Response of Florunner and Southern Runner Peanut Cultivars to Chemical Management of Late Leaf Spot, Southern Stem Rot, and Nematodes

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ABSTRACT

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A field experiment was conducted in 1989 and 1990 to study the effects of chlorothalonil, flutolanil, and aldicarb, singularly and in combination, on late leaf spot, caused by *Cercosporidium personatum,* southern stem rot, caused by *Sclerotium rolfsii,* and root-knot nematodes, *Meloidogyne arenaria,* on Florunner and Southern Runner peanut (*Arachis hypogaea*) cultivars. In a split-plot experiment, Florunner and Southern Runner were treated with chlorothalonil at 0, 0.6, or 1.2 kg a.i./ha; flutolanil at 0 or 2.2 kg a.i./ha; and aldicarb at 0 or 3.4 kg a.i./ha. Southern stem rot and nematode pressure were severe in both years, and late leaf spot was severe in 1989. Leaf spot was more severe in Florunner than in Southern Runner in control plots both years and in plots receiving the low rate of chlorothalonil in 1990. In both years, the high rate of chlorothalonil reduced late leaf spot severity more than the low rate. Aldicarb and flutolanil did not affect late leaf spot severity. Flutolanil and aldicarb reduced the incidence of southern stem rot in both cultivars in both years, but flutolanil was more effective than aldicarb. Chlorothalonil had little or no effect on incidence of southern stem rot, and both cultivars were equally susceptible. Aldicarb reduced root-gall indices in both years, but no effects were attributable to cultivar or fungicide. Yields for the two cultivars were not different. In both cultivars, effects of chlorothalonil, flutolanil, and aldicarb were additive on yield increases for both years.

Sustained peanut (*Arachis hypogaea* L.) production in the United States is dependent upon the management of several pathogens that alone or in combination can cause severe loss in pod yield and quality. In peanut production areas of Georgia, Alabama, and Florida, three of the most important diseases are late leaf spot caused by *Cercosporidium personatum* (Berk. & Curt.) Deighton, southern stem rot caused by *Sclerotium rolfsii* Sacc., and root-knot caused by the nematode *Meloidogyne arenaria* (Neal) Chitwood. Deleterious effects of these individual diseases on peanut yield have been documented (2,20,22,25). Often, however, these diseases occur together in the field, and control measures applied for one disease may affect the severity of another disease (15–17,19,21). Therefore, the effect of a disease on peanut yield and quality may be influenced, directly or indirectly, by other diseases or by pesticides targeted to manage a different disease. This may be of great importance where cultivars are used that have moderate resistance to one or two of these pathogens. The cultivar Southern Runner is moderately resistant to *C. personatum* (11,12) and *S. rolfsii* (1,6). Resistance to these pathogens provides a potential for reducing the amounts of fungicide required for control of these pathogens (6,11,12). However, it is not known how heavy infestations of *M. arenaria* influence the resistance of Southern Runner to *C. personatum* and *S. rolfsii* or affect the performance of this cultivar when fungicides for their control are reduced.

Existing labeled and experimental chemicals are available that provide a moderate to high level of control for all of these pathogens. Growers in the southeastern United States currently obtain excellent control of late leaf spot using biweekly applications of chlorothalonil. The experimental fungicide, flutolanil, is superior to the registered materials pentachloronitrobenzene and chlorpyrifos for control of southern stem rot but has little effect on leaf spot development (10). The nematicide, aldicarb, suppresses population densities of *M. arenaria* (18,23) but has not been demonstrated to have direct effects on development of leaf spot or stem rot. The objectives of this study were to use chlorothalonil, flutolanil, and aldicarb, singularly and in combination, to determine the effects on leaf spot, southern stem rot, and root-knot nematode control on Florunner and Southern Runner peanut cultivars in soil heavily infested with *S. rolfsii* and *M. arenaria*, and to determine the effects of *M. arenaria* on severity of these fungal diseases in both cultivars and on yield of Southern Runner.

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MATERIALS AND METHODS

Experiments were conducted in 1989 on a commercial farm near Chula, Georgia, and in 1990 on a research field at Abraham Baldwin Agricultural College, Tifton, Georgia. Soils in both fields were Tifton loamy sands (fine, loamy, siliceous, thermic Plinthic Paleudult) with a pH of 6.2 at the Chula site and 6.3 at the Tifton location. Both fields had a history of moderate to heavy infestations of *S. rolfsii* and *M. arenaria* and had been planted to peanut the previous year.

