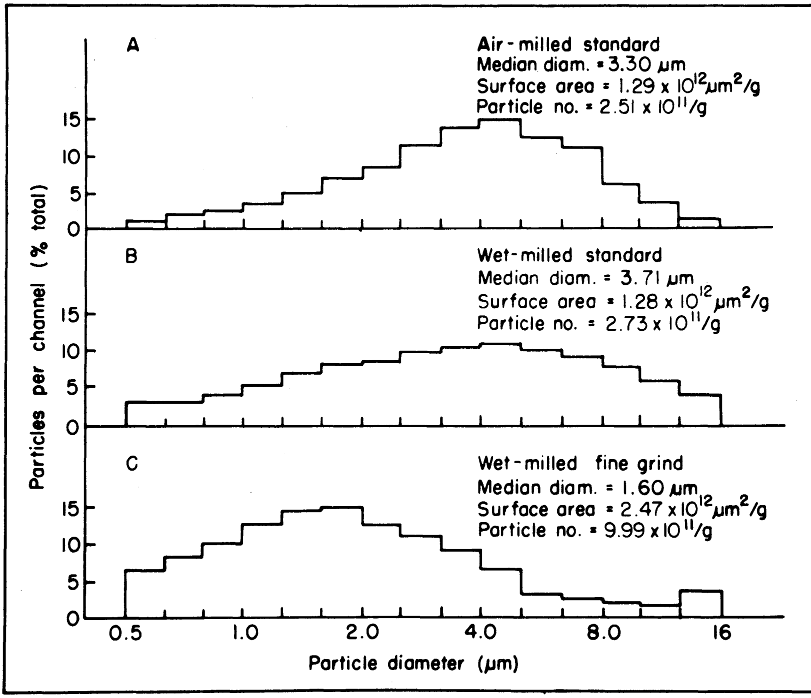

FIG. 2. Effects of air-milling (commercial formulation) and wet-milling of technical chlorothalonil on particle-size distribution of 1975 samples.

WET WEATHER AT HARVEST: WHEN DO YOU DIG?

Sometimes needed information is developed purely by accident. Such was the case when Hurricane Eloise passed over experimental plots at the Wiregrass Substation on September 23, 1975. Peanuts in a leafspot control study were mature and ready to be harvested when the hurricane appeared. One-half of each plot was dug the day before the hurricane arrived, and remained inverted and on the ground through the storm. The other half was dug as soon as possible after the storm had passed.

The results of this test are shown in Table 22. These data show that most of the peanuts from the delayed final harvest were lost because of senesence and heavy wet soil. Only a few peanuts were lost by digging just before the hurricane, and none of these were found to have *Aspergillus flavus* (Segregation 3). These data indicate that, should a warning for prolonged wet weather be

TABLE 22. EFFECT OF HURRICANE ELOISE[1] ON PEANUT YIELDS, 1975

Fungicide	Yield, by fungicide and harvest timing		
	Dug and harvested before hurricane	Dug before, harvested after	Dug and harvested after
	Lb.	*Lb.*	*Lb.*
Bravo	3,981	3,761	2,982
Difolatan	4,095	4,037	2,950
Kocide 404S	3,615	2,976	2,314
Duter + S	3,639	3,528	2,555
Nontreated control	2,970	2,402	1,226
Digging date	9/12	9/22	9/30
Harvest date	9/17	9/30	10/5

[1] Hurricane Eloise passed Headland September 23, 1975.

announced, a grower would do better by digging his mature peanuts than by leaving them in the ground until after the wet weather.

SUMMARY

The data presented here indicate that control of peanut leafspot is a complex matter and that the researcher must evaluate much more than just control of the leafspot fungus. Fungicides were shown to affect soil-borne diseases, kernel quality, and insects, as well as yields. Yields have not always been related to crop value per acre.

Appendix 2 lists the fungicides and combinations recommended for control of peanut leafspot. These recommendations reflect most of the information developed since 1970 and presented in this bulletin. Experiments are continuing to develop control systems that will require less time, equipment, and money. Should peanut prices revert to the world market price, economy in disease control will be necessary for profitable farm operation. Appendix 3 illustrates the progress made in peanut yields and crop value in the past 15 years. Only through continued research can these curves continue their upward trend.

