The Role of Partial Resistance in the Management of Cercospora Leaf Spot of Peanut in North Carolina

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ABSTRACT

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The effects of partial resistance to *Cercospora arachidicola* in combination with various rates of chlorothalonil were tested in field experiments conducted in North Carolina in 1982–1984. Areas under disease progress curves (AUDPCs) for percent infected leaflets and percent defoliation were lower on NC 5 than on Florigiant in 1982 and 1984. AUDPCs declined linearly with increasing fungicide rate on both cultivars. Proportional reductions in AUDPCs per unit of fungicide applied were similar for both cultivars in 1982. Infection and defoliation rates were reduced by both host resistance and increasing dosages of chlorothalonil. Infection rates declined more rapidly with increasing fungicide dosages on Florigiant than on NC 5. Decreases in defoliation rates, however, were similar for the two cultivars over all chlorothalonil dosages tested. Effects of disease control on yield, gross economic value, and net return to management of Cercospora leaf spot were observed only in 1982. Higher yields and economic returns were observed with NC 5 than with Florigiant at all levels of control. The "fungicide equivalence" of NC 5 relative to Florigiant was estimated to be 1.4 L/ha per application when AUDPCs for percent infected leaflets were regressed against fungicide rate. Net return to leaf spot management activities on Florigiant was optimized at 2.5 L of chlorothalonil per hectare. Yields and economic returns, however, continued to increase with increasing dosage of fungicide on NC 5. The greatest benefit from the partial resistance to Cercospora leaf spot possessed by NC 5 appears to be in terms of increasing yield and gross economic value rather than in the reduction of recommended fungicide dosage.

Additional key words: *Arachis hypogaea*, early leaf spot, epidemiology.

Peanut leaf spots are considered the most important diseases of peanut (*Arachis hypogaea* L.) worldwide. Early leaf spot is caused by *Cercospora arachidicola* Hori; late leaf spot is caused by *Cercosporidium personatum* (Berk. & Curt.) Deighton. These diseases occur wherever peanuts are grown and can cause yield losses of 50% or more (11). Backman and Crawford (2) reported that early and late leaf spots caused similar crop losses on runner-type peanut. They also reported yield reductions of 57 kg/ha for each 1% of disease-induced defoliation assessed 2 wk before harvest.

Peanut leaf spots in the United States are controlled primarily by the application of fungicides on a 10- to 14-day calendar schedule during most of the peanut-growing season (21). The cost of this relatively expensive spray program has spurred research into alternative tactics for peanut leaf spot management (18,19).

Cultivars with partial resistance to peanut leaf spots are currently being developed in a number of peanut breeding programs (12). Although most agronomically acceptable peanut genotypes do not possess sufficient resistance to preclude the use of fungicides, they may allow modification of conventional fungicide regimes for peanut leaf spot management. The objectives of this study were to assess the impact of partial resistance on production of Virginia-type peanuts and to project net revenue-optimizing uses for partial resistance in peanut leaf spot management.

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MATERIALS AND METHODS

Field experiments were conducted in 1982, 1983, and 1984 at the Peanut Belt Research Station in Lewiston, NC. Tests were located in fields planted with corn in the previous year as part of a 2-yr, corn-peanut rotation. Except for peanut leaf spot control, standard cultural practices were followed each year. Herbicides (vernolate, alachlor, naptalam plus dinoseb, benefin, and bentazon), nematicides (carbofuran and fenamiphos), insecticides (carbaryl, ethoprop, methomyl, monocrotophos, and phorate) and fertilizers (calcium sulfate, boron, and manganese) were applied according to recommendations of the North Carolina Cooperative Extension Service (1). Pentachloronitrobenzene (quintozene) was applied as 10% granules at 112 kg/ha to all plots about 10 wk after planting for control of southern stem rot caused by *Sclerotium rolfsii* Sacc.

A randomized complete block experimental design was used with five replications in 1982. Plots consisted of two 6.2-m-long rows spaced 0.9 m apart. Plots within the same tier were separated by eight border rows planted with peanut cultivar Florigiant. Adjacent plots lying in different ranges were separated by 4.6 m of fallow ground. Plots were planted on 7 May 1982 with Florigiant (susceptible) or NC 5 (resistant) peanut. Chlorothalonil was applied to each genotype on a 14-day calendar schedule at rates of 0.6, 1.2, 1.9, or 2.5 L/ha. Unsprayed control plots were also maintained for each cultivar.

