Analysis of Changes in Area of Cylindrocladium Black Rot in Peanut Fields Utilizing False-Color Infrared Photography

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ABSTRACT

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Changes in Cylindrocladium black rot (CBR) area in 31 Virginia peanut fields were assessed over a 6-yr period (1974–1979) with aerial, false-color infrared photography. A general increase in CBR area per field and total number of CBR foci was found for the period, except in 1978. For fields planted in peanuts during 1974, 1976, and 1978, the disease was found to be greatest in 1976, when the mean area of CBR per field was 2,935 m^2. A decrease in CBR area per field in 1978 (1,835 m^2) was believed to result from low temperatures during the winters of 1976–1977 and 1977–1978. For fields planted in peanuts in 1975, 1977, and 1979, the largest areas of CBR per field were found in 1977 (2,734 m^2) and 1979 (2,660 m^2), even though one or two severe winters intervened. Less CBR area per field in 1975 (2,187 m^2) than in later years may have been due in part to a summer drought, which slowed CBR symptom development. Individual fields sometimes showed distinct patterns on CBR area change. Decreases in CBR area in a few fields between 1974 and 1976 or 1977 and 1979 suggest these fields should be investigated as potential disease-suppressive soils. Patterns of new CBR focus development and enlargement in fields were consistent with proposed means of microsclerotial dispersal.

Additional keywords: *Cylindrocladium crotalariae*, groundnut

Cylindrocladium black rot (CBR), caused by *Cylindrocladium crotalariae* (Loos) Bell & Sobers, has been a devastating soilborne disease of peanut in Virginia over the past 16 yr. In some instances, aerial photographs and on-site observations indicate that all peanut plants in large areas of a field have been killed (10,11). In other instances, only small spots or foci of diseased plants have been found in fields (11). Using aerial photograph estimates, Powell et al (10) showed that often less than 0.01 ha in a field may have CBR. However, changes over time in the area of CBR-symptomatic plants (CBR area) in individual fields have not been documented. Presently, the disease is found in many fields, but extensive areas of peanut fields are generally not affected.

In order to measure changes in CBR area in individual peanut fields over time, we studied false-color infrared photographs taken over a period of 6 yr. Measurements of changes in CBR area in individual fields may provide information for studies on spread of CBR, the effect of physical factors on CBR development, the development or lack of development of disease suppression in soils, the influence of cultural practices on CBR development, and the assessment of CBR disease losses (10).

MATERIALS AND METHODS

In the peanut-growing area of Southampton County, VA, growers typically follow a rotation scheme of peanuts followed by corn. Peanut fields in 2-yr schemes beginning in 1974 and 1975 were analyzed for spatial changes in the CBR spectral signatures, using aerial infrared photography. Eighteen fields were selected in order to evaluate CBR during the years 1974, 1976, and 1978. Thirteen fields were selected to evaluate CBR during the years 1975, 1977, and 1979. Each group of fields was evaluated and recorded together as a unit. These fields were selected based on ground verification of the presence of the disease in the fields (10,11).

Peanut fields selected for this study were all located in a rectangular area within Southampton County, VA. Maps of the Geological Survey of the United States Department of the Interior were used to locate fields. The maps are quadrangles covering 7.5 minutes of latitude and longitude and published at a representative fraction of 1:24,000. The study area has been mapped as the Capron, Courtland, and Holland quadrangles in the north and the Margrettsville, Boykins, and Gates quadrangles in the south. Fields selected for study of CBR during the years 1974, 1976, and 1978 were dispersed across the entire rectangular study area. Fields selected to assess the progress of CBR during the years 1975, 1977, and 1979 were primarily located near the towns of Capron and Newsoms in Virginia. Each field studied was designated by a field code of alpha-numeric characters. The alpha component is the first letter of the 7.5 minute quadrange map where the field is located.

Aerial, false-color infrared imagery was collected during the latter weeks of September in 1974, 1975, 1976, 1977, and 1978 and early October of 1979. NASA aircraft, originating from NASA Wallops Flight Center at Wallops Island, VA, made the aerial reconnaissance flights at an altitude of approximately 3,500 m.

