Peanut Science (1985) 12:82-85

# Cercospora Leafspot Management Decisions: An Economic Analysis of a Weather-Based Strategy for Timing Fungicide Applications[1,2]

C. S. Johnson, P. M. Phipps, and M. K. Beute*[3]

**ABSTRACT**

The average savings in peanut leafspot control costs from use of the Virginia leafspot advisory program versus the conventional 14-day application schedule ranged from $70.95/ha for cupric hydroxide plus sulfur to $97.39/ha for benomyl plus sulfur in 1980-1983. Increases in net returns from use of benomyl plus sulfur, chlorothalonil, or cupric hydroxide plus sulfur with the leafspot advisory were attributed to increases in yield as well as decreased control costs. Average annual increases in net return from use of the advisory in comparison to standard 14-day programs of the same fungicides were $259.99, $200.21, $192.55, and $220.57/ha for 1980, 1981, 1982, and 1983, respectively. Annual variation in economic returns was similar for all fungicides and for both application schedules tested.

Key Words: Budget analysis, disease forecast models, disease management, epidemiology.

Early leafspot of peanut (*Arachis hypogaea* L.) is caused by *Cercospora arachidicola* Hori. This disease, along with late leafspot caused by *Cercosporidium personatum* (Berk. & Curt.) Deighton, occurs wherever peanuts are grown and has been reported to induce yield losses of up to 50% in some areas of the world (21). Annual estimates of regional losses in the U. S. range from 5 to 10% (4). In Alabama, the cultivar, Florunner lost 57 kg/ha (14.0 lb/acre) for each 1% infection assessed at the end of the growing season (1). In addition to the yield losses caused by this disease, control costs for peanut leafspot are a major production expense.

Recommended management tactics for peanut leafspot include crop rotation (10), destruction of peanut debris (4), and application of fungicides (21). Fungicides are the primary control measure in the U.S. Fungicides have traditionally been applied as foliar sprays on a 10- to 14-day schedule beginning 30 to 60 days after planting and ending 14 to 21 days before digging. The cost of such an intense program has spurred research on alternative control methods. Partial host resistance and different fungicide application achedules have received the most attention. Spray programs based on scouting models and economic thresholds (6,11) and environmentally based advisory models have been tested for their effectiveness in scheduling fungicide applications (2,16,17).

Jensen and Boyle (7,8) correlated increases in the severity of peanut leafspot with periods of relative humidity above 95% and minimum temperatures of 21 C. Parvin, Smith, and Crosby (15) used Jensen and Boyle's model to construct decision rules to schedule leafspot fungicide applications in Georgia. These same rules are the basis for peanut leafspot advisory programs for the peanut growing areas in North Carolina and Virginia. The Virginia advisory system has been evaluated on the basis of disease severity (17), numbers of fungicide applications (9,17) and yield/ha (17). These reports, however, did not include cost analyses of the various fungicide application schedules, nor the relationships between the costs and benefits of the alternatives over more than an annual period. The objective of this study was to compare the annual net returns from use of the Virginia leafspot advisory program with various fungicides to use of the traditional 14-day schedule.

## Materials and Methods

Field experiments were conducted in southeastern Virginia in 1980-1983 in order to evaluate various fungicide application schedules for control of Cercospora leafspot. Annual experiments were conducted at a single location each year. The location of the tests varied every year. Peanuts were planted on May 9, 12, 3, and 10 in 1980-1983, respectively. Plots consisted of two rows 12.2m long and spaced 0.91m apart, except in 1981 when rows were 10.7m long. Plots were planted to approximately 120 seed/row with the cultivar Florigiant. A randomized complete block design was used each year with four replications. Two border rows separated each plot from those immediately adjacent to it within each block. A 2.1m-wide alleyway separated blocks. Except for leafspot fungicide applications, standard cultural practices were followed each year. Herbicides (vernolate, alachlor, dinoseb plus alanap, and bentazon), a nematicide (fenamiphos), insecticides (aldicarb, carbaryl, and fonofos), and fertilizers (calcium sulfate, boron, and manganese) were applied routinely according to recommendations of the Virginia Cooperative Extension Service. PCNB (quintozene) was also applied as 10% granules at 112 kg/ha to all plots about ten weeks after planting to control southern stem rot.

