Composition and Decomposition of Peanut Residues in Georgia

K.S. Balkcom[1]*, C.W. Wood[2], J.F. Adams[2], and B.H. Wood[2]

ABSTRACT

Legumes typically mineralize rapidly and can contribute to nitrogen (N) requirements of succeeding crops, but limited information exists on the mineralizable N content of peanut (*Arachis hypogaea* L.) residue. The objective of this study was to determine net N mineralization from two types of peanut residue for two soil types. Aboveground peanut residue (cv. Georgia Green) was collected 1 d prior to digging (PRE) and immediately after peanut threshing (POST). Leaf and stem residues were mixed and analyzed for carbon (C), N, lignin, and cellulose. Peanut residue equivalent to 4.5 Mg/ha was applied to a Greenville fine sandy loam (fine, kaolinitic, thermic Rhodic Kandiudults) and a Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudult) and aerobically incubated for 98 d in the dark at 25 C to determine C and N mineralization. Each soil was incubated simultaneously, with and without residue. PRE harvest residue had lower C, lignin, and cellulose concen-trations, but higher N concentrations than POST harvest residue. Differences in residue quality corresponded to differences in cumulative C mineralized and C turnover for the Tifton soil, but did not result in differences for cumulative N mineralized or relative N mineralized within either soil type. These data indicate that peanut residue will not supply significant amounts of N to a subsequent crop for these two soil types.

Key Words: *Arachis hypogaea*, mineralization, Georgia Green, nitrogen, carbon.

In the southern coastal plains of Georgia, peanuts are grown on highly weathered Ultisols that are generally characterized by coarse textures, poor structure, and organic matter content below 1.0% (Radcliffe *et al.*, 1988). Slight increases in organic matter content of these soils can significantly improve soil structure, water holding capacity, and infiltration. An option to facilitate the build-up of organic matter is to maintain crop residue by utilizing conservation tillage practices.

In addition to improving soil physical properties, crop residues are a potential source of nutrients, which may be released during their decomposition and become available for uptake by a subsequent crop (Sharpley and

[1]Res. Agron., USDA, ARS, National Soil Dynamics Lab., 411 S. Donahue Dr., Auburn, AL 36832.

[2]Prof., Assoc. Prof., and Res. Assoc., respectively, Dept. of Agronomy and Soils, 202 Funchess Hall, Auburn Univ., Auburn, AL 36849.

*Corresponding author (email: kbalkcom@ars.usda.gov).

Smith, 1989). The amount of a particular nutrient released is influenced by residue type and composition. Generally, N content of a residue determines its value, and the amount of potentially available N contained in organic substrates has concerned agronomists for many years (Castellanos and Pratt, 1981). As a result, general rules have been developed to estimate the net N mineralization potential of residues. Palm and Sanchez (1991) stated that net N mineralization occurs with residue N concentrations above 2%, and immobilization of N occurs with concentrations below 2%. The C/N ratio of residues has also been shown to indicate the likelihood of N mineralization. Low ratios (i.e., < 20 to 1) result in net N mineralization, while high ratios (i.e., > 30 to 1) result in net immobilization of N (Tisdale *et al.*, 1993).

Typically, release of nutrients from crop residues has focused on legumes, such as crimson clover (*Trifolium incarnatum* L.) and hairy vetch (*Vicia villosa* Roth.), used as mulches in conservation tillage systems and as a N source for summer crops (Touchton *et al.*, 1984; Brown *et al.*, 1985). In this role, legumes are planted after harvest, allowed to mature over the winter, chemically terminated in the spring, and then a summer crop is planted into the remaining residue. Residues from summer cash legumes like alfalfa (*Medicago sativa* L.) and soybean (*Glycine max* L. Merr.) have been shown to reduce N fertilizer requirements for a succeeding corn (*Zea mays* L.) crop (Bundy *et al.*, 1993; Morris *et al.*, 1993).

