Effect of Irrigation on Expression of Stem Rot of Peanut and Comparison of Aboveground and Belowground Disease Ratings

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ABSTRACT

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Field tests were conducted in 1993 and 1994 at a site with replicated irrigated and nonirrigated sections to evaluate the effect of irrigation on stem rot disease severity and on yield loss models, and to assess the relationship between aboveground and belowground disease ratings. The relationship between the number of cyproconazole applications and stem rot severity and peanut yield also were examined. Rainfall amounts were higher in 1994 than in 1993. Area under the disease progress curve (AUDPC) was calculated from weekly measurements of aboveground stem rot lesions. AUDPC, belowground disease ratings, and peanut yield were increased by irrigation in 1993 but not in 1994. Belowground disease ratings reflected AUDPC in irrigated and nonirrigated plots in 1993 and 1994, but the slopes of regression lines were greater in nonirrigated plots. Also, for any given AUDPC, the belowground rating was higher in the nonirrigated plots than in the irrigated plots. Increasing the number of cyproconazole applications decreased AUDPC and belowground disease ratings and increased yield. The results of this study indicate that the interrelationships of AUDPC, belowground stem rot ratings, and yield are strongly influenced by irrigation, but these effects do not carry over to subsequent crops. Either AUDPC or belowground stem rot ratings may be used in yield loss models, except in nonirrigated fields in dry years when belowground ratings must be used.

Additional keywords: *Arachis hypogaea, Sclerotium rolfsii*, white mold

Stem rot of peanut (*Arachis hypogaea* L.), caused by *Sclerotium rolfsii* Sacc., is found throughout peanut-producing areas of the world and causes the greatest yield losses of any peanut disease in the United States (3). Germination of sclerotia of *S. rolfsii* is favored by drying and rewetting of sclerotia (5,14), though alternate wet and dry periods can sometimes inhibit disease development (21). Sclerotia germinate best in wet but not saturated soil (1,15), and diseases caused by *S. rolfsii* are more severe at these high moisture levels (8,11,16). Thus, epidemics of stem rot are most often observed in wet years (2,3,10,27), though some severe epidemics have been observed in dry years (25). Some studies have implicated irrigation as the cause of increased stem rot incidence and severity on peanuts (4,6), but the relationship was not specifically tested. Such an increase was observed in a microplot study (19) but has not been documented in field tests. Increased irrigation led to a 13-fold increase in white mold disease, caused by *Sclerotinia sclerotiorum* (Lib.) de Bary, of Great Northern bean (26).

Yield loss in peanut due to stem rot is influenced significantly by environmental factors including moisture (7,17). This may be due to the effects of microclimate under the peanut canopy on the growth and spread of the fungus (19,20,22). A severe epidemic in one year may be followed by high initial disease the following year (19), so increased inoculum density in irrigated fields may increase the severity of epidemics in subsequent years. The influence of irrigation and the irrigation history of a field on peanut yield loss and stem rot disease progress has not been reported.

Stem rot severity may be measured either by belowground disease ratings after peanut inversion at harvest or by aboveground disease ratings at any time before harvest. Multiple aboveground ratings may be used to compute area under the disease progress curve (AUDPC), which incorporates time as a variable in the disease severity assessment (23,25). It is not known if the multiple disease ratings necessary to calculate AUDPC will provide improved yield loss models. Stem rot is caused by a soilborne pathogen, so belowground ratings may provide a more accurate measurement of disease severity, but belowground ratings cannot be obtained until the plants are inverted.

The objectives of this project were to evaluate the effect of irrigation on stem rot yield loss models and to examine the relationship between aboveground stem rot severity ratings as measured by AUDPC and belowground severity ratings. Cyproconazole was applied to generate a range of stem rot severity levels for use in yield loss models, but the relationships among the number of cyproconazole applications, stem rot severity, and peanut yield also were examined.

