Response of Strip-Tilled Peanut to Broiler Litter, Starter Fertilizers, and Fungicide in an Irrigated Cropping System

G.J. Gascho* and T.B. Brenneman[1]

ABSTRACT

Peanut (*Arachis hypogaea* L.) production in the Southern Coastal Plain of the U.S. is being impacted by increased use of broiler litter and by conservation tillage. There are no studies on the use of broiler litter for peanut grown in strip tillage and very little information on the use of starter fertilizers. Runner-type peanut was included in a 3 yr, double-cropped, irrigated rotation to determine the effects of broiler litter rates and starter fertilizers on disease development, pod yield, market grade, and gross economic value of runner market type peanut. Broiler litter rates of 0, 4.5, 9.0, and 13.5 Mg/ha were applied to the soil surface without incorporation prior to seeding. Within each broiler litter rate there were three starter fertilizer regimes (none, 93 L 10-34-0/ha, and 93 L 12-22-5/ha) each with and without flutolanil {*N*-[3-(1-methylethoxy) phenyl]-2-(trifluoromethyl) benzamide}applied twice at 1.12 kg ai/ha/application. Over 4 yr, broiler litter either decreased or did not affect pod yield, market grade, or gross economic value of peanut. Southern stem rot (*Sclerotium rolfsii*) incidence was not affected by broiler litter, but Rhizotonia limb rot (*Rhizoctonia solani*, AG-4) incidence increased with broiler litter rate, possibly accounting for some of the decreases in production variables. Broiler litter application was neither an agronomic nor economic best management practice for peanut in this strip-tilled study. Flutolanil increased pod yield, market grade, and gross economic value of peanut regardless of broiler litter rate by decreasing the incidence of southern stem rot and Rhizotonia limb rot. Starter fertilizer had little effect on any of the measured parameters.

Key Words: *Arachis hypogaea* L., manure, plant nutrition, Rhizoctonia limb rot, southern stem rot.

A rapid increase in broiler production is occurring in the Southeastern U.S. Georgia is now the number one state in the production of broilers, with farm gate sales of \$3.2 billion in 2001 (Doherty *et al.*, 2002). Much of the expansion is in south Georgia where 40% of the nation's peanuts are produced. Broiler litter applications are made most often prior to planting crops that are rotated with peanut; however, farmers who have broiler houses often make application on lands to be planted to peanut (Balkcom *et al.*, 1996). Most of the litter application for peanut has been in conventional tillage (moldboard plowing following application) where the litter is mixed with the top soil. Such tillage reduces losses of nitrogen (N) from volatilization of ammonia, runoff losses of N and phosphorus (P), and odors from the applied litter in comparison to soil surface application without incorporation (Cabrera and Sims, 2000).

Literature on the effects of poultry litter on peanut is limited. Peanut in the Coastal Plain generally does not respond to P and K fertilization due to the fertilizer applied to previous rotational crops unless the initial soil test is low (Mitchell and Adams, 1994); and N is only recommended for cases where poor inoculation with *Rhizobium* spp. is anticipated or N uptake is limited by adverse soil conditions (Kidder, 1994). Therefore, fertilizer application is limited and animal manures are not commonly applied. Two studies on the effects of poultry litter on peanut yield and percentage of sound mature kernels (SMK) have been reported from work in Alabama. Hartzog and Adams (1994) found that poultry litter turned deeply into an infertile soil prior to seeding increased yield above that of the control. In one of their two experiments, pod yield was greater where poultry litter versus where commercial fertilizer was applied. However, commercial fertilizer resulted in a greater percentage of sound mature kernels (SMK) in one of the experiments. In a second study, Balkcom *et al.* (1996) compared the effects of commercial fertilizer, sewage sludge, and poultry litter in conventionally tilled (deeply turned) peanut production in Alabama. They found variable results in two on-farm experiments, but concluded that poultry litter may be beneficial for peanut in some instances.

Use of strip tillage for peanut is increasing rapidly in the Southern Coastal Plain due to the needs to conserve moisture, reduce input costs, and save time. Litter incorporation is minimal in strip tillage. No previous studies of the effects of broiler litter for strip-tilled peanut were found in the literature.

Starter fertilizers can increase grain yields of conservation-tilled corn (*Zea mays* L.) and lint yields of strip-tilled cotton (*Gossypium hirsutum* L.) (Touchton and Karim, 1986; Gascho *et al.*, 2001). However, since peanut in the Coastal Plain has not been very responsive to P and K fertilization, in most instances there has been little interest in evaluating starter fertilizers for peanut. Oyer and Touchton (1988) determined the effects of several combinations of starter fertilizers on the yield of both conventionally tilled and no-tilled peanut. Some pod yield responses to starter fertilizer were recorded each year of the 3 yr study for no-till peanut, but only in 2 of 3 yr in conventionally tilled peanut. Data were inconsistent as to the nutrient element responsible for the yield response, as application of only N produced the greatest yield 1 yr, but both N and K were required in another year. They concluded that the best placement of the starter fertilizer was shallow incorporation near the seed with in-row subsoiling for the no-tillage system and without in-row subsoiling for the conventional tillage system. No publications were found that evaluated starter fertilizers in strip-tilled peanut.