A split-plot experimental design with four replications was used. Whole plots consisted of four rows 7.5-m long and 0.9-m apart and were divided into two subplots with two rows each. Whole-plot treatments consisted of five fungicide treatments combined with Florunner and Southern Runner cultivars. Fungicide treatments were the control; chlorothalonil, 0.6 kg a.i./ha (Bravo 720, ISK Biotech, Mentor, Ohio); chlorothalonil, 1.3 kg a.i./ha; flutolanil, 2.2 kg a.i./ha (Moncut 50W, Nor-Am Agricultural Products, Wilmington, Delaware); and chlorothalonil (1.3 kg a.i./ha) plus flutolanil (2.2 kg a.i./ha). Subplot treatments were the control and aldicarb (3.4 kg a.i./ha) (Temik 15G, Rhône Poulenc Ag Company, Monmouth Junction, New Jersey).

Peanuts were planted on 12 May 1989 and on 20 May 1990. Aldicarb was applied ahead of the planter in a 30-cm band centered over the planting row. Chlorothalonil was applied at 2-wk intervals beginning 21 June and ending 11 September 1989 and beginning 16 June and ending 6 September 1990. Seven applications were made each year.

Chlorothalonil was diluted in water (114 L/ha) and applied at 345 kPa using a tractor-mounted boom sprayer with three D2-13 hollow-cone nozzles per row. Flutolanil was applied in 187 L of water per hectare in a 30-cm band centered over each planted row on 18 July and 29 August in 1989 and on 19 July and 9 August in 1990. Three D2-25 nozzles were used per row.

Calcium sulfate was applied as gypsum (560 kg/ha broadcast) at early bloom (growth stage = R_1) (5). Carbaryl (Sevin 4E, Rhône Poulenc), methomyl (Lannate, E. I. Du Pont de Nemours & Co., Wilmington, Delaware), and acephate (Orthene 75W, Valent Corp., Memphis, Tennessee) were applied as needed for insect control. Plots were maintained as recommended for peanut production in Georgia (14), except for control of the target pathogens. Rainfall from 1 May to 30 September was 55.3 cm in 1989 and 31.5 cm in 1990. Plots were not irrigated in 1989, but in 1990 irrigation was applied with a traveling gun system. Plots received 2.54 cm of water on 29 June, 11 July, 30 July, 15 August, 22 August, and 20 September, and 3.81 cm of water on 27 August.

Leaf spot assessments were made on 18 August and 17 September 1989 and on 28 August and 24 September 1990. A scale of 1 to 10 (1 = no disease and 10 = completely defoliated dead plants) was used to assess severity and defoliation attributed to late leaf spot (7).

Soil samples were collected from the root zone in each subplot on 12 September 1989 and 8 August and 9 September 1990 and were assayed for nematodes. Nematodes were extracted by use of a centrifuge-sugar flotation method (13) and counted. Florunner and Southern Runner plants were inverted on 19 September and 4 October, respectively, in 1989 and on 24 September and 3 October in 1990. Immediately after inverting, the incidence of southern stem rot was estimated by counting the number of disease loci in each row (a locus consisted of one or more plants infected with *S. rolfsii* within 30 cm of row) (22). Roots, pegs, and pods were evaluated at harvest for degree of galling by *M. arenaria*; a 1 to 5 index scale (1 = no galls, 2 = 1–25%, 3 = 26–50%, 4 = 51–75%, and 5 = 76–100% of roots, pegs, and pods galled) was utilized to assess galling severity (19). Florunner and Southern Runner peanuts were harvested 145 days and 153 days after planting, respectively, in 1989 and 134 days and 142 days after planting in 1990.

Analysis of variance was used to determine main treatment and interaction effects (26,28). Fisher's protected least significant difference (LSD) values were used for comparisons among the individual treatments (26,28). Differences referred to in the text were significant at $P \leq 0.05$ unless otherwise stated. Contributions of the various treatments to yield were calculated based upon yield for a particular treatment in comparison to the nontreated average.