Plots consisted of four 6.2-m-long rows in the 1983 and 1984 tests. Treatments were replicated seven times in 1983 and five times in 1984. Plots were planted on 13 May and 18 May in 1983 and 1984, respectively. Six border rows, rather than eight, separated plots lying within the same range. A split-plot experimental design was used in 1983 and 1984. Main plots consisted of chlorothalonil rates of 0.6, 1.2, 1.9, 2.5, or 3.1 L/ha applied on a 14-day schedule.

Unsprayed control plots were not included in these experiments. Subplots were planted with either Florigiant or NC 5 peanut.

Fungicide applications were made by using a tractor-mounted hydraulic sprayer. Four rows were sprayed simultaneously with three D3-23 disk-core combination (Spraying Systems Co., Wheaton, IL) nozzles per row. Spray nozzles delivered 140 L of solution per hectare at 276 kPa of pressure.

Epidemics resulted from naturally occurring inoculum. Disease severity (percentage of leaflets infected) and percent defoliation were both assessed every 4–14 days beginning in late June or early July of each year. Final assessments were made about 14 days prior to digging. Disease severity was assessed on each observation date as the proportion of leaflets containing at least one visible lesion. Estimates were made from randomly selected, 0.6-m lengths of row in each of the center two rows of each plot. Two of these "rating segments" per row were observed in the field on each observation date in 1982. One rating segment per row was observed on each date in 1983 and 1984. Each plot was rated by four assessors on each date. Assessors worked in pairs, with each pair making observations on a different row within each plot. Percent defoliation was assessed by further subdividing the selected rating segments into four 0.2-m lengths of row. One of these 0.2-m "rating units" was randomly selected each week. The number of nodes and the number of missing leaflets were counted on one vertical stem from each side of the row within each rating unit. The proportion of leaflets defoliated was calculated by dividing the number of missing leaflets by the number of nodes multiplied by four (since peanuts have four leaflets per leaf and one leaf per node).

Averages for percent infected leaflets and percent defoliation for each plot on each observation date were used for subsequent data analysis. The Gompertz, logistic, and monomolecular models were fitted to disease data, and rates of increase in percent infection and defoliation were estimated from regression coefficients obtained by regressing transformed disease data against time, expressed as days after planting. Residual plots were examined for systematic patterns for each regression. Statistically significant differences in rates of increase were identified by using the full versus reduced model method (5,22).

Areas under disease progress curves (AUDPCs) were calculated for percent infected leaflets (AUDPC-DL) and percent defoliation (AUDPC-DF) from the equation (20):

$$\text{AUDPC} = \Sigma[(Y_{i+1} + Y_i)/2]\,(X_{i+1} - X_i) \qquad (1)$$

in which Y_i = percent infection or defoliation at the ith observation and X_i = the date of the ith assessment in days after planting. Differences in AUDPCs among genotypes and fungicide treatments were examined by using regression analysis.

Peanuts were dug with a commercial digger-inverter 154, 171, and 143 days after planting in 1982, 1983, and 1984, respectively. Plots were picked with a commercial peanut combine within 7–12 days after digging. Pods and seeds were weighed after seed had been dried to approximately 10% moisture. Yields were expressed in kilograms per hectare.

Pod samples (700 g) were taken from each plot and analyzed for market grades. The effects of treatments on percent foreign material (FM), percent fancy-size pods (FS = nonshelled fruit that remain on sizing rollers spaced 1.35 cm apart), percent extra large kernels (ELK = kernels that remain on a 0.85 × 2.54-cm screen after shaking for 10 sec), percent sound mature kernels (SMK = kernels that remain on a 0.60 × 2.54-cm screen shaken for 10 sec), percent sound splits (SS = split or broken kernels without damage), and percent other kernels (OK = kernels that pass through a shaking 0.60 × 2.54-cm screen). Total sound mature kernels (TSMK) was calculated by adding SMK and SS. Peanut support prices (SP) in dollars per hundred weight were calculated as:

$$\text{SP} = (a \times \text{TSMK}) + (0.07 \times \text{OK}) + (0.0225 \times \text{ELK}) - (0.05 \times \text{FM}) \qquad (2)$$

if FS =>40, or

$$\text{SP} = (0.3195 \times \text{TSMK}) + (0.07 \times \text{OK}) - (0.05 \times \text{FM}) \qquad (3)$$

if FS = <40

in which a = 0.3988 in 1982 and 1983 and a = 0.39895 in 1984. Gross economic value (dollars per acre) was calculated from the formula:

$$\text{Value} = [((\text{SP} \times \text{yield}) - (\text{yield} \times \text{LS} \times 0.01)) + (0.07 \times (\text{yield} \times \text{LS} \times 0.01)) - (0.001 \times \text{yield})]/100 \qquad (4)$$

in which yield is in pounds per acre. Gross economic values in dollars per acre were multiplied by 2.471 for conversion to dollars per hectare.

