Seven Years of *Sclerotium rolfsii* in Peanut Fields: Yield Losses and Means of Minimization

K. L. BOWEN, Assistant Professor, and A. K. HAGAN, Associate Professor (Extension Specialist), Department of Plant Pathology, and R. WEEKS, Associate Professor (Extension Specialist), Department of Entomology, Alabama Agricultural Experiment Station and Alabama Cooperative Extension Service, Auburn University, Auburn, AL 36849

ABSTRACT

Bowen, K. L., Hagan, A. K., and Weeks, R. 1992. Seven years of *Sclerotium rolfsii* in peanut fields: Yield losses and means of minimization. Plant Dis. 76:982-985.

Yield losses in peanut (*Arachis hypogaea*) caused by southern stem rot were evaluated in growers' fields at 44 individual sites over a 7-yr period from 1983 through 1989. Differential disease levels were obtained through different levels of infestation among sites and applications of pesticides, including PCNB, chlorpyrifos, ethoprop, diniconazole, tebuconazole, propiconazole, and fonofos. Peanut yields were reduced by 2.9 or 0.9% for each locus or "hit" of southern stem rot disease per 30.5-m row; losses were greater when the crop was stressed by high temperatures. Yields of untreated plots averaged 785 kg/ha less than those of plots receiving the best treatments. Yield potential was shown to be greater with the use of newly developed pesticides and fungicide/insecticide combinations than potential estimated from loss models developed 20 yr ago.

Additional keywords: groundnut, white mold

Southern stem rot, or white mold, caused by the fungus *Sclerotium rolfsii* Sacc. is among the most damaging diseases of peanut (*Arachis hypogaea* L.). This disease annually accounts for 5–10% loss in peanut yields (10) despite crop management practices that decrease disease incidence. Rotation to cotton, pasture grasses, sorghum, or corn is recommended when the incidence of southern stem rot is high (2), but rotation is not economically feasible for many growers. Several pesticides are currently recommended that reduce occurrence of southern stem rot (3,4,8).

Pesticides recommended for control of southern stem rot have changed considerably over the past 20 yr. In 1978, pentachloronitrobenzene (PCNB), carboxin, and PCNB in combination with ethoprop were the only pesticides recommended for control of southern stem rot (5). Fensulfothion was added a few years later (8). More recently, several insecticides have been labeled for disease suppression, and new fungicides are becoming available that are more effective against southern stem rot than products currently on the market (6,7). When compared with older compounds, these new compounds, including tebuconazole, flutolanil, and diniconazole, reduced southern stem rot occurrence by more than 50%; yield increases of 224 kg/ha or more were associated (6).

Enumeration of southern stem rot incidence for comparison of treatment effects has been uniformly applied since the early 1970s. Disease loci, or "hits," of southern stem rot are counted after peanut plants are dug and are defined as an infected area equal to or less than 30 cm (1 ft) in a standard row (9). Nearly two decades ago, numbers of disease loci were found to be linearly related to yield loss in peanut (9). Parameters of yield loss models developed by Rodríguez-Kábana et al (9) were found to be variable depending on the particular environment and cultural practices, e.g., pesticide usage (9).

The objectives of this study were to confirm continued yield improvements with products introduced within the past 10 yr, to validate the model(s) proposed by Rodríguez-Kábana et al (9), and to develop generalized loss models for southern stem rot in a variety of Alabama environments.

MATERIALS AND METHODS

Peanuts (cv. Florunner) were planted in conventionally tilled fields over a 3-wk period from late April to mid-May 1983 through 1989. In each year, five to eight growers' production fields were selected for a total of 44 sites with a history of southern stem rot. Soil types at the test sites were either an Orangeburg fine sandy loam (fine-loamy, siliceous, thermic Typic Palendults) or a Dothan sandy loam (fine-loamy, siliceous, thermic Plinthic Palendults). Tillage, fertility, weed control, and insect control followed recommendations of the Alabama Cooperative Extension Service (4). Chlorothalonil, which has never shown an effect on southern stem rot (A. K. Hagan, *personal observation*), was applied for control of leaf spot (4). Several fields each year were irrigated with center pivot systems. Plots at all sites consisted of two rows 15.2–24.7 m long and 0.9 m apart. Treatments at each site were randomized in complete blocks with at least four replications per site.