Table 1. Effects of chlorothalonil on severity of late leaf spot, caused by *Cercosporidium personatum*, on Florunner and Southern Runner peanuts in 1989 and 1990[a]

Rates of chlorothalonil (kg a.i/ha)	Initial rating[b] Florunner	Initial rating[b] Southern Runner	LSD[c] ($P \leq 0.05$)	Final rating[b] Florunner	Final rating[b] Southern Runner	LSD[c] ($P \leq 0.05$)
1989						
0[d]	6.7	5.2	0.6	8.8	6.9	0.6
0.6	3.3	2.3	0.6	2.6	2.3	NS
1.3[e]	1.9	1.4	NS[f]	1.4	1.3	NS
LSD[g] ($P \leq 0.05$)	0.7	0.4	...	0.4	0.4	...
1990						
0[d]	5.4	4.9	NS	7.2	6.1	0.6
0.6	3.1	2.2	0.8	3.2	2.6	0.6
1.3[e]	1.3	1.1	NS	1.4	1.3	NS
LSD[g] ($P \leq 0.05$)	1.1	0.4	...	0.4	0.4	...

[a] Data were averaged across aldicarb treatments (0 and 3.4 kg a.i./ha).
[b] Leaf spot rating: 1 = no disease, 10 = completely defoliated dead plants. Initial ratings were made on 18 August 1989 and 28 August 1990; final ratings were made on 17 September 1989 and 24 September 1990.
[c] For comparison of cultivar effects within fungicide treatments.
[d] Means were derived by combining data for the control and the flutolanil (2.2 kg a.i./ha) treatments.
[e] Means were derived by combining data for the chlorothalonil (1.3 kg a.i./ha) and the chlorothalonil (1.3 kg a.i./ha) plus flutolanil (2.2 kg a.i./ha) treatments.
[f] Not significant.
[g] For comparison of fungicide effects within cultivars.

Table 2. Effects of chlorothalonil, flutolanil, and aldicarb on the incidence of southern stem rot, caused by *Sclerotium rolfsii*, in 1989 and 1990[a]

Fungicide treatments	Rate (kg a.i./ha)	Stem rot loci[b]: Aldicarb rate 1989[c] 0	Aldicarb rate 1989[c] 3.4	LSD[d] ($P \leq 0.05$)	Aldicarb rate 1990[c] 0	Aldicarb rate 1990[c] 3.4	LSD[d] ($P \leq 0.05$)
Control	...	20.6	15.6	4.3	16.6	11.0	3.5
Chlorothalonil	0.6	23.0	18.5	4.3	19.6	13.0	3.5
Chlorothalonil	1.3	19.6	19.8	NS[e]	17.5	15.2	NS
Flutolanil	2.2	8.3	6.4	NS	3.6	0.6	NS
Chlorothalonil + flutolanil	1.3 + 2.2	5.2	3.6	NS	5.4	1.2	3.5
LSD[f] ($P \leq 0.05$)		5.7	4.9	...	4.9	4.3	...

[a] Data were averaged across two cultivars, Florunner and Southern Runner.
[b] Number of southern stem rot loci per 15.4 m of row, where a disease locus represents one or more infected plants in 30 cm of row.
[c] Rate expressed as kilograms of active ingredient per hectare.
[d] For comparison of aldicarb treatments within fungicide treatments.
[e] Not significant.
[f] For comparison of fungicide treatments within aldicarb treatments.

RESULTS

Leaf spot infestations were high in both years, but epidemics began earlier in 1989 than in 1990. Florunner and Southern Runner plants that were not treated with chlorothalonil had high leaf spot ratings and were heavily defoliated at harvestime in both years (Table 1). On both evaluation dates for both years, leaf spot severity and defoliation were affected by chlorothalonil and differed by cultivar but were unaffected by flutolanil or aldicarb. Since flutolanil had no effect on leaf spot ratings, the data for the control and flutolanil were combined, resulting in the data shown as chlorothalonil rate 0 in Table 1. Data for chlorothalonil (1.3 kg a.i./ha) and chlorothalonil (1.3 kg a.i./ha) plus flutolanil treatments were combined and are shown as chlorothalonil 1.3 kg a.i./ha in Table 1. Also, since aldicarb and fungicide × aldicarb interactions had no effect on the severity of leaf spot, data presented in Table 1 are means across aldicarb treatments. At both evaluation dates, chlorothalonil at 0.6 and 1.3 kg a.i./ha reduced leaf spot ratings for both cultivars in both years. However, leaf spot was more severe in plots treated with 0.6 kg a.i./ha chlorothalonil than in those treated with 1.3 kg a.i./ha. Final leaf spot severity and defoliation were greater in Florunner than in Southern Runner in control plots in 1989 and in control plots and plots treated with 0.6 kg a.i./ha of chlorothalonil in 1990.