Leaf spot fungicide costs were estimated by multiplying the total amount of chlorothalonil used on each treatment by estimated average annual prices for chlorothalonil in North Carolina (data were obtained from the North Carolina Agricultural Extension Service). These prices were \$7.24/L for 1982 and 1983 and \$6.08/L for 1984. Leaf spot fungicide costs and an average estimate of all other peanut production costs (also obtained from the North Carolina Agricultural Extension Service) were then subtracted from the gross economic value of each plot in order to estimate net returns to leaf spot management for each plot.

Yield, gross economic return, and net economic return from the use of chlorothalonil with different peanut genotypes were subjected to regression analysis. The fungicide equivalence (8–10) of the resistance to early leaf spot in NC 5 was estimated by comparing the relationship between AUDPCs, infection rate, yield, and economic value and fungicide dosage for NC 5 versus Florigiant. Fungicide equivalence (10) was estimated as the rate of chlorothalonil that produced a level of disease control on the susceptible cultivar (Florigiant) equivalent to the level observed on the resistant cultivar (NC 5) in the absence of fungicide. Economically optimal rates of chlorothalonil were calculated as the fungicide rate on each cultivar at which the net return to leaf spot management was maximized. Optimal rates were found by taking the first derivative of the regression function relating net return to fungicide dosage for each cultivar, setting these equations to zero, and then solving for the optimal fungicide rates. The long-term effect of fungicide use with NC 5 and Florigiant was further investigated by calculating the expected net return for treatment with chlorothalonil at 2.5 L/ha from 1982–1984 data. Probabilities of disease conditions similar to those in 1982 and in 1983–1984 were estimated from historical weather data (16). Data from 1983 and 1984 were combined to represent low disease severity conditions. Mean net returns in 1982 and in 1983–1984 were weighted by the probabilities of similar disease conditions, and the expected net returns for NC 5 and Florigiant were calculated as the sum of the weighted means for each cultivar.

RESULTS

Epidemics of early leaf spot occurred in 1982 and 1984. Only trace levels of leaf spot caused by *C. arachidicola* were observed in 1983, probably because of dry weather and low nighttime temperatures. Leaf spot epidemics began in July of 1984, but the disease did not increase in midseason, probably because of dry weather. Data from plots receiving chlorothalonil at 0.6 L/ha were not included in analyses of 1984 test results. Levels of disease were unreasonably low, while yields and economic returns were so high that the effects of experimental error or some extraneous factor was implied.

AUDPC-DLs and AUDPC-DFs differed among cultivars and among rates of chlorothalonil within cultivars in 1982 and 1984 (Figs. 1 and 2). The following regression models were obtained relating mean AUDPCs to fungicide dosage in 1982:

for Florigiant—

$$\text{AUDPC-DL} = 49.573 - 10.262\,X,\ R^2 = 0.977\ (\text{df} = 4) \qquad (5)$$

and

$$\text{AUDPC-DF} = 24.347 - 5.763\,X,\ R^2 = 0.991\ (\text{df} = 4); \qquad (6)$$

for NC 5—

$$\text{AUDPC-DL} = 35.307 - 10.649\ X,\ R^2 = 0.932\ (\text{df} = 4) \quad (7)$$

and

$$\text{AUDPC-DF} = 20.448 - 4.833\ X,\ R^2 = 0.968\ (\text{df} = 4). \quad (8)$$