Limited information exists on the nutrient contribution of peanut residues. Constantinides and Fownes (1994) used incubation bags to measure net N mineralization from a mixture of fresh peanut leaflets and a Kapaa soil series. After 16 wk of incubation, amounts mineralized were equivalent to 60% of initial leaf N present. Smith and Sharpley (1990) demonstrated that peanut residue collected after harvest increased mineralization of indigenous and fertilizer-derived soil N after 84 d of incubation for eight soils, regardless of whether the residue was incorporated or surface applied. These studies, however, do not represent soil types or the major peanut cultivar grown in the southern coastal plain of Georgia. Therefore, the objective of this study was to determine the N contribution of PRE and POST harvest peanut residue from a major cultivar grown on two southern coastal plain soils.

Materials and Methods

A laboratory incubation study using the procedure of Nadelhoffer (1990) was used to determine C and N mineralization for PRE and POST harvest peanut residue applied to two soil series. A Greenville fine sandy loam and Tifton loamy sand were chosen for this incubation because they represent two extremes in soil types utilized for peanut production in Georgia. Thirty-two soil cores (2.5 cm diam.) were randomly collected from a depth of up to 15 cm and composited from each location. The Greenville soil was taken from a field near Shellman, GA that was in peanut and had been fallow the previous year. The Tifton soil was taken from a producer's field located near Dawson, GA that was in peanut following cotton (*Gossypium hirsutum* L.).

Soils were air dried on a laboratory bench and then sieved with a 2 mm screen. Three subsamples of each soil were analyzed for total C and N using a LECO CHN-600 analyzer (Leco Corp., St. Joseph, MI). Field capacity was determined for each soil by placing three subsamples on pressure plate extractors and applying a vacuum of -10 kPa. The soil water content measured at this pressure represented the field capacity for this experiment. A subsample of each soil was collected to determine particle size by the pipette method (Gee and Or, 2002). Physical and chemical characteristics of each soil are shown in Table 1.

Peanut residues were collected from the study site located near Shellman, GA. Residues were collected from the cv. Georgia Green, a predominant cultivar grown in the Southeast. The PRE harvest residue was collected 1 d prior to peanut digging by clipping all aboveground portions of the plants from a 1 m length of row. The POST harvest residue was collected immediately after peanut threshing from grab samples at three locations within a 30.5 m harvest row and composited from each replication. PRE harvest residue included leaves, stems, and pegs, while POST harvest residue included leaves, stems, pegs, and a small portion (3-5 cm) of the taproot included in the digging operation of peanut. Elapsed time between PRE and POST harvest residue collection was 4 d to allow peanut drying prior to harvest. Plant residues were dried at 60 C for 72 h and then ground to pass through a 1 mm mesh screen. Plant parts were ground simultaneously to represent residue under field conditions. Tissue subsamples were ground to pass a 0.2 mm mesh screen and analyzed for total C and N using a LECO CHN-600 analyzer. Standard permanganate lignin and cellulose procedures were performed on tissue samples

Table 1. Soil physical and chemical properties measured from a Greenville and Tifton soil collected from two sites in southwest Georgia.

	Soil type	
Soil parameter	Greenville	Tifton
Sand (%)	59.9	69.2
Silt (%)	17.1	15.1
Clay (%)	23.0	15.7
Field capacity (%)	16.8	14.4
C (%)	0.62	0.51
N (%)	0.016	0.020
C/N ratio	41.3	25.3
pH	6.08	6.06

ground to pass a 1 mm mesh screen (Goering and Van Soest, 1970).

Fifty mg of PRE and POST harvest residue were mixed separately with 25 g of each soil. This corresponded to a rate of 4.5 Mg/ha in the field, a typical yield of peanut residue observed in previous studies (unpubl. data). Deionized water was added to each mixture to bring the soil moisture content to 70% of field capacity at a bulk density of 1.27 g/cm^3. The mixtures were placed in micro-lysimeters (Falcon Filter units, Model no. 1702, Becton Dickinson Labware, Lincoln Park, NJ) arranged in a completely randomized design with three replications enabling aerobic incubation in the dark at 25 C. Soil (25 g) and deionized water were mixed, placed in micro-lysimeters, maintained under identical conditions, and used as controls.