Leafspot fungicides were applied with a $CO_2$ pressure-regulated backpack sprayer. Both rows of each plot were sprayed simultaneously with three D2-13 (disc-core combination) nozzles/row. Spray nozzles were calibrated to deliver 140L of solution per hectare at 345kPa of

[1]Paper No. 9856 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, N. C. 27695-7601.

[2]The use of trade names in this publication does not imply endorsement by the North Carolina Agricutural Research Service of the products named, nor criticism of similar ones not mentioned.

[3]Former Graduate Research Assistant, Department of Plant Pathology, North Carolina State University, Raleigh, N. C. 27695-7616, Associate Professor of plant pathology, Tidewater Research and Continuing Education Center, Suffolk, Va. 23437, and Professor, Department of Plant Pathology, North Carolina State University, Raleigh, N. C. 27695-7616.

pressure and walking speed of 10 sec./12.2m. Border rows were left unsprayed in an effort to minimize interplot interference.

The Virginia leafspot advisory issues daily reports on the effect of weather conditions over the past five days on leafspot development and spread. Fungicide applications based on the advisory were made following a report of favorable conditions for infection and secondary disease spread. Spray decisions were based upon data from the weather station nearest the test plots (Suffolk, VA). Fungicide applications were made when foliage was dry and within one to five days of a favorable advisory, but never more frequently than intervals of 10 days.

Percent infected leaflets and percent defoliation were assessed in each plot at approximately 12, 16, and 20 weeks after planting. Plots were dug between 135 and 145 days after planting with a commercial digger-inverter and then picked with a commercial combine within 5 to 10 days after digging. Pod yields were obtained after the seed had been dried to approximately 10% moisture. A market grade analysis was performed on 500g samples of pods taken from each plot. Support prices for each plot were calculated from the results of the market grade analysis and used to derive an estimate of the economic value of the yield from each plot. Fungicide material costs were estimated from the results of a confidential survey of agrichemical dealers in the Virginia peanut growing area (Phipps, unpublished). Estimates of typical fungicide application costs due to fuel, labor and equipment were obtained from the Virginia Cooperative Extension Service. Net returns to growers from leafspot management activities were estimated by subtracting the total estimated control costs (material plus application costs) from the estimated gross value from each treatment unit. Gross economic value and net return were analyzed on an annual basis as well as by a weighted ANOVA of pooled 1980-1983 data. The following fungicides (or combinations of fungicides) were used at the rates indicated: 0.56kg/ha Benlate 50W (benomyl) plus 4.7L/ha sulfur (718 g/L), 2.3L/ha Bravo 500F (chlorothalonil), 4.7L/ha Kocide (cupric hydroxide (17.5 % Cu) plus sulfur (15.5%)), 0.42 or 0.56kg/ha Duter 47.5W (triphenyltin-hydroxide plus 2.34L/ha sulfur (718 g/L)), and no fungicide treatment. The economic benefits from timing fungicide applications according to the advisory versus those of the 14-day achedule were compared using data from tests conducted from 1980 to 1983.

## Results

In each year, fewer sprays were applied when the Virginia peanut leafspot advisory program was consulted than when the 14-day schedule was followed. Seven sprays were applied on the 14-day schedule in 1980, 1981, and 1983. Only six fungicide applications were made in 1982 because the crop matured earlier than normal. One (7/14), three (7/6, 7/20, 8/10), two (7/12 and 8/2), and three (6/23, 7/7, and 8/31) sprays were applied according to advisories in 1980, 1981, 1982, and 1983, respectively. A severe drought occurred in 1980 which depressed yield as well as suppressed disease. Conditions were also dry in 1983, resulting in little disease. Such conditions are considered rare for this area. Record yields, however, were obtained in 1981.

