Control of Cylindrocladium Black Rot of Peanut with Cultural Practices That Modify Soil Temperature

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ABSTRACT

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Development of Cylindrocladium black rot (CBR), a root and pod rot disease of peanut caused by *Cylindrocladium crotalariae*, is slowed when soil temperatures exceed 25 C and stops if temperatures exceed 35 C. Cultural practices that modify soil temperature were evaluated in 1985 and 1986 for their effect on CBR development in susceptible (Florigiant) and moderately resistant (NC 18416) peanut genotypes. Cultural practices included delayed planting (the recommended planting date was compared with planting 2 and 4 wk later), two row preparations (bedded and flat rows), and two row orientations (north-south and east-west). In both years, CBR incidence was less for NC 18416 than for Florigiant. Disease incidence was least at the last planting date for both genotypes in both years. Maximum and minimum soil temperatures in the row at 10 cm deep were greater in the 3-wk period following the last planting date than in a similar period following the first planting date. The decrease in disease incidence at the last planting date did not result in an increase in yield because of the shortened growing season. Disease incidence was less in bedded rows in 1985 than in flat rows. In 1986, there was more disease present in all treatments, and disease incidence that year was not affected by row preparation. Yields, however, were greater in bedded rows. Row orientation did not affect CBR development or yield for either genotype or year.

Additional keywords: *Arachis hypogaea*

Cylindrocladium black rot (CBR) is a serious disease of peanut (*Arachis hypogaea* L.) and limits yields in North Carolina and Virginia. *Cylindrocladium crotalariae* (Loos) Bell & Sobers (2), the soilborne fungal pathogen causing the disease, attacks the roots, pegs, and pods of peanut. Yield is lost through destruction of the taproots, resulting in debilitation and death of the plant as well as pod rot. Microsclerotia are produced in host tissues and serve as inoculum (13). Disease severity increases as microsclerotia density in soil increases (5).

CBR is managed by using partially resistant peanut cultivars and by reducing initial inoculum densities through crop rotation and fumigation with metham-sodium. Resistant plants are not immune to infection but are better able to produce periderms induced by infection that wall off the pathogen from the vascular system, thereby stopping spread of the fungus into the taproot (6). Susceptible plants also produce periderm, but these defenses are breached by the pathogen more often than in resistant plants (6). Reduction of inoculum density is therefore important in limiting the number of infections in resistant plants. In spite of these control measures, disease incidence can still be high if the environment is conducive for disease development.

Soil temperature is one of the most critical environmental factors affecting disease development (1,9). In a greenhouse study, Phipps and Beute (9) observed greater CBR severity in plants grown in soil maintained at 25 C with moisture at field capacity. Severity was reduced if the soil was either warmer (30 C), cooler (20 C), or allowed to dry to the wilting point before watering (9). Nine hours at 35 C stopped CBR from developing even if soil temperature was lowered to 25 C for the remainder of each day (9). Severity of CBR in peanut grown in microplots was also affected by temperature. Planting on 2 May, when the minimum soil temperature was below 18 C, resulted in more severe disease than planting on 17 or 30 May, when the minimum soil temperature was above 18 C (3).

Temperature affects both the pathogen and host. Radial growth of *C. crotalariae* on agar plates is fastest at 26–28 C (2). At 20 C, growth rate is reduced by 50% (2), whereas no growth occurs at 35 C (12). Peanuts grow best in a growth chamber at temperatures of 30 C day/ 26 C night (4).

Disease incidence should be reduced if the duration of temperatures conducive for disease can be shortened by cultural manipulations. The objective of this study was to determine if cultural practices including delayed planting, row preparation, and row orientation would reduce CBR development. It is currently recommended that growers plant only after soil temperature at 10 cm exceeds 18 C at noon for 3 consecutive days (15). In North Carolina, this usually occurs around 1 May. Delaying planting is usually associated with increasing soil temperature, reducing growth of the pathogen, and increasing seedling growth. Bedded rows should be both warmer and drier than flat rows because of greater exposure to the air. Row orientation may also influence soil temperature by affecting the number of hours the soil is directly exposed to the sun as a result of plant canopy partially shading the soil. The effects of these practices on CBR incidence and peanut yield were studied in field tests with two peanut genotypes, one susceptible (Florigiant) and one partially resistant (NC 18416), to determine whether response to environmental factors is similar.

