Accepted for publication 14 April 2009. Published 12 June 2009.

Comparison of Cropping Systems Including Corn, Peanut, and Tobacco in the North Carolina Coastal Plain

David L. Jordan, Professor, and **Loren R. Fisher,** Associate Professor, Department of Crop Science, Box 7620, North Carolina State University, Raleigh, NC 27695-7620; **Barbara B. Shew,** Research Assistant Professor, Department of Plant Pathology, Box 7903, North Carolina State University, Raleigh, NC 27695-7903; **Ty Marshall,** former Superintendent, Border Belt Tobacco Research Station, North Carolina Department of Agriculture and Consumer Services, 86 Border Belt Drive, Whiteville, NC 28472-6828; **P. Dewayne Johnson,** Research Specialist, Department of Crop Science, Box 7620, Raleigh, NC 27695-7620; **W. Ye,** Nematologist, North Carolina Department of Agriculture and Consumer Services, 4300 Reedy Creek Road, Raleigh, NC 27607-6465; and **Rick L. Brandenburg,** William Neal Reynolds Professor, Department of Entomology, Box 7613, Raleigh, NC 27695-7613

Corresponding author: David L. Jordan. david_jordan@ncsu.edu

Jordan, D. L., Fisher, L. R., Shew, B. B., Marshall, T., Johnson, P. D., Ye, W., and Brandenburg, R. L. 2009. Comparison of cropping systems including corn, peanut, and tobacco in the North Carolina Coastal Plain. Online. Crop Management doi:10.1094/CM-2009-0612-01-RS.

Abstract

Research was conducted in North Carolina from 2001 to 2006 to determine disease development, parasitic nematode population in soil, crop yield, and cumulative economic return in rotation systems including corn, peanut, and tobacco. Specific rotations included two consecutive cycles of corn-corn-peanut, corn-tobacco-peanut, or tobacco-corn-peanut; five years of corn followed by peanut, and corn-corn-tobacco-corn-corn-peanut. In the final year of the experiment when only peanut was planted, the Cylindrocladium black rot (caused by *Cylindrocladium parasiticum*) (CBR)-susceptible cultivar Gregory and the CBR-resistant cultivar Perry were included. Increasing the number of years between peanut plantings increased yield of peanut in the final year of the experiment when Gregory was planted but not when Perry was planted. Incidence of CBR was highest when peanut was planted twice during the duration of the experiment compared with only once. No difference in ring nematode was observed regardless of rotation in the final year of the experiment. The highest soil population of stunt nematode was noted when five years of corn was followed by peanut with the lowest soil population of this nematode noted following two cycles of tobacco-corn-peanut. Cropping systems that included tobacco provided higher cumulative economic returns regardless of rotation sequence in most instances.

Introduction

Corn (*Zea mays* L.), peanut (*Arachis hypogaea* L.), and tobacco (*Nicotiana tabacum* L.) are commonly grown in several regions of the coastal plain of North Carolina. Economic value of these crops varies considerably and influences producers' decisions on crop selection (26). Crop rotation can have a dramatic impact on development of pests and subsequent crop yield, especially for peanut.

Although rotations are an important tool for disease suppression, economic return over years is associated with income generated by each crop in the rotation and not necessarily the rotation that is most biologically advantageous for a particular crop (26). Growers must balance benefits of rotating lower value crops that are effective in reducing pest and pathogen populations with the desire to plant higher value crops in shorter rotations in an effort to optimize economic return over the length of the cropping system in a given field (17,19).

Peanut and tobacco have several pathogens in common, including *Sclerotium rolfsii*, *Rhizoctonia solani*, *Meloidogyne arenaria*, and *Tomato spotted wilt virus*. In addition, tobacco supports populations of *Cylindrocladium parasiticum* Crous, Wingfield, and Alfenas, cause of CBR in peanut, although disease does not usually develop in tobacco (23). Producers, extension publications, and peer-reviewed publications often mention that crop rotation is the most important component of pest management strategies for profitable peanut production (15,17,18,19,24,25,28,30). Benefits of increasing the number of non-legume crops between peanut plantings have been well documented (1,2,18,19,20,21,22,27). Cultivar also can have a major impact on yield and subsequent economic return of peanut because of differences in disease resistance (2,15,25). Virginia market-type peanut cultivars offer a wide range of agronomic and disease resistance characteristics (10,11,13,25). Defining interactions between cultivar selection and cropping sequence is important in developing appropriate pest management strategies and in helping producers compare and contrast cropping systems they could implement.