When all fungicide treatments were averaged together within years, annual increases in gross and net returns from fungicides used on the calendar schedule were greater (P = 0.05) than control only in 1982 (Table 1). In that year, use of any fungicide with the Virginia leafspot advisory increased net returns over those obtained using the calendar schedule. Application of triphenyltin hydroxide plus sulfur with the advisory in 1980 resulted in less economic value and net return than was associated with use of the same chemical on the 14-day schedule. Net return increased in 1982 when triphenyltin hydroxide plus sulfur was applied according to leafspot advisories versus the 14-day schedule. More net income was received in 1981 when cupric hydroxide plus sulfur was applied according to the Virginia leafspot advisory than was obtained using the 14-day schedule.

Table 1. Annual mean economic returns for peanut leafspot fungicides applied according to the Virginia leafspot advisory system or on the standard 14-day achedule in 1980-1983.[a]

| Year | Fungicide | Gross Return ($/ha) 14-day | Gross Return ($/ha) Advisory | Net Return ($/ha) 14-day | Net Return ($/ha) Advisory |
|---|---|---|---|---|---|
| 1980 | benomyl + sulfur | 901.3ab | 907.5a | 780.6ab | 887.4a |
| | chlorothalonil | 580.1ab | 558.5ab | 469.6ab | 540.0ab |
| | cupric hydroxide + sulfur | 428.1b | 946.4a | 326.7b | 929.5a |
| | triphenyltin hydroxide + sulfur | 1145.9a | 453.4b | 1056.7a | 438.6b |
| | control | 539.9 | | 539.9 | |
| 1981 | benomyl + sulfur | 2539.6a | 2454.9bc | 2381.9a | 2387.4bc |
| | chlorothalonil | 2508.7a | 2740.3a | 2366.2a | 2679.3a |
| | cupric hydroxide + sulfur | 2377.7a | 2590.8ab | 2256.8a | 2539.0ab |
| | triphenyltin hydroxide + sulfur | 2535.9a | 2252.9c | 2430.1a | 2207.6c |
| | control | 2312.2 | | 2312.2 | |
| 1982 | benomyl + sulfur | 3059.7a | 3034.4a | 2914.3a | 2985.9a |
| | chlorothalonil | 2841.6a | 3070.2a | 2709.1a | 3026.0a |
| | cupric hydroxide + sulfur | 2923.8a | 3038.1a | 2823.3a | 3004.6a |
| | triphenyltin hydroxide + sulfur | 3004.7a | 3128.9a | 2890.2a | 3090.7a |
| | control | 2310.4 | | 2310.4 | |
| 1983 | benomyl + sulfur | 1949.6a | 2087.4a | 1767.5a | 2009.3a |
| | chlorothalonil | 1952.9a | 2023.1a | 1790.3a | 1953.4a |
| | cupric hydroxide + sulfur | 1903.9a | 2089.2a | 1790.3a | 1953.4a |
| | triphenyltin hydroxide + sulfur | ——— | 2081.2a | ——— | 2019.8a |
| | control | 1915.6 | | 1915.6 | |

a Means followed by the same letter were not significantly different at P=0.05 using Duncan's Multiple Range Test.

b Triphenyltin hydroxide + sulfur was not tested with the 14-day schedule in 1983. Means for this treatment, therefore, include data fpr 1980-1982 oply.

Variation from year to year in economic return was similar for all fungicides and application schedules (Table 2). Differences in mean annual gross returns with benomyl plus sulfur, chlorothalonil, or cupric hydroxide plus sulfur ranged from losses of $34.30 /ha (benomyl + sulfur, 1981) to gains of $209.76 /ha (cupric hydroxide + sulfur, 1980) when the advisory was compared with the calendar schedule. Differences in mean annual net returns ranged from $2.15 /ha to $243.97 /ha. Results obtained using triphenyltin hydroxide plus sulfur according to the advisory versus the 14-day schedule ranged from losses in net return of $250.24 /ha in a severe drought year (1980) to gains of $81.20 /ha in 1982. Mean increases in annual net return from use of the advisory with benomyl plus sulfur, chlorothalonil, and cupric hydroxide plus sulfur ranged from $76.83 /ha in 1982 to $105.22 /ha in 1980.