MATERIALS AND METHODS

Field plots were established in 1985 and 1986 in different locations in a commercial peanut field in Martin County, NC, where a high incidence of CBR had previously been observed. Main plot treatments in a split-split plot experimental design were row orientation (north-south [N-S] or east-west [E-W]); row preparation (bedded or flat) and planting date (three planting dates 2 wk apart) randomized within the main plot; and peanut genotypes (susceptible [Florigiant] and partially resistant [NC 18416]) randomized within each row preparation by planting date combination. Planting dates were 29 April and 13 and 27 May in 1985 and 1, 17, and 31 May in 1986. The treatment design was complete factorial with four replications.

Each sub-subplot consisted of two 9.1-m rows. Each subplot (row preparation by planting date combination) was four rows (3.7 m) × 9.1 m. The N-S main plots were 21.9 × 9.1 m with all six subplots laid side by side. The E-W main plots were 7.3 × 27.4 m with three

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subplots placed end to end and only two subplots side by side. This arrangement was used to reduce the total area required for the experiment. Areas around main plots were fallow.

Bedded row treatments were approximately 10 cm high. Seeds were hand-planted 5 cm deep in all treatments on each of the three planting dates. Alachlor (0.1 kg a.i./ha) was applied after the first planting date to the entire field and was reapplied after each planting date to the rows planted; all subsequent weed control was done by hand to maintain the integrity of the bedded rows. Plants were sprayed for peanut leaf spot control with a backpack sprayer every 2 wk from mid-July to mid-September with chlorothalonil (0.45 kg a.i./ha). Peanuts were not irrigated.

Plots were sampled for an estimation of preplant inoculum density of *C. crotalariae*. Soil samples were taken 15–20 cm deep with a 2-cm-diameter soil-sampling tube. Twelve to 18 samples taken on a zigzag pattern in each subplot were bulked and mixed. From this composite sample, a single subsample (about 200 g) was assayed for the pathogen by elutriating and plating on a semiselective medium (10). Inoculum densities in microsclerotia per gram of oven-dried soil were calculated.

Soil temperature at a depth of 10 cm in the row was recorded every hour from the first planting date until harvest with thermistors attached to a Campbell CR21 micrologger (Campbell Scientific, Inc., Logan, UT). Temperatures were measured in two bedded rows oriented E-W, two flat rows oriented E-W, two bedded rows oriented N-S, and one flat row oriented N-S. Daily mean, maximum, and minimum temperatures for each row orientation by row preparation combination were determined for each day where temperature data were complete. In addition, the hours per day that the temperature exceeded 28 C were calculated to give an indication of the daily duration of soil temperatures unfavorable for disease development. The maximum and minimum temperatures per day and the hours per day that the temperature exceeded 28 C were averaged for the 3 wk following each planting date in 1985. A similar calculation could not be made for 1986 because temperature data were not complete.

Disease development was assessed from the aboveground symptoms of CBR, which included wilting, chlorosis, and plant death. Assessments were made from mid-July until harvest every other week in 1985 and every week in 1986. The number of symptomatic plants was determined in each row, and the counts of diseased plants were converted to percent of disease incidence by dividing by the number of plants per row.

Plants were dug for harvest on 23 September 1985 and 2 October 1986. Yield was determined in 1986 from each two-row sub-subplot. Dry weight of the yield was calculated by determining from a representative sample the percent of loss of moisture in pods after drying at 105 C overnight.

Data were analyzed separately for each year and assessment date by analysis of variance ($P \leq 0.05$, unless otherwise stated). Area under the disease progress curve (14) was calculated but yielded results similar to the analysis of disease incidence at harvest, and only these data are reported. An analysis of covariance with microsclerotial density as the covariate ($P \leq 0.05$) was calculated for each cultivar to account for uncontrollable differences in inoculum densities between plots.

RESULTS

Soil temperatures in 1985 increased from the first to the last planting date. Daily maximum and minimum temperature and the duration temperature exceeded 28 C for 3 wk following each planting date; all increased at each successive planting date (Table 1). Temperatures were monitored every hour. Mean soil temperature was generally greater in E-W than N-S rows (Fig. 1) and were greater in bedded than flat rows (Fig. 2). The soil remained warmer than 28 C longer each day in bedded rows (Fig. 3), especially after canopy closure in mid-July (approximately day 200). The mean temperature for the growing season was less in 1986 than 1985.