Successful peanut culture in the Southeastern U.S. requires the control of southern stem rot (*Sclerotium rolfsii* Sacc.) and Rhizoctonia limb rot (*Rhizoctonia solani* Kuhn, AG-4). Losses to these diseases can be severe, especially in fields with poor crop rotations or where other conditions are favorable for the pathogens. Brenneman (1997) found that Rhizoc-

[1]Prof., Depts. of Crop and Soil Sciences and Plant Pathology, respectively, Univ. of Georgia, Coastal Plain Exp. Sta., P. O. Box 748, Tifton, GA 31793-0748.

*Corresponding author (email: gascho@tifton.cpes.peachnet.edu).

tonia limb rot incidence was increased by excessive irrigation and excessive fertilization. The effects of broiler litter on the development of these soil-borne diseases is largely unknown. Several fungicides that reduce losses of pod yield to these diseases have been registered in the past decade. Flutolanil, a registered fungicide for use in peanut, is effective on soil-borne diseases in conventionally tilled as well as in reduced tillage culture (Johnson *et al.*, 2001). Since flutolanil is not active on foliar pathogens, it is an ideal fungicide for evaluation of the effects of soil-borne diseases of peanut without influencing yield-limiting foliar diseases.

Determining interactions among broiler litter, starter fertilizer, and fungicide applications in a strip tillage production system is important for determining how best to use these resources efficiently. Therefore, the objectives of this study were to determine pod yield, market grade, gross economic value, and soil-borne disease responses of runner market-type peanut to broiler litter, starter fertilizer, and fungicide in an irrigated, conservation-tilled 3 yr double cropping system.

Materials and Methods

The study was conducted from 1996 to 2000 at the Coastal Plain Exp. Sta. near Tifton, GA (31°28' N, 83° W) on Tifton loamy sand (fine-loamy siliceous Plinthic Kandiudults). Crops cultured just previous to establishment of the study were corn followed by wheat (*Triticum aesitivum* L.). Surface soil (0 to 15 cm) pH (water) was 6.1 on 16 April 1996, 2 mo following application of 1.8 Mg dolomite/ha. Organic matter was 6 g/kg. Mehlich-1 soil test P, K, Ca, and Mg were 23 mg/kg (high), 57 mg/ kg (high), 201 mg/kg (adequate), and 22 mg/kg (medium), respectively (Plank, 1989).

Three cropping cycles were established so that each summer and each winter crop were grown every year in a consistent sequence (Table 1). Cotton, runner-market-type peanut, and pearl millet [*Pennisetum glaucum* (L.) R. Br.] for grain were planted in the spring. Wheat and canola (*Brassica napus* L.) for grain were planted in the fall. Following cotton, plots were winter-fallowed. Production data for responses of the rotational crops to broiler litter are published elsewhere (Gascho *et al.*, 2001).

Florunner peanut was planted in 1996. Due to heavy damage from tomato spotted wilt virus (TSWV) that year,

Table 1. Sequence of crops in a 3-yr double-cropped rotation practiced from 1996 to 2000.[a]

Season and year	Cycle 1	Cycle 2	Cycle 3
Summer 1996	Cotton	Millet	Peanut[b]
Winter 1996-1997	Fallow	Wheat	Canola
Summer 1997	Peanut[b]	Cotton	Millet
Winter 1997-1998	Canola	Fallow	Wheat
Summer 1998	Millet	Peanut[b]	Cotton
Winter 1998-1999	Wheat	Canola	Fallow
Summer 1999	Cotton	Millet	Peanut[b]
Winter 1999-2000	Fallow	Wheat	Canola

[a]Each crop is grown every year in one of the three crop cycles.

[b]Peanut crops that are included in this study.

Georgia Green, a cultivar with some resistence to TSWV (Branch, 1996) was planted in the following years. The experimental design of the study was a randomized complete block with a split-plot arrangement of treatments and four blocks. Four rates of broiler litter [manure and pine (*Pinus palustris* L. and *P. elliotti* L.) tree wood shavings] were main plots (11 by 23 m). Six combinations of three starter fertilizers regimes and two fungicide rates were the randomized subplots (5.5 by 7.6 m) within each main plot.

Broiler litter was broadcast by a cone-shaped fertilizer spreader 1 to 3 wk before planting at rates of 0, 4.5, 9.0, and 13.5 Mg/ha. Starter fertilizers (none, 10-34-0, and 12-22-5 with 2% sulfur) were injected at rates of 93 L/ha and placed 5 cm to the side and 5 cm below the seed at planting. Starter fertilizer was delivered behind a knife which followed a straight coulter. Flutolanil (Moncut 50WP, AgrEvo, Wilmington, DE) was applied as a broadcast spray at 1.12 kg ai/ha in a spray volume of 200 L/ha at first bloom and again 4 wk later.