Gross economic value and net return varied among years and between application schedules in the analysis of pooled date (Tables 1 and 2). Significant year x fungicide, fungicide x schedule, and year x fungicide x schedule and year x schedule interactions, however, resulted from the poor performance of triphenyltin hydroxide when it was used with the advisory in 1980. The year x fungicide interaction resulted from the variation in disease pressure among the years tested, and was not included in the analysis. Use of any fungicide increased the average gross return for the four years studied over that observed for the non-sprayed control (Table 2.) Use

**Table 2. Means and their standard errors for annual economic returns for peanut leafspot fungicides and application schedules tested in Virginia in 1980-1983.[a]**

| Schedule | Fungicide | Mean Gross Return ($/ha) | Net Return ($/ha) Mean | Net Return ($/ha) Standard Error of Mean |
|---|---|---|---|---|
| 14-day | benomyl + sulfur | 2123.39ab | 1973.98ab | 245.46 |
| | chlorothalonil | 1972.02bc | 1836.72b | 239.60 |
| | cupric hyrodxide + sulfur | 1908.40bc | 1796.48b | 244.60 |
| | triphenyltin hydroxide + sulfur[b] | 2228.84a | 2125.65a | 250.59 |
| Advisory | benomyl + sulfur | 2121.07ab | 2067.46ab | 208.58 |
| | chlorothalonil | 2098.05ab | 2049.69ab | 250.71 |
| | cupric hydroxide + sulfur | 2166.13a | 2127.23a | 213.16 |
| | triphenyltin hydroxide + sulfur | 1979.11b | 1939.17b | 251.50 |
| 14-day | Mean[c] | 1999.3a | 1867.5a | |
| Advisory | Mean | 2128.4b | 2081.5b | * |
| Mean | benomyl + sulfur | 2122.2a | 2022.2a | |
| Mean | chlorothalonil | 2037.1a | 1946.6a | |
| Mean | cupric hydroxide + sulfur | 2037.3a | 1961.9a | |
| Mean | triphenyltin hydroxide + sulfur | 2086.1a | 2019.1a | |
| Mean | control | 1769.5b | 1769.5b | |

a Means followed by the same letter were not significantly different at P=0.05 using Duncan's Multiple Range Test.
b Means and their standard errors for triphenyltin hydroxide + sulfur applied on the 14-day schedule include only 1980-1982 data. This treatment was not tested in 1983.
c Means for the 14-day and advisory programs do not include data for triphenyltin hydroxide + sulfur since results using this fungicide were not consistent between application schedules and among years.

of cupric hydroxide plus sulfur resulted in higher average gross and net returns than did triphenyltin hydroxide plus sulfur when the Virginia leafspot advisory was used. Application of triphenyltin hydroxide on the 14-day schedule resulted in higher average gross and net returns for 1980-1983 than did chlorothalonil or cupric hydroxide plus sulfur. Use of the advisory produced a higher average net return than did the standard 14-day calendar schedule or the unsprayed control.

Average savings in control costs and increases in economic value and net return from use of each fungicide with the Virginia leafspot advisory versus the 14-day schedule are compared in Table 3. Use of the advisory with all of the peanut leafspot fungicides tested reduced estimated leafspot control costs. Increase in gross returns from use of the advisory relative to the calendar schedule were frequently larger than the savings from reduced fungicide use.

## Discussion

Phipps and Powell (17) recently reported that use of the Virginia leafspot advisory program resulted in fewer fungicide applications and equivalent yield and quality to those obtained using the conventional 14-day schedule. They also suggested that the advantages of the advisory system over the 14-day schedule would include a decrease in production costs as well as reduced direct and indirect effects attributable to vine injury (14,18) and non- target effects of leafspot fungicides (5,20). Reductions in the total amount of fungicide applied over the

**Table 3. Average annual increases in gross and net returns and decreases in peanut leafspot control costs for 4 peanut leafspot fungicides applied according to the Virginia penaut leafspot fungicide advisory system in 1980-1983. Values are derived from comparison with treatments receiving fungicides on the 14-day schedule.**

| Fungicide | Increased Gross Return ($/ha) | Decreased Control Cost ($/ha) | Increased Net Return ($/ha) |
|---|---|---|---|
| benomyl + sulfur | 8.49 | 97.93 | 106.42 |
| chlorothalonil | 127.19 | 88.69 | 215.89 |
| cupric hydroxide + sulfur | 257.75 | 72.97 | 330.72 |
| triphenyltin hydroxide + sulfur[a] | -283.47 | 70.40 | -213.40 |

a Triphenyltin hydroxide + sulfur was not tested with the 14-day schedule in 1983. Means for this fungicide, therefore, include data for 1980-1982.