In 1985, the average inoculum density across the field was 0.3 microsclerotia per gram of soil (SD = 0.48, range of 0–1.6 microsclerotia per gram). Microsclerotial densities were below detection limits (0.2 microsclerotia per gram) in 34 of 48 plots. Plots in which no inoculum was detected and no aboveground symptoms were evident by the end of the season were dropped from the analysis because the pathogen may have been absent in these plots. This did not result in any change in the signif-

Table 1. Daily temperature parameters averaged for 3 wk after planting in 1985

Planting date	Maximum temperature (C)	Minimum temperature (C)	Temperature >28 C (hr/day)
29 April	25.2[z]	16.2	0.5
13 May	28.0	18.9	3.0
27 May	30.0	21.5	5.0

[z] Values are average of seven probes averaged over 3 wk following each planting date.

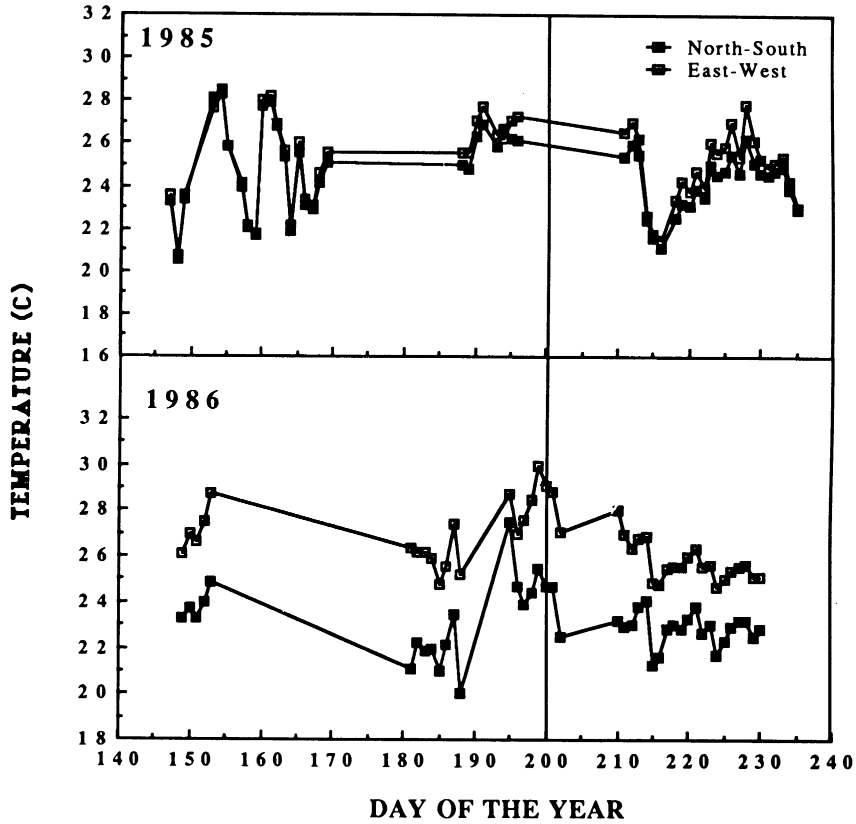

Fig. 1. Daily mean soil temperature 10 cm deep for rows oriented north-south (average, three locations) or east-west (average, four locations) from 20 May to 29 August in 1985 and 1986. Line indicates approximate date of canopy closure.

icance of treatments. In 1986, the average inoculum density was 1.8 microsclerotia per gram (SD = 1.51, range of 0–7.6 microsclerotia per gram). Only three of 48 plots had inoculum levels below detectable limits, but because aboveground symptoms occurred in every plot, all data were included in analyses. Microsclerotial density was not a significant covariate and did not alter any of the treatment effects in either year.