The micro-lysimeters enabled nondestructive long-term measurements of microbial mineralized C and N (Nadelhoffer, 1990). The units have upper and lower chambers fitted with ports that enable gas sampling from the upper chamber and solution extractions from the lower chamber. Gas samples and solution extractions were performed prior to incubation and again at 1, 3, 7, 14, 28, 42, 70, and 98 d after initiation of incubation. Nitrogen mineralization was determined by equilibrating soil samples in the upper chambers with 100 mL of 0.01 M $CaCl_2$ for 30 min. Leachate was removed with a vacuum of -45 kPa and a portion of the leachate was analyzed for NH_4-N and NO_3-N using a microplate reader (Sims *et al.*, 1995).

Carbon mineralization (evolved CO_2) was determined after the leaching procedure by purging the headspace of the micro-lysimeters with a stream of CO_2-free air at a flow rate of 1.5 L/min. Efflux rates were determined by measuring CO_2 accumulation in the headspace of micro-lysimeters that were sealed for less than 3 h. At the end of the respiration period, air inside the headspace was mixed before sampling with a 20 mL syringe. Air samples were collected from the air inside the headspace to measure CO_2 concentrations. A 3 mL syringe was used to collect the gas samples in 3 mL sealed glass vials and stored at 4 C until analysis. Carbon dioxide concentrations were measured in a 7.6 m Hayesep Q column with a flow rate of 17 mL/min using a Varian star 3600 cx gas chromatograph (Varian Instruments, Walnut Creek, CA) and converted to mg CO_2-C/kg soil. The temperature for the thermal conductivity detector (TCD) was set to 200 C.

Carbon turnover and relative N mineralized were calculated as the fraction of C or N mineralized from total pools of C or N, respectively (Burke *et al.*, 1989). Carbon/N mineralized was calculated by dividing the cumulative amount of C mineralized by the cumulative amount of N mineralized. Relative residue N mineralized was calculated by subtracting the cumulative amount of N mineralized from the soil from the cumulative amount of N mineralized from the soil plus residue and dividing by the total N present in the residue (Isaac *et al.*, 2003). Differences between residue quality variables for PRE and POST harvest residue and relative residue N mineralized were analyzed using a t-test procedure provided by Statistical Analysis System (SAS Institute, 2001). Amounts of C and N mineralized along with calculated values for C turnover and N mineralized were analyzed by analyses of variance using a general linear model procedure provided by Statistical Analysis System. Separate analyses of variances were computed for each soil. Treatment differences were considered significant when $P > F$ was ≤ 0.05. Orthogonal contrast statements were used to further distinguish treatment differences.

Results and Discussion

The composition of PRE and POST harvest residue was different for each residue quality parameter examined (Table 2). The percentage of C was lower for the PRE harvest residue than POST harvest residue, but both residues were close to 40% C, typical of many aboveground plant tissues (Brady and Weil, 1999). The N content of PRE harvest residue was also higher than POST harvest residue. Higher C and lower N contents measured in the POST harvest residue resulted in a significant difference between C/N ratios of PRE and POST harvest residues. PRE harvest residue lignin and cellulose percentages were also lower than POST harvest residues.

Both types of residue increased microbial respiration for the Tifton soil, while only a strong trend for increased microbial respiration was observed for the Greenville soil (Fig. 1). These increases in microbial respiration resulted in higher cumulative amounts of C mineralized compared to the controls for both soils, but only the Tifton soil resulted in a significant difference (Table 3). No differences were detected in cumulative amounts of C mineralized between residues for either soil.