Prices for Virginia market type peanut since 2002 has ranged from $425 US/ton to $600 US/ton contracted for domestic consumption, with a guaranteed loan rate value of approximately $355/ton (4). Recently, prices for corn and soybean [*Glycine max* (L.) Merr.] have increased and resulted in competition with peanut for suitable acreage. Growers in the coastal plain of North Carolina also grow tobacco, and economic return from tobacco is considerably higher than possible return from other row crops even though production costs for tobacco are also considerably higher than corn, cotton (*Gossypium hirsutum* L.), peanut, or soybean. Determining agronomic response and economic return of cropping systems that include these crops is important in assisting farmers in their management decisions.

The objectives of this project were to: (i) compare crop yield and cumulative economic return of five cropping systems that included corn, peanut, and tobacco over a 6-year cycle; (ii) determine long-term impacts of these cropping systems on incidence of CBR, populations of plant parasitic nematodes in soil, and peanut yield; and (iii) determine interactions of cultivar selection and cropping system with respect to incidence of CBR and peanut yield.

General Procedures

The experiment was conducted in North Carolina from 2001-2006 at the Border Belt Tobacco Research Station located near Whiteville. Soil was a Norfolk sandy loam (fine-loamy, siliceous, thermic Aquic Paleudalts) with pH ranging from 5.9 to 6.2 over the duration of the experiment and 1.9% organic matter. Plot size was 12 rows (36-inch spacing for corn and peanut) or 8 rows (tobacco) by 75 feet. Conventional tillage included disking twice, field cultivating, and ripper-bedding within one week prior to planting.

Crop Rotations, Cultivars, and Production and Pest Management Practices

Specific rotations included two consecutive cycles of corn-corn-peanut, corn-tobacco-peanut, and tobacco-corn-peanut; corn-corn-corn-corn-corn-peanut, and corn-corn-tobacco-corn-corn-peanut (Table 1). In the final year of the experiment, the cultivars Gregory and Perry were planted in each plot. Corn hybrids included Pioneer 3223 (2001), Dekalb 697 (2002-2004), and Dekalb 6971 RR (2005). The peanut cultivar Gregory (11) was the only cultivar planted in 2003. In 2006, the cultivar Perry (10) was planted in four of the 12 rows. The cultivar Gregory was planted in the eight remaining rows. The cultivar Gregory is susceptible to most peanut diseases including CBR (11,25). The cultivar Perry has moderate resistance to CBR (10, 25). The tobacco cultivar was NC 71. Tobacco, while not affected by CBR, is an alternative host to peanut for CBR and plant parasitic nematodes (23,25). Corn is not considered a host for CBR (25) but is considered a host for plant parasitic nematodes (8,9,25,29). Production and pest management practices for peanut and other crops were held constant regardless of cropping system and were standard practices for the region (3,13,14,25). Fungicides were applied bi-weekly to peanut during each year beginning in early July and continuing through mid September to control early leaf spot (caused by *Cercospora arachidicola* Hori), late leaf spot (caused by *Cercosporidium personatum* (Berk. & M.A. Curtis), web blotch (casued by *Phoma arachidicola* Marasas et al.), and stem rot (caused by *Sclerotium rolfsii* Sacc.) (25). Peanut was not fumigated with metam sodium to control CBR and suppress plant parasitic nematodes.

Table 1. Crop rotations including corn, cotton, peanut, and soybean from 2001-2006 at Whiteville, NC.