For the initial summer crops in 1996, broiler litter was broadcast on fallow soil and incorporated to a depth of 15 cm by a disk harrow prior to planting. For the remainder of the 4 yr experiment, winter crops were no-tilled and summer crops were strip-tilled into residues remaining from the previous crop. The strip-till implement included an in-row subsoiler set to penetrate to 35 cm. No additional tillage or synthetic fertilizers were applied in the study. Irrigation was applied to maximize peanut yield using a lateral-move sprinkler system. Peanut was planted in the first 10 d of May each year. Peanut was grown with best management practices including six biweekly sprays beginning 40 d following emergence with chlorothalonil (Bravo 500, Zeneca, Wilmington, DE) at 0.23 kg ai/ha in a spray volume of 200 L/ha.

Broiler litter used throughout the study originated from the same broiler houses, but was stored in a covered stack house for variable amounts of time before transportation and application to the plots each spring and fall. Samples were analyzed for total N (Bremner and Mulvaney, 1982) and total concentrations of other elements by inductively coupled plasma analyses. The mean N concentration in broiler litter used in this study was 27 ± 5 kg/Mg, which is less than the N concentration in fresh litter reported by Vest *et al.* (1994). The difference was likely due to NH_3 losses by volatilization during stacking. Total P (12 ± 2 kg/Mg), K (16 ± 2 kg/Mg), Ca (16 ± 3 kg/Mg), Mg (3 ± 0.5 kg/Mg), and S (4 ± 0.5 kg/Mg) concentrations also were slightly less than those reported by Vest *et al.* (1994). In spite of the care to obtain uniform litter, analyses of the litter transported from the stack house prior to planting crops each spring and fall season varied considerably. Such variability is inherent in litter due to differences in the ratios of manure to wood shavings, time of house cleaning, feed conversion, and length of time and temperature conditions for stacking. Because of the heterogeneous composition of broiler litter, precise analyses are often difficult to obtain and variation in analyses was expected. Due to the sensitivity of peanut to Zn toxicity and the potential toxicity of Cu to plants, we also determined the concentrations of those elements in the broiler litter. Zinc concentration was 228 ± 54 g/Mg and Cu concentration was 181 ± 24 g/kg. Heavy metal concentrations were 3, 0.4, 6, and 5 g/Mg of broiler litter for Pb, Cd, Ni, and Cr, respectively.

Peanut was harvested mechanically from the center two rows of the subplots to determine pod yield and for sampling to determine the percentage of total sound mature kernels (TSMK) and gross economic value per kilogram peanut and per hectare (Georgia State Inspection Serv.). All residues were left on the plots for peanut and rotational crops.

Soil analyses were made on samples collected each February from 1997 to 2000 in all subplots that received no starter fertilizer or fungicide. Samples were collected by combining two 4.5 cm dia. cores from a depth of 0 to 15 cm. Soil pH was determined in a 1:2 soil:water suspension after mixing and an equilibration period of 30 min. Phosphorus, K, Ca, Mg, Cu, Mn, and Zn were extracted by Mehlich-1 (Donohue *et al.*, 1983). Phosphorus was determined by colorimetric spectroscopy and the other elements by atomic absorption spectroscopy (Donohue *et al.*, 1983). Soil organic matter was determined by the Walkley-Black titration method (Nelson and Sommers, 1982).

Following dry ashing at 500 C, P (colorimetric spectroscopy), and K (atomic absorption spectroscopy) were analyzed in harvested seeds and P (colorimetric spectroscopy) and K, Ca, and Mg (atomic absorption) were analyzed in hull samples collected in 1997, 1998, and 1999. Total N and S in seeds and hulls were analyzed by combustion in a Leco CNS analyzer.

Rhizoctonia limb rot and Southern stem rot were evaluated in peanut immediately after the plants were dug and inverted in the last week of September each year. Incidence of southern stem rot (percentage of 30.5 cm sections of a linear row per plot with at least one diseased locus) was evaluated in 1996, 1998, and 1999. Incidence of rhizoctonia of limb rot (percentage of vines colonized by *R. solani* in six 0.6 m sections of a linear row per plot) was evaluated in 1998 and 1999.

Data for soil tests, plant nutrient concentrations, soil-borne disease incidences, pod yields, TSMK, gross value/Mg, and gross value/ha of peanut were statistically analyzed using the GLM procedure of SAS (SAS Inst., 1999). Soil tests were analyzed as a split-plot arrangement of a randomized complete block design. Years were the main plots and broiler litter rates the subplots. All other data were analyzed as a split-split-plot arrangement of a randomized complete block design. The main plots were years, the subplots were broiler litter rates, and the sub-subplots were combinations of starter fertilizer and flutolanil. All interaction terms were included in the models. Main effect means and significant interaction means are presented and separated by Fisher's protected LSD (P = 0.05).