Several compounds were evaluated for control of southern stem rot: chlorpyrifos (Lorsban 15G) at 2.24 kg a.i./ha, PCNB (Terrachlor 10G) at 11.21 kg a.i./ha, propiconazole (Tilt 2.5G) at 0.84 kg a.i./ha, ethoprop (Mocap 10G) at 3.36 kg a.i./ha, fonofos (Dyfonate 10G) at 2.24 kg a.i./ha, diniconazole (Spotless 25W) at 1.12 kg a.i./ha, and tebuconazole (Folicur 3.6F) at 0.11 kg a.i./ha. Propiconazole, diniconazole, and tebuconazole were banded over the row center with one D4-25 solid cone nozzle (Spray Systems, Wheaton, IL) in a spray volume of 94 L/ha. Chlorpyrifos, PCNB, and ethoprop were applied once with a 10-cm bander on a 30-cm band width centered over the row with a two-row Gandy granular applicator approximately 80–90 days after planting.

At least four treatments were included at all sites. Common among all sites were an untreated control and the chlorpyrifos or PCNB treatment. A treatment of chlorpyrifos + PCNB was included at most sites through 1987. Propiconazole was evaluated in 1983, 1984, and 1986. Ethoprop, fonofos, and diniconazole were included in evaluations in 1985 through 1987. In 1988 and 1989, treatments included tebuconazole.

After peanuts were inverted, southern stem rot disease loci were counted in a single row in each plot at each site, and the count was adjusted to disease loci per 30.5-m row. Plots were harvested 5–14 days later, and yields were adjusted to 10% moisture.

Means were calculated for yields and disease loci from each treatment at every site over the 7 yr of this study. Separate

Accepted for publication 8 May 1992.

analyses of variance were performed on data from each of the 44 sites over the 7-yr period.

Data from each site also were ranked, and analysis of variance was conducted on the rankings of treatments over all sites of the study. Rankings were used because every treatment was not included at all sites of the study, and this would allow comparison of pesticide performance, relative to untreated plots, at individual sites. Analysis of variance with data arranged in a complete block design nested within year and site also was performed on actual yields and numbers of disease loci from only the three treatments included in all years of the study (untreated, chlorpyrifos, and PCNB).

Data were plotted and examined for outliers and trends. Linear models were calculated from data from each site by regressing disease loci on yield. Intercepts of resultant linear models were considered the best estimates of maximum yield in each environment (site by year). Percent yield loss was calculated by dividing individual plot yields by the intercept values. Regression models with calculated percent yield loss as a function of the number of southern stem rot loci were calculated for each site. *F* statistics were examined to compare overall significance of models ($P < 0.05$). Coefficients of determination (r^2) estimated the proportion of variation in yield reduction explained by numbers of disease loci. Coefficients of variation estimated the variation in the data. Linear and simple nonlinear (including natural logarithm, square, or square root transformations of the independent variable) models were compared. Residuals were tested for homogeneity, appropriateness of the model, and outliers. Generalized (i.e., over multiple sites) loss models were constructed by combining data from sites and regressing yield or percent yield loss on number of disease loci.

RESULTS

Average yield from all treated plots over all sites was approximately 15% greater than that from untreated plots. However, yield increase resulting from treatment was not consistent. For example, treatment with chlorpyrifos at a site in Crenshaw County in 1984 reduced yield an average of 9.14% with 4.5 disease loci compared with untreated plots with 10.2 disease loci, whereas at a site in Houston County in 1986, chlorpyrifos-treated plots had 6.7 disease loci and yield was 63.6% greater than that of untreated plots with 11.3 disease loci.

