A Decision Model for Use of Fumigation and Resistance to Control Cylindrocladium Black Rot of Peanuts

J. E. BAILEY, Assistant Professor, and C. A. MATYAC, Research Associate, Department of Plant Pathology, North Carolina State University, Raleigh 27612

ABSTRACT

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Expected yields of resistant peanuts in fumigated (treated with metham-sodium) and nonfumigated fields were calculated from yield and disease incidence in a susceptible cultivar in the same field. Calculations were based on known relationships between disease incidence and yield loss of resistant and susceptible cultivars. The dollar-value increase expected from the use of a resistant cultivar with or without soil fumigation was then compared with that expected from the use of a susceptible cultivar without soil fumigation. The utility of the model as a means of selecting the most cost-effective control measure is discussed.

Additional keywords: *Arachis hypogaea*, CBR, *Cylindrocladium crotalariae*, economics, genetic resistance

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Cylindrocladium black rot (CBR) of peanut (*Arachis hypogaea* L.) is caused by *Cylindrocladium crotalariae* (Loos) Bell & Sobers, which produces microsclerotia in rotted roots and pods. Densities of microsclerotia are maintained in soil well beyond the common 2- or 3-yr rotation of peanut with nonhost crops in North Carolina (8). As a result, disease reappears in previously infested areas.

Since its discovery in 1970 (3), CBR has spread to all North Carolina peanut-producing counties, with severely infested fields often being unsuitable for peanut production. The introduction of the partially resistant cultivar NC8C represented a breakthrough in control efforts (9). When this cultivar is used in combination with the soil fumigant metham-sodium, effective control of CBR can be achieved (1,2,4,6). Most growers currently plant susceptible cultivars without soil fumigation because of limited availability of NC8C seed, preference for more popular cultivars, and lack of awareness of the effective disease control and economic benefits of this treatment.

Economical control of CBR is a function of disease severity, cost of control measures, and value of peanut production. Management strategies must take into account the dynamics and interactions of these factors. Because fumigation and cultivar selection are preplant decisions, field histories must be used to determine which treatments will most likely give the greatest economic return. Accurate field records on disease incidence and yield can provide an economic basis for decisions.

Weather patterns affect both the survival of microsclerotia (8) and the infection process (7). Ideally, a predictive model based on field records and weather information should be developed to estimate the likelihood of specific disease levels and economic return for various treatments. Unfortunately, our ability to estimate densities of microsclerotia and to forecast weather patterns over a 2- to 3-yr period is inadequate for this purpose. We do know, however, that numbers of microsclerotia remain fairly constant under typical environmental conditions for several years (8). Continued heavy disease pressure persists even after planting a nonhost crop for 2–3 yr. Therefore, one method to evaluate disease control options could be based on estimates of economic benefit of disease control practices the last year peanuts were grown in the field.

In this paper we present a method that uses the history of disease incidence and yield to estimate the dollar value of growing a resistant cultivar with or without soil fumigation, as compared with growing a susceptible cultivar without chemical treatment. This approach might serve as a model for similar decisions on the use of preplant disease control measures for other soilborne pathogens.

Table 1. Comparison of real and estimated yield (lb/ha) of the peanut cultivar NC8C, resistant to Cylindrocladium black rot, at 0 and 93.5 L/ha of formulated metham-sodium using a paired comparison t test ($n = 29$, df = 28)

Treatment	Model[a]	Real	t	$PR>t$
No fumigation	3,067	3,085	0.86	0.395(NS)
Fumigation	3,583	3,562	0.28	0.781(NS)

[a] Model values were computed using a mathematical algorithm to estimate yield of a resistant cultivar grown with and without prior soil fumigation. Inputs were disease incidence and yield in plots of an untreated susceptible cultivar in the same blocks from which the real values were obtained.

MATERIALS AND METHODS

Dosage response of metham-sodium on CBR. Field tests were conducted in 1982, 1983, and 1985 to determine the effectiveness of metham-sodium (formulated as 0.38 kg a.i./L) in reducing CBR incidence on both the partially resistant cultivar NC8C and the susceptible cultivar Florigiant. Florigiant is a commonly grown cultivar in North Carolina, and NC8C is the only commercially available cultivar with CBR resistance. Both cultivars have similar yield and value in noninfested fields (9). Metham-sodium was injected (one shank per row) 20–25 cm below the soil surface of newly bedded soil (Norfolk sandy loam) at each site approximately 2 wk before planting. Rates of 0, 93.5, and 187 L/ha (row treatment) of formulated metham-sodium were used in 1982 in Bertie and Martin counties, North Carolina. In 1983, 0, 47, and 93.5 L/ha were used in Martin County; 0, 93.5, and 187 L/ha in Chowan County; and 0, 47, 93.5, and 187 L/ha in Bertie and Perquimans counties. In 1985, 0 and 93.5 L/ha were used in Bladen, Chowan, Bertie, Gates, and Northampton counties. A randomized complete block design with 15.2 × 1.8 m plots and four replications was used at each location. All fields had a history of severe CBR and had been in 1- to 2-yr rotations of nonhost crops, including at least 1 yr of corn. One-half of the replications from all experiments were used to determine the dose/response relationship between CBR incidence and metham-sodium. Data were utilized from blocks of each experiment where the untreated, susceptible cultivar plots had 25% or greater disease incidence. Percent disease from these blocks was regressed against metham-sodium concentration for both the resistant and the susceptible cultivars.