Peanut residue increased microbial respiration immediately and increased throughout the 98 d of incubation for both soils (Fig. 1). This increase in microbial respiration is common when plant residues are added to soils (Jenkinson, 1981). The observed increase in microbial respiration did not result in differences between cumulative amounts of N mineralized for either

Table 2. Carbon, N, C/N ratio, lignin, and cellulose measured in PRE and POST harvest peanut residues collected from a site near Shellman, GA.

Residue parameter	PRE harvest	POST harvest	P > F
C (%)	39.8	42.1	0.0300
N (%)	1.8	1.4	0.0080
C/N ratio	22.7	31.2	0.0020
Lignin (%)	6.7	9.0	0.0032
Cellulose (%)	26.5	32.3	0.0255

Table 3. Cumulative C and N mineralized, C turnover, relative N mineralized, and C/N mineralized after 98 d of incubation from two soil types amended with two types of residue.

Soil type	Treatment	Cumulative C mineralized	Cumulative N mineralized	C turnover	Relative N mineralized	C/N mineralized
		mg/kg		%		
Greenville	Control	421.4	34.7	6.8	21.7	12.9
	PRE harvest	1164.6	23.6	16.7	12.1	48.8
	POST harvest	1256.6	28.4	17.8	15.1	45.5
Tifton	Control	330.0	24.8	6.5	12.4	13.3
	PRE harvest	1055.3	26.9	17.9	11.4	39.6
	POST harvest	1129.3	27.7	19.0	12.2	42.9
		P > F				
Greenville	C vs. Ra	0.0524	0.1739	0.0669	0.0591	0.0491
	PRE vs. POST	0.8157	0.4880	0.8325	0.4756	0.8428
Tifton	C vs. R	0.0085	0.2839	0.0121	0.5582	0.0364
	PRE vs. POST	0.7574	0.7498	0.7869	0.5161	0.7935

[a]C = control; R = residue.

soil and residue combination (Table 3). These findings were contradictory to previous studies (Smith and Sharpley, 1990; Constantinides and Fownes, 1994). However, Constantinides and Fownes (1994) used fresh peanut leaflets, which had higher initial N contents, while Smith and Sharpley (1990) conducted their incubations with soils that contained higher indigenous N contents than the soils utilized in this study. These factors may explain the conflicting results. Differences were not significant between measured mineralization parameters for PRE and POST harvest residue in either soil (Table 3).

A slight increase, although not significant ($P > 0.1739$), in amounts of N mineralized from the Greenville soil without residue after 98 d of incubation provided evidence of immobilization of N resulting from the addition of residues. Immobilization of N began after 42 d of incubation, but no evidence of immobilization existed for the Tifton soil (Fig. 2). Kuo and Sainju (1998) reported a critical N concentration of 3.2%, below which immobilization of N occurred for various types of residues and mixtures of residues. The N concentrations of residues utilized in this study were approximately half of the critical N concentration and below the 2% N concentration reported by Palm and Sanchez (1991) for net N immobilization (Table 2).

Percentages of C turnover support results observed for cumulative amounts of C and N mineralized from each soil and residue combination. Carbon turnover percentages were similar for each soil type, but only amounts observed between the residue and Tifton soil were significant (Table 3). No differences in C turnover were detected between types of residue within either soil type. No differences were detected in relative N mineralized between the soil and residue or between types of residue added to each soil (Table 3). Relative N mineralized was lower in each soil with the addition of residue, although not significantly. The lack of