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APPENDIX 1

List of Trade, Chemical, and Common Names for Fungicides in Text

Trade name	Common name	Chemical name
1. Benlate 50 WP	benomyl	methyl 1-(butylcarbamoyl)-2-benzimidazole-carbamate
2. Manzate 200 Dithane M-45	mancozeb	coordination product of zinc & manganese ethylenebisdithiocarbamate
3. Kocide 101 (WP)	copper hydroxide	cuprous hydroxide
4. Kocide 404 (F)	copper hydroxide	cuprous hydroxide
5. Kocide 404-S (F)	copper hydroxide	cuprous hydroxide + sulfur
6. Difolatan 4F	captafol	cis-N-(1,1,2,2-tetrachloroethylthio)-4-cyclohexene-1,2-dicarboximide
7. Du-Ter 47WP	fentin hydroxide	triphenyltin hydroxide
8. Bravo 6F	chlorothalonil	tetrachloroisophthalonitrile
9. Oxycop 8L Copper-Count-N	copper ammonium carbonate	copper ammonium carbonate (exact formula unknown)
10. Topsin-M 70WP	thiophanate methyl	1,2 Bis (3-methoxycarbonyl-2-thioureido) benzene
11. Bay Meb 6447 50WP	bayleton	1-(4-chlorophenoxy)-3-3 dimethyl-1-(1H-1,2,4-triazol-1-yl)-2 butanone
12. Super-6 (F)	sulfur (wet-mill)	elemental sulfur
13. DPX-112	delsan + manzate	methyl benzimidazolecarbamate + manzate 200
14. DPX-110	delsan + sulfur	methyl benzimidazolecarbamate + sulfur

Continued

List of Trade, Chemical, and Common Names for Fungicides in Text (continued)

Trade name	*Common name*	*Chemical name*
15. Fungisperse	copper sulfate + sulfur	copper sulfate + sulfur
16. SN-513 (GTA)	guazatine triacetate	9-aza-1,17 diguanidinoheptadecane triacetate
17. EL 222 (Bloc)	fenarimol	α- (2-chlorophenyl) -α- (4-chlorophenyl) -5-pyrimidene-methanol
18. EL 228	nuarimol	α- (2-florophenyl) -α- (4-florophenyl) -5-pyrimidene-methanol
19. Oxycop LS	copper ammonium carbonate + sulfur	copper ammonium carbonate + sulfur
20. Kylar (hormone)	daminazole	succinic acid 2,2-dimethylhydrazide
21. Oil	72 second summer oil	parafrinic series oil

APPENDIX 2

Leafspot Disease Control Recommendations (1977)

Fungicides	*Amount of formulated fungicide to use per acre*
Bravo 6F	1½ pints
Difolatan 4F	3 pints
Du-Ter 47 WP	6 ounces
Du-Ter 47 WP + Micronized Sulfur	6 ounces + 1.5 pounds
Du-Ter 47 WP + Flowable Sulfur 6 lb./gal.	6 ounces + 1.0 quart
Kocide 404 S	2 quarts
Kocide 404 + Micronized Sulfur	2 quarts + 1.5 pounds
Kocide 404 + Flowable Sulfur 6 lb./gal.	2 quarts + 1.0 quart

Always follow these suggestions:

1. Apply fungicides on a 10-14 day schedule. In fields under continuous peanut production or during periods of high rainfall, benefits may be obtained by reducing the spray intervals to as little as 7 days.

2. Inspect peanut fields closely for signs of leafspot to determine the proper time to initiate fungicide applications. The first fungicide application should begin at the **first sign** of leafspot or no later than when peanuts are 6 inches across in any direction (45-50 days after planting).

3. For the first fungicide application, open only the nozzle directly over the row and leave the two side nozzles closed. At this early stage of peanut development, one nozzle will provide ample spray coverage. The tank mix concentration will be the same concentration used in subsequent fungicide application. However, since only one of the three nozzles is open, approximately ⅓ the normal spray volume per acre will be delivered during this first application.

4. In subsequent sprays when the vines are greater than 12 inches in diameter, use 3 nozzles per row adjusted to give broadcast fungicide application. Correct nozzle height to 18-20 inches over the tops of "center" vines. Direct side nozzles for best coverage.