Model development. A model was developed to predict the effect of CBR control procedures on crop value. The purpose of this model was to assemble all currently available knowledge into an equation to aid in evaluating the economics of various alternative strategies. The mathematical outcome of the model was an estimate of value ($/ha) increase over growing a susceptible cultivar by growing a resistant cultivar with or without prior soil fumigation.

Yield and percent disease in nonfumigated plots of Florigiant peanut were measured and used to compute resistant cultivar yield with or without fumigation. Computed yield was used to calculate increase in value resulting from growing a resistant cultivar with or without prior fumigation.

Model validation. Field data not used to determine dosage response for metham-sodium were used to estimate the effect on revenue per hectare (value of growing a resistant cultivar with and without metham-sodium). Even-numbered replications were used for dose/response and odd-numbered replications, for effect on revenue. The goal of the analysis was to determine if disease and yield of the untreated susceptible cultivar could be used to estimate the value (yield × $0.66/kg) of using a resistant cultivar with and without soil fumigation. The dollar value per kilogram ($0.66) was selected as representative of the 1986 season and may be changed to match other market prices. Peanuts were not graded, as CBR affects value by reducing yield rather than quality (5). Comparisons were made between plots in the same replication by using the observed disease and yield values from the nonfumigated susceptible plot as model inputs. Estimates of value of the susceptible plots with or without prior fumigation were compared with actual data values using a t test.

Threshold determinations. The treatment threshold was the level of disease that, if treated, would increase crop value enough to pay for the cost of treatment. Two control options were considered: a resistant cultivar and fumigation in combination with a resistant cultivar. The first option will be considered to have no cost because yield levels, quality, and cost of seed are essentially the same as those for the susceptible cultivar. In 1987, fumigation costs were $124/ha (at 93.5 L/ha of formulated metham-sodium). The model takes into account the yield potential, price per kilogram of peanuts, and percent disease. Users must determine their costs of application and compare these with the estimated increase in value to determine if the threshold value was obtained.

Table 2. Increase in dollars per hectare expected if the preceding peanut crop had been the cultivar NC8C, resistant to Cylindrocladium black rot (CBR). instead of the susceptible cultivar Florigiant[a]

Preceding Florigiant crop yield (kg/ha)	Increase ($/ha) according to percent visual observation of CBR in preceding crop					
	5%	10%	20%	30%	40%	50%
1,122	17	37	82	133	198	272
1,683	27	57	124	200	294	413
2,244	37	74	163	267	393	549
2,805	44	94	205	334	492	687
3,366	54	114	245	400	591	823
3,926	64	131	287	469	689	961
4,487	72	151	326	536	788	1,097
5,048	82	168	368	603	885	1,236
5,609	91	188	408	670	983	1,371

[a] Price of peanuts set at $0.66/kg; value can be changed to reflect current market prices.

RESULTS

Dosage response for metham-sodium vs. CBR. The relationships between disease incidence and rate of fumigant for the susceptible and resistant cultivars were: $D_S = 1.0 - 0.00413x$ ($R^2 = 0.48$) and $D_R = 0.36 - 0.0017x$ ($R^2 = 0.32$), where D_S = proportion disease for susceptible cultivar, D_R = proportion disease for resistant cultivar, 1.0 = y intercept for susceptible cultivar, 0.36 = y intercept for resistant cultivar, and x = formulated metham-sodium in liters per hectare.

Proportion disease was computed by dividing disease readings for each treatment by the untreated susceptible plot readings in the same replication. Statistics were performed on data transformed by the arcsin square roots. Intercepts ($x = 0$) were best estimates of disease levels for the resistant and susceptible cultivars in nonfumigated fields. Y_R at $x = 93.5$ L/ha of formulated metham-sodium (the recommended use rate) was used as the best estimate for the disease occurring on the resistant cultivar grown in fumigated soil. Disease proportion values for nonfumigated/susceptible, nonfumigated/resistant, and fumigated/resistant cultivars were 1.0, 0.36, and 0.20, respectively. For every percent disease observed in nonfumigated fields planted to the susceptible cultivar, approximately 36% of that amount of disease would have been present on the nonfumigated/resistant or 20% on the fumigated/resistant cultivar planted in the same field at the same time.

