Involvement of Nutrition and Fungi in the Peanut Pod Rot Complex

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ABSTRACT

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Several fungi-specific fungicides and the chemicals $CaSO_4$, $CaCO_3$, S, and $MgSO_4$ were evaluated for their influence on development of peanut pod rot in field test plots at Tifton, GA, in 1980–1983. Isolations for *Pythium, Rhizoctonia*, and *Fusarium* spp. were made from soil and decaying pods and pegs throughout the growing season. Yield and sound mature kernel (SMK) were determined and chemical analyses of mature seed and hulls were made. There were no consistent differences found among treatments for fungal soil populations (1980) or isolations from decaying pods (1980 through 1982). Plots treated with a Ca source were generally higher in yield and SMK and lower in pod rot than other treatments. There was a significant positive relation with most elements in fruits and pod rot except Ca, which had a significant inverse relation to pod rot. Most elements in fruits were related inversely to Ca concentration. We propose that fungi are secondary to the disease complex and nutritional deficiency or imbalance may be the primary cause.

Peanut pod rot is a serious problem worldwide (4,6,8,14,17). The disease cannot be treated symptomatically because it occurs on pods in the ground and foliar symptoms do not occur. Garren (9) has demonstrated the involvement of both *Pythium myriotylum* Drechs. and *Rhizoctonia solani* Kühn in pod breakdown. He has also demonstrated that addition of gypsum ($CaSO_4$) decreased pod rot, which has been verified by the work of Walker and Csinos (17). Hallock and Garren (10) have also reported that KSO_4 and $MgSO_2$ increased pod rot.

In direct conflict with these findings, Moore and Wills (14) found that Ca did not influence the susceptibility of peanut to infection by *P. myriotylum* or *R. solani*. Garcia and Mitchell (6) studied simultaneous and serial independent inoculation of peanut pods with fungi implicated in the disease complex. *P. myriotylum* appeared to be the major pathogen involved in the disease, but disease and reisolation was influenced by several other fungi such as *R. solani*, *Fusarium solani* (Mart.) Appel. & Wr. emend Snyd. & Hans., *Macrophomina phaseolina* (Tassi) Goid., and *Trichoderma viride* Pers. ex Fries. Although they used sophisticated inoculation sequences, they were unable to reproduce the disease in a high percentage of inoculation attempts, even under conditions of high fungal inoculum.

Only control measures suggested by Hallock and Garren (10) and Walker and Csinos (17) are available for this disease. Since those studies, which involved gypsum, PCNB, and cultural practices of deep turning and nondirting cultivation, several fungi-specific chemicals have been developed that have activity against fungal pathogens implicated in the disease complex.

Research presented in this paper incorporated use of fungicides and various nutrient compounds such as $CaSO_4$ and $MgSO_4$ to determine their effects on pathogen involvement in the disease, subsequent severity of disease, and resultant quality and yield of treated peanuts. In addition, chemical analyses of peanut hulls and seed sampled at harvest was performed to determine the chemical composition of peanuts and its relation to disease.

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MATERIALS AND METHODS

Plots were established in 1980 through 1982 in an area with a history of peanut peg and pod rot (17). Peanut (*Arachis hypogaea* L.) cultivars Early Bunch and Florunner were seeded at about 140 kg/ha on 19 May 1980 and 12 May 1981, and Early Bunch only was seeded on 20 May 1982. Cultural and production practices were consistent with University of Georgia Extension Service recommendations. Plots were four rows 6.1 m long on 0.91-m centers, with four replicates in a randomized complete block design. Two rows were used for sampling throughout the season and two rows were maintained for yield determinations. Plots were separated by two border rows. Plants were irrigated as required. The liquid $CaCO_3$ plus liquid sulfur treatment in 1980 was broadcast without incorporation before planting. All other materials were applied initially at early bloom in a 0.45-m band over the row. Materials evaluated as split applications were applied at early bloom and 2 wk later. Materials applied as sequential treatments are listed in the tables. Granular materials were weighed and distributed uniformly over the plots. Materials applied in water were sprayed using a hand-held sprayer at 467 or 935 L/ha.