The following regression models were obtained relating mean AUDPCs to fungicide dosage in 1984:

for Florigiant—

$$\text{AUDPC-DL} = 35.312 - 7.705\ X,\ R^2 = 0.859\ (\text{df} = 4) \quad (9)$$

and

$$\text{AUDPC-DF} = 12.395 - 1.957\ X,\ R^2 = 0.663\ (\text{df} = 4); \quad (10)$$

for NC 5—

$$\text{AUDPC-DL} = 12.056 - 2.900\ X,\ R^2 = 0.919\ (\text{df} = 4) \quad (11)$$

and

$$\text{AUDPC-DF} = 9.790 - 1.445\ X,\ R^2 = 0.956\ (\text{df} = 4) \quad (12)$$

in which X = the rate of chlorothalonil in liters per hectare. The regression coefficient for AUDPC-DF versus fungicide rate in 1984 was significant at $P = 0.19$. All other model parameters were significant at $P <= 0.07$. Resistance to Cercospora leaf spot reduced AUDPC-DL and AUDPC-DF in the absence of fungicide. AUDPCs also declined linearly with increasing dosages of chlorothalonil. Proportional reductions in AUDPCs per unit of fungicide applied (slopes of regressions for AUDPCs versus fungicide rates) were similar for Florigiant and NC 5 in 1982. Reductions in AUDPC-DL with increasing fungicide rate were larger for Florigiant than for NC 5 in 1984.

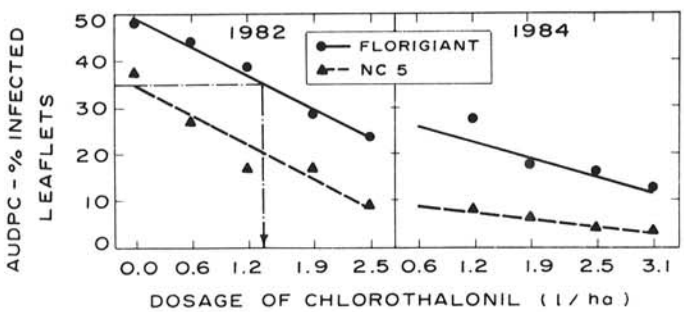

Fig. 1. Area under disease progress curves for percent infected leaflets (AUDPC-DL) versus dosage of chlorothalonil on peanut leaf spot-resistant (NC 5) and -susceptible (Florigiant) cultivars in 1982 and 1984. Disease levels, as well as the slopes of the regression lines, differed significantly among cultivars and years.

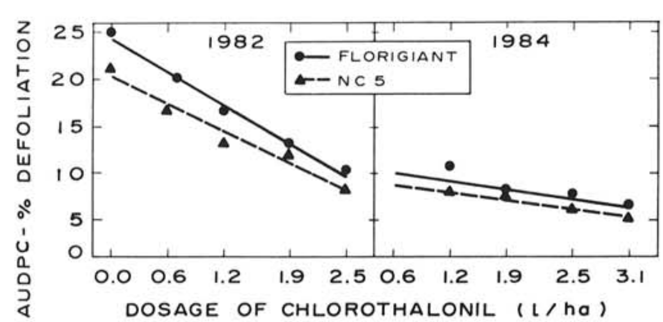

Fig. 2. Area under disease progress curves for percent defoliation (AUDPC-DF) versus dosage of chlorothalonil on peanut leaf spot-resistant (NC 5) and -susceptible (Florigiant) cultivars in 1982 and 1984. Disease severities, as well as the slopes of the regression lines, varied significantly between years. Differences in defoliation between the two cultivars were only significant in 1984 and only at chlorothalonil rates of 0.6, 2.5, and 3.1 L/ha. Rates of change in defoliation were not significantly different between cultivars in either 1982 or 1984.

Rates of disease increase were calculated for the percentage of leaflets infected and percent defoliation for all treatments in 1982 (Table 1). Use of the Gompertz model to describe disease increase resulted in higher coefficients of determination and a more random pattern of residuals than those obtained using either the logistic or the monomolecular models. Rates of disease increase are, therefore, reported by using the Gompertz model (Table 1). Rates of increase in percent leaflets infected were lower on NC 5 than on Florigiant ($P = 0.01$). Similar defoliation rates were observed on the two cultivars. Plots of infection and defoliation rates versus fungicide dosage indicated that rates of disease increase declined logarithmically with increasing dosages of fungicide. Coefficients of determination, however, were higher for linear regressions of rates of disease increase versus fungicide dosage than for models relating log-transformed rates of disease increase to dosage of chlorothalonil. Proportional reductions in infection and defoliation rates on Florigiant and NC 5 with increasing dosages of chlorothalonil were also similar.