Infrared, false-color film (Kodak Aerochrome 2443) was used. Vertical imagery was collected by using a T-11 camera having a lens focal length of 152 mm and 12AV and CC10M filters. All three emulsion layers of the film are sensitive to blue light. Reduction of blue light provides maximum contrast in the transparencies. The CC10M filter is a gelatin filter with magenta added to reduce or exclude blue light (6). The film format was a positive transparency, 22.68 × 22.86 cm. The approximate representa-

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tive fraction of the imagery was 1:23,000.

Aerial photographs collected during the growing seasons were viewed on a Richards light table (model GFL-940). The CBR spectral signatures were located based on the technique developed by Powell et al (11). The image of each of the selected fields found on the aerial, infrared film was photographed using Kodak Ektachrome 64 true color film. The true color photographs (approximately 1:1 scale) were projected to a scale of 10:1 for closer evaluation and quantitative measurement of the CBR spectral signatures. The area of CBR images of projected peanut fields were measured using a medium density dot graph with 9.9 dots per square centimeter. The CBR signatures within the projected peanut field images were measured four times to limit sampling error.

Due to possible differences in altitude among flights, the infrared imagery was scaled for each year. The spectral signatures for each field were measured with a dot graph, and the number of square centimeters of signature on the field image were then converted to square meters in the field by multiplying the signature square centimeter count by the calculated representative fraction of the infrared image. The product was then divided by 10 to account for the 10× enlargement made for accurate signature determination.

The number of independent local concentrations of symptomatic plants, or foci, were assessed in each field for each year. The geographic orientation of new foci relative to previously established foci was noted. Any topographical features observable on the aerial imagery that appeared to be associated with the locations of new foci were noted also. Area measurements of prominent foci were taken to assess disease spread in these foci from year to year.

The 13 fields selected in the odd-year scheme were visited during the 1981 growing season. The presence of perithecia on dead or dying plants was noted and diseased plant samples were collected for laboratory confirmation of the pathogen. The isolation of *C. crotalariae* from peanut plant tissue was done on sucrose-QT selective medium (4). Additionally, each of the fields assessed during this study had, during previous studies, been confirmed to have CBR by ground observation of peanut plants, or by the presence of microsclerotia in soil samples (10,11).

The term focus is used frequently throughout this paper. The term is used to imply the site of local concentration of symptomatic plants about a presumed primary source of infection (15).

RESULTS

Each field had specific and separate changes in CBR area and number of foci. For example, field N-7 contained four foci in 1975 for a total signature area of 638 m^2 (Table 1). Three main CBR areas or apparent foci were present in N-7 in 1977; two foci identified in 1975 had combined and increased in size. This area aligned with the rows from east to west and the area had increased to 1,417 m^2. In 1979, there were six main foci discernable in N-7, but there were also a number of small, secondary foci that surrounded the main foci. This pattern gave the CBR signature a mosaic appearance. Only the main foci were counted. One-third to one-half of the field was affected for a total signature area in 1979 of 3,907 m^2. This was greater than in 1977.

Some overall tendencies were noted among fields. Of the three odd-numbered years evaluated, 1975 had the lowest CBR area per field. The average signature size was 2,187 m^2 per field (Table 1). A total of 42 foci were identified in 1975 (Table 1). The average signature size was 2,734 m^2 in 1977, or the largest average signature area per field in the odd-year evaluations. Fifteen new foci were identified in 1977. The average signature area per field was slightly less in 1979 than in 1977. This average signature size of 2,660 m^2 per field was not different ($P = 0.05$) from the average signature size per field in 1977. There were 15 new foci identified overall in 1979.

During the odd-year scheme, eight of 13 fields had the greatest CBR area during 1979 (Table 1). Only five fields had the greatest CBR area in 1977. In 1975, nine fields out of 13 exhibited their least CBR area.

Field C-3 had relatively large signature areas in 1975 and 1977, both over 12,000 m^2. This signature area had a profound influence on the statistical analysis of data in this study (Table 1). When field C-3 was deleted from the analysis, the mean signature area per field was greatest ($P = 0.05$) in 1979 (2,248 m^2).

All fields evaluated in the odd-year scheme contained plants with CBR symptoms. Several of the fields also contained plants with characteristic red perithecia near the soil line. After 5 days of incubation at 25 C, typical colonies of *C. crotalariae* formed on the sucrose-QT medium for tissue samples from all fields visited.