Materials tested were 1) $CaCO_3$ (calcite lime, liquid 16% and dry 85%), 2) $CaSO_4$ (gypsum, 68%), 3) PCNB 10G, 4) metalaxyl 2E and 5G, 5) CGA-64250 5G and 3.5EC, 6) copper ammonium carbonate (8% Cu) $Cu{\cdot}NH_4{\cdot}CO_3$; 7) sulfur (liquid 52% and dry 80%), 8) $MgSO_4$, 9) Bay NTN 19701 25WP, and 10) tolclofos-methyl 5G. Rates of materials are listed in the tables.

Pods and pegs were sampled throughout the growing season and 50 pods and/or pegs from each plot were evaluated for disease. Five or six lesions from pods or pegs from each replicate were trisected and placed on three fungi-specific media for isolation. *Pythium* spp. were isolated on a pimaricin-ampicillin-rifampicin (PAR) medium (13), *Rhizoctonia* spp. on tannic acid benomyl (TAB) medium (16), and *Fusarium* spp. on PCNB medium (15). Soil populations were determined from plots in 1980 using the same media by diluting the soil for PAR and PCNB media and using a soil pelleter (11) for enumeration of *Rhizoctonia* spp. on TAB.

Chemical analyses were made for seed and hulls sampled at harvest using methods described by Gaines and Mitchell (5). Peanut pods were dug at maturity, inverted, and combined with tractor-mounted equipment. Yields and percent sound mature kernels (%SMK) were determined for plots after drying. Percent pod rot at harvest was determined by counting decayed pods per 100 for each plot. All data were analyzed using analysis of variance (ANOVA) and Duncan's multiple range test.

RESULTS

1980 Test. There were no differences in soil populations of *Pythium* spp. (range 7.3–12.5 propagules per 100 g soil [P/100 g]) or of *R. solani* (range 1375–3607 P/100 g) detected 67 and 135 days after seeding among treatments planted to Florunner except for *Pythium* spp. at 135 days. Plots treated with PCNB at 11.2 kg a.i./ha had *Pythium* spp. populations (29.7 P/100 g) higher than plots treated with copper ammonium

carbonate at 28.1 L/ha (8.6 P/100 g) 135 days after seeding.

Soil populations of *Pythium* spp. from Early Bunch, determined 67 days after seeding, were higher in plots treated with $CaSO_4$ at 381 + 381 kg/ha as a split application 2 wk apart (34.3 P/100 g) than any other treatment. Other treatments ranged from 5.7 to 14.2 P/100 g but were not different from each other. By 135 days after seeding, only soil from plots treated with metalaxyl 1.12 kg a.i./ha (4.3 P/100 g) had populations of *Pythium* spp. lower ($P = 0.05$) than the control (24.2 P/100 g). There were no differences in soil populations of *R. solani* among treatments either 67 or 135 days after seeding. Soil populations of *F. solani* 67 days after seeding were not different among treatments. However, by 135 days, soil from plots treated with copper ammonium carbonate at 28.1 L/ha (818 P/100 g) and plots treated with CGA-64250 at 1.12 kg a.i./ha plus metalaxyl at 1.12 kg a.i./ha (904 P/100 g) had lower populations than soil from plots treated with $CaSO_4$ at 1,120 kg/ha (2104 P/100 g). Populations of *F. solani* tended to be higher in $CaSO_4$ and $CaCO_3$ plus S treatments.

Percent isolation of fungi from necrotic lesions on pods from Florunner were related to sampling date rather than treatment (Table 1). A high percentage of lesions yielded *Rhizoctonia* spp. by 93, 106, and 128 days after seeding, but relatively fewer *Rhizoctonia* spp. were isolated at harvest (143 days after seeding) than any time thereafter. *Fusarium* spp. were isolated at a very high percentage on all sampling dates. The same trends were noted for isolations from pegs made 78 days after seeding from Florunner and from Early Bunch pods and pegs on the same sampling dates.

In 1980, there were no differences in percent pod rot detected among treatments in Florunner peanut 78, 106, and 128 days after seeding. However, in Early Bunch peanut (evaluated at 106 days) the two $CaSO_4$ treatments (762 kg/ha and 381 + 381 kg/ha, split application) had less pod rot than PCNB-treated peanut (Table 2). Pod decay evaluated at harvest was less from peanut treated with $CaCO_3$ plus S than pods from peanut treated with PCNB, CGA-64250, or copper ammonium carbonate. Plot yields and %SMK were higher for peanut treated with $CaCO_3$ plus S and $CaSO_4$ made in one application or in a split application than peanut treated with CGA-64250 or copper ammonium carbonate (Table 2).