Results and Discussion

Pod yield, TSMK, gross economic value/Mg, and gross value/ha of peanut varied significantly among years (Table 2). Values for these parameters were lower in 1996 than in subsequent years (Table 3). The lower production in 1996 was due to the high incidence of TSWV in the Florunner cultivar (data not shown). Georgia Green, a cultivar with greater tolerance to TSWV (Branch, 1996), was planted in 1997, 1998, and 1999. Pod yield and gross value/ha varied in those 3 yr due to normal fluctuations in weather, but TSMK and value/Mg did not fluctuate. Peanut pod yield and its gross economic value/ha in 1998 were 1250 kg/ha and $918/ha, respectively greater than the 4 yr mean.

Over the 4 yr. study, TSMK and gross value/Mg of peanut were affected by broiler litter rate, but pod yield and gross value/ha of peanut were not affected (Table 2). Total sound mature kernels and gross value/Mg were decreased by the application of broiler litter (Table 3). One interesting point is that no additional reduction was determined for application rates greater than 4.5 Mg/ha. Considering the cost and effort

Table 2. Analyses of variance for pod yield, total sound mature kernels, gross value/Mg, and gross value/ha.

Source	df	Pod yield	TSMK[a]	Value Mg	Value ha
		P value			
Block	3	0.0109	0.0056	0.0057	0.0144
Year	3	<0.0001	0.0058	0.0005	<0.0001
Block × year[b]	9	0.2066	<0.0001	<0.0001	0.0515
Broiler litter rate	3	0.4022	0.0319	0.0391	0.2418
Year × litter	9	0.2700	0.1895	0.4197	0.2317
Block × year × litter[c]	36	0.0003	0.0759	0.0157	0.0004
Subplot[d]	5	<0.0001	<0.0001	<0.0001	<0.0001
Year × subplot[d]	15	0.0002	0.4386	0.3472	0.0003
Litter × subplot[d]	15	0.0579	0.1973	0.0779	0.0463
Year × litter × subplot[d]	45	0.0506	0.9402	0.8398	0.0570
Residual	240				
Total	383				
C.V.		16.1	2.5	2.4	16.7

[a]TSMK, total sound mature kernels.

[b]Error a for testing block and year.

[c]Error b for testing broiler litter and year x litter.

[d]Subplot, starter fertilizer, and flutolanil combinations randomized in the litter plots.

to apply broiler litter, its application was neither an agronomic nor economic best management practice for peanut in this study. That conclusion may appear initially to be in contrast to the positive responses found by Hartzog and Adams (1994) and by Balkcom *et al.* (1996). However, in their studies, poultry litter was incorporated into soils with "low" soil tests for P and K; and litter may have provided more positive effects in our study if soil P and K levels were also "low". It may have had less of a negative effect if it had been incorporated rather than being left on the surface in the pegging zone of the developing seeds.

Starter fertilizer-flutoanil combinations significantly affected all of the measured production variables, but there were significant interactions between year and fertilizer-fungicide combinations for pod yield and gross value/ha and a significant interaction between broiler litter rate and fertilizer-flutolanil combinations for gross value/ha (Table 2). Mean separation indicates that the differences recorded for the fertilizer-flutolanil combinations were due to the flutolanil and not to starter fertilizer (Table 3). Flutolanil significantly increased pod yield, TSMK, value/Mg, and gross economic value/ha peanut each year at all litter rates and for all starter fertilizer treatments. Similar effects on market grade have been reported earlier due to the application of fungicides for control of southern stem rot (Brenneman and Culbreath, 1994). Starter fertilizer did not result in any increases in pod yield, TSMK, or gross values of peanut (Table 3). Pod yield and gross value/ha were inexplicably decreased by application of 12-22-5 (2S). In 1997, application of flutolanil did not increase pod yield or gross economic value/ha when either no starter was applied or

Table 3. Peanut yield, grade, and value by year, broiler litter rate, starter fertilizer, and fungicide for 4 yr experiment.

Factor		Pod yield	TSMK	Gross value Mg	Gross value ha
		kg/ha	%	--------$--------	
Year					
1996		2870 d[a]	71 b	670 b	1940 d
1997		3730 b	73 a	700 a	2610 b
1998		5010 a	73 a	700 a	3540 a
1999		3430 c	74 a	700 a	2400 c
Litter (Mg/ha)					
0		3880 a	73 a	700 a	2730 a
4.5		3730 a	72 b	690 b	2600 ab
9.0		3760 a	72 b	690 b	2620 ab
13.5		3670 a	72 b	690 b	2540 b
Starter and Flutolanil Combinations					
Starter	Flutolanil[b]				
None	No	3380 c	72 c	690 b	2340 c
10-34-0	No	3440 c	72 c	690 b	2380 c
12-22-5	No	3300 c	72 c	690 b	2300 c
None	Yes	4220 a	74 a	700 a	2970 a
10-34-0	Yes	4240 a	73 b	700 a	2960 a
12-22-5	Yes	3990 b	73 b	700 a	2790 b

[a]Values in a group and column followed by a common letter are not different by Fisher's Protected LSD (P = 0.05).