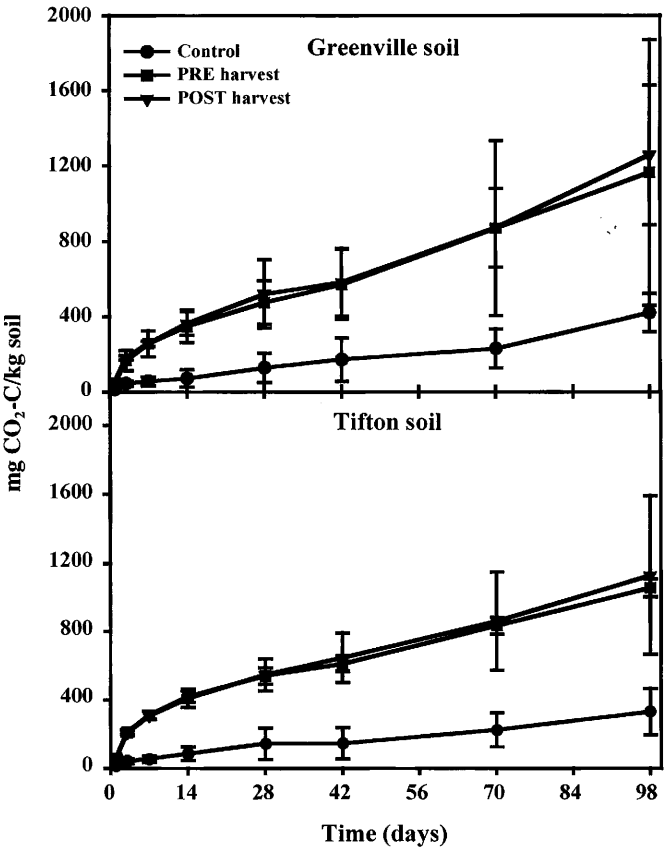

Fig. 1. Cumulative amounts of C evolved during a laboratory incubation from a Greenville and Tifton soil amended with two types of peanut residue. Error bars indicate standard deviations (n = 3).

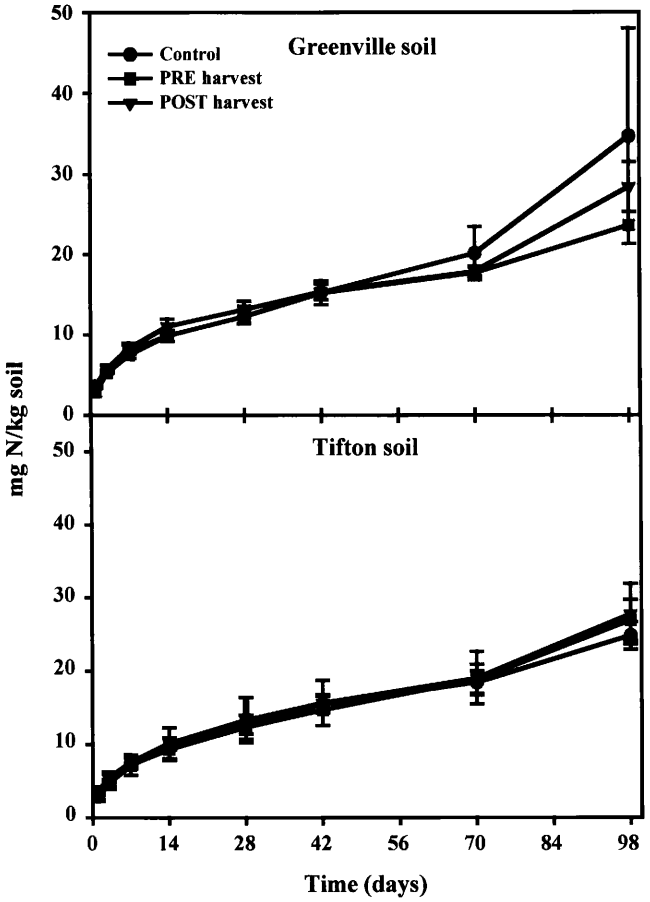

Fig. 2. Cumulative amounts of N mineralized during a laboratory incubation from a Greenville and Tifton soil amended with two types of peanut residue. Error bars indicate standard deviations (n = 3).

significance for relative N mineralized between the soils and residue additions may be attributed to the higher soil N content compared to the N content of the residues. Soil N content accounted for the majority of the total N pool present, and the amount of N added from the residues was not high enough to detect differences between soils receiving and not receiving residue. The C/N mineralized was affected by the addition of residue for both soils, but no differences were detected between types of residue (Table 3). Residue increased microbial respiration, but amounts of cumulative N mineralized remained constant, which increased the ratio of C/N mineralized for each soil. High ratios of C/N mineralized indicate an N limitation for decomposition (Wood and Edwards, 1992).