At harvest, there were no differences detected in percent P, K, or Ca in seed among treatments. However, K content of hulls was lowest in peanut treated with $CaSO_4$ at 762 kg/ha but not less than the control, and Ca content of hulls was highest in peanut treated with $CaSO_4$ (381 + 381 kg/ha) but not more than the control. Significant ($P = 0.01$) correlation coefficients from analysis of hulls were pod rot vs. P (0.43), Zn (0.43), Fe (0.41), and Ca (−0.34).

1981 Test. Isolations were made from decaying pods 110, 125, and 146 days after seeding from Florunner peanut and 110, 125, and 133 days after seeding from Early Bunch. Percent isolations from

Table 1. Isolation of *Fusarium*, *Pythium*, and *Rhizoctonia* spp. from decaying Florunner pods treated with chemicals and sampled throughout the season in 1980

Treatment and rate[w]	Isolation (%)														
	80 Days[x]			93 Days			106 Days			128 Days			143 Days		
	F[y]	P	R	F	P	R	F	P	R	F	P	R	F	P	R
$CaCO_3$ (1147 kg/ha) + S (932 kg/ha)	6 c[z]	0 a	0 a	100 a	42 a	25 b	100a	8 a	100 a	92 a	0 a	100 a	100 a	0 a	0 a
$CaSO_4$ (762 kg/ha)	13 bc	0 a	13 a	100 a	8 a	84 a	100 a	8 a	100 a	100 a	0 a	92 a	100 a	0 a	8 a
$CaSO_4$ (381 + 381 kg/ha)	13 bc	0 a	6 a	100 a	33 a	59 ab	100 a	17 a	100 a	92 a	0 a	100 a	83 a	0 a	17 a
PCNB (11.2 kg a.i./ha)	38 ab	0 a	0 a	100 a	25 a	50 ab	100 a	17 a	100 a	100 a	0 a	100 a	75 a	0 a	8 a
CGA-64250 (1.12 kg a.i./ha) + metalaxyl (1.12 kg a.i./ha)	19 abc	0 a	0 a	100 a	42 a	67 ab	100 a	0 a	92 a	100 a	0 a	92 a	75 a	0 a	8 a
Metalaxyl (1.12 kg a.i./ha)	6 c	0 a	0 a	100 a	25 a	50 ab	100 a	0 a	100 a	100 a	0 a	100 a	100 a	0 a	17 a
CGA-64250 (1.12 kg a.i./ha)	19 abc	0 a	0 a	100 a	42 a	67 ab	100 a	8 a	100 a	92 a	0 a	92 a	84 a	0 a	0 a
$Cu{\cdot}NH_4{\cdot}CO_3$ (28.1 L/ha)	13 bc	0 a	0 a	100 a	34 a	84 a	100 a	0 a	100 a	100 a	0 a	100 a	83 a	0 a	17 a
Control	44 a	0 a	0 a	100 a	42 a	59 ab	100 a	0 a	100 a	100	0 a	100 a	83 a	0 a	33 a

[w] $CaCO_3$ + S was applied as a preplant incorporated; $CaSO_4$ (381 + 381 kg/ha) was applied as a split application at early flower (53 days after seeding) and 65 days after seeding. All other materials, alone or in combinations, were applied 53 days after seeding.
[x] Days after seeding.
[y] F = *Fusarium* spp., P = *Pythium* spp., and R = *Rhizoctonia* spp.
[z] Means in columns followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 2. Effect of chemicals on pod decay throughout the season and percent sound mature kernels (SMK) and yield of Early Bunch in 1980