Of the three even-numbered years evaluated for CBR, 1974 had the second lowest ($P = 0.05$) mean CBR area per field. The mean CBR area was 2,324 m^2 per field (Table 2). There were 65 foci identified in 1974 (Table 2). The disease was most extensive ($P = 0.05$) in 1976; the mean diseased area was 2,935 m^2 per field. Nineteen new foci appeared that year. The lowest CBR area was found in 1978; a mean signature area of 1,835 m^2 per field was determined. Six foci were identified in 1978 that were not found in the two previous years.

Thirteen of 18 fields assessed for CBR signature area over even-numbered years had their greatest area in 1976 (Table 2). Ten of the 18 fields measured in 1978 exhibited the least CBR area during that year.

DISCUSSION

The general pattern found in this study for change in CBR area per field was an increase over the first two peanut crops

Table 1. Mean total signature areas and number of foci of Cylindrocladium black rot (CBR) present in peanut fields in 1975, 1977, and 1979 based on false-color infrared film interpretations

	Area and total foci identified in each field[x]						New foci identified[y]	
	1975		1977		1979			
Field code	Area (m^2)	Foci	Area (m^2)	Foci	Area (m^2)	Foci	1977	1979
N-1	648	3	1,053	6	1,549	3	3	0
N-2	800	3	810	3	1,528	6	1	3
N-3	1,204	3	1,154	4	2,348	6	1	3
N-4	617	3	1,500	3	1,184	4	0	1
N-5	324	1	587	3	1,002	5	2	2
N-6	830	2	1,336	5	1,425	6	3	2
N-7	638	4	1,417	3	3,907	6	0	3
N-8	1,457	3	1,640	3	1,751	4	0	1
C-3	12,800	1	13,100	1	7,186	1	0	0
C-4	1,741	3	1,893	7	1,366	6	4	0
C-5	3,153	10	2,055	10	3,300	9	0	0
C-6	2,804	5	3,101	5	3,019	5	0	0
C-7	1,408	1	6,082	2	3,836	2	1	0
Field mean	2,187 b[z]		2,734 a[z]		2,660 a[z]			
Field mean (minus field C-3)	1,302 c		1,864 b		2,248 a			
Total for year		42		55		63	15	15

[x] The total number of foci of CBR observed on aerial infrared imagery found in each field for each year.

[y] The total number of new foci observed on aerial infrared imagery found in each field for each year.

[z] Means are the average of four replications of measurements of the CBR signature area in each field. Field means compared horizontally and followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

for both the even-year (1974–1976) and odd-year (1975–1977) sequences. This trend continued into the third crop of peanuts (1975–1979) for the odd-year sequence, when field C-3 was not considered in the analyses. Thus, a general increase in spread of the disease over time was found for the fields studied, except in 1978. A similar trend in the total number of foci was observed. In 1978, the mean area of CBR per field was significantly less than found in 1976 or 1974, and the total number of foci was less in 1978 than in 1976.

Physical factors may have been largely responsible for the decline in CBR noted in 1978. The winter of 1976–1977 was very cold in the Virginia peanut region and the winter of 1977–1978 was almost as severe. Freezing and chilling soil temperatures are detrimental to the survival of *C. crotalariae* microsclerotia (3,5,9,12,14), which is the main survival propagule of the pathogen. During January and February of 1977, soil water froze in the plow layer for several weeks (9,12,14). An overall decrease of 95% was noted in microsclerotial population densities in Virginia field plot soils in 1977 at soil depths up to 25 cm (14). Similar findings were made in North Carolina (9). Significant decreases in microsclerotial densities in Virginia field soils were also noted from November 1977 to April 1978 (3).