[b]Flutolanil applied two times at 1.12 kg/ha.

12-22-5 (2S) was applied (Table 4). In 1999, flutolanil did not increase pod yield or gross economic value/ha where the 12-2205 (2S) was applied. In all other combinations, flutolanil increased pod yield and gross economic value/ha. Over all fertilizer-flutolanil combinations, pod yield was increased by 780 kg/ha and gross economic value/ha was increased by $570/ha by applications of flutolanil. Neither starter fertilizer increased pod yield nor gross value/ha. These results are consistent with many studies indicating that peanut responds greater to residual soil nutrient reserves than to direct fertilization (Gascho and Davis, 1995).

The interaction of broiler litter rate with the starter fertilizer-flutolanil combinations (Table 5) is likely of little agronomic consequence as the subplots receiving flutolanil within plots receiving a given rate of broiler litter always produced a numerically greater gross economic value/ha than those not receiving flutoanil; however, the differences were not significant (P = 0.05) in two incidences.

Analyses of variance for southern stem rot incidence, evaluated 3 yr and rhizoctonia limb rot incidence, evaluated for 2 yr, are presented in (Table 6). Southern stem rot incidence varied significantly with year. It was low in 1998 in comparison to the 2 other yr where it was recorded (Table 7). That low incidence may have been partially responsible for the greater pod yield and economic value of the peanut crop in 1998. Rhizoctonia limb rot incidence did not vary significantly with year, but it was significantly affected by broiler litter rate (Table 6). Incidence increased with increasing broiler litter rate to a maximum at 9.0 Mg broiler litter/ha. Southern stem rot incidence was not affected by broiler litter rate (Table 6). There were no significant interactions between year and broiler litter rate for disease incidences, but both diseases evaluated were affected by starter fertilizer-flutolanil combinations. Application of flutolanil decreased the incidences of both Rhizoctonia limb rot and southern stem rot (Table 7). Application of 12-22-5 as a starter fertilizer increased the incidence of Rhizoctonia limb rot when no flutolanil was applied and tended to increase it where flutolanil was applied. An interaction was determined between year and the fertilizer-flutolanil combinations for stem rot (Table 8). In 1996 and 1999 flutolanil decreased the incidence of stem rot regardless of the starter fertilizer treatment; but in 1998, a year of low incidence of the soilborne disease, subplots receiving no starter and flutolanil as well as subplots receiving 12-22-5 and flutolanil had equal incidences of stem rot as subplots not receiving flutolanil.

Concentrations of all hull nutrients analyzed, except K and Mg, and P and K in seeds, varied significantly (P = 0.05) with year (Table 6) and also were lowest in 1998 (Table 7). That result may have been due to better utilization of nutrients or it may indicate that less nutrients were available for uptake in 1998. Many studies have indicated that peanut requires less nutrient availability than the other crops in this rotation (Gascho and Davis, 1995; Gascho *et al.*, 2001). Hull elemental concen-

Table 4. Interaction of year and starter-flutolanil combinations for peanut pod yield and gross value/ha.[a]

Year	Pod yield: No flutolanil[b] No starter	10-34-0	12-22-5	Pod yield: Flutolanil[b] No starter	10-34-0	12-22-5	Gross value: No flutolanil[b] No starter	10-34-0	12-22-5	Gross value: Flutolanil[b] No starter	10-34-0	12-22-5
	----------kg/ha----------						----------$/ha----------					
1996	2340 c[c]	2160 c	2400 c	3820 a	3220 b	3270 b	1550 c	1440 c	1610 c	2640 a	2190 b	2230 b
1997	3620 bc	3650 bc	3420 c	3760 abc	4040 a	3860 ab	2540 bc	2530 bc	2400 c	2650 abc	2840 a	2720 ab
1998	4590 bc	4760 b	4270 c	5470 a	5710 a	5270 a	3210 b	3350 b	3000 b	3890 a	4040 a	3720 a
1999	2960 c	3200 bc	3110 bc	3810 a	3970 a	3550 ab	2070 c	2210 bc	2180 bc	2700 a	2780 a	2500 ab
Flutolanil mean		3370			4150			2340			2910	

[a]Each value is a mean of 16 observations.

[b]No flutolanil applied or applied twice at 1.12 kg/ha.

[c]Values for each year followed by a common letter are not significantly different by Fisher's Protected LSD (P = 0.05).

Table 5. Interaction of broiler litter rate and starter-flutolanil combinations for peanut gross value/ha.[a]

	No flutolanil[b]			Flutolanil[b]		
Broiler litter rate	No starter	10-34-0	12-22-5	No starter	10-34-0	12-22-5
Mg/ha	-------------$/ha-------------			-------------$/ha-------------		
0.0	2280 b[c]	2360 b	2270 b	3260 a	3220 a	3000 a
4.5	2450 bc	2260 c	2440 bc	2980 a	2780 a	2700 ab
9.0	2410 b	2400 b	2210 b	2930 a	3020 a	3000 a
13.5	2220 c	2500 bc	2260 c	2720 ab	2830 a	2740 ab

[a]Each value is a mean of 16 observations.