Treatment and rate[x]	Pod decay (%)				SMK (%)	Yield (kg/ha)
	78 Days[y]	106 Days	121 Days	Harvest		
$CaCO_3$ (1,147 kg/ha) + S (932 kg/ha)	2.7 a[z]	7.2 ab	15.8 a	20.3 b	49.2 a	4,781 a
$CaSO_4$ (762 kg/ha)	10.2 a	3.4 b	12.2 a	24.3 ab	48.6 a	4,568 a
$CaSO_4$ (381 + 381 kg/ha)	9.3 a	2.1 b	10.7 a	25.5 ab	47.9 a	4,252 ab
Control	1.3 a	12.3 ab	13.7 a	26.3 ab	41.8 ab	3,805 abc
PCNB (11.2 kg a.i./ha)	7.0 a	23.5 a	23.8 a	42.8 a	41.1 ab	3,367 bc
CGA-64250 (1.12 kg a.i./ha) + metalaxyl (1.12 kg a.i./ha)	13.7 a	6.5 ab	14.0 a	38.8 ab	45.7 ab	3,367 bc
Metalaxyl (1.12 kg a.i./ha)	11.7 a	14.1 ab	13.1 a	35.3 ab	39.8 ab	3,316 bc
CGA-64250 (1.12 kg a.i./ha)	9.9 a	14.8 ab	25.8 a	42.3 a	35.1 b	3,184 c
$Cu{\cdot}NH_4{\cdot}CO_3$ (28.1 L/ha)	11.0 a	13.9 ab	21.4 a	43.0 a	34.5 b	3,103 c

[x] $CaCO_3$ + S was applied as a preplant incorporated; $CaSO_4$ (381 + 381 kg/ha) was applied as a split application at early flower (53 days after seeding) and 65 days after seeding. All other materials, alone or in combinations, were applied 53 days after seeding.
[y] Days after seeding.
[z] Means in columns followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Early Bunch or Florunner were not statistically different ($P = 0.05$) among treatments for any of the fungi isolated throughout the sampling period. *Fusarium* spp. were isolated at the highest frequency and *Pythium* and *Rhizoctonia* spp. were isolated erratically throughout the sampling period. Occasionally, a treatment had a higher (not significant) isolation frequency of a specific fungus than another treatment, but this was not consistent over the sampling period.

Pegs from Early Bunch plots treated with sulfur, metalaxyl, and $MgSO_4$ were higher in peg decay than the control and $CaSO_4$-treated plots 90 days after seeding, but 104 days after seeding, only pegs from metalaxyl-treated plots had higher peg decay than the control (Table 3). By 104 days after seeding, only pods from the $CaSO_4$-treated plots had less decay than the control, and at 121 days, pods from the $CaSO_4$ and $CaCO_3$ plus S treatments had less pod decay than pods from the control. Florunner showed similar, but generally lower, peg and pod decay. Pods from plots treated with $CaSO_4$, $CaCO_3$ plus S, and $CaCO_3$ had less decay than pods from control plots at harvest. Percent SMK was higher in $CaSO_4$ and $CaCO_3$ plus S than in the control, and yields of plots treated with $CaSO_4$ and $CaCO_3$ were higher than those of the control.

Early Bunch plots treated with $CaSO_4$ or $CaCO_3$ plus S had hulls lowest in P, and peanuts treated with $CaSO_4$, $CaCO_3$ plus S, or $CaCO_3$ had hulls highest in Ca and lowest in Mg (Table 4). Sulfur was highest in hulls of peanuts treated with sulfur, $MgSO_4$, $CaCO_3$ plus S, and $CaSO_4$. Total nitrogen was lowest in plots

Table 3. Effect of calcium sources and fungicides on pod and peg rot during the season on Early Bunch peanut in 1981

	Percent decay								
	90 Days[x]		104 Days		121 Days		Harvest	SMK[y]	Yield
Treatment and rate[w]	Peg	Pod	Peg	Pod	Peg	Pod	Pod	(%)	(kg/ha)
$CaSO_4$ (1,523 kg/ha)	22.0 c[z]	14.5 a	7.0 c	5.0 c	21.5 b	13.5 d	8.0 e	58.4 a	3,405 a
$CaCO_3$ (1,120 kg/ha)	35.0 bc	15.5 a	18.5 bc	20.0 abc	33.5 ab	35.0 abc	18.0 bcd	53.0 ab	3,090 a
Metalaxyl (1.12 kg a.i./ha) + Bay NTN 19701 (6.1 + 6.1 kg a.i./ha)	47.0 abc	14.0 a	19.0 bc	17.5 abc	39.0 ab	25.5 bcd	15.5 cde	47.3 bc	2,704 ab
Bay NTN 19701 (6.1 + 6.1 kg a.i./ha)	50.5 abc	13.5 a	23.0 abc	30.0 a	40.5 ab	44.0 a	25.5 ab	43.3 c	2,409 ab
S (357 kg/ha)	73.0 a	20.5 a	35.0 ab	20.0 abc	57.2 a	37.2 ab	22.5 abc	45.4 bc	2,094 ab
Metalaxyl (1.12 kg a.i./ha)	62.8 ab	17.5 a	47.0 a	30.0 a	63.0 a	52.5 a	22.5 abc	47.4 bc	2,063 ab
Control	26.5 c	12.5 a	19.5 bc	24.5 ab	39.5 ab	39.5 ab	29.3 a	45.1 bc	2,043 ab
$CaCO_3$ (1,120 kg/ha) + S (357 kg/ha)	34.0 bc	12.0 a	15.0 bc	7.0 bc	33.5 ab	18.5 cd	12.0 de	56.7 a	2,033 ab
$MgSO_4$ (1,344 kg/ha)	79.5 a	25.3 a	36.5 ab	26.5 a	61.3 a	47.3 a	25.3 ab	41.8 c	1,179 b