MATERIALS AND METHODS

Peanut seed (cv. Florunner) were planted at 112 kg/ha on 17 May 1993 and 24 May 1994 in a field with a history of southern stem rot at the University of Georgia, Coastal Plain Experiment Station, Blackshank Farm in Tifton, GA. The soil was a Tifton loamy sand (fine-loamy, siliceous, thermic Plinthic Paleudults). Peanuts were grown on this field from 1988 to 1992. A solid-set, overhead irrigation system was installed prior to 1988 to divide the field into blocks, each containing an irrigated and a nonirrigated whole-plot unit. The irrigated and nonirrigated sections of the field were maintained in the same place. Water (2.54 cm) was applied weekly during the growing season unless there had been an equivalent amount of rainfall that week. This study used five blocks and was arranged in a split-plot design with irrigated and nonirrigated whole-plots and timing of cyproconazole applications (Alto 100SL at 1.0 liter/ha) as sub-plots. Treatments were applied with a CO_2-pressurized backpack sprayer with three D2-23 nozzles per row delivering 124 liters/ha at 345 kPa. Sub-plot treatments either were untreated or were treated with cyproconazole on an approximately 17-day spray schedule with initial sprays beginning 45, 63, 79, 95, or 113 days after planting (DAP) in 1993 and 45, 62, 79, 97, or 113 DAP in 1994.

Two-row sub-plots were 1.8 × 12.2 m and blocks were separated by 2.4-m unplanted alleys. Chlorothalonil (Bravo 720 at 1.75 liters/ha) was applied at 2-week intervals for control of late leaf spot caused by *Cercosporidium personatum* (Berk. & M. A. Curtis) Deighton. Fertilizer was applied on 21 April 1993 (224 kg/ha of 0-0-

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22) and 17 May 1994 (448 kg/ha of 5-10-15). Gypsum was applied on 6 July 1993 (504 kg/ha) and on 14 July 1994 (560 kg/ha). Aldicarb (7.8 kg/ha) was applied in furrow at planting in 1993 and 1994. Peanuts were dug and inverted on 11 October 1993 and 21 October 1994 and harvested by combine on 14 October 1993 and 28 October 1994. Pods were dried to approximately 10% (wt/wt) moisture prior to storage at room temperature.

AUDPC values were calculated from weekly disease evaluation data. All aboveground disease loci were identified, flagged, and measured each week. A disease locus was defined as any length of row with signs of *Sclerotium rolfsii* or symptoms of southern stem rot and was measured as the maximum length of row that was affected by that locus. AUDPC was calculated by the following formula:

$$AUDPC = \sum_{i=1}^{n} [(X_i + X_{i-1})/2](t_i - t_{i-1})$$

where i is the number of the week in which observations were made, n is the last week in which observations were made, X_i is the total length of stem rot lesions in week i, and t_i is the DAP on which lesions were measured in week i.

Belowground disease ratings were made following inversion of the plants as the number of disease loci per plot. A locus of infection was defined as a diseased length of row equal to or less than 30 cm (17). This definition of disease locus is different from the definition used for the aboveground measurement. For purposes of statistical analysis and presentation, belowground ratings were converted to a percent-of-row measurement and yield was converted to a kg/ha equivalent.

The data were subjected to analysis of covariance to examine the relationship between the dependent variable and the independent variable within irrigated and nonirrigated plots and to determine if the two slopes in each model were statistically different ($P \le 0.05$) (12,13). Analyses examined the relationships between belowground stem rot ratings and AUDPC, AUDPC and the number of cyproconazole applications, belowground stem rot ratings and the number of cyproconazole applications, yield and the number of cyproconazole applications, yield and AUDPC, and yield and belowground stem rot ratings.

Table 1. Rainfall and irrigation data for irrigated and nonirrigated plots in 1993 and 1994

	Total rainfall plus irrigation (cm)			
	1993		1994	
	Irrigated	Nonirrigated	Irrigated	Nonirrigated
June	6.9	6.9	29.0	29.0
July	26.9	25.7	22.4	22.4
August	17.8	11.4	20.6	14.7
September	20.8	13.2	20.8	13.0
October	6.6	4.1	29.2	29.2
Total	79.0	61.3	122.0	108.3