Rotation sequence	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
A	Corn	Corn	Corn	Corn	Corn	Peanut
B	Corn	Corn	Tobacco	Corn	Corn	Peanut
C	Corn	Corn	Peanut	Corn	Corn	Peanut
D	Tobacco	Corn	Peanut	Tobacco	Corn	Peanut
E	Corn	Tobacco	Peanut	Corn	Tobacco	Peanut

Experimental Design and Data Collected

The experimental design from 2001-2005 was a randomized complete block with cropping systems replicated four times. In 2006, subplots consisted of combinations of the non-randomized cultivar treatments. In all years, the experimental unit consisted of two rows by 75 feet. Yield was determined for all crops during each year at optimum crop maturity and were harvested under appropriate environmental and edaphic conditions. Rainfall data in each year from April through September are presented in Table 2.

Table 2. Monthly rainfall from April through September at Whiteville, NC, during 2001-2006 and 30-year average.

	2001	2002	2003	2004	2005	2006	30-year avg
Month	**Rainfall** (inches)						
Apr	0.97	1.31	12.63	6.54	1.41	4.49	2.94
May	5.83	6.63	10.06	3.70	3.75	3.27	4.54
Jun	4.72	8.77	1.92	2.68	4.51	8.90	4.69
Jul	4.94	10.55	9.17	3.58	3.92	2.97	5.64
Aug	16.63	12.97	2.51	7.45	3.27	7.04	5.65
Sep	5.04	4.54	5.90	2.59	1.44	3.42	5.44
Total	38.13	44.77	42.19	26.54	18.3	30.09	28.9

Within 2 weeks of harvest during 2006, a visual estimate of plants expressing symptoms associated with CBR was recorded for each subplot on a scale of 0 to 100% where 0 = no disease symptoms and 100 = the entire plot was expressing typical CBR symptoms of wilting, yellowing, or plant death (25). The predominant disease in this field was CBR, and few plants expressed symptoms characteristic of Tomato spotted wilt virus or other diseases of peanut (25). In each plot, 15 soil cores were collected from a depth of 4 inches on each bed and pooled from the two rows planted with the cultivar Gregory within 2 weeks prior to digging in 2006. Populations of plant parasitic nematodes in 500 cm^3 soil were assayed by the North Carolina Department of Agriculture and Consumer Service and data were transformed to the log of nematode population prior to analyses to normalize data. Samples were assayed by a combination of elutriation (7) and centrifugation (12).

Net return during each year for each crop was calculated from crop prices, excluding loan deficiency payment, less production and pest management practices. Net returns reflect return to overhead, risk, and management after fixed and variable costs were considered. Returns were based on corn prices set at $2.50 and $4.00/bu at 12% moisture. Peanut price was set at $500/ton farmer stock peanut at 8% moisture. Production costs were estimated at $278/acre for corn (R. E. Heiniger, 2007, North Carolina State University, *personal communication*) and $726/acre for peanut (6). Tobacco price was set at $1.50/lb with a total production cost of $3,062/acre (5). Net return over the six years was referred to as cumulative net return.

Data for crop yield within each year, cumulative net return over the six years of the experiment for each rotation, plant condition rating, and the log of soil nematode population were subjected to analysis of variance for each cultivar and fumigation combination. Means were separated using Fisher's Protected LSD at $P \leq 0.05$. Analyses were conducted using the general linear model procedure of SAS V 9.1 (SAS Institute Inc., Cary, NC).

Peanut Yield, Nematode Population, and Plant Condition Rating in 2006

In 2006, crop rotation affected yield of the cultivar Gregory but not yield of Perry (Table 3). Yield for Gregory was higher when peanut followed five years of corn or four years of corn and one year of tobacco compared with shorter rotation cycles including corn or combinations of corn and tobacco with peanut planted in 2003. No difference in yield for Gregory was noted when comparing cycles of corn-corn-peanut, corn-tobacco-peanut, or tobacco-corn-peanut.

Table 3. Peanut pod yield, incidence of CBR, and population of stunt and ring nematodes in soil during 2006 at Whiteville, NC, in rotations including corn (CR), peanut (PN), and tobacco (TB).