[w] All materials were applied at early bloom (30 days after seeding) except Bay NTN 19701, which was reapplied 63 days after seeding.
[x] Days after seeding.
[y] SMK = sound mature kernels.
[z] Means in columns followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 4. Elemental analyses of Early Bunch peanut hulls treated with fungicides and calcium sources in 1981

	Percent of Tissue						ppm			
Treatment and rate[y]	P[z]	K	Ca	Mg	S	N	Zn	Mn	Fe	Cu
$CaSO_4$ (1,523 kg/ha)	0.06 c	0.57 b	0.35 a	0.05 c	0.20 bc	1.02 c	9 a	34 b	90 bc	10 abc
$CaCO_3$ (1,120 kg/ha)	0.09 bc	0.62 b	0.16 c	0.06 c	0.16 d	1.42 bc	9 a	32 b	84 c	9 bc
S (357 kg/ha)	0.14 ab	0.66 ab	0.10 d	0.10 b	0.28 a	1.62 b	13 a	78 a	76 c	10 abc
$MgSO_4$ (1,344 kg/ha)	0.16 a	0.74 a	0.12 d	0.18 a	0.23 b	2.15 a	12 a	33 b	122 a	9 bc
$CaCO_3$ (1,120 kg/ha) + S (357 kg/ha)	0.07 c	0.61 b	0.21 b	0.05 c	0.22 b	1.07 c	9 a	45 b	77 c	11 a
Metalaxyl (1.12 kg a.i./ha)	0.12 ab	0.63 b	0.11 d	0.10 b	0.17 cd	1.63 b	14 a	33 b	80 c	11 a
Bay NTN 19701 (6.1 + 6.1 kg a.i./ha)	0.16 a	0.65 ab	0.13 d	0.10 b	0.19 cd	1.86 ab	13 a	42 b	117 ab	11 a
Metalaxyl (1.12 kg a.i./ha) + Bay NTN 19701 (6.1 + 6.1 kg a.i./ha)	0.13 ab	0.66 ab	0.13 d	0.11 b	0.17 d	1.69 b	13 a	36 b	95 abc	10 abc
Control	0.12 ab	0.64 b	0.13 d	0.09 b	0.17 d	1.53 b	9 a	35 b	89 bc	8 c

[y] All materials were applied at early bloom (30 days after seeding) except Bay NTN 19701, which was reapplied 63 days after seeding.
[z] Means in columns followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 5. Correlation coefficients among elemental concentrations in Early Bunch hulls and pod rot at harvest in 1981

	P	K	Ca	Mg	S	N	Zn	Mn	Fe	Cu	PR[a]
P	1.00	...	...	...	...	...	...	...	...	...	...
K	0.67**[b]	1.00	...	...	...	...	...	...	...	...	...
Ca	−0.59**	−0.29	1.00	...	...	...	...	...	...	...	...
Mg	0.79**	0.71**	−0.52**	1.00	...	...	...	...	...	...	...
S	0.25	0.36*	0.01	0.26	1.00	...	...	...	...	...	...
N	0.92**	0.73**	−0.55**	0.85**	0.17	1.00	...	...	...	...	...
Zn	0.62**	0.49**	−0.40*	0.60**	0.20	0.58**	1.00	...	...	...	...
Mn	0.21	0.11	−0.26	0.03	0.76**	0.01	0.21	1.00	...	...	...
Fe	0.65**	0.68**	−0.08	0.62**	0.14	0.71**	0.30	−0.11	1.00	...	...
Cu	0.01	−0.07	0.03	−0.08	0.03	−0.04	0.17	0.08	−0.08	1.00	...
PR	0.62**	0.38*	−0.66**	0.54**	−0.05	0.53**	0.29	0.08	0.24	−0.23	1.00

[a] PR = pod rot.
[b] * = Significant at $P = 0.05$ and ** = significant at $P = 0.01$.

treated with $CaSO_4$ and $CaCO_3$ plus S. Treatments affected Mn, Fe, and Cu concentration but not Zn. Peanuts treated with $CaSO_4$ had seed lowest in P, K, and total N and highest in Ca, whereas peanut treated with $CaCO_3$ were lowest in S. Peanut treated with $MgSO_4$ had the highest Mg concentration.