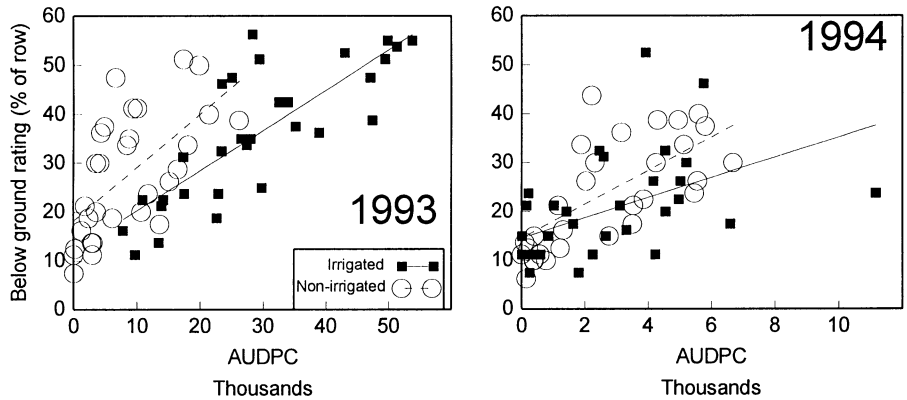

Fig. 1. Relationship of belowground stem rot ratings to area under the disease progress curve (AUDPC) in irrigated and nonirrigated plots in 1993 and 1994. Analysis of covariance ($P \le 0.05$) $R^2 = 0.58$ in 1993 and $R^2 = 0.36$ in 1994. Regression equations: Y (1993 irrigated) = 12.1 + 0.000821X; Y (1993 nonirrigated) = 18.3 + 0.00109X; Y (1994 irrigated) = 14.6 + 0.00206X; Y (1994 nonirrigated) = 14.6 + 0.00344X.

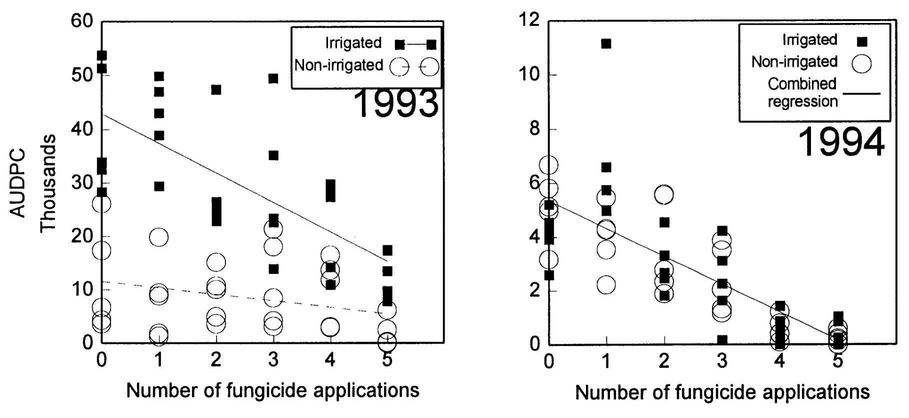

Fig. 2. Relationship of areas under disease progress curves (AUDPC) to the number of cyproconazole applications in irrigated and nonirrigated plots in 1993 and 1994. Analysis of covariance ($P \le 0.05$) $R^2 = 0.70$ in 1993 and $R^2 = 0.61$ in 1994. Regression equations: Y (1993 irrigated) = 42,920 – 5,520X; Y (1993 nonirrigated) = 11,607 – 1,232X; Y (1994 irrigated) = 5,360 – 1,041X; Y (1994 nonirrigated) = 5,360 – 1,041X.

RESULTS

Stem rot incidence was higher and signs appeared earlier in 1993 than in 1994 resulting in higher AUDPC values in both irrigated and nonirrigated plots in 1993. Rainfall and irrigation data for both years are presented in Table 1. In both years, belowground disease ratings increased linearly as AUDPC increased, and the slope of the regression line was greater in nonirrigated plots than in irrigated plots (Fig. 1). In 1993, AUDPC values in irrigated plots were generally higher than values in nonirrigated plots, whereas irrigation had little effect on AUDPC values in 1994.

Increasing the number of cyproconazole applications decreased AUDPC in both irrigated and nonirrigated plots in both years (Fig. 2). In 1993, increasing the number of fungicide applications reduced AUDPC more in irrigated plots than in nonirrigated plots, but a common regression fit both sets of data in 1994.

Increasing the number of fungicide applications also reduced the belowground stem rot ratings in irrigated and nonirrigated plots in both years (Fig. 3). In 1993, the regression slopes were equal but the intercept for irrigated-plot data was higher than for nonirrigated-plot data. In 1994, a common regression described both data sets.

Peanut yield was increased by increasing the number of cyproconazole applications (Fig. 4). A common regression adequately described the data in both irrigated and nonirrigated plots in 1994. In 1993, irrigation had a significant effect on yield, which resulted in a higher intercept for the irrigated plot regression, though irrigated- and nonirrigated-plot data shared a common slope.