5. Broadcast fungicide application should be made with 10 to 15 gallons of water per acre.

6. Pressure should be adjusted somewhere between 60 and 80 p.s.i.

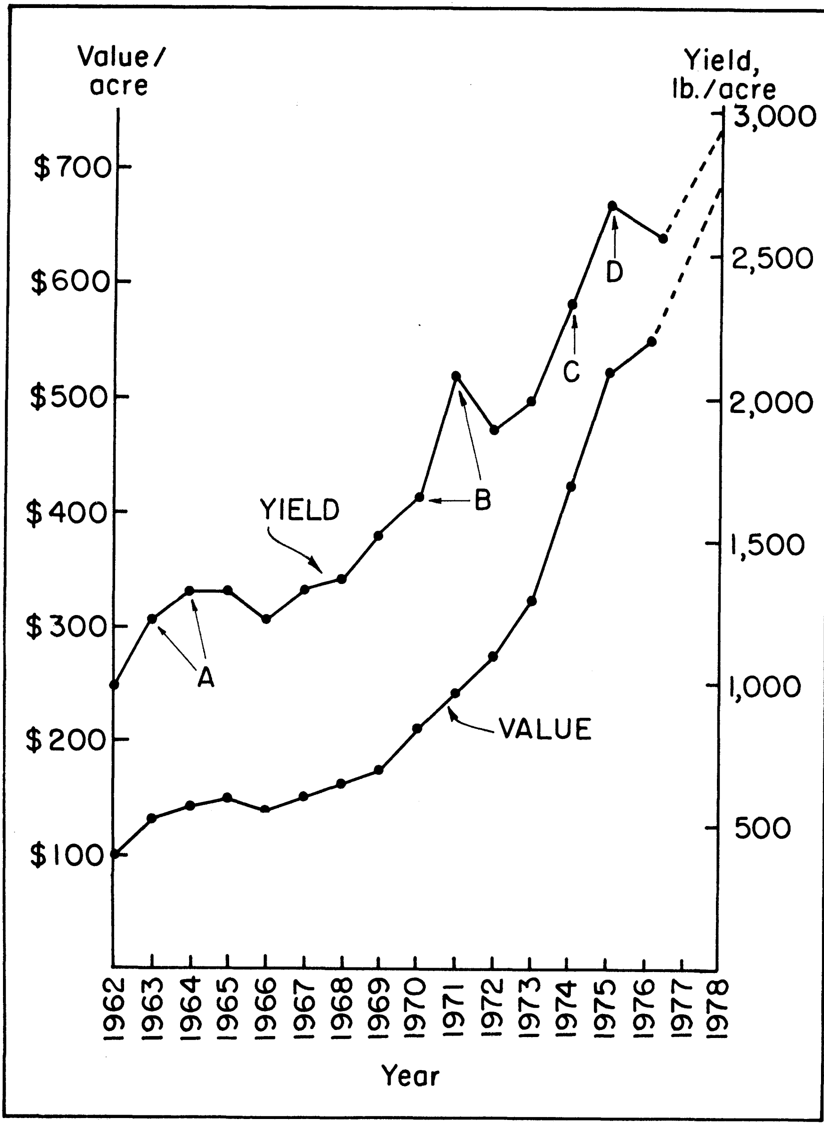
7. When Bravo, Difolatan, or Duter are applied, a 14-day waiting period is necessary before peanuts may be harvested. Do not allow livestock to graze treated areas. Do not feed hay from treated fields to livestock.

8. Do not mix Duter with Toxaphene since leaf burning may occur.

9. There are no limitations on sulfur and copper fungicides.

APPENDIX 3

Contributions of Plant Pathology to Peanut Production



Contributions of plant pathology to peanut production are illustrated by curves showing steadily increasing yield and value per acre of peanut production. The letter designations indicate the time of practices being adopted or fungicides becoming available for farm use: A—organic fungicides for leafspot control; B—second generation fungicides for leafspot; C—nematicides adopted; and D—soil fungicides for white mold.

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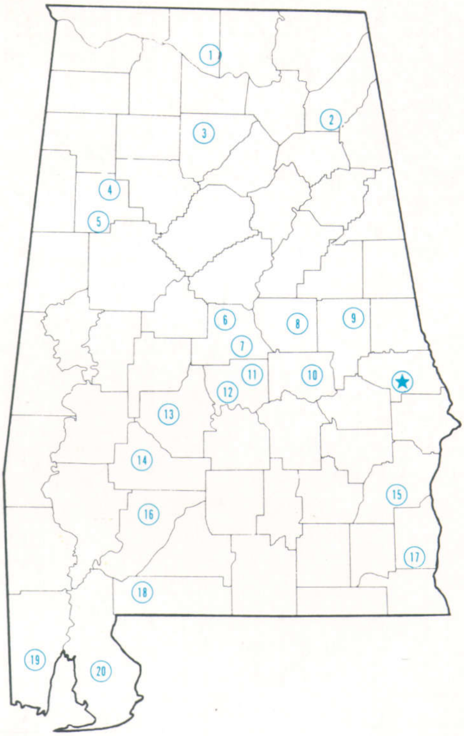

Research Unit Identification

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1. Tennessee Valley Substation, Belle Mina.
2. Sand Mountain Substation, Crossville.
3. North Alabama Horticulture Substation, Cullman.
4. Upper Coastal Plain Substation, Winfield.
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6. Thorsby Foundation Seed Stocks Farm, Thorsby.
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8. Forestry Unit, Coosa County.
9. Piedmont Substation, Camp Hill.
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11. Forestry Unit, Autauga County.
12. Prattville Experiment Field, Prattville.
13. Black Belt Substation, Marion Junction.
14. Lower Coastal Plain Substation, Camden.
15. Forestry Unit, Barbour County.
16. Monroeville Experiment Field, Monroeville.
17. Wiregrass Substation, Headland.
18. Brewton Experiment Field, Brewton.
19. Ornamental Horticulture Field Station, Spring Hill.
20. Gulf Coast Substation, Fairhope.