course of the growing season may help to stabilize natural populations of pathogens of the two-spotted spider mite (3). Possible direct, yield-limiting effects of leafspot fungicides might also be reduced (12,13,22).

Use of the Virginia peanut leafspot advisory always reduced estimated control costs and generally increased net economic return to the grower. Factors other than decreased control costs were often responsible for a significant portion of the benefits realized from use of the advisory (Table 3.) These increases did not result from greater disease control, since levels of peanut leafspot were somewhat greater when the advisory was used versus the 14-day schedule (17). They must, therefore, have resulted from reductions in the undesirable side-effects of disease management activities and materials.

Phipps and Powell (17) concluded that fungicide selection was not a major factor affecting the utility of the Virginia leafspot advisory system because all compounds increased yield significantly over that of the unsprayed control. Use of the 14-day schedule, however, also consistently produces higher yields and economic returns than does no treatment with a fungicide. The 14-day spray schedule should, therefore, be the alternative treatment used to evaluate timing programs for peanut leafspot fungicides in Virginia. Use of the advisory with some fungicides and under certain environmental or disease conditions could result in reduced farmer income. Use of triphenyltin hydroxide plus sulfur with the Virginia leafspot advisory in 1980 resulted in less economic return than that obtained with the 14-day schedule. Some phytotoxicity was observed in 1980 in plots treated with triphenyltin hydroxide. These results, along with differences which were not significant in analyses of data from individual years, may have contributed to a significant interaction between fungicides and application schedules when data for all fungicides was pooled for 1980-1983. The significance of the interaction between fungicides and application schedules indicated that fungicide choice was important in assessing the potential benefits of following the Virginia leafspot advisory, especially when the 14-day spray schedule was used as the basis of comparison.

Increased risk of disease loss is frequently assumed to be a major reason for not using a disease forecast or advisory model for disease management. Use of the Virginia leafspot advisory was not associated with a significant increase in such risk. Variation in economic return over years was about the same for both application schedules (Table 2). Average annual increases in net return from use of the Virginia leafspot advisory with benomyl plus sulfur, chlorothalonil, and cupric hydroxide plus sulfur were surprisingly constant given the range of disease conditions observed. These average annual increases in net return were $259.99, $200.21, $192.58, and $220.95 /ha for 1980, 1981, 1982, and 1983, respectively.

The results of this study also illustrate the benefits of pooling data from field experiments over years. Field studies conducted within a single growing season often lack enough precision to conclude that "small" but systematic treatment differences are statistically significant. If these tests are repeated over years (as fungicide screening trials frequently are), pooling data can increase the degrees of freedom for error terms and decrease treatment variance, thus increasing the "power" of an analysis of variance to declare treatment differences to be significant. Standard errors of treatment means from analyses of individual years averaged about 27. The average standard error for treatment means from the analysis of pooled data was about 15. This increase in precision may be particularly important when treatment differences in individual tests are not statistically significant. A $76.60 /ha ($31.00/acre) difference in net return between the advisory and the 14-day schedule was usually not significant in our analysis of results from individual years, but was significant in the analysis of pooled data. Such a difference would be important to peanut growers. Analysis of pooled data over 1980-1983 demonstrated that these differences were real and enables us to recommend the Virginia leafspot advisory to growers as a reliable means to increase their net return.