Yield was inversely related to AUDPC in irrigated plots in 1993 and in both irrigated and nonirrigated plots in 1994 (Fig. 5). Yield was not affected (slope = 0) by changes in AUDPC in nonirrigated plots in 1993. A common regression described the data in both irrigated and nonirrigated plots in 1994.

Yield was inversely related to belowground stem rot ratings in both irrigated and nonirrigated plots in 1993 and 1994 (Fig. 6). A common regression described the data in both irrigated and nonirrigated plots in 1994, whereas in 1993, regressions for irrigated and nonirrigated plots had different slopes and intercepts. Yield loss per belowground stem rot locus was estimated from regression equations to be 0.7% per locus in irrigated plots in 1993, 0.5% per locus in nonirrigated plots in 1993, and 1.0% loss per locus in both irrigated and nonirrigated plots in 1994.

DISCUSSION

Cyproconazole applications also may suppress *Rhizoctonia solani* Kühn. Rhizoctonia disease levels ranged from 3.6 to 15.7% of vines infected in 1993 and from 5.0 to 10.4% of vines infected in 1994. These Rhizoctonia disease levels likely had little effect on yield or on our stem rot yield loss models.

Epidemics of stem rot were more severe in irrigated than in nonirrigated plots in 1992 (T. B. Brenneman, unpublished) and 1993. It is interesting that stem rot was more severe in the drier year of 1993 than in 1994, although alternating wet and dry periods have been reported to be more conducive to disease development (24). Though not measured, we believe soil moisture was near field capacity throughout most of the 1994 growing season due to the frequency of rains (R. F. Davis, personal observation). Most of the differences between irrigated and nonirrigated plots observed in 1993 were not observed in 1994, when there was abundant rainfall, minimal irrigation, and cooler temperatures. This is evidence that there is little or no carry-over effect of irrigation from year to year on at-harvest belowground stem rot ratings or AUDPC. Pre-plant inoculum density was not measured, but since no differences in AUDPC were observed in 1994, any differences in inoculum density that may have existed had no significant effect on disease incidence, severity, or rate of increase. If environmental conditions become favorable for stem rot development, the irrigation history of a field does not appear to affect stem rot severity.

Rotem (18) notes that if one factor is unfavorable for disease but another factor is very favorable, the favorable factor may be able to compensate partially for the unfavorable factor. This has been demonstrated for stem rot of peanuts in a microplot experiment (19) in which increasing soil moisture partially compensated for a low initial inoculum level. Differences in initial inoculum led to similar disease severities if plots received similar amounts of water. The field tests reported herein support results from the previous microplot study. Even though irrigated plots had much higher disease levels in 1993, few differences were observed in 1994 between irrigated and nonirrigated plots when nonirrigated plots received nearly as much water as irrigated plots.

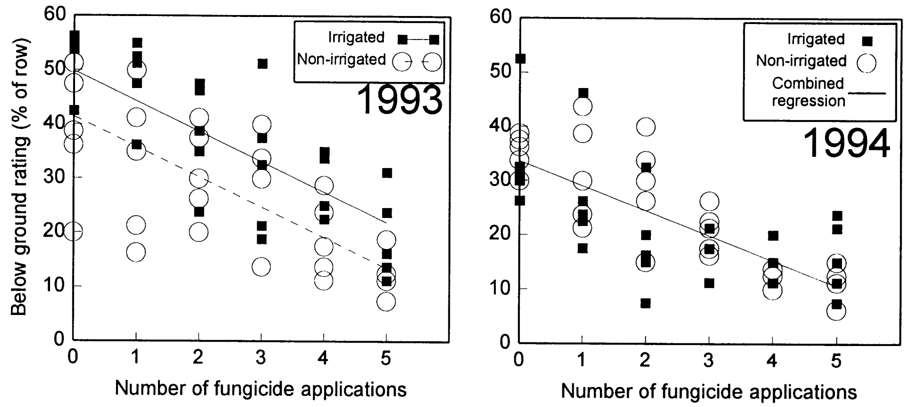

Fig. 3. Relationship of belowground stem rot ratings to the number of cyproconazole applications in irrigated and nonirrigated plots in 1993 and 1994. Analysis of covariance ($P \le 0.05$) $R^2 = 0.58$ in 1993 and $R^2 = 0.55$ in 1994. Regression equations: Y (1993 irrigated) = 49.9 – 5.6X; Y (1993 nonirrigated) = 41.5 – 5.6X; Y (1994 irrigated) = 33.7 – 4.6X; Y (1994 nonirrigated) = 33.7 – 4.6X.