Model development. A method was developed to estimate yield of the resistant cultivar both with and without fumigation. The data needed to develop these estimates were yield and percent disease on the susceptible cultivar the last time peanuts were grown. Yield (Y_H) of the susceptible cultivar without disease was expressed as: $Y_H = Y_S/(1 - 0.73\ D_S)$, where Y_S = yield of previous susceptible crop and D_S = CBR incidence in previous susceptible crop.

Yield for the resistant cultivar (Y_R) was: $Y_R = Y_H\ (1 - (0.36 * 0.73\ D_S))$ or $Y_R = Y_H\ (1 - 0.26\ D_S)$.

An estimate of yield for the resistant cultivar treated with metham-sodium (Y_{RM}) was developed from the expression: $Y_{RM} = Y_H\ (1 - (0.20 * 0.73\ D_S))$ or $Y_{RM} = Y_H\ (1 - 0.15\ D_S)$.

The estimated yield increase (Y_I) from planting the resistant cultivar was ($Y_R - Y_S$), which can now be estimated: $Y_I = Y_R - Y_S = Y_H\ (1 - 0.26\ D_S) - Y_S$. Substituting $Y_S/(1 - 0.73\ D_S)$ for Y_H, we find: $Y_I = [Y_S/(1 - 0.73\ D_S)](1 - 0.26\ D_S) - Y_S$, which simplifies to: $Y_I = (0.47\ D_S * Y_S)/(1 - 0.73\ D_S)$. Similarly, the yield increase expected with the resistant cultivar treated with metham-sodium was $Y_{RM} - Y_S$: $Y_{RM} - Y_S = (0.58\ D_S * Y_S)/(1 - 0.73\ D_S)$.

Model validation. Field data gathered in 1982, 1983, and 1985 were divided into two categories: data for model development and data for model validation. The wide range of values encountered between years and locations produced a data set representative of the diversity of growing conditions encountered in North Carolina.

A comparison was made between measured (real) and predicted yields (model estimate) for the resistant cultivar with and without fumigation (Table 1). Model estimates of yield for fumigated and nonfumigated fields were in good agreement with harvested yields.

Use of thresholds. Model information was designed to be used in the field to aid growers in making disease management decisions. Table 2 shows the estimated dollar value of planting the resistant cultivar NC8C above that achieved with the susceptible cultivar Florigiant at various yield/disease combinations, and Table 3 gives the equivalent information for NC8C planted in fumigated soil. Table 4 shows the differences between the two practices, determined by subtracting the data in Table 2 from the data in Table 3. Chemical application costs would be subtracted from the values in the appropriate table to calculate net return for each practice. The values shown in Table 4, therefore, represent the action thresholds for fumigation relative to a grower's treatment costs.

DISCUSSION

Prophylactic CBR control treatments have been recommended on the basis of field histories for many years in North Carolina peanut production. The assumption has been that if CBR was a problem last time peanuts were grown, it will be a problem again if all conditions are equal. We cannot predict if conditions will be equal. Once *C. crotalariae* becomes established in a field, however, populations of microsclerotia will increase in the following years if peanuts or soybeans are grown. CBR usually becomes increasingly more severe as populations of microsclerotia increase, until a field equilibrium is established (M. K. Beute, *personal communication*). Therefore, disease incidence under normal circumstances will equal or exceed that occurring the last time peanuts were grown.

Economic benefits must justify the costs associated with adoption of new disease management strategies. The cost of planting the resistant cultivar NC8C is no greater than that of planting a susceptible cultivar, because the yield and value are similar. Most growers, however, are primarily interested in planting a cultivar with high yield and quality potential rather than disease resistance per se. Therefore, the cost of growing NC8C is relative to the

Table 3. Increase in dollars per hectare expected if the preceding peanut crop had been the cultivar NC8C, resistant to Cylindrocladium black rot (CBR), planted in soil fumigated with 93.5 L/ha of formulated metham-soldium instead of the susceptible cultivar Florigiant planted in nonfumigated soil[a]

Preceding Florigiant crop yield (kg/ha)	Increase ($/ha) according to percent visual observation of CBR in preceding crop					
	5%	10%	20%	30%	40%	50%
1,122	22	47	101	166	242	339
1,683	35	69	151	247	363	509
2,244	44	94	200	331	487	677
2,805	57	116	252	413	608	848
3,366	67	138	301	497	729	1,016
3,926	79	163	353	578	850	1,186
4,487	89	185	403	660	971	1,354
5,048	101	208	452	744	1,092	1,525
5,609	111	232	504	850	1,216	1,693

[a] Price of peanuts set at $0.66/kg; value can be changed to reflect current market prices.