Cropping system (2001-2006)	Peanut response during 2006				Log parasitic nematode population in soil (no. 500 cc)	
	Pod yield (lb/acre)		CBR incidence (%)			
	Gregory	Perry	Gregory	Perry	Stunt	Ring
CR-CR-CR-CR-CR-PN	3380 a	3570 a	0 c	0 a	4.93 a	6.25 a
CR-CR-TB-CR-CR-PN	4030 a	4140 a	3 c	0 a	4.15 bc	7.21 a
CR-CR-PN-CR-CR-PN	2420 b	3520 a	10 b	2 a	4.75 ab	6.85 a
CR-TB-PN-CR-TB-PN	2060 b	3310 a	29 a	3 a	4.29 bc	6.72 a
TB-CR-PN-TB-CR-PN	2220 b	3220 a	17 b	2 a	3.69 c	7.07 a
F statistic	8.02	1.34	6.47	2.79	4.11	1.19
P>F	0.0022	0.3124	0.0052	0.0754	0.0365	0.3653

* Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD.

The experimental design did not allow a direct comparison of cultivars, however, response of each cultivar within a cropping system revealed the relationship of peanut yield and CBR relative to cultivar resistance. Cultivar differences in response to rotation between CBR susceptible Gregory (11) and resistant Perry (10) were noted (Table 3). For Gregory, five years of corn or four years of corn plus one year of tobacco averaged 3710 lb/acre. Rotations involving two cycles of corn-corn-peanut, corn-tobacco-peanut, and tobacco-corn-peanut resulted in an average decrease in yield of 1470 lb/acre or approximately 40%. For the same comparisons, yield of the cultivar Perry did not differ when comparing rotations. Incidence of CBR followed a similar trend (Table 3). For Gregory, CBR was three percent or less for the two higher yielding rotations and 10 to 29% for the three lower yielding rotations. Other research (16) has demonstrated a 12 to 25% reduction in pod yield of the cultivar Gregory when CBR incidence was 12 to 23% compared to peanut in absence of CBR. In contrast to results with Gregory, CBR incidence for Perry was three percent or less regardless of rotation (Table 3). Previous research has demonstrated that increasing the number of non-leguminous crops between peanut plantings decreases incidence of CBR (2,15,22,27). Additionally, planting CBR-resistant cultivars can reduce incidence of CBR and maintain yield potential of peanut in short rotations (15,16).

Stunt nematode populations in 2006 were highest following five years of corn preceded peanut compared with rotations that included one year of tobacco between two years of corn and then peanut or cropping systems with two cycles of corn-tobacco-peanut or tobacco-corn-peanut (Table 3). The rotation of corn-corn-tobacco-corn-corn-peanut resulted in a higher population of stunt nematode compared with the rotation of tobacco-corn-peanut-tobacco-corn-peanut. In contrast to results with stunt nematode, no difference in ring nematode soil population was noted when comparing crop rotations (Table 3).

Variation in Crop Yield from 2001 to 2005

Corn yield varied when comparing crop rotation in 2004 and 2005 but not in 2001 or 2002 (Table 4). In 2001 and 2002 corn yield ranged from 127 to 132 bu/acre and 74 to 83 bu/acre, respectively. Corn yield was lower when three years of corn preceded corn during 2004 compared with corn-corn-peanut or corn-tobacco-peanut preceding corn. In 2005, corn yield was lower when the preceding rotation had four of five years with corn compared with only one year of corn (Table 4). Although soil nematode populations were not determined in 2004 or 2005, populations noted in 2006 in peanut suggest that stunt nematode populations may have increased as the number of corn plantings increased within the rotation (Table 3). Previous research (8,9,29) has demonstrated that soil nematode populations can increase in continuous corn. Peanut yield in 2003 did not vary when following corn-tobacco, tobacco-corn, or corn-corn (Table 4). Practitioners often express concern over planting peanut the year following tobacco due to excessive application of potassium fertilizer that can affect calcium absorption in developing peanut pegs and pods (13) and due to possible development of disease and parasitic nematode populations unfavorable for peanut (25). However, peanut yield in our study was not compromised when peanut followed tobacco in either 2003 or 2004 when compared with following corn only (Tables 3 and 4).