Pod rot at harvest and concentration of elements in the hull correlated significantly and positively for pod rot vs. P (0.62), K (0.38), Mg (0.54), and N (0.53) and negatively for pod rot vs. Ca (−0.66) (Table 5). Correlation coefficients for elemental concentration in seed and pod rot followed very similar trends. Generally, most elements correlated positively with each other, except Ca, which correlated negatively with P, K, Mg, N, and Zn.

1982 Test. Isolations were made from pods collected 77, 97, and 133 days after seeding. There were no differences in frequency of isolation noted for *Pythium* and *Rhizoctonia* spp. at any sampling dates. However, frequency of isolation of *Fusarium* spp. was different among several of the treatments 77 and 97 days after seeding, but this difference was not consistent over the sampling period.

Pegs were sampled 92 days after seeding and pods evaluated 74, 95, and 133 days after seeding (Table 6). There were no differences in peg or pod rot and %SMK among treatments although $CaSO_4$-treated plots tended to be most consistent in having fewer decayed pods. Plots treated with $CaSO_4$ and metalaxyl had higher yields than the control.

Plots treated with $CaSO_4$ had the highest Ca and S concentrations in the hulls (Table 7). Peanuts treated with Bay NTN 19701 had the highest Fe concentration and plots treated with copper ammonium carbonate had the highest Cu. Seed from these plots generally followed the same trend except plots treated with metalaxyl plus CGA-64250

Table 6. Effect of fungicides and $CaSO_4$ on peg and pod decay throughout the season and percent sound mature kernels (SMK) and yield in 1982

Treatment and rate[x]	Peg decay (%)	Pod decay (%)			SMK	Yield
	74 Days[y]	74 Days	95 Days	133 Days	(%)	(kg/ha)
$CaSO_4$ (1,142 kg/ha)	11.0 a[z]	16.0 a	16.5 a	19.3 a	66.1 a	3,459 a
Metalaxyl (1.12 kg a.i./ha)	15.0 a	13.5 a	26.5 a	19.5 a	64.8 a	3,332 a
Tolclofos-methyl (5.6 kg a.i./ha) + metalaxyl (1.12 kg a.i./ha)	16.0 a	19.0 a	25.0 a	29.3 a	61.1 a	2,980 ab
Metalaxyl (1.12 kg a.i./ha) + CGA-64250 (1.12 kg a.i./ha)	12.5 a	10.0 a	16.5 a	22.5 a	60.8 a	2,561 ab
Tolclofos-methyl (5.6 kg a.i./ha)	24.5 a	21.8 a	37.3 a	28.5 a	49.5 a	2,324 ab
$Cu{\cdot}NH_4{\cdot}CO_3$ (28.1 L/ha)	24.5 a	25.0 a	29.5 a	27.5 a	52.5 a	2,105 ab
Bay NTN 19701 (2.24 kg a.i./ha) + metalaxyl (1.12 kg a.i./ha)	13.5 a	11.0 a	18.0 a	26.8 a	52.8 a	1,962 ab
Bay NTN 19701 (2.24 kg a.i./ha)	14.5 a	15.0 a	25.5 a	29.0 a	46.1 a	1,469 b
Control	31.0 a	28.0 a	28.5 a	26.0 a	46.4 a	1,396 b

[x] All materials applied at early flower (48 days after seeding).
[y] Days after seeding.
[z] Means in columns followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 7. Elemental analyses after harvest of Early Bunch peanut hulls treated with fungicides and $CaSO_4$ in 1982