Untreated plots at all sites over the 7 yr of the study yielded an average of 4,096 kg/ha with 11.65 disease loci (Table 1). Treatment with any of the fungicides increased yield by an average of 10.6% (significant, $P < 0.05$, by rank) and decreased average disease incidence by 52.6% (significant, $P < 0.05$, by rank)

Table 1. Average yields and numbers of southern stem rot disease loci from plots of peanut cv. Florunner for all treatments over all sites and years

Treatment	No. of years	No. of sites	No. of observations	Yield (kg/ha)	Disease loci[y]
Chlorpyrifos + PCNB	6	31	123	4,884.23 a[z]	3.61 a
Ethoprop + PCNB	4	9	33	4,752.34 a	3.62 ab
Diniconazole	4	12	41	4,382.84 a	3.44 ab
Tebuconazole	2	6	23	4,600.29 ab	5.60 ab
PCNB	7	43	167	4,561.18 a–c	6.16 a–c
Propiconazole	4	12	71	4,575.69 a–c	6.88 b–d
Chlorpyrifos	7	39	164	4,488.70 b–d	6.64 cd
Ethoprop	3	9	42	4,395.79 b–d	5.63 cd
Fonofos	3	9	30	4,076.80 cd	6.92 d
Untreated	7	47	208	4,095.95 d	11.65 d

[y] Areas of southern stem rot infection ≤ 30 cm long in a 30.5-m row.

[z] Data are means over all observations and when followed by the same letter within a column are not significantly different by rank within each site according to Fisher's least significant difference ($P < 0.05$).

Table 2. Summary of regression coefficients from linear models describing yield loss of peanut cv. Florunner due to southern stem rot at individual sites and average temperature and rainfall deviation from 30-yr normals for May through September at the Wiregrass Substation, Headland, Alabama, for 1983 through 1989

Year	Regression coefficients[x] Range	Regression coefficients[x] Mean	Average deviation[y] Temperature (C)	Average deviation[y] Rainfall (cm)
1983	−1.52 to −0.74	−1.07 ab[z]	−0.56	−0.60
1984	−1.30 to 0.21	−0.42 a	−0.49	−2.71
1985	−3.40 to 0.33	−1.04 ab	−0.46	−1.74
1986	−3.07 to −1.85	−2.52 c	0.43	−2.44
1987	−3.20 to −0.42	−1.38 b	0.41	−0.56
1988	−2.54 to −0.16	−1.33 b	−0.15	−0.89
1989	−1.03 to −0.16	−0.66 ab	−0.72	1.67

[x] Percent maximum yield loss regressed on disease incidence.

[y] Calculated by comparing the average of the departures from normal for each month, May through September, with normal values, obtained from Alabama Agricultural Experiment Station weather data (1).

[z] Data are means over all sites per year and when followed by the same letter within a column are not significantly different according to Fisher's least significant difference ($P < 0.05$).

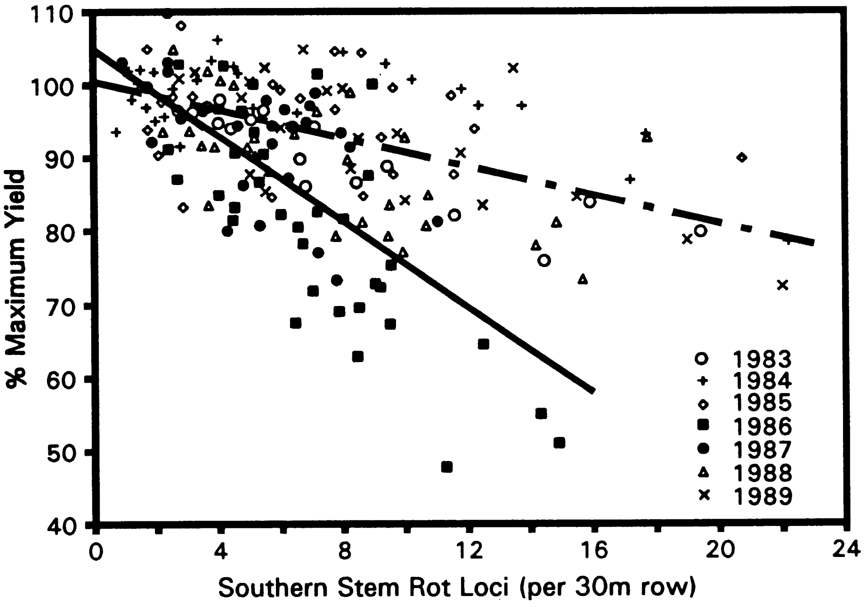

Fig. 1. Regressions of percentage of maximum yield from peanut cv. Florunner on number of loci of southern stem rot disease, defined by infection of up to 30 cm of the row area, after digging. Markers are data means over replications for treatments; not all data points are included. Solid line represents regression model for 1986–1987 and dashed line represents model for the remaining years.