Tobacco yield varied although the rotation scheme did not allow comparison of tobacco yields among cropping systems. Differences in yield across years could have been affected by previous cropping history or weather conditions during each year or the interaction of these factors (Table 2).

Table 4. Yield of corn (CR), peanut (PN), and tobacco (TB) at Whiteville, NC.

Cropping system (2001-2006)	Corn					Peanut	Tobacco				
	2001	2002	2003	2004	2005	2003	2001	2002	2003	2004	2005
	Crop yield (bu/acre)					**Crop yield** (lb/acre)					
CR-CR-CR-CR-CR-PN	132 a	74 a	185	174 b	165 b	-	-	-	-	-	-
CR-CR-TB-CR-CR-PN	127 a	77 a	-	174 b	165 b	-	-	-	1990	-	-
CR-CR-PN-CR-CR-PN	137 a	83 a	-	201 a	160 b	3760 a	-	-	-	-	-
CR-TB-PN-CR-TB-PN	123 a	-	-	203 a	-	4420 a	-	3000	-	-	2030
TB-CR-PN-TB-CR-PN	-	78 a	-	-	186 a	4050 a	3450	-	-	2480	-
F statistic	0.82	0.40	-	4.87	3.72	0.48	-	-	-	-	-
P>F	0.5151	0.7573	-	0.0208	0.0546	0.6421	-	-	-	-	-

* Means within a column followed by the same letter are not significantly different according to Fisher's protected LSD.

Cumulative Net Return

Relative ranking of cumulative economic return for cropping systems over the six years of the experiment did not vary when the peanut price ranged from $350 US/ton up to $500 US/ton when comparing within a corn price ($2.50/bu or $4.00/bu) (Table 5). Substantially higher cumulative net returns were noted when two years of tobacco was included compared with corn or peanut only when the corn price was set at $2.50/bu regardless of peanut price (Table 5). However, when the corn price was set at $4.00/bu, the rotation with five years of corn and one year of peanut provided economic returns similar to the rotation of corn-tobacco-peanut-corn-tobacco-peanut (Table 5). In contrast, the rotation containing similar crops but with tobacco planted in 2001 or 2004 rather than 2002 or 2005 provided the highest cumulative net returns (Table 5). Although differences could have been associated with rotation sequence for corn and tobacco, it is also possible that the difference reflected yield of tobacco independent of cropping system. For example, tobacco yield in both 2001 and 2004 was higher than yield in 2002 or 2005 when comparing within each of the two year cycles. Additional research is needed to determine the causal agent of differences in tobacco yield with these rotations.

Table 5. Influence of corn price and peanut cultivar on cumulative economic return from 2001-2006 from cropping systems including corn (CR), peanut (PN), and tobacco (TB) at Whiteville, NC.

Cropping system (2001-2006)	Corn price at $2.50/bu				Corn price at $4.00/bu			
	Peanut price ($/US ton)							
	350	400	450	500	350	400	450	500
	Cumulative net return ($/acre)							
CR-CR-CR-CR-CR-PN	236 c	342 c	387 c	463 c	1156 bc	1260 bc	1307 bc	1382 bc
CR-CR-TB-CR-CR-PN	75 c	201 c	254 c	345 c	735 c	861 c	915 c	1006 c
CR-CR-PN-CR-CR-PN	-77 c	105 c	219 c	367 c	606 c	788 c	902 c	1050 c
CR-TB-PN-CR-TB-PN	1345 b	1596 b	1666 b	1863 b	1470 b	1720 b	1792 b	1952 b
TB-CR-PN-TB-CR-PN	2448 a	2655 a	2743 a	2892 a	2922 a	3129 a	3217 a	3366 a
F statistic	54.1	51.8	59.2	60.7	23.1	21.9	24.1	24.4
P>F	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

* Means within a corn and peanut pricing structure followed by the same letter are not significantly different according to Fisher's protected LSD.