Because neither cultivar nor cultivar × treatment interaction affected incidence of southern stem rot, data in Table 2 were averaged from both cultivars. Incidence of southern stem rot was moderate to high for all chemical treatments except those that included flutolanil (Table 2). Flutolanil and aldicarb, independent or combined, reduced the incidence of southern stem rot in both years, but flutolanil was more effective than aldicarb. Chlorothalonil had little or no effect on incidence of southern stem rot. The mean numbers of loci in aldicarb-treated and control plots were reduced by flutolanil in both years, whether it was used alone or combined with chlorothalonil. There was no significant difference in numbers of loci between flutolanil and chlorothalonil plus flutolanil treatments in either year. Stem rot incidence was not significantly different between chlorothalonil treatments at 0.6 kg and 1.3 kg a.i./ha. Aldicarb reduced the numbers of southern stem rot loci in chlorothalonil (0.6 kg a.i./ha) and fungicide control treatments in both years and in the chlorothalonil plus flutolanil treatment in 1990. Average southern stem rot incidence (calculated across cultivars, flutolanil, and chlorothalonil treatments) for 0 and 3.4 kg a.i./ha of aldicarb were 15.3 and 12.8 (LSD = 1.9) in 1989 and 12.5 and 8.2 (LSD = 1.6) in 1990. These differences were significant ($P < 0.05$) in both years of the study.

Small but significant differences in root-gall indices occurred in 1989 for means calculated across cultivars and flutolanil and chlorothalonil treatments; means for 0 and 3.4 kg a.i./ha aldicarb treatments were 4.8 and 4.5 (LSD = 0.2), respectively. Respective root-gall indices for Florunner for 0 and 3.4 kg a.i./ha of aldicarb were 4.8 and 4.2 (LSD = 0.5) in the fungicide control, 4.5 and 3.8 in the flutolanil treatment, and 4.9 and 4.3 (LSD = 0.5) in the chlorothalonil plus flutolanil treatments. Root-gall indices were 5.0 and 4.5 (LSD = 0.4) in control and aldicarb-treated subplots in the 0.6 kg a.i./ha chlorothalonil treatment in Southern Runner. Although the analysis of variance indicated that cultivars and fungicides collectively influenced root-gall indices, there were no identifiable patterns for the effects of the different variables.

Root-gall indices in 1990 were extremely high in the nematicide control plots: 4.9 and 2.9 (LSD = 0.2) for 0 and 3.4 kg a.i./ha of aldicarb, respectively, across cultivar and fungicide treatments. The difference was significant ($P \leq 0.05$). Aldicarb reduced root-gall indices in all fungicide treatments for both cultivars (*data not shown*). As in 1989, comparisons suggested that differences between cultivars and effects of fungicide treatments were random, and no identifiable pattern of influence on root-gall indices was established.

No treatment, including aldicarb, affected the numbers of *M. arenaria* juveniles in the soil at the time of sampling in 1989 or at the later time 1990. The mean numbers of *M. arenaria* juveniles per 150 cm^3 across cultivars, fungicide, and nematicide treatments for those samplings were 3,369 in 1989 and 2,068 in 1990. Aldicarb effects on *M. arenaria* populations were significant for the early sampling in 1990, but no other main effect or interaction was significant. For the early sampling, average numbers of *M. arenaria* juveniles per 150 cm^3 of soil (calculated across cultivars and fungicide treatments) for 0 and 3.4 kg a.i./ha of aldicarb were 2,032 and 1,494 (LSD = 476), respectively.

Although leaf spot severity and defoliation ratings were greater in Florunner than in Southern Runner (Table 1), this difference was not reflected in yield. No fungicide × cultivar interactions occurred in either year, therefore data for both cultivars were averaged in Table 3. For some treatments, yields differed between years, whereas for others they did not.