Yields (Y) in kilograms per hectare, gross economic value (V) in dollars per hectare, and net returns (NR) in dollars per hectare to peanut leaf spot management varied among disease control treatments in 1982 (Fig. 3), but not in 1983 or 1984. Although Florigiant produced higher yields than NC 5 in the absence of leaf spot, NC 5 outproduced Florigiant over all levels of fungicide use in 1982. Y, V, and NR varied in a curvilinear manner on susceptible cultivar Florigiant:

$$Y = 2{,}230.90 + 1{,}393.21\ X - 241.74\ X^2,\ R^2 = 0.995\ (\text{df} = 4) \quad (13)$$

$$V = 1{,}354.30 + 967.68\ X - 173.07\ X^2,\ R^2 = 0.992\ (\text{df} = 4) \quad (14)$$

$$\text{NR} = -470.48 + 926.69\ X - 173.89\ X^2,\ R^2 = 0.991\ (\text{df} = 4) \quad (15)$$

but apparently in a linear manner on resistant cultivar NC 5:

$$Y = 3{,}756.25 + 278.79\ X,\ R^2 = 0.984\ (\text{df} = 4) \quad (16)$$

$$V = 2{,}415.31 + 180.13\ X,\ R^2 = 0.987\ (\text{df} = 4) \quad (17)$$

$$\text{NR} = 591.15 + 137.10\ X,\ R^2 = 0.978\ (\text{df} = 4) \quad (18)$$

in which X = dosage of chlorothalonil in liters per hectare. All regression coefficients were significant at $P \leqslant 0.05$.

The resistance to early leaf spot in NC 5 was estimated to be equivalent to 0.8 or 1.4 L/ha based on infection rate or AUDPC-DL (Fig. 1), respectively. The fungicide equivalence of NC 5 was calculated to be 1.4 L/ha when yield or economic value was used as the dependent variable in the regression analysis. The estimated optimal rate of chlorothalonil for use with Florigiant was 2.5 L/ha. The apparent linear relationships between dosage of chlorothalonil

TABLE 1. Estimated rates of disease increase observed after application of chlorothalonil to peanut leaf spot-resistant (NC 5) and -susceptible (Florigiant) cultivars at five different dosages in 1982; fungicide applications all made on a 14-day calendar schedule

Fungicide rates (L/ha)	Cultivar	Apparent infection rates for: Infection (%)	Defoliation (%)
0.0	Florigiant	0.0392 a[z]	0.0352 a
	NC 5	0.0357 b	0.0305 a
0.6	Florigiant	0.0354 a	0.0281 a
	NC 5	0.0230 b	0.0242 a
1.2	Florigiant	0.0285 a	0.0250 a
	NC 5	0.0130 b	0.0219 a
1.9	Florigiant	0.0207 a	0.0217 a
	NC 5	0.0112 b	0.0203 a
2.5	Florigiant	0.0174 a	0.0190 a
	NC 5	0.0089 b	0.0184 a

[z] Rates of increase followed by different letters are significantly different, $P = 0.05$. Comparisons were made between cultivars, within each fungicide rate, by using a full versus reduced model approach (5,22).

and yield, gross economic value, and net return on NC 5 precluded estimation of an optimal fungicide rate for the resistant cultivar. The maximum yield, gross value, and net return observed for NC 5 were 4,435 kg/ha, \$2,859.00/ha, and \$831.14/ha, respectively. Expected net return from use of chlorothalonil at 2.5 L/ha was \$576.04 and \$697.44/ha/yr for Florigiant and NC 5, respectively (Table 2). The difference in expected net return between these two treatments, however, was not significant at $P = 0.05$.

DISCUSSION

Infection and defoliation rates were not calculated from 1983 data because of the extremely low levels of disease observed in that year. The low levels of disease observed in 1983 and in mid-to-late season in 1984 are probably the reason that differences were not detected in yields and gross economic value among disease control treatments in those years.

The resistance to early leaf spot in NC 5 appears to reduce rates of infection but not defoliation. Differences among treatments in AUDPC-DL were greater than differences in AUDPC-DF in 1982 and 1984. These results imply that crop losses due to early leaf spot in Virginia-type peanut are not caused solely by disease-induced abscission of leaflets. Timing of defoliation may be very important in determining the extent of resulting crop losses. Reduced infection rates may delay the onset of defoliation beyond some critical point in host development and yield accumulation. Previous reports on the role of toxins in early leaf spot (23) as well as the effects of leaf spot incidence on peanut photosynthesis indicate that peanut leaf spots influence peanut yields by reducing photosynthetic efficiency (4,17) and partitioning of photosynthates (25) as well as by decreasing photosynthetic area (4,6,7,17,24–26).