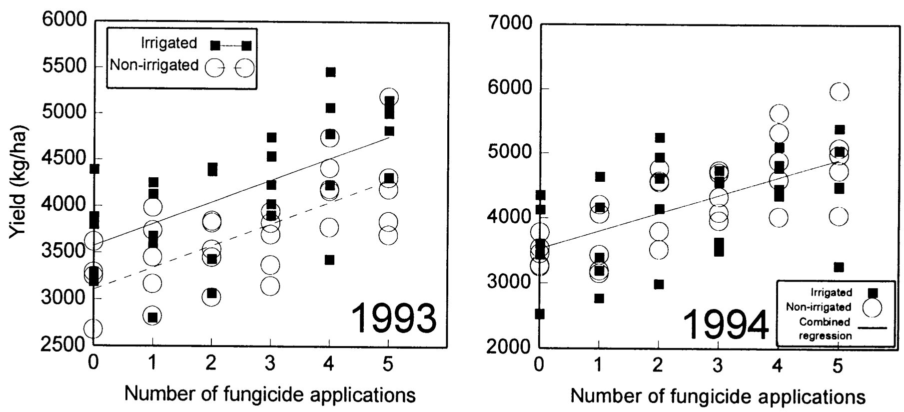

Fig. 4. Relationship of peanut yield to the number of cyproconazole applications in irrigated and nonirrigated plots in 1993 and 1994. Analysis of covariance ($P \le 0.05$) $R^2 = 0.52$ in 1993 and $R^2 = 0.39$ in 1994. Regression equations: Y (1993 irrigated) = 3,577 + 235.0X; Y (1993 nonirrigated) = 3,109 + 235.0X; Y (1994 irrigated) = 3,532 + 273.4X; Y (1994 nonirrigated) = 3,532 + 273.4X.

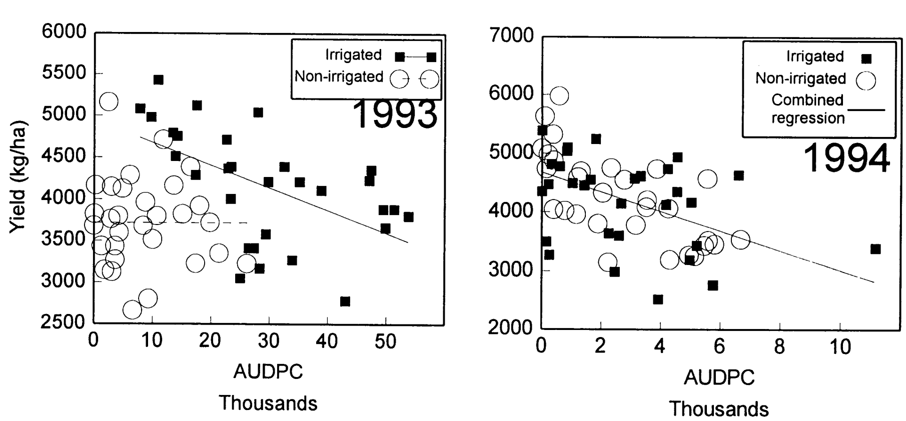

Fig. 5. Relationship of peanut yield to areas under disease progress curves (AUDPC) in irrigated and nonirrigated plots in 1993 and 1994. Analysis of covariance ($P \le 0.05$) $R^2 = 0.29$ in 1993 and $R^2 = 0.26$ in 1994. Regression equations: Y (1993 irrigated) = 4,951 – 0.0271X; Y (1993 nonirrigated) = 3,719; Y (1994 irrigated) = 4,673 – 0.166X; Y (1994 nonirrigated) = 4,673 – 0.166X.