Table 3. Parameters describing linear regression models constructed from disease incidence and yield for selected treatments to control southern stem rot in peanut cv. Florunner

Treatment	Disease loci^z Range	Disease loci^z Mean	Mean yield (kg/ha)	Intercept	Slope	r^2	$P < F$
Untreated	7.2-31.4	13.37	3,367.8	3,893.7	−39.20	8.10	0.0024
PCNB	2.7-17.2	6.61	3,981.9	4,497.6	−77.14	16.88	0.0001
Chlorpyrifos	3.2-22.2	7.67	3,889.5	4,451.6	−73.18	16.64	0.0001
Chlorpyrifos + PCNB	1.7-9.4	3.75	4,411.9	5,119.7	−185.19	34.34	0.0001

^{z}Areas of southern stem rot infection ≤ 30 cm long in a 30.5-m row.

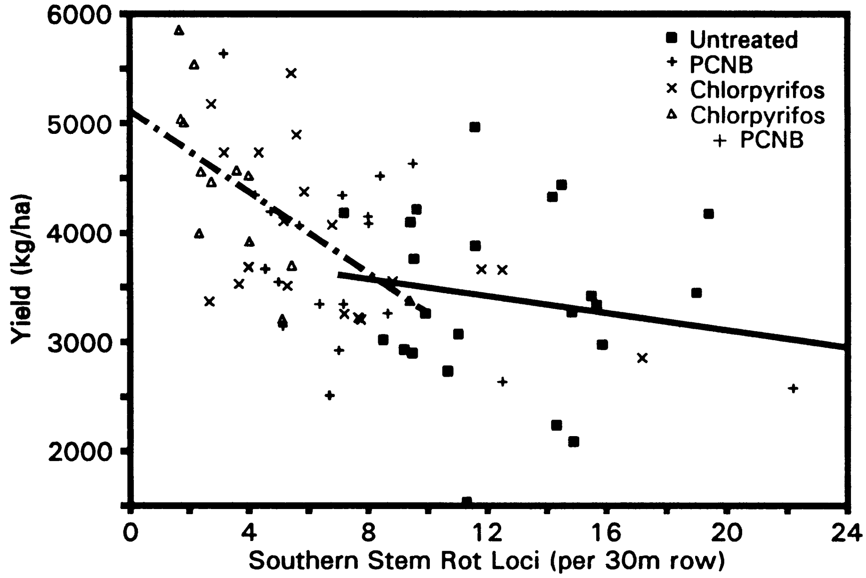

Fig. 2. Regressions of yield of peanut cv. Florunner on number of loci of southern stem rot disease, defined by infection of up to 30 cm of the row area, after digging, for selected treatments over all years of the study (1983–1989). Markers are data means over replications for treatments. Solid line represents regression model for the control and dashed line represents model for the chlorpyrifos + PCNB treatment.

compared with the untreated plots. Insecticide treatments yielded approximately 5.5% more (average over all) and had 45.1% fewer southern stem rot loci than the untreated plots. Plots treated with a combination of insecticide and PCNB had the highest yields (average, 17.6% greater than the control) and the lowest disease incidence (69.0% less than the control) of all treatments. Analysis of variance on those treatments included in all years of the study revealed that chlorpyrifos alone and PCNB alone significantly ($P < 0.05$) decreased disease incidence and increased yield compared with the untreated plots.

Linear regression models with number of disease loci as an independent variable and yield as a dependent variable generally had low coefficients of determination and were not significant. Intercepts of linear models from 44 individual sites ranged from 2,173.74 to 6,555.66 and regression coefficients ranged from 1.95 to −194.83. Models from 24 sites (at least one in each year of the study) did have coefficients of determination (r^2) greater than 0.20 or a high overall significance ($P < 0.10$). Use of intercepts as estimates of maximum yield for each site adjusted for differences in environment and cultural practices (excluding pesticides) when combined data were used for determining generalized yield loss models.