Summary

Results from these experiments demonstrate the value of crop rotation in maintaining peanut yield when a susceptible cultivar is planted and the soil-borne disease CBR is present in the field. Planting a CBR-resistant cultivar minimized the negative impact of CBR in the shorter rotation. Increasing the number of non-corn crops in the rotation generally increased corn yield, most likely by affecting soil nematode population. These data also reveal that tobacco continues to provide the greatest economic return of any row crop produced in North Carolina and the ability to include tobacco in any crop rotation dramatically increases farm revenue compared to cropping systems that do not include tobacco. It should be noted, however, that tobacco acreage in North Carolina is small relative to other crops such as corn, cotton, or soybean. Therefore, growers can only rotate a portion of these crops with tobacco. Total revenue, on a per acre basis, would be less across a farming enterprise than is reflected in rotation trials as presented here.

Acknowledgments

The North Carolina Peanut Growers Association Inc. provided partial financial support for these studies. Appreciation is expressed to Barry Thompson for assistance with these studies. Carl Murphey and Brenda Penny provided technical support.

Literature Cited

1. Ayers, A. R., Duncan, H. E., Barker, K. R., and Beute, K. M. 1989. Effects of crop rotation and nonfumigant nematicides on peanut and corn yields in fields infested with *Criconemella* species. J. Nematol. 21:268-275.
2. Bailey, J. E., and Matyac, C. A. 1988. A decision model for use of fumigation and resistance to control *Cylindrocladium* black rot of peanuts. Plant Dis. 73:323-326.
3. Brandenburg, R. L. 2007. Peanut insect management. Pages 75-93 in: 2007 Peanut Information. Series AG-331, N. Car. Coop. Ext. Serv., Raleigh, NC.
4. Brown, A. B. 2007. Virginia-type peanuts: situation and outlook. Pages 1-6 in: 2007 Peanut Information. Series AG-331, N. Car. Coop. Ext. Serv., Raleigh, NC.
5. Brown, A. B. 2007. Considering the economic situation and outlook. Pages 5-8 *in* 2007 Tobacco Information. Series AG-187, N. Car. Coop. Ext. Serv., Raleigh, NC.
6. Bullen, S. G., and Jordan, D. L. 2007. Peanut production budgets. Pages 6-18 *in* 2007. Peanut Information. Series AG-331, N. Car. Coop. Ext. Serv., Raleigh, NC
7. Byrd, D. W., Jr., Barker, K. R., Ferris, H., Nusbaum, C. J., Griffin, W. E., Small, R. H., and Stone, C. A. 1976. Two semi-automatic elutriators for extracting nematodes and certain fungi from soil. J. Nematol. 8:206-212.
8. Crookston, R. K., Durle, J. E., Copeland, P. J., Ford, J. H., and Lueschen, W. E. 1991. Rotational cropping sequence affects yield of corn and soybean. Agron. J. 83:108-113.
9. Howard, D. D., Chambers, A. Y., and Lessman, G. M. 1998. Rotation and fertilization effects on corn and soybean yields and soybean cyst nematode populations in a no-tillage system. Agron. J. 90:518-522.
10. Isleib, T. G., Rice, P. W., Bailey, J. E., Mozingo, R. W., and Pattee, H. E. 2003. Registration of 'Perry' peanut. Crop Sci. 43:739-740.
11. Isleib, T. G., Rice, P. W., Mozingo, R. W., and Pattee, H. E. 1999. Registration of 'Gregory' peanut. Crop Sci. 39:1526-1526
12. Jenkins, W. R. 1964. A rapid centrifugal-floatation technique for separating nematodes from soil. Plant Dis. Rep. 48:692.
13. Jordan, D. L. 2007. Peanut production practices. Pages 23-46 in: 2007 Peanut Information. Series AG-331, N. Car. Coop. Ext. Serv., Raleigh, NC.
14. Jordan, D. L. 2007. Peanut weed management: Pages 47-74 in: 2007 Peanut Information. Series AG-331, N. Car. Coop. Ext. Serv., Raleigh, NC.
15. Jordan, D. L., Bailey, J. E., Barnes, J. S., Bogle, C. R., Bullen, S. G., Brown, A. B., Edmisten, K. L., Dunphy, E. J., and Johnson, P. D. 2002. Yield and economic return of ten peanut-based cropping systems. Agron. J. 94:1289-1294.
16. Jordan, D. L., Shew, B. B., Barnes, J. S., Corbett, T., Alston, J., Johnson, P. D., Ye, W., and Brandenburg, R. L. 2008. Pest reaction, yield, and economic return of peanut based cropping systems in the North Carolina coastal plain. J. Crop Management. doi:10.1094/CM-2008-1008-01-RS.
17. Lamb, M. C., Davidson, J. I., and Butts, C. L. 1993. Peanut yield decline in the Southeast and economically reasonable solutions. Peanut Sci. 20:36-40.
18. Lynch, R. E., and Mack, T. P. 1995. Biological and biotechnical advances for insect management in peanut, Pages 95-159 in: H. E. Pattee and H. T. Stalker, eds. Advances in Peanut Science. Am. Peanut Res. Educ. Soc., Stillwater, OK.
19. 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. Phytopathol. 73:1559-1563.
20. Phipps, P. M., and Beute, M. K. 1979. Population dynamics of *Cylindrocladium crotalarie* microsclerotia in naturally infested soil. Phytopathol. 69:240-243.
21. Rodriguez-Kabana, R., Ivey, H., and Backman, P. A. 1987. Peanut-cotton rotations for management of *Meloidogyne arenaria*. J. Nematol. 19:484-487.
22. Rodriguez-Kabana, R., and Touchton, J. T. 1984. Corn and sorghum rotations for management of *Meloidogyne arenaria* in peanut. Nematropica 14:26-36.
23. Rowe, R. C., and Beute, M. K. 1973. Susceptibility of peanut rotational crops (tobacco, cotton and corn) to cylindrocladium-crotalariae. Plant Disease Rep. 57:1035-1039.
24. Sherwood, J. L., Beute, M. K., Dickson, D. W., Elliot, V. J., Nelson, R. S., Opperman, C. H., and Shew, B. B. 1995. Biological and biotechnological control advances in *Arachis* diseases, pp. 160-206. In H. E. Pattee and H. T. Stalker, eds. Advances in Peanut Science. Am. Peanut Res. Educ. Soc., Stillwater, OK.
25. Shew, B. B. 2007. Peanut disease management. Pages 94-118 in: 2007 Peanut Information. Series AG-331, N. Car. Coop. Ext. Serv., Raleigh, NC.