Treatment and rate[y]	Percent of tissue						ppm			
	N	P	K	Ca	Mg	S	Zn	Mn	Fe	Cu
$CaSO_4$ (1,523 kg/ha)	1.65 a	0.12 a	0.70 a	0.19 a	0.10 a	0.32 a	10 a	33 ab	146 b	7 b
Metalaxyl (1.12 kg a.i./ha)	1.77 a	0.15 a	0.62 a	0.10 b	0.10 a	0.22 b	11 a	32 ab	164 ab	7 b
Metalaxyl (1.12 kg a.i./ha) + CGA-64250 (1.12 kg a.i./ha)	2.04 a	0.16 a	0.68 a	0.09 b	0.10 a	0.21 b	9 a	32 ab	171 ab	7 b
Bay NTN 19701 (2.24 kg a.i./ha)	1.89 a	0.17 a	0.67 a	0.09 b	0.10 a	0.23 b	12 a	32 ab	204 a	7 b
Bay NTN 19701 (2.24 kg a.i./ha) + metalaxyl (1.12 kg a.i./ha)	1.82 a	0.15 a	0.66 a	0.09 b	0.11 a	0.22 b	10 a	31 ab	176 ab	7 b
Tolclofos-methyl (5.6 kg a.i./ha) + metalaxyl (1.12 kg a.i./ha)	1.73 a	0.16 a	0.72 a	0.11 b	0.12 a	0.22 b	9 a	31 ab	180 ab	7 b
$Cu{\cdot}NH_4{\cdot}CO_3$ (28.1 L/ha)	1.87 a	0.17 a	0.64 a	0.08 b	0.11 a	0.25 ab	11 a	29 b	145 b	14 a
Control	1.68 a	0.15 a	0.62 a	0.10 b	0.09 a	0.23 b	11 a	34 ab	138 b	7 b
Tolclofos-methyl (5.6 kg a.i./ha)	1.78 a	0.16 a	0.69 a	0.08 b	0.09 a	0.28 ab	8 a	39 a	158 ab	7 b

[y] All materials applied at early flower (48 days after seeding).
[z] Means in columns followed by the same letters are not significantly different ($P = 0.05$) according to Duncan's multiple range test.

Table 8. Correlation coefficients among elemental concentrations in Early Bunch hulls and pod rot at harvest in 1982

	N	P	K	Ca	Mg	S	Zn	Mn	Fe	Cu	PR[a]
N	1.00	...	...	...	...	...	...	...	...	...	...
P	0.93**[b]	1.00	...	...	...	...	...	...	...	...	...
K	0.74**	0.78**	1.00	...	...	...	...	...	...	...	...
Ca	−0.74**	−0.43**	−0.21	1.00	...	...	...	...	...	...	...
Mg	0.92**	0.92**	0.86**	−0.42**	1.00	...	...	...	...	...	...
S	0.78**	0.79**	0.60**	−0.14	0.75**	1.00	...	...	...	...	...
Zn	0.82**	0.82**	0.64**	−0.23	0.77**	0.77**	1.00	...	...	...	...
Mn	0.66**	0.66**	0.51**	−0.13	0.60**	0.62**	0.79**	1.00	...	...	...
Fe	0.62**	0.63**	0.58**	−0.12	0.60**	0.56**	0.69**	0.55**	1.00	...	...
Cu	0.46**	0.49**	0.46**	−0.33*	0.40**	0.44**	0.36*	0.28	0.30	1.00	...
PR[a]	0.57**	0.51**	0.52**	−0.41**	0.61**	0.42**	0.50**	0.13	0.36*	0.34*	1.00

[a] PR = pod rot.
[b] * = Significant at $P = 0.05$ and ** = significant at $P = 0.01$.

had seed high in K, differences in Ca were not detected among treatments, and metalaxyl plus CGA-64250 and copper ammonium carbonate-treated peanut were highest in Mg.

Concentration of elements in hulls correlated positively with pod rot recorded at harvest, except Ca, which correlated negatively (Table 8). Similar correlations were noted for pod rot and concentrations of elements in seed but at a lower probability, except pod rot vs. Ca (−0.53), which was highly significant ($P < 0.01$). Generally, elements correlated positively with most other elements, except Ca, which correlated negatively with Mg, N, P, and Cu.

P. myriotylum, *R. solani*, and *F. solani* were the predominant species isolated from decayed pegs and pods during the 3-yr test; however, total numbers of colonies on specific media are reported. Generally, materials such as $MgSO_4$, which depressed yields, caused a proliferation of peg and pod development, but only a small percentage of the pods matured and were filled. Foliage on low-yielding plots appeared more vigorous and greener than high-yielding plots near the end of the growing season.