Table 4. Increase in dollars per hectare expected if the peanut cultivar NC8C, resistant to Cylindrocladium black rot (CBR), had been planted in soil fumigated with 93.5 L/ha of formulated metham-sodium instead of in nonfumigated soil and if the preceding crop had been the susceptible cultivar Florigiant planted in nonfumigated soil[a]

Preceding Florigiant crop yield (kg/ha)	Increase ($/ha) according to percent visual observation of CBR in preceding crop					
	5%	10%	20%	30%	40%	50%
1,122	5	10	19	33	44	67
1,683	8	12	27	47	69	96
2,244	7	20	37	64	94	128
2,805	13	22	47	79	116	161
3,366	13	24	56	97	138	193
3,926	15	32	66	109	161	225
4,487	17	34	77	124	183	257
5,048	19	40	84	141	207	289
5,609	20	44	96	180	233	322

[a] Price of peanuts set at $0.66/kg; value can be changed to reflect current market prices.

importance a grower places on growing a preferred cultivar. The dollar value of this decision will vary with the individual. Fumigation costs are a substantial investment that requires assurance that commensurate returns are likely. Our model uses all available information to guide peanut growers in choosing the most profitable disease control practices.

Each season, growers make complex pest control decisions whether or not adequate scientific information is available to guide them. Before the extensive use of chemicals became commonplace, farming experience was often all that was needed to make informed decisions. Control practices such as rotation, tillage, and planting date had known effects that were enshrined in common sense and experience passed from generation to generation. The rapid introduction of new pesticides and genetically resistant plants, however, has created a quagmire of interrelated and overlapping control strategies. The opportunity to lose money through overzealous chemical usage has never been greater. Often, risk aversion becomes antithetical to low production cost, particularly when the economics of disease loss are poorly understood.

The extension service has the responsibility to deploy research information to the farming community as soon as possible. Timeliness dictates that "best guesses" are often used for advice instead of "scientific fact." The model described in this paper is an example of advice undergirded by a series of best guesses. However, empirical testing showed that these value estimates were in good agreement with observed values of alternative control practices.

A distinct advantage of developing an analytical decision-making scheme is that it invites both improvement to its logic and criticism. The model was developed on a spread sheet (Lotus 1 2 3, Lotus Development Corporation, Cambridge, MA) that makes it readily available even to those with the most modest computing capabilities. This avenue of communication, more than any other, makes the dynamics of a decision transparent to others and, consequently, invites refinement or replacement by another method.

The vast majority of epidemiological literature remains unused at the farm level. Cooperation is needed between extension specialists and more fundamental epidemiologists to apply known information. Information from fungicide and nematicide tests and biological and cultural tests can also be extracted and used for model development. It should be emphasized that disease control recommendations are inadequate unless the end user can understand the ramifications of each decision option in terms of economics. We believe that our approach is a good method to aid growers in making disease control decisions based on estimated economic consequences.

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LITERATURE CITED

1. Bailey, J. E. 1987. Peanut disease control. Pages 174-175 in: 1988 North Carolina Agricultural Chemicals Manual. SALS NCSU Raleigh, NC.
2. Cline, W. O., and Beute M. K. 1986. Effect of metam sodium, peanut genotype and inoculum density on incidence of Cylindrocladium black rot. Peanut Sci. 13:41-45.
3. Garren, K. H., Beute, M. K., and Porter, D. M. 1972. The Cylindrocladium black rot of peanut in Virginia and North Carolina. J. Am. Peanut Res. Educ. Assoc. 4:66-71.
4. Linker, H. M., Coble, H. D., Bailey, J. E., and Brandenburg, R. L. 1986. Scouting peanuts in North Carolina. CS-IPM 1 V3. North Carolina State University, Raleigh.
5. Pataky, J. K., Beute, M. K., Wynne, J. C., and Carlson, G. A. 1983. A critical-point yield loss model for Cylindrocladium black rot of peanut. Phytopathology 73:1559-1563.
6. Phipps, P. M. 1987. Strategies for chemical control of Cylindrocladium black rot (CBR) of peanut in Virginia, 1986. Fungic. Nematicide Tests 42:119.
7. Phipps, P. M., and Beute, M. K. 1977. Influence of soil temperature and moisture on the severity of Cylindrocladium black rot in peanut. Phytopathology 67:1104-1107.
8. Phipps, P. M., and Beute, M. K. 1979. Poplulation dynamics of *Cylindrocladium crotalariae* microsclerotia in naturally-infested soil. Phytopathology 69:240-243.
9. Wynne, J. C., and Beute, M. K. 1983. Registration of NC8C peanut. Crop Sci. 23:184.