Linear regression coefficients for yield loss models from each of the 44 sites were between 0.33 and −3.40 (Table 2). Analysis of variance on regression coefficients indicated a significant effect ($P < 0.10$) by year; the linear model calculated from 1986 data had a significantly steeper slope ($P < 0.05$) than models from data from other years (Table 2). When percent maximum yields were plotted against number of southern stem rot disease loci, data from 1987 were distributed similarly to those from 1986. In addition, both 1986 and 1987 had higher temperatures (1) during the peanut growing season (May through September) than any of the other years in this study (Table 2). Thus, two generalized yield loss relationships were determined (Fig. 1): 1986 and 1987, $YLS = 104.73 - 2.92(loci)$, $r^2 = 0.39$, $n = 74$; remaining years, $YLS = 100.47 - 0.97(loci)$, $r^2 = 0.35$, $n = 154$, where *YLS* is percent of maximum yield, *loci* are numbers of southern stem rot disease loci per 30.5-m row, and *n* is number of observations. Residuals of both models were acceptable; quadratic models had slightly lower coefficients of determination, as did other curvilinear models.

Loss models (i.e., across multiple sites) also were developed for individual treatments in order to determine whether the relationship between numbers of loci and yield changed at low disease incidence. Individual treatment models were developed from data from those 24 sites that had shown significant treatment differences. Data from plots treated with chlorpyrifos, PCNB, or chlorpyrifos + PCNB and from untreated plots were modeled. Numbers of disease loci in plots treated with chlorpyrifos + PCNB were consistently lower than numbers of disease loci in untreated plots, whereas the chlorpyrifos and the PCNB treatments had intermediate numbers of disease loci (Table 3). Coefficients of determination for these treatment models were generally low ($r^2 < 0.35$) and approximately equal for best nonlinear vs. linear models. Models calculated over all data had parameters similar to those models for the PCNB and the chlorpyrifos treatments, with $r^2 = 0.23$ and $P < 0.0001$. The linear model for the combination treatment had a higher intercept and a lower regression coefficient than the linear models with data from the other treatments (Table 3 and Fig. 2). All models were highly significant ($P < 0.0024$).

DISCUSSION

Average yields and numbers of southern stem rot disease loci observed in our study were similar to field observations made nearly 20 yr ago (9) despite changes in pesticide usage. However, pesticides currently used for southern stem rot control do not cause the phytotoxicity that had been observed with potassium azide, the compound used by Rodríguez-Kábana et al (9). Also, the chlorpyrifos + PCNB treatment, which performed best in this study, provided insect control, thus effecting multiple pest control. Therefore, although southern stem rot incidence may be similar to that of 20 yr ago, the compounds used for control of this disease have improved. In addition, intercepts of linear regression models developed from each site in the 1980s tended to be greater than those determined by Rodríguez-Kábana et al (9), indicating a higher yield potential than previously described.

Rodríguez-Kábana et al (9) indicated that generalized loss models may be difficult to develop given the differential yield response to southern stem rot under different climatic influences or cultural practices. We were able to develop generalized loss models over multiple sites and years because of the number of observations made. We also corrected for any "site effect" (particular environment or cultural practices other than pesticides) by calculating a yield loss, by site, for every plot in the study. The slopes of the loss models presented in the previous paper range from −0.4% to −2.4% of the values of the intercepts and are similar to slopes of the generalized loss models presented here. These generalized loss models also had coefficients of determination (r^2) similar to those observed by Rodríguez-Kábana et al (9). This indicates that the data from 1971 and 1973 would probably fit into our models and also that the generalized loss models presented here are equivalent to those previously described.

Two generalized loss models are presented because of distinct differences in yield response between data sets. The trials from 1983 through 1985 and from 1988 and 1989 consistently had higher values for percent maximum yield than the trials from 1986 and 1987. The model that fit data from 1986 had a higher regression coefficient than the other models, and data from 1987 were distributed similarly to data from 1986 (Fig. 1). These differences probably reflect environmental variability in that 1986 was an exceptionally hot, dry year and 1987 also was warmer than usual (Table 2). Because southern stem rot is known to be favored by relatively high temperatures, i.e., 30–35 C (8), it is not surprising that yields in 1986 and 1987 were more adversely affected (as indicated by the steeper slope of the regression model) in these years. Although southern stem rot may be limited by moisture, relative humidity under the peanut canopy is sufficient for fungal growth (8). Also, sclerotial germination throughout the growing season is favored by low humidity, particularly with drying and rewetting of sclerotia (8). All years of this study, except 1989, had less rainfall than the 30-yr normal. Thus, the high temperatures, such as those predominating in 1986 and 1987, appear to be the primary factor in increased loss attributed to southern stem rot.