Aldicarb increased yields consistently in both years, regardless of whether it was used alone or combined with chlorothalonil, flutolanil, or chlorothalonil plus flutolanil. Chlorothalonil (1.3 kg a.i./ha) applied without flutolanil did not increase yields in comparison with nontreated plots or plots treated with 0.6 kg a.i./ha of chlorothalonil in aldicarb-treated or control plots either year. However, when chlorothalonil was combined with flutolanil, yields were greater than those of the control with or without aldicarb for both years. Flutolanil alone increased yields in 1989 in aldicarb-treated and nontreated plots and in 1990 only in aldicarb-treated plots.

In contrast to nontreated plots, chemical treatments increased yields in 1989 as follows: flutolanil, 666 kg/ha or 27.5%; flutolanil plus chlorothalonil, 772 kg/ha or 31.8%; and flutolanil plus chlorothalonil plus aldicarb, 986 kg/ha or 40.7%. In 1990, yield increases related to treatments were as follows: flutolanil, 94 kg/ha or 5.2%; flutolanil plus chlorothalonil, 465 kg/ha or 25.7%; and flutolanil plus chlorothalonil plus aldicarb, 1,251 kg/ha or 69.1%. In 1990, applying chlorothalonil had no beneficial effect on yield when flutolanil was applied in aldicarb-treated plots.

DISCUSSION

The earlier and more severe occurrence of leaf spot in 1989 than in 1990 was apparently caused by the greater amount of rainfall and irrigation water received during June in 1989 (23.4 cm) than in 1990 (9.6 cm). There also were more rainfall or irrigation events in 1989 (16 events) than in 1990 (seven events). Our data corroborate those of Gorbet et al (11) indicating that Southern Runner has some resistance to *C. personatum*. As expected, the 0.6 kg a.i./ha rate of chlorothalonil did not control leaf spot as effectively as the 1.3 kg a.i./ha rate on either cultivar.

Our data indicate that southern stem rot was also more severe in 1989 than in 1990, which may have been caused by moisture and/or other environmental effects. Our data did not corroborate those of Arnold et al (1) and Brenneman et al (6) indicating resistance to *S. rolfsii* in Southern Runner. The extreme amount of root damage by *M. arenaria* may have predisposed plants to infection by *S. rolfsii*, thereby masking resistance to this pathogen in Southern Runner. There was some indication in both years that aldicarb may have had a limited suppressive effect on southern stem rot. However, direct fungicidal effects of aldicarb on *S. rolfsii* have not been reported, and in vitro studies (A. S. Csinos, *personal communication*) indicate aldicarb has no effect on growth of *S. rolfsii*. Fungicidal effects of other soil nematicides/insecticides, or their decomposition products, have been reported (8,9,21). Aldicarb may have reduced predisposition of the peanut plant to *S. rolfsii* by *M. arenaria*. In addition, aldicarb enhances the growth of peanuts and other plants (4) in the absence of nematodes and insects. Thus, a more vigorous plant may tend to resist attack by *S. rolfsii*. Chlorothalonil alone or combined with flutolanil had no effect on southern stem rot, which corroborates the results of Backman et al (3) and Smith (27).

Table 3. Effects of chlorothalonil, flutolanil, and aldicarb on peanut yields in 1989 and 1990[a]

		Yield (kg/ha)					
		Aldicarb rate 1989[b]			Aldicarb rate 1990[b]		
Fungicide treatments	Rate (kg a.i./ha)	0	3.4	LSD[c] ($P \leq 0.05$)	0	3.4	LSD[c] ($P \leq 0.05$)
Control	...	1,148	1,636	402	554	1,816	306
Chlorothalonil	0.6	1,188	2,063	402	568	2,150	306
Chlorothalonil	1.3	1,476	1,994	402	372	1,946	306
Flutolanil	2.2	1,814	2,554	402	648	2,308	306
Chlorothalonil + flutolanil	1.3 + 2.2	2,586	3,572	402	1,113	2,364	306
LSD[d] ($P \leq 0.05$)		642	377	...	348	446	...

[a] Data were averaged for cultivars Florunner and Southern Runner.
[b] Rate expressed as kilograms of active ingredient per hectare.
[c] For comparison of aldicarb treatments within fungicide treatments.
[d] For comparison of fungicide treatments within aldicarb treatments.