26. Sholar, R. E., Mozingo, R. W., and Beasley, J. P., Jr. 1995. Peanut cultural practices. Pages 354-382 in: H. E. Pattee and T. H. Stalker, eds. Advances in Peanut Science. Am. Peanut Res. and Educ. Soc., Stillwater, OK.
27. Sidebottom, J. R., and Beute, M. K. 1989. Inducing soil suppression to *Cylindrocladium* black rot of peanut through crop rotations and soybean. Plant Dis. 73:679-685.
28. Toth, S. J., Jr. 1998. Peanut pesticide use survey in North Carolina. Data report to the USDA NAPIAP. North Carolina Cooperative Ext. Ser., Raleigh, NC.
29. West, T. D., Griffith, D. R., Steinhardt, G. C., Kladivko, E. J., and Parsons, S. D. 1996. Effect of tillage and rotation on agronomic performance of corn and soybean: twenty-year study on dark silty clay loam soil. J. Prod. Agric. 9:241-248.
30. Wilcut, J. W., York, A. C., Grichar, W. J., and Wehtje, G. R. 1995. The biology and management of weeds in peanut (*Arachis hypogaea).* Pages 207-224 in: Advances in Peanut Science. H. E. Pattee and H. T. Stalker, eds. Am. Peanut Res. and Educ. Soc., Stillwater, OK.