[b]No flutolanil applied or applied twice at 1.12 kg/ha.

[c]Values for each broiler litter rate followed by a common letter are not significantly different by Fisher's Protected LSD (P = 0.05).

trations were generally less in 1998 than in 1997 or 1999 (Table 7). Pod yield in 1998 was the highest of the 3 yr from 1997 to 1999 (Table 3). The lower elemental concentrations in 1998 could be accounted for by their dilution in the tissue of hulls.

All hull and seed nutrient element concentrations increased or had a tendency to increase with increasing broiler litter rate (Tables 6 and 7), providing some proof that nutrients in the broiler litter were taken up by peanut in this study. However, those increases were generally quite small, likely indicating that adequate nutrition was supplied without the addition of broiler litter. Uptake into seeds and hulls is largely via mass flow into the developing gynophore rather than by root uptake (Gascho and Davis, 1995). Therefore, nutrient concentration in seeds and hull is largely a reflection of the availability of those nutrients in the soil of the pegging zone. For those elements affected by broiler litter, the greatest concentrations were reached by the application rate of 4.5 Mg/ha or for the 9.0 Mg/ha rate for K and Mg in hulls. The lack of an increase to the highest rate of broiler litter application indicates the satisfied capacity of the seeds and hulls to absorb nutrients via mass flow.

Soil pH for samples collected following harvest was similar each year (Table 9). It was not affected by the rate of broiler litter application and was maintained near pH 6, regardless of broiler litter application (data not shown). Incorporation of broiler litter increases soil pH very rapidly following application, but upon nitrification of the large amount of ammonium-N added to the soil as broiler litter, soil pH can decrease to initial values or possibly even to values less than the initial value. Sims (1986) determined that soil pH of an Evesboro loamy sand was raised from 6.5 to 7.5 shortly following application of poultry manure, but it then decreased to 5.5 by the end of a 20 wk study.

Soil test values for nutrient elements varied with year (Table 9). For all elements except Mg they also varied significantly due to broiler litter rate. In addition, the interaction of year and broiler litter rate was significant (P = 0.05) for all elements except K and Ca. Means for years, broiler litter rates, and the interaction between year and broiler litter rate are reported in Table 10. Broiler litter application more than doubled surface soil P over the 4 yr of the study. It was increased to the "very high" range for the 9 Mg/ha broiler litter rate by 1997 and was "very high" for the 4.5 Mg/ha rate thereafter. Very high P soil tests in surface soil increase the possibility of P losses to waterways by surface erosion of particulate-P (Sharpley *et al.*, 1993; Sims and Wolf, 1994). The continuous application of litter at these rates and timings is most likely not sustainable. Soil test K, Ca, and Mg appeared

Table 6. Probabilities of significance from analyses of variance for disease ratings and hull and seed elements.

Source	Limb rot	Stem rot	Hull N	Hull P	Hull K	Hull Ca	Hull Mg	Hull S	Seed P	Seed K
	---	---	---	---	---	P value	---	---	---	---
Block	0.5099	0.6976	0.5362	0.1513	0.5812	0.6066	0.8107	0.5230	0.1873	0.1871
Year[a]	0.3050	0.0020	0.0012	<0.0001	0.1521	0.0029	0.5624	0.0194	0.0168	0.0054
Block × year[b]	<0.0001	0.0032	<0.0001	0.0696	<0.0001	<0.0001	<0.0001	<0.0001	0.0456	0.3530
Broiler litter rate	<0.0001	0.5106	0.0500	0.0021	<0.0001	0.0081	<0.0001	0.0513	0.0032	0.4368
Year × litter	0.4894	0.0517	0.9218	0.8279	0.1416	0.9554	0.1209	0.9561	0.3962	0.8806
Block × year × litter[c]	0.0132	<0.0001	0.0725	0.0729	0.1447	0.0282	0.1234	0.4523	0.1544	0.2939
Subplot[d]	0.0003	<0.0001	0.3119	0.8033	0.8899	0.9044	0.7389	0.1689	0.4952	0.1573
Year × subplot[d]	0.7411	<0.0001	0.3418	0.0878	0.2412	0.1276	0.2782	0.9583	0.9269	0.9986
Litter × subplot[d]	0.7953	0.3646	0.6178	0.4688	0.5636	0.8890	0.3331	0.2894	0.9216	0.6639
Year × litter × subplot[d]	0.9586	0.3792	0.2046	0.1565	0.5762	0.5178	0.4976	0.3719	0.1288	0.1320
C.V.	33.6	39.8	20.8	25.3	14.5	20.4	17.2	26.6	6.4	10.8

[a]Data for southern stem rot and hull nutrient concentrations are for 1996, 1998, and 1999. Data for Rhizoctonia limb rot are from 1998 and 1999. Data for seed nutrient concentrations are for 1997 and 1999.