Chlorothalonil controlled disease as effectively on NC 5 as it did on Florigiant. Host resistance and fungicide dosage thus appeared to be acting in an additive manner. Fry (10) has also noted that partial resistance and fungicide rate acted additively in controlling potato late blight. Partial resistance appears to reduce disease severities in this pathosystem and to increase crop yields and economic returns in these cases. Incremental disease control benefits resulting from pesticide application are unchanged. The resistance to peanut leaf spot in NC 5 hinders epidemics of Cercospora leaf spot by reducing sporulation per lesion and the proportion of lesions sporulating, rather than by increasing latent period (14). The possibility of synergistic interactions between increasing dosages of protectant fungicides and partial host resistance based on increased latent periods, rather than decreased sporulation, deserves further research attention.

Fry's (8–10) "fungicide equivalence" approach compares disease levels among resistant and susceptible cultivars at various rates of fungicide. Effects of disease and costs of disease management tactics are not reflected in the "fungicide equivalence" of a particular host genotype. Use of an estimated net revenue optimizing concentration of chlorothalonil with the resistant and susceptible cultivars allows consideration of fungicide costs and the economic value of the crop, as well as the yield, tolerance, and resistance characteristics of the host genotypes. Below the optimal fungicide rate, incremental crop losses caused by disease are greater than the unit costs of disease control. Fungicide rates above the optimal dosage result in increases in gross return smaller than the increases in leaf spot control costs required to obtain them. At the optimal fungicide rate, the added benefit from fungicide use just equals its added cost. The partial resistance possessed by a given genotype should, therefore, be evaluated at the optimal fungicide rate for that genotype. The difference in net return between resistant and susceptible cultivars at their optimal fungicide dosages should be a more complete description of the benefits of the resistant cultivar because disease effects, costs of additional disease control activities, and agronomic characteristics of the genotypes are considered as well as disease severity.

The apparent linearity of the relationship between yield and economic return for NC 5 and rate of chlorothalonil prevented us from calculating an optimal rate of chlorothalonil for NC 5. We were not able to detect a curvilinear response due to experimental variance and the significant, but limited, response by NC 5 to disease control from fungicide use. Increases in yield and economic return from NC 5 with increasing dosages of chlorothalonil, however, indicate that some level of fungicide use should accompany use of the partial resistance in NC 5. Maximum net return was observed for NC 5 when chlorothalonil was applied at 2.5 L/ha. We believe that the optimal rate of chlorothalonil for NC 5 should, therefore, lie near that for Florigiant (2.5 L/ha).

Partial host resistance could increase net economic return by reducing disease control costs or by increasing yield and, consequently, gross economic value. Results from this study

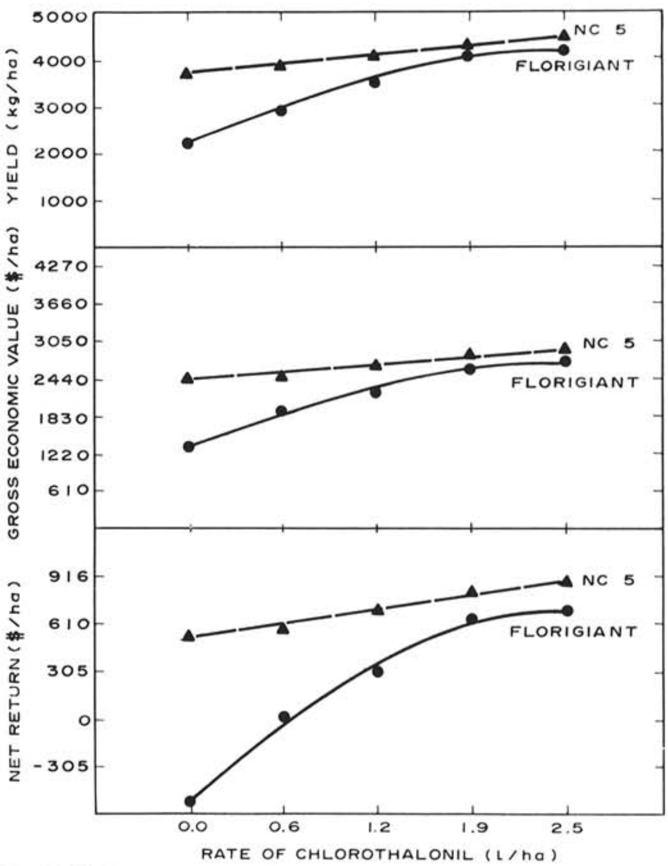

Fig. 3. Yields, gross economic value, and net return to peanut leaf spot management versus chlorothalonil concentration in 1982.