Further evidence for the lack of N mineralized from these residues is provided by a measure of relative residue N mineralized (Fig. 3). This variable distinguishes N mineralized from the residue as opposed to the relative N mineralized, which includes N present in the residue and soil. Differences observed between residues were not significant, but residue N mineralized provided evidence that N immobilization occurred when both residues were added to the Greenville soil (Fig. 3). Net N mineralization of residue N was observed in the Tifton soil, but no more than 10%. Apparently, decomposition of peanut residue does not result in significant amounts of net N mineralization under soil conditions encountered in this study, and may cause N immobilization.

Lack of net N mineralization from PRE harvest residue was unexpected. This type of residue was included in the study to demonstrate a higher level of N mineralization and illustrate the difference in N mineralization between residues, based on differences in residue quality that resulted from harvest (Table 2). Differences in residue quality were expected to translate into differential N mineralization. However, the observed differences in residue quality were not great enough to influence amounts of net N mineralized for either soil type.

Observed differences in residue quality, particularly the N content and C/N ratio, indicate that PRE harvest residue would mineralize only limited amounts of N, while the POST harvest material would immobilize N (Palm and Sanchez, 1991; Tisdale *et al.*, 1993). Although differences between amounts of N mineralized were not significant, POST harvest residue appeared to mineralize more than PRE harvest residue. Slight evidence for N immobilization in the Greenville soil was observed with the addition of both residues. The immobilization observed for this soil may be attributed to the high C/N ratio of this soil in combination with the low N contents of the residues (Tables 1 and 2).

Conclusions

Net N mineralization attributed to the addition of PRE or POST harvest residue was not observed in this study. The findings associated with POST harvest residue are more relevant to production agriculture because this is the form of residue remaining in the field after peanut

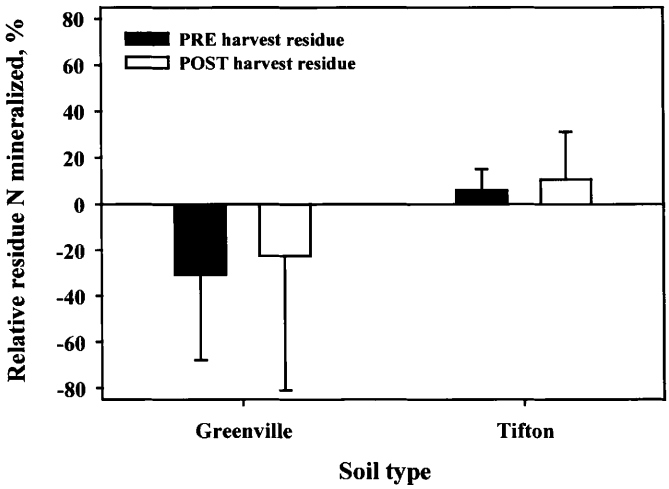

Fig. 3. Percentage of relative residue N mineralized from PRE and POST harvest residue from a Greenville and Tifton soil after 98 d of laboratory incubation. Error bars indicate standard deviations (n = 3).

harvest. The ability of POST harvest residues tested in this study to supply N to a subsequent crop appears minimal. However, maintaining residue in the field could help increase organic matter content over time, which can provide positive benefits for these soils. Future field research will confirm the low N contribution of peanut residue in typical southeastern peanut soils by utilizing a trap crop in conjunction with different N rates.

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