[b]Error a for testing block and year.

[c]Error b for testing broiler litter and year × litter.

[d]Subplot, starter fertilizer, and flutolanil combinations randomized in the litter plots.

Table 7. Incidences of Rhizoctonia limb rot and southern stem rot and of hull and seed nutrient concentrations as affected by year, broiler litter rate, and fertilizer-flutolanil combinations.[a]

Factor	Limb rot	Stem rot	Hull N	Hull P	Hull K	Hull Ca	Hull Mg	Hull S	Seed P	Seed K
	%									
Year										
1996	nd[d]	16 a[e]	nd	nd	nd	nd	nd	nd	nd	nd
1997	nd	nd	1.74 b	0.12 b	0.70 a	0.14 b	0.12 a	0.12 b	0.39 b	0.57 b
1998	20 a	4 c	1.17 c	0.10 c	0.52 a	0.11 c	0.11 a	0.12 b	nd	nd
1999	16 a	11 b	2.19 a	0.18 a	0.62 a	0.16 a	0.11 a	0.16 a	0.42 a	0.64 a
Litter rate (Mg/ha)										
0	12 c	11 a	1.56 b	0.11 b	0.55 c	0.12 b	0.10 c	0.12 b	0.39 b	0.59 a
4.5	16 b	11 a	1.72 ab	0.13 a	0.62 b	0.14 a	0.11 b	0.12 b	0.40 ab	0.60 a
9.0	21 a	10 a	1.76 a	0.14 a	0.64 ab	0.14 a	0.12 a	0.13 ab	0.40 ab	0.60 a
13.5	22 a	10 a	1.75 a	0.14 a	0.66 a	0.14 a	0.12 a	0.14 a	0.41 a	0.61 a
Starter-Flutolanil Combinations										
Starter Flutolanil										
None No	17 bc	15 a	1.74 ab	0.13 a	0.61 a	0.14 a	0.12 a	0.14 a	0.40 a	0.58 b
10-34-0 No	19 ab	14 a	1.69 ab	0.14 a	0.62 a	0.13 a	0.11 a	0.13 ab	0.39 a	0.59 ab
12-22-5 No	22 a	14 a	1.68 ab	0.13 a	0.61 a	0.14 a	0.12 a	0.12 b	0.41 a	0.61 a
None Yes	16 c	7 b	1.71 ab	0.14 a	0.63 a	0.14 a	0.12 a	0.13 ab	0.40 a	0.62 a
10-34-0 Yes	16 c	6 b	1.75 a	0.14 a	0.61 a	0.13 a	0.12 a	0.13 ab	0.40 a	0.62 a
12-22-5 Yes	17 bc	7 b	1.61 b	0.13 a	0.61 a	0.14 a	0.11 a	0.13 ab	0.40 a	0.62 a

[a]Data for southern stem rot and hull nutrient concentrations are for 1996, 1998, and 1999. Data for Rhizoctonia limb rot are from 1998 and 1999. Data for seed P and K concentrations are for 1997 and 1999.

[b]Percent 30.5-cm sections of linear row per plot with at least one disease locus.

[c]Visual estimate of the percentage of vines colonized by *Rhizoctonia solani* in six 0.6-m sections of linear row per plot.

[d]Not determined.

[e]Values within a column for a given factor followed by a common letter are not different by Fisher's Protected LSD (P = 0.05).

Table 8. Interaction of year and the starter-flutolanil combinations for the incidence of southern stem rot.[a]

Fertilizer	Flutolanil[b]	Disease 1996	Disease 1998	Disease 1999
		%		
None	No	23 a[c]	6 a	15 a
10-34-0	No	22 a	5 a	14 a
12-22-5	No	22 a	6 a	15 a
None	Yes	10 b	4 ab	8 b
10-34-0	Yes	9 b	2 b	7 b
12-22-5	Yes	9 b	4 ab	8 b

[a]Percent 30.5-cm sections of linear row per plot with at least one disease locus.

[b]Flutolanil applied two times at 1.12 kg/ha.

[c]Values for a given year followed by a common letter are not significantly different by Fisher's Protected LSD (P = 0.05).

Table 9. Analyses of variance for soil tests from samples collected from the upper 15 cm of depth for 4 yr as affected by broiler litter.

Source	df	pH	P	K	Ca	Mg
		P value				
Block	3	0.6001	0.1296	0.5091	0.8057	0.3109
Year	3	0.6662	0.0045	0.0058	0.0254	0.0297
Block × year[a]	9	<0.0001	0.0738	0.0822	0.0005	<0.0001
Broiler litter rate	3	0.4808	<0.0001	0.0006	0.0091	0.0788
Year × litter	9	0.5491	<0.0001	0.2122	0.3216	0.0296
Residual	164[b]					
Total	191					
C.V.		5.0	45.4	54.2	33.3	51.1

[a]Error a for testing block and year.