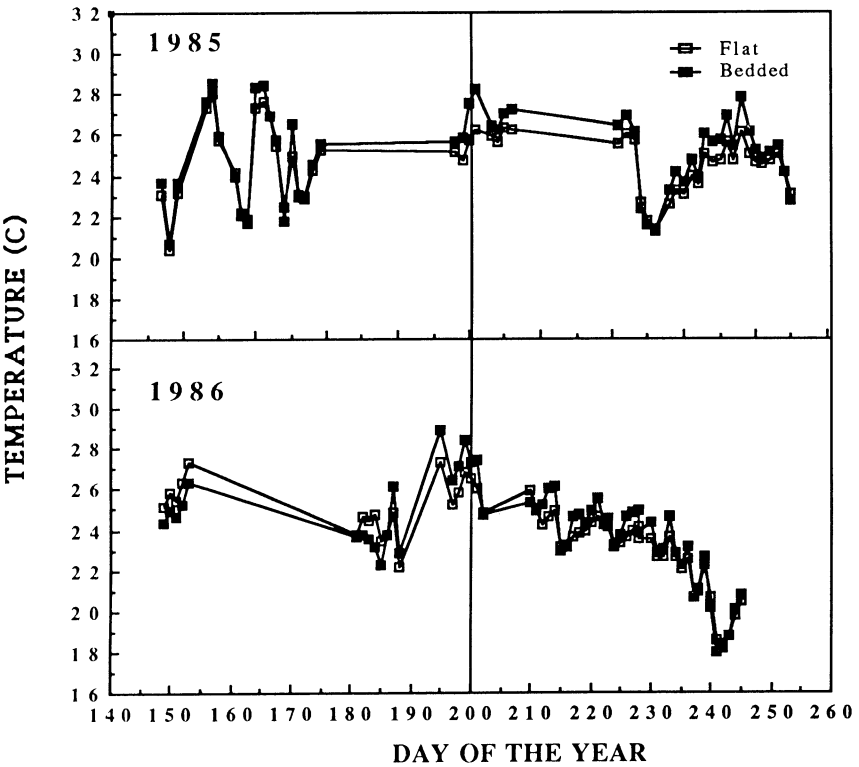

Fig. 2. Daily mean soil temperature 10 cm deep in bedded (average, four locations) or flat (average, three locations) rows from 20 May to 29 August in 1985 and 1986. Line indicates approximate date of canopy closure.

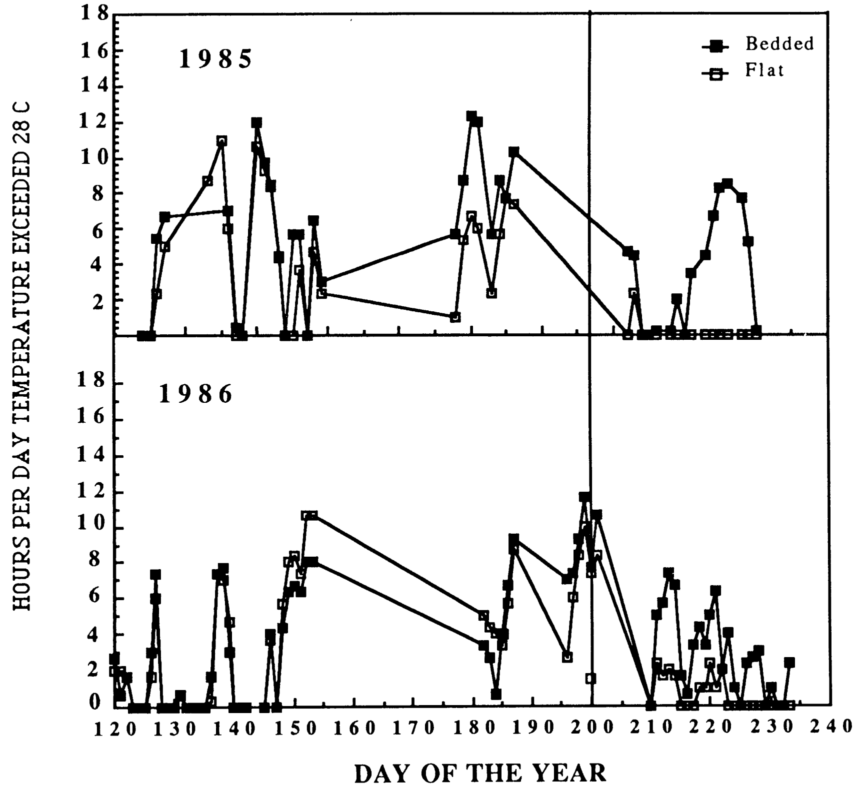

Fig. 3. Hours per day soil temperature 10 cm deep exceeded 28 C in bedded (average, four locations) or flat (average, three locations) rows from 20 May to 29 August in 1985 and 1986. Line indicates approximate date of canopy closure.

Incidence of aboveground symptoms of CBR was greater in Florigiant than in NC 18416 in both years and with all cultural treatments and was greater for both genotypes in 1986 than in 1985 (Table 2).