## Literature Cited


1. Backman, P. A., and Crawford, M. A. 1984. Relationship between yield loss and severity of early and late leafspot diseases of peanut. Phytopathology 74:1101-1103.
2. Bailey, J. E., and Spencer, S. 1982. Feasibility of peanut leafspot forecasting in North Carolina. Proc. Amer. Peanut Res. Educ. Soc. 14:101. (Abstr.)
3. Boykin, L. S., Campbell, W. V., and Beute, M. K. 1984. Effect of pesticides on *Neozygites floridana* (Entomophthorales: Entomophthoraceae) and arthropod predators attacking the twospotted spider mite (*Acari: Tetranychidae*) in North Carolina peanut fields. J. Econ. Entomol. 77:969-975.
4. Garren, K. H., and Jackson, C. R. 1973. p. 429-494. Peanut diseases, *In* Peanuts: Culture and uses. Amer. Peanut Res. & Educ. Assoc., Stillwater, OK.
5. Hau, F. C., and Beute, M. K. 1983. Effects of chlorothalonil on the virulence and physiology of a non-targeted pathogen, *Sclerotinia minor.* Phytopathology 73:475-479.
6. Highland, H. B. 1981. Integrated pest management in south Texas peanuts. Proc. Amer. Peanut Res. Educ. Soc. 13:113. (Abstr.)
7. Jensen, R. E., Boyle, L. W. 1965. The effect of temperature, relative humidity and precipitation on peanut leafspot. Plant Dis. Reptr. 49:975-978.
8. Jensen, R. E., and Boyle, L. W. 1966. A technique for forecasting leafspot on peanuts. Plant Dis. Reptr. 50:810-814.
9. Johnson, C. S., and Beute, M. K. 1984. Evaluation of a fungicide advisory system using historical weather data. Phytopathology 74:819. (Abstr.)
10. Kucharek, T. A. 1975. Reduction of cercospora leafspots of peanut with crop rotation. Plant Dis. Reptr. 59:822-823.
11. Kucharek, T. A. 1976. Peanut leafspot assessment and control. Extension Plant Pathology Report No. 19, Fla. Coop. Ext. Serv., Institute of Food and Agricultural Sciences, Univ. of Florida, Gainesville, Florida. 3pp.
12. Middleton, K. J. 1980. The interaction between fungicide rate, application equipment and adjuvant use on leafspot control in virginia bunch peanuts. Proc. Amer. Peanut Res. Educ. Soc. 12:35. (Abstr.)
13. Middleton, K. J. 1981. The effects of using CDA equipment to apply chlorothalonil to Florunner peanuts in Georgia. Proc. Amer. Peanut Res. Educ. Soc. 13:96. (Abstr.)
14. Mozingo, R. W. 1981. Effect of cultivar and field traffic on the fruiting patterns of virginia-type peanuts. Peanut Sci. 8:103-105.
15. Parvin, D. W., Smith, D. H., and Crosby, F. L. 1974. Development and evaluation of a computerized forecasting method for Cercospora leafspot of peanuts. Phytopathology 64:385-388.
16. Phipps, P. M. 1981. Virginia growers to test leafspot advisories in 1981. Proc. Amer. Peanut Res. Educ. Soc. 13:113. (Abstr.)
17. Phipps, P. M., and Powell, N. L. 1984. Criteria for utilization of peanut leafspot advisories in Virginia. Phytopathology 74:1189-1193.
18. Porter, D. M., and Powell, N. L. 1980. Scerotinia blight development in peanut vines injured by tractor tires. Peanut Sci. 5:87-90.
19. Shaffer, S. D., Martin, T., and Powell, N. L. 1983. Virginia's automated weather data collection network for disease modeling and forecasting. Proc. Amer. Peanut Res. Educ. Soc. 15:98. (Abstr.)
20. Shokes, F. M., and Arnold, J. A. 1982. Effect of ground spray equipment on the distribution of *Sclerotium rolfsii* in peanut fields. Proc. Amer. Peanut Res. Educ. Soc. 14:50-59.
21. Smith, D. H., and Littrell, R. H. 1980. Management of peanut foliar diseases with fungicides. Plant Disease 64:356-361.
22. Wood, B. W., Payne, J. A., and Gottwald, T. R. 1985. Reduced leaf net photosynthesis of orchard grown pecan by pesticide sprays. p. 69. *In* Proc. Southeastern Pecan Growers Assoc. 78'th Annual Mtg. Orlando, FL.


Accepted October 8, 1985.