TABLE 2. Expected gross economic value and net return for NC 5 and Florigiant when chlorothalonil was applied at 2.5 L/ha in 1982–1984

Variable (\$/ha/yr)	Cultivar	Mean response when disease pressure was similar to:[a] 1982 ($P = 0.8235$)	1983–1984 ($P = 0.1765$)	Expected net return[b]
Gross value	Florigiant	2,685.44	1,718.75	2,514.82
	NC 5	2,859.15	1,595.78	2,636.49
Net return	Florigiant	752.74	−248.39	576.04
	NC 5	926.51	−371.36	697.44

[a]Disease pressure was described in terms of areas under disease progress curves (AUDPCs) estimated from historical rainfall data. Disease pressures were grouped into two classes (low, AUDPC ≤29.81; high, AUDPC >29.81) and the frequencies of these classes were estimated from a cumulative probability curve for Cercospora leaf spot (15). Data from 1982 fit into the high-disease-pressure class, while 1983–1984 data fit into the low-disease-pressure class.

[b]Expected gross economic value and net return were calculated by summing the products of mean economic return and probability of similar disease pressure for each cultivar. Differences in expected economic returns between peanut genotypes were not statistically significant.

suggest that partial resistance to early leaf spot of peanut can be used to reduce the amount of fungicide necessary to obtain a given level of disease control or to enable the peanut plant to approach its genetic potential for yield more closely over a range of disease pressures. Planting NC 5 rather than Florigiant could enable North Carolina peanut growers to cut their leaf spot fungicide rates approximately in half and still maintain levels of disease control similar to those now achieved on Florigiant. Such a strategy, however, assumes that further increases in disease control would not result in increased (economic return) and that no differences in yield potential or disease tolerance exist between the two cultivars. One or more of these assumptions may often be erroneous. Florigiant, for example, usually produces higher yields than NC 5 in the absence of leaf spot. Yields and economic returns for NC 5 increased with use of fungicide rates above the fungicide equivalence level. Increases of 307 kg/ha, $198.15 and $150.81/ha in yield, gross economic value, and net return to leaf spot management, respectively, were predicted for use of NC 5 with the chlorothalonil dosage recommended by the N.C. Agricultural Extension Service rather than the rate indicated by the "fungicide equivalence" of NC 5 compared to Florigiant.

Gorbet et al (13) concluded that the ultimate value of partial resistance to control of peanut leaf spots was as a means to reduce fungicide use. Although the increase in the expected net return for NC 5 versus Florigiant was not significant at the 2.5 L/ha rate of chlorothalonil, the response of NC 5 to increasing dosages of fungicide in this study suggests that the most beneficial role for partial resistance to peanut leaf spot may be to increase yield and thereby gross economic return, rather than to reduce leaf spot control costs. Further research is needed to demonstrate conclusively which strategy (reduced or conventional levels of fungicide use with partial disease resistance) would result in higher long-term net returns to growers.

Application schedules that control disease with fewer sprays should reduce equipment, fuel, and labor costs as well as fungicide expenditures. Undesired nontarget effects of fungicide applications should also be reduced. Two weather-based fungicide advisory systems are currently being tested for these purposes (3,18). Research in Virginia (15) indicates that gross economic value as well as net economic return increased with use of the Virginia advisory system over the conventional calendar fungicide application schedule. The addition of partial resistance to these programs could increase their economic benefits further, and perhaps allow these systems to be incorporated in areas where leaf spot disease pressure is too severe for their use with contemporary susceptible cultivars.