Delayed planting reduced CBR incidence in both genotypes during both years. For Florigiant, disease incidence was significantly lower with a 2-wk delay in planting in 1985, whereas in 1986 a 4-wk delay was required to reduce disease incidence. For resistant NC 18416, the effect of planting date was not significant in 1985, even though CBR incidence was lower with delayed planting. Whereas in 1986, CBR incidence was significantly lower with a 4-wk delay. Florigiant yielded the same regardless of planting date, whereas yield in NC 18416 was least at the last planting, resulting in a cultivar by planting date interaction ($P \leq 0.09$). (Table 3).

Less CBR developed on Florigiant in bedded rows than in flat rows in 1985 (Table 2). In contrast, mean CBR incidence was the same in bedded and flat rows on resistant NC 18416 (Table 2). In 1986, row preparation did not affect CBR incidence in either genotype (Table 2), but both genotypes yielded better in bedded rows (Table 3).

Row orientation did not affect CBR incidence in 1985 (Table 2) or yield in 1986 (Table 3). A significant cultivar by row orientation interaction in 1986 was apparently caused by unusually high disease incidence in a single plot. When data from this plot were removed from the analysis, the interaction was no longer significant at $P \leq 0.05$. In addition, row orientation by row preparation interactions were not significant.

DISCUSSION

The strategy for CBR control in North Carolina is twofold: to use partially resistant peanut cultivars and to reduce initial inoculum density of the pathogen (through crop rotation with nonhosts and fumigation with metham-sodium). In this study, the primary factors affecting CBR incidence were inoculum density and disease resistance. Although microsclerotial density was not a significant covariate to disease incidence, this does not mean that inoculum density did not affect disease development. Inoculum densities in 1985 were very low and only detectable in a few plots even though disease later developed in almost all plots. In 1986, all plots had higher and similar inoculum densities. The higher inoculum density in 1986 resulted in much greater disease incidence. As a result, the resistant genotype, NC 18416, had a higher percent of incidence in 1986 than Florigiant had in 1985 (Table 2). Under similar inoculum densities and environmental conditions, NC 18416 consistently had lower CBR incidence than did Florigiant (Table 2).

Table 2. Effect of cultural practices on percent of peanut plants with symptoms of Cylindrocladium black rot

Cultural practices	Cylindrocladium black rot incidence (%)			
	Susceptible[w]		Resistant[w]	
	1985	1986	1985	1986
Row orientation				
North-south	6.4 a[x]	18.4 a	0.7 a	7.8 a
East-west	8.2 a	24.8 a	0.5 a	8.4 a
Planting date[y]				
1	11.9 a	28.1 a	1.0 a	9.5 a
2	5.9 b	24.3 a	0.7 a	10.7 a
3	3.9 b	14.9 b	0.1 a	4.0 b
Row preparation				
Bedded[z]	4.0 b	23.2 a	0.6 a	8.5 a
Flat	11.9 a	21.7 a	0.6 a	7.7 a

[w] Susceptible genotype = Florigiant; resistant genotype = NC 18416.

[x] Values followed by different letters in the same set and column differ with each other. Values are the average of four blocks. Means exclude plots with no detectable inoculum that had no aboveground symptoms of disease by harvest.

[y] Planting dates: 1) 29 April, 2) 13 May, and 3) 27 May in 1985; 1) 1 May, 2) 17 May, and 3) 31 May in 1986.

[z] Rows bedded to a height of approximately 10 cm.

The cultural practices tested in this experiment increased soil temperature, thereby modifying the environment. Cultural practices were not able to negate the effects of high inoculum densities or low plant resistance, but did reduce disease severity at low inoculum densities even in resistant plants.

Of the cultural practices tested, planting date produced the most repeatable effect on disease incidence. In both years and for both genotypes, CBR incidence was reduced by planting at the end of May rather than the first of May, due to warmer soil temperatures. Black et al (3) reported similar findings in microplots. The earliest planting date that produced a reduction in CBR incidence varied with the year. In 1985, delaying planting by 2 wk was enough to reduce incidence (Table 2). In 1986, a delay longer than 2 wk was necessary (Table 2). Delayed planting in itself was not enough to counteract the effects of high inoculum densities. Disease incidence in both genotypes was greater for plants planted at the end of May in 1986 than for those planted the first of May in 1985 (Table 2).