The high root-gall indices and numbers of *M. arenaria* juveniles in the soil at the end of the growing season were indicative of the severity of this pathogen in both years. In 1989, the contrast of small effects of aldicarb on end-of-season root-gall indices and *M. arenaria* juveniles in the soil and the relatively large effects of aldicarb on yields is a paradox that may be related to rainfall. Apparently, aldicarb reduced the initial nematode population, allowing peanut plants to grow well early in the season (24). However, after initial reduction by aldicarb, uninhibited secondary nematode infection may have occurred after much of the aldicarb had leached below the root zone. Aldicarb treatment may have provided early season protection, as indicated by fewer *M. arenaria* juveniles in the aldicarb-treated plots on the first sample date in 1990, allowing the production of a relatively large crop of mature peanuts in spite of the severe late-season root galling. These results indicate the need for nematicides that provide better nematode control. Control of root knot nematodes may be more critical for Southern Runner than for Florunner because of the lower seedling vigor and the longer growing season required for pod maturity of Southern Runner. The level of nematode control in aldicarb-treated plots in 1990 was similar to that typically observed in small-plot experiments for this chemical in heavily infested soil with the amount of rainfall that occurred in June. The equally high levels of *M. arenaria* juveniles in soil of aldicarb-treated and control plots at the later sampling in 1990 can be attributed to a high level of reproduction in both treatments. Although populations of *M. arenaria* in the August sampling were lower in plots treated with aldicarb than in nontreated plots, and galling on roots of plants in aldicarb-treated plots was reduced, there was adequate infection, as indicated by the amount of galling, to permit a high level of reproduction late in the season.

Peanut yields were lower, even in the best treatments, than would have been expected in soil free of *S. rolfsii* and *M. arenaria.* Flutolanil and aldicarb treatments did not adequately reduce the high population densities of *S. rolfsii* and *M. arenaria*, respectively, to obtain the high potential yields that should have been possible without these pathogens. In addition, the earlier than normal development of leaf spot in 1989 may have affected yield, especially in the 0.6 kg a.i./ha rate of chlorothalonil, flutolanil, and control treatments. The early defoliation in these treatments may have resulted in an abundance of organic matter that served as a food base for *S. rolfsii*; therefore, defoliation possibly increased the incidence of southern stem rot (3).

Although leaf spot ratings were lower for Southern Runner than Florunner, yields of the two cultivars did not differ. Any yield advantage that may have been imparted to Southern Runner by the lower severity of leaf spot may have been nullified by the overriding effects of southern stem rot and root-knot nematodes. Although, Southern Runner is reported to possess resistance to *S. rolfsii* (1,6), we did not detect any differences in susceptibility between the two cultivars in this experiment. Thus, nematode damage, even in plots treated with aldicarb, may have been sufficient to enhance *S. rolfsii* development in Southern Runner and nullify the resistance in this cultivar. Beneficial effects on yield of resistance to *C. personatum* and *S. rolfsii* in Southern Runner may be suppressed in the presence of high levels of *M. arenaria* and *S. rolfsii.*

Chlorothalonil applications controlled leaf spot but did not control southern stem rot. Conversely, flutolanil controlled southern stem rot but had little or no effect on leaf spot. Therefore, when the two treatments were combined in 1989, there appeared to be an additive effect on yield. In 1990, the additive effect occurred in only the plots not treated with aldicarb. There were indications that a yield plateau was reached in the aldicarb-treated plots in 1990 and that combined effects of the three chemical treatments were not fully expressed. This may have been caused by the overwhelming effects of drought, high temperatures, and root-knot nematodes. Although there appeared to be some indirect, if not direct, effects of aldicarb on southern stem rot, the yield response to this material was attributed primarily to nematode control. These results suggest the need to select soils free of *S. rolfsii* and *M. arenaria* or to control these pathogens when evaluating peanut genotypes for resistance to *C. personatum*, especially when yield is a consideration. Our results also indicated that it is desirable to have soil free of *M. arenaria* in fields in which Southern Runner is to be grown or in which peanut genotypes are to be evaluated for *S. rolfsii* resistance. Heavy infestations of these three pests in growers' fields usually warrant implementation of control measures to obtain profitable yields. This is true even for the cultivar Southern Runner, which has moderate levels of resistance to both fungal pathogens but no resistance to *M. arenaria.*

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