DISCUSSION

Numbers of fungal colonies recovered from soil and percent isolations from decaying pods were inconsistent during the sampling period and within treatments. Most striking differences in percent isolations occurred among sampling dates rather than treatments. All three fungi, *P. myriotylum*, *R. solani*, and *F. solani*, were recovered from decaying pods during the 3-yr test period, and in some instances, from the same decaying pod. Although Garcia and Mitchell (5) reported that *P. myriotylum* was the most important pathogen in the complex, that was not evident from our data. *Fusarium* spp. were isolated most frequently from the decaying pods. However, Garcia and Mitchell (5) indicated that the fungus may be present as a common inhabitant even on healthy pods.

Metalaxyl is fungi-specific for the class Oomycetes, which includes *Pythium*; however, the fungicide did not reduce the percent isolation of *Pythium* spp. or reduce pod decay consistently. In 1982, plots treated with metalaxyl were higher in yield than the control but not in 1980 or 1981. In addition, combinations of metalaxyl with other fungicides specific for *Rhizoctonia* spp., such as CGA-64250, Bay NTN 19701, and Tolclofos-methyl, did not increase yield and decreased pod decay only in 1981.

Over the 3-yr test period, materials that provided a Ca source tended to decrease pod decay and increase %SMK and yield. In 1981, peanuts treated with $CaCO_3$ plus S (Table 3) did not increase yield; however, pod decay at harvest was less than in the control and %SMK was higher. These data support earlier findings of Garren (7), Hallock and Garren (10), and Walker and Csinos (17), who demonstrated the beneficial effects of decreasing pod decay and increasing yield by applying gypsum.

The varying degrees of susceptibility of Florunner and Early Bunch were evident in this test. Early Bunch consistently had more pod rot than Florunner and responded positively to Ca treaments as indicated previously by Walker and Csinos (17).

Several researchers have cited the possible roles of Ca in increasing disease resistance (1,3,10,17). Hallock and Garren (10) have indicated that the formation of Ca pectate may function in a possible role in decreasing pod decay in peanut. Bateman (1) has indicated that resistance of bean hypocotyls to *R. solani* has been directly related to calcium concentration of the host tissues and inversely related to methyloxyl content of pectic substances. The polygalacturonase associated with *R. solani*-infected bean hypocotyls does not hydrolyze calcium pectate, and it appears that the susceptibility of the host may be regulated in part by its calcium pectate content. Studies with soybeans have indicated a beneficial role of Ca in relation to resistance to *R. solani* (3).

In 1947, Brady (2) photographed and documented the effect of supplying Ca to only one side of a peanut plant. Many of the fruits on the check side were discolored and most of the undeveloped gynophores were diseased or dead. This was in contrast with the healthy-looking pods to which Ca was supplied. In 1954, Higgins (12) noted that drought and Ca deficiency in the soil were the primary causes of "black pod" of peanuts, and the condition could usually be corrected by a timely application of gypsum. "Black pod," although scantly described, is most likely pod rot as described by Garren (7) and other workers.

In light of this study, employing fungi-specific chemicals to control pod rot, we suggest that involvement of plant pathogens in pod rot may be secondary in the disease complex. Generally, across and within tests, plots that had the lowest incidence of pod decay also had the highest Ca concentration. Materials such as $MgSO_4$, which tended to decrease Ca, increased concentrations of K, N, Fe, and Mg in hulls (Table 5). Treatments that decrease Ca in pods or increase the concentration of elements that are in competition with Ca may cause a nutrient imbalance, which tends to increase pod decay. Thus, we suggest that initiation of pod rot may be caused primarily by either a Ca deficiency or an excess of other competitive cations in pods.

Several questions concerning pod rot remain unanswered. Although we suggest only a secondary role of the fungi in disease, several researchers believe that microorganisms are the primary cause of disease (4,6,8,9) and under certain conditions, have yet gone undefined; they may be. Certainly they are involved in the expression of the final symptoms that are normally associated with pod rot. The involvement of Ca is not totally clear and is apparently influenced by other elements that are in competition with Ca absorption. Very little is known about the balance of elements in seed and hulls as it relates to pod rot. Even where large amounts of Ca are supplied, why some of the pods still decay and what is the availability of Ca from different Ca sources are other questions that remain unanswered.

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