The mean CBR area per field in 1979 was significantly greater than in 1975, even though the severe winters of 1976–1977 and 1977–1978 intervened. Similarly, the mean CBR area in 1977 was greater than in 1975. In addition to inoculum buildup in peanut roots during the 1975 and 1977 growing seasons, several factors may account for these differences. Environmental conditions during the 1975 growing season may have influenced disease expression and, thus, the CBR signature. Rainfall was very limited during the early weeks and the latter part of the 1975 growing season (14). Powell et al (10) reported that, of the fields they surveyed, a greater proportion had severe CBR in 1974 than in 1975. Whereas a late drought may favor CBR symptom expression, Phipps and Beute (8) found CBR development is favored by soil moisture levels near field capacity. An area in one Virginia field, having severe CBR (imagery showed a large, gray, or bare-soil area [10,11]) in the previous peanut crop, only had 2.6% CBR incidence for 1975 in the same area (14). Soil assays in 1975 showed the entire area was infested. Such an area with low CBR incidence would probably not be observable on the imagery. In contrast, gray or apparently bare-soil areas in the CBR signature (10,11) typically have 100% CBR incidence. Thus, the CBR signatures may have been greater in area in 1975 during this study had environmental conditions been more favorable for disease development. Further, the aerial infrared photographs were taken about 3 wk before harvest in 1975, which is relatively early. Ideally, CBR photographs should be taken as near to harvest as possible in order to get maximal symptom development and CBR area.

Another factor that may be important is the reversal of low-temperature injury to microsclerotia by moderate (26 C) temperatures (12). Some *C. crotalariae* microsclerotia, nongerminable after exposure to 0 C, were germinable if they were exposed to 26 C for 1 mo before germination tests (12). Also, microsclerotia in the lower parts of the plow layer may have less exposure to low temperatures and may be brought to the upper soil horizons by spring plowing. These points should be generally applicable to microsclerotium survival in both 1977 and 1978.

Increase in the areas of CBR in peanut fields appeared to result from both an increase in size of foci and an increase in the number of foci. At least one-third of the fields evaluated in this study contained foci that were oriented parallel to the peanut rows, and about one-third of the fields contained foci that aligned with drainage patterns. Krigsvold et al (7) found that *C. crotalariae* may be spread along drainage patterns and that the fungus can be spread along peanut rows by cultivation. Similarly, Powell et al (11) reported that CBR signatures often tended to align with the plant rows. Other new foci may originate from dispersal of microsclerotia during the combining of peanuts (13).

Fields that show a decline in CBR area, apart from effects of low temperature or drought, may be candidates for investigations on CBR-suppressive soils that have been demonstrated in greenhouse tests (1,2). Fields such as C-10, C-11, N-9, and possibly C-3, are examples. Fields C-10 and N-9 showed decreases in CBR area from 1974 to 1976, and field C-3 exhibited a decrease in CBR area from 1977 to 1979. These changes were opposite those changes in most fields during these time intervals.

Table 2. Mean total signature areas and number of foci of Cylindrocladium black rot (CBR) present in peanut fields in 1974, 1976, and 1978 based on false-color infrared film interpretations

	Area and total foci identified in each field[w]						New foci identified[x]	
	1974		1976		1978			
Field code	Area (m^2)	Foci	Area (m^2)	Foci	Area (m^2)	Foci	1976	1978
M-1	1,315	6	1,963	7	1,356	6	1	0
M-2	6,073	3	7,338	7	1,953	8	4	1
M-3a	1,619	3	4,686	4	941	1	1	0
M-3b	364	1	698	3	...[y]	...[y]	2	...[y]
B	3,522	8	3,947	10	2,814	9	2	1
S	435	2	921	2	645	2	0	1
G	1,368	5	2,860	5	3,340	5	0	0
H	1,417	1	2,844	1	2,297	2	0	1
Ct-1	1,113	6	6,113	10	1,953	4	4	0
Ct-2	1,741	6	5,567	6	1,710	5	0	0
C-9	850	4	2,014	4	1,083	3	0	0
C10	1,923	6	1,255	7	1,154	7	1	0
C-8	1,457	1	2,216	4	1,200	3	3	0
C-11	2,257	6	1,962	5	496	5	0	0
N-10	617	1	2,581	2	1,548	3	1	1
N-11	860	3	2,520	3	709	3	0	0
N-12	9,919	1	5,567	1	4,129	1	0	0
N-9	3,077	2	2,358	2	1,528	3	0	1
Field mean	2,324 b[z]		2,935 a[z]		1,835 c[z]			
Total for year		65		83		70	19	6

[w] The total number of foci of CBR observed on aerial infrared imagery found in each field for each year.
[x] The total number of new foci observed on aerial infrared imagery found in each field for each year.
[y] Harvested before photographs were made.
[z] Means are the average of four replications of measurements of the CBR signature area in each field. Field means compared horizontally and followed by the same letter are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

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