Treatments that were included at all sites and years of the study were compared for elucidation of possible differential responses with low disease incidence. Treatment with chlorpyrifos + PCNB resulted in less disease and higher yields (Table 3) than chlorpyrifos or PCNB alone or no treatment. Individual loss models developed from data from selected treatments indicate that the yield loss caused by southern stem rot at low disease incidence may be proportionally greater than the yield loss at higher disease incidence (Fig. 3). These results indicate that the relationship between peanut yield and southern stem rot incidence may be nonlinear, although several simple nonlinear models were not consistently better than linear models. Also, other factors may be affecting these relationships. For example, chlorpyrifos affects pests other than *S. rolfsii.* In addition, treatments that resulted in very low disease levels may have a physiological effect on the plants.

Plots treated with the newest fungicides, e.g., tebuconazole, consistently outyielded untreated plots as well as those treated with currently recommended pesticides, e.g., PCNB and chlorpyrifos. The combined treatment of chlorpyrifos + PCNB also outyielded single treatment applications. Apparently, the use of insecticide/fungicide combination treatment or fungicides that are being labeled will raise the yield potential of peanuts in Alabama.

This study indicates that products currently recommended for control of southern stem rot, such as PCNB and/or chlorpyrifos, are more efficacious than products used 20 yr ago, yet the peanut yield loss/southern stem rot disease incidence relationship has remained approximately the same. As products that provide even better control become more widely used, loss at low levels of disease may become more important, and the effects of low levels of disease will need to be examined in more detail.

LITERATURE CITED

1. Anonymous. 1989. Weather data. Ala. Agric. Exp. Stn. Agric. Weather Ser. 29.
2. Backman, P. A. 1984. Stem rot. Pages 15-16 in: Compendium of Peanut Diseases. D. M. Porter, D. H. Smith, and R. Rodríguez-Kábana, eds. American Phytopathological Society, St. Paul, MN.
3. Csinos, A. S. 1989. Targeting fungicides for control of southern stem rot on peanut. Plant Dis. 73:723-726.
4. French, J. C., Weeks, J. R., Mack, T. P., Hagan, A. K., Hartzog, D., and Everest, J. W. 1991. Peanut insect, disease, nematode, and weed control recommendations. Ala. Coop. Ext. Serv. Circ. ANR-360.
5. Gray, F. A., Gazaway, W. S., Backman, P. A., and Rodríguez-Kábana, R. 1978. Peanut disease and nematode control recommendations. Ala. Coop. Ext. Serv. Circ. ANR-1.
6. Hagan, A. K., Weeks, J. R., and Bowen, K. L. 1991. Effects of application timing and method on control of southern stem rot of peanut with foliar-applied fungicides. Peanut Sci. 18:47-50.
7. Minton, N. A., Csinos, A. S., Lynch, R. E., and Brenneman, T. B. 1991. Effects of two cropping and two tillage systems and pesticides on peanut pest management. Peanut Sci. 18:41-46.
8. Porter, D. M., Smith, D. H., and Rodríguez-Kábana, R. 1982. Peanut plant diseases. Pages 326-410 in: Peanut Science and Technology. H. E. Pattee and C. T. Young, eds. American Peanut Research and Education Society, Yoakum, TX.
9. Rodríguez-Kábana, R., Backman P. A., and Williams, J. C. 1975. Determination of yield losses to *Sclerotium rolfsii* in peanut fields. Plant Dis. Rep. 59:855-858.
10. Sturgeon, R. V., Jr. 1986. Peanut disease loss estimates for major peanut producing states in the United States for 1984 and 1985. Proc. Am. Peanut Res. Educ. Soc. 18:24-25.