[b]Error b for testing broiler litter rate and year × litter.

Table 10. Nutrient elemental means by year, broiler litter rate, and interaction of year and broiler litter rate for soil analyses from samples collected following harvest from a depth of 0 to 15 cm[a].

Litter rate	Year 1996	1997	1998	1999	Litter means
	---------------- mg/kg			----------------	mg/kg
Phosphorus					
0	24 a[b]	19 b	16 c	21 c	20 C
4.5	21 a	21 b	35 b	38 b	29 B
9.0	27 a	33 a	43 ab	46 b	37 A
13.5	20 a	34 a	52 a	61 a	42 A
Yearly means	23 B	27 B	37 A	41 A	
Potassium					
0	53 a	31 b	28 a	38 A	38 C
4.5	58 ab	39 ab	28 a	60 ab	47 BC
9.0	57 a	45 ab	37 a	77 a	54 AB
13.5	59 a	59 a	35 a	88 a	60 A
Yearly means	57 AB	44 BC	32 C	66 A	
Calcium					
0	168 b	189 a	191 a	273 b	205 B
4.5	225 a	183 a	238 a	265 b	228 B
9.0	164 b	208 a	265 a	296 ab	234 AB
13.5	206 ab	224 a	263 a	346 a	260 A
Yearly means	191 B	201 B	239 AB	295 A	
Magnesium					
0	25 ab	30 b	25 a	44 b	31 B
4.5	30 a	29 b	34 ab	48 b	35 AB
9.0	18 ab	33 ab	36 ab	56 ab	36 AB
13.5	15 b	38 a	39 a	72 a	41 A
Yearly means	22 B	33 B	34 B	55 A	
Copper					
0	0.6 a	0.7 b	0.4 a	0.7 c	0.6 B
4.5	0.4 a	0.6 b	0.6 a	1.0 b	0.6 B
9.0	0.6 a	0.8 ab	0.7 a	1.4 a	0.9 A
13.5	0.6 a	0.9 a	0.8 a	1.4 a	0.9 A
Yearly means	0.5 B	0.6 B	0.7 B	1.1 A	
Zinc					
0	1.5 a	0.9 c	0.8 b	1.0 c	1.1 C
4.5	1.5 a	1.1 bc	1.4 b	2.1 bc	1.5 B
9.0	1.5 a	1.4 b	1.6 ab	2.8 ab	1.8 B
13.5	1.5 a	1.9 a	2.2 a	3.9 a	2.4 A
Yearly means	1.5 A	1.3 B	1.5 B	2.5 A	

[a]Samples were collected in February each year from each main plot where neither starter fertilizers nor treatment fungicides were applied.

[b]Yearly and litter rate means followed by a common upper case letter and interaction means followed by a common lower case letter indicate that there is no significant difference by Fisher's Protected LSD (P = 0.05).

to increase more from 1998 to 1999 than from 1997 to 1998.

Weather records indicate that rainfall was much less than average in winters since 1997-1998. Our determinations of soil tests to 90 cm (not shown) indicate that K, Ca, and Mg were not moved to greater depths in 1998-1999 as they were in the earlier winters of the study. Since these elements all are leachable in the Tifton soil, soil test K, Ca, and Mg in the surface soil increased little with broiler litter rate. However, unlike P, concentrations of these elements increased with increasing soil depth. Calcium was low (< 250 mg/kg) for peanut pod development at all litter rates in 1996 and 1997 and for the 0 rate in 1998. Initially, Mg was adequate and then tended to increase with increasing broiler litter rates.

Fertilizer recommendations are made from analyses of top soil samples collected to depths of 15 to 20 cm. Nitrogen is not recommended for peanut in Georgia and P and K soil tests were always in the "medium and high" ranges according to the Georgia Ext. Serv. (Plank, 1989). Therefore, fertilizers other than Ca would not have been recommended for peanut at the P and K soil tests (> 15 mg P/kg and > 30 mg K/kg) in plots receiving no litter in this study. Data from the rotational crops in this study support the value of application of broiler litter, especially for cotton (Gascho *et al.*, 2001). If a good rotation is maintained and the rotational crops are fertilized well with either inorganic or organic fertilizers (such as broiler litter at approximately 4.5 Mg/ha), it appears unlikely that any broiler litter or fertilizer, with the possible exceptions of Ca and B, will need to be applied for peanut. Surface-applied broiler litter in strip tillage actually decreased TSMK, gross economic value/Mg, and gross economic value/ha in this study. Only in cases of peanut grown in poor rotations with low soil tests for P and K is preplant application of broiler litter likely to provide increased yield, market grade, and economic value. Production responses to incorporated poultry litter were found in low fertility soils in Alabama (Hartzog and Adams, 1994; Balkcom *et al.*, 1996). Cooperative interstate research is now being conducted to determine if the litter has to be incorporated to realize benefits in the production of peanut.

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