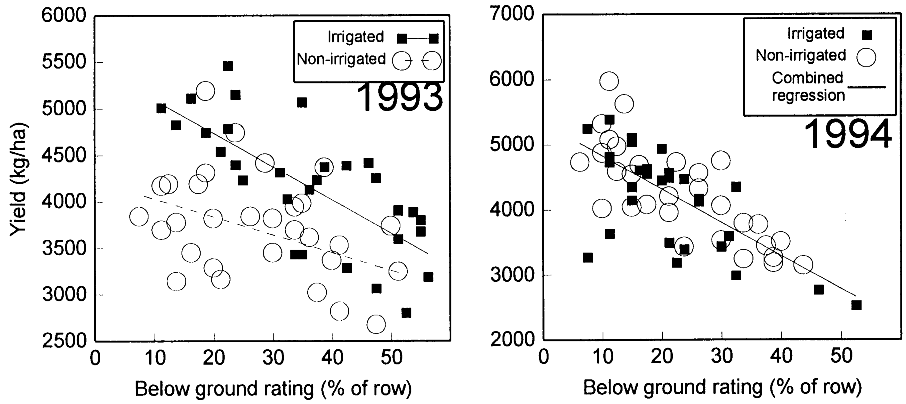

Fig. 6. Relationship of peanut yield to belowground stem rot ratings in irrigated and nonirrigated plots in 1993 and 1994. Analysis of covariance ($P \leq 0.05$) $R^2 = 0.48$ in 1993 and $R^2 = 0.53$ in 1994. Regression equations: Y (1993 irrigated) = 5,453 – 35.8X; Y (1993 nonirrigated) = 4,225 – 19.2X; Y (1994 irrigated) = 5,349 – 51.2X; Y (1994 nonirrigated) = 5,349 – 51.2X.

Belowground disease ratings could be predicted by AUDPC but, for any given AUDPC, the belowground disease rating was higher in the nonirrigated than in the irrigated plots. Even in a year with above-average rainfall and soil moisture levels, aboveground signs or symptoms of disease were more evident in irrigated than in nonirrigated plots, though increased rainfall does appear to reduce the magnitude of this difference. This is consistent with observations that the microclimate under the plant canopy plays a significant role in aboveground growth of *Sclerotium rolfsii* (19,20,22). In nonirrigated plots in a dry year, aboveground disease progress as measured by AUDPC may provide a misleading picture of belowground disease levels since small changes in AUDPC may reflect large changes in belowground disease levels. Under dry conditions, such as those found in nonirrigated plots in 1993, infections tend to occur deeper in the soil rather than at the soil surface (2).

Yield losses per locus in irrigated and nonirrigated plots in 1993 and 1994 appear to be consistent with the 0.9% loss per locus predicted by the generalized loss model proposed by Bowen et al. (6). In a wet year, yield losses to stem rot in irrigated or nonirrigated fields may be predicted either by belowground ratings or by AUDPC but, in a dry year, AUDPC cannot be used to predict yield loss in nonirrigated fields. The relationship between AUDPC and belowground stem rot ratings and between AUDPC and yield are influenced strongly by rainfall and irrigation. This influence must be accounted for if AUDPC is to be used to predict yield loss. Though rainfall and irrigation also affect the relationship of belowground stem rot ratings to yield, the effect is not as strong as it is on the relationship of AUDPC to yield. This is probably due to the effect of microclimate under the peanut canopy on the ability of the fungus to grow above ground. The effect of rainfall and irrigation levels on the interrelationships of AUDPC, belowground stem rot ratings, and yield is consistent with observations that the parameters of yield loss models for stem rot on peanut are influenced by environmental conditions (7,17). These findings also support the widespread reliance on "at digging" stem rot ratings rather than more labor-intensive efforts to determine AUDPC.

Cyproconazole is known to suppress stem rot of peanut (9), so it is not surprising that increasing the number of cyproconazole applications decreased AUDPC and belowground disease ratings and increased yield, though it is useful to know that these were linear responses. In practical terms, this means that it is still beneficial to begin a cyproconazole spray schedule near the end of the season because there is a measurable response to even a single application as peanuts near harvest, though beginning a spray schedule earlier provides more benefit. In a wet year, the effect of cyproconazole on AUDPC, belowground ratings, and yield can be expected to be similar in magnitude in irrigated and nonirrigated fields. In a dry year, the magnitude of the effect on yield and belowground disease ratings will be similar in irrigated and nonirrigated fields, but the effect on AUDPC will be much greater in irrigated fields, where the microclimate under the peanut canopy is more conducive to aboveground fungal growth.

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