If all other factors are equal, a decrease in CBR development should result in an increase in yield. A 7.5% loss in yield occurs for each 10% increase in CBR incidence for Florigiant (8). However, in this test the reduction in CBR incidence resulting from delayed planting did not result in an increase in yield for NC 18416. The lowest yield was produced with the 4-wk delay in planting, even though CBR incidence was lowest. This is because Virginia-type peanut (*A. hypogaea* subsp. *hypogaea*) requires a long growing season to produce maximum yields. In North Carolina, Florigiant requires an average 150–160 days. Due to potential frost damage, peanut planted late will not have a long enough growing season to produce high yields. The planting date that will maximize yield depends on weather conditions throughout the growing season, which cannot be predicted in the spring when the grower must decide when to plant.

Delayed planting would be a viable control practice for genotypes that mature faster than Florigiant. A delay of 2 wk was sufficient to reduce CBR incidence in susceptible Florigiant in 1985. In 1986, a 4-wk delay in planting was required to reduce disease incidence in both susceptible and resistant genotypes. Cultivars that combine early maturity with CBR resistance would offer an effective means of reducing yield losses due to the disease. Two Virginia-type peanut cultivars (NC 7 and NC 9) that mature 7–14 days earlier than Florigiant have recently been developed for North Carolina. Use of these cultivars in a delayed-planting strategy should reduce disease incidence and maintain high yields when low-to-moderate inoculum densities occur in the soil.

Bedding had a more subtle effect on CBR incidence. Bedding reduced disease incidence in Florigiant only in 1985 (Table 2). The greater disease pressure in 1986 may have masked any effect of row preparation on disease incidence, but yields were greater for both genotypes grown in bedded rows (Table 3). Reduced incidence of CBR in bedded rows has been reported (11).

Table 3. Effect of cultural practices on yield of peanut in soil infested with *Cylindrocladium crotalariae*

Cultural practices	Yield[w]	
	Susceptible[x]	Resistant[x]
Row orientation		
North-south	5.4 a[y]	6.1 a
East-west	5.4 a	5.8 a
Planting date		
1 May	5.2 a	6.1 a
17 May	5.4 a	6.4 a
31 May	5.6 a	5.3 c
Row preparation		
Bedded[z]	6.0 a	6.4 a
Flat	4.8 b	5.5 b

[w] Kilograms harvested per 16.8 m^2, equivalent to two 9.1-m rows.

[x] Susceptible genotype = Florigiant; resistant genotype = NC 18416.

[y] Values followed by different letters in the same set and column differ with each other. Values are the average of four blocks. Average yield can be converted to kilograms per hectare by multiplying by 1,196.

[z] Rows bedded to a height of approximately 10 cm.

The mean soil temperature at 10 cm below the surface was only slightly higher in bedded rows in both years, but the daily temperature varied more in bedded rows than flat rows. Soil temperature generally exceeded 28 C longer each day in bedded rows, especially after canopy closure (mid-July). The wider temperature extremes in bedded rows are due to the greater exposure to air temperature. It was observed through the course of the experiment that surface soil in flat rows was generally wetter than surface soil in bedded rows. The increased mass due to the higher water content of soils in flat rows would require more net energy flow for each degree of temperature change than would the drier bedded rows (7). This could account for the more moderate temperature fluctuations in flat rows.

Bedding, therefore, creates an environment in which soil temperature is frequently too warm for CBR development. This appears to be especially true after canopy closure when peanut pods are forming in the soil. Bedded rows may protect pods from rot due to *C. crotalariae*, with a subsequent increase in yield, even though percent of incidence of aboveground disease symptoms did not differ between bedded and flat rows.

There was no apparent effect of row orientation on CBR incidence or yield. Row orientation, however, was the main plot effect. The large size of main plots encompasses a wide range of soil properties and inoculum densities that could mask effects of orientation on disease. Rows oriented E-W, however, were warmer than N-S rows and therefore may have provided some protection against CBR.

Inoculum density and the level of resistance were the most important determinants of CBR incidence in this study. The effects of cultural practices were more apparent at low microsclerotial densities and were not sufficient alone to allow the profitable growth of a susceptible cultivar in lieu of a resistant one. Delayed planting and planting in bedded rows offer costfree methods of CBR control that will augment, and can be used in conjunction with, the current control practices of reducing inoculum density and planting resistant cultivars.

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