LITERATURE CITED

1. Anonymous. 1984. Peanuts. North Carolina Agricultural Extension Bull. AG-331. North Carolina Agricultural Extension Service, North Carolina State University, Raleigh. 67 pp.
2. 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.
3. Bailey, J. E., and Spencer, S. 1982. Feasibility of peanut leafspot forecasting in North Carolina. Proc. Am. Peanut Res. Educ. Soc. 14:101.
4. Boote, K. J., Jones, J. W., Smerage, G. H., Barfield, C. S., and Berger, R. D. 1980. Photosynthesis of peanut canopies as affected by leafspot and artificial defoliation. Agron. J. 72:247-252.
5. Draper, N. R., and Smith, H. 1981. Applied Regression Analysis. 2nd ed. John Wiley & Sons, New York. 709 pp.
6. Elston, J., Harkness, C., and McDonald, D. 1976. The effects of *Cercospora* leaf disease on the growth of groundnuts (*Arachis hypogaea*) in Nigeria. Ann. Appl. Biol. 83:39-51.
7. Enyi, B. A. C. 1975. Effects of defoliation on growth and yield in groundnut (*Arachis hypogaea*), cowpeas (*Vigna unguiculata*), soyabean (*Glycine max*) and green gram (*Vigna aurens*). Ann. Appl. Biol. 79:55-66.
8. Fry, W. E. 1975. Integrated effects of polygenic resistance and a protective fungicide on development of potato late blight. Phytopathology 65:908-911.
9. Fry, W. E. 1977. Integrated control of potato late blight: Effects of polygenic resistance and techniques of timing fungicide applications. Phytopathology 67:415-420.
10. Fry, W. E. 1978. Quantification of general resistance of potato cultivars and fungicide effects for integrated control of potato late blight. Phytopathology 68:1650-1655.
11. Garren, K. H., and Jackson, R. H. 1973. Peanut diseases. Pages 429-494 in: Peanuts—Culture and Uses. Am. Peanut Res. Educ. Soc., Stillwater, OK. 684 pp.
12. Gorbet, D. W., Norden, A. J., and Shokes, F. M. 1982. Evaluation of peanut genotypes for resistance to leafspot and for agronomic performance. Proc. Am. Peanut Res. Educ. Soc. 14:71.
13. Gorbet, D. W., Shokes, F. M., and Jackson, L. F. 1982. Control of peanut leafspot with a combination of resistance and fungicide treatment. Peanut Sci. 9:87-90.
14. Johnson, C. S., Beute, M. K., and Ricker, M. D. 1986. Relationship between components of resistance and disease progress of early leaf spot on Virginia-type peanut. Phytopathology 76:(In press).
15. Johnson, C. S., Phipps, P. M., and Beute, M. K. 1986. Cercospora leafspot management decisions: An economic analysis of a weather-based strategy for timing fungicide applications. Peanut Sci. In press.
16. Johnson, C. S., Phipps, P. M., and Beute, M. K. 1986. Cercospora leaf spot management decisions: Uses of a correlation between disease severity and rainfall to evaluate the Virginia leaf spot advisory. Phytopathology 76:(In press).
17. Jones, J. W., Barfield, C. S., Boote, K. J., Smerage, G. H., and Mangold, J. 1982. Photosynthetic recovery of peanuts to defoliation at various growth stages. Crop Sci. 22:741-746.
18. Kucharek, T. A. 1976. Peanut leafspot assessment and control. Extension Plant Pathology Report 19. Fla. Coop. Ext. Serv., Institute of Food and Agricultural Sciences, University of Florida, Gainesville. 3 pp.
19. Phipps, P. M., and Powell, N. L. 1984. Criteria for utilization of peanut leafspot advisories in Virginia. Phytopathology 74:1189-1193.
20. Shaner, G., and Finney, R. E. 1977. The effect of nitrogen fertilization on the expression of slow-mildewing resistance in knox wheat. Phytopathology 67:1051-1056.
21. Smith, D. H., and Littrell, R. H. 1980. Management of peanut foliar diseases with fungicides. Plant Dis. 64:356-361.
22. Steel, R. G. D., and Torrie, J. H. 1980. Principles and Procedures of Statistics, a Biometrical Approach. 2nd ed. McGraw-Hill, New York. 633 pp.
23. Stoessl, A. 1984. Dothistromin as a metabolite of *Cercospora arachidicola*. Mycopathologia 86:165-168.
24. Subrahmanyam, P., Williams, J. H., McDonald, D., and Gibbons, R. W. 1984. The influence of foliar diseases and their control by selective fungicides on a range of groundnut (*Arachis hypogaea* L.) genotypes. Ann. Appl. Biol. 104:467-476.
25. Teare, I. D., Shokes, F. M., Gorbet, D. W., and Littrell, R. H. 1984. Peanut growth responses to different levels of leafspot. Agron. J. 76:103-106.
26. Turner, J. W. 1982. Effect of defoliation on yield of peanuts (*Arachis hypogaea*). Queensl. J. Agric. Anim. Sci. 39:183-185.