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Peanut Residue Carbon and Nitrogen Mineralization under Simulated Conventional and Conservation Tillage

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ABSTRACT

Residue management is an important aspect of cropping systems. Availability of plant residue N to succeeding crops depends on N mineralization rates. Cooperative Extension currently recommends 22 to 67 kg N ha^{-1} credit to subsequent crops following peanut (*Arachis hypogaea* L.), but these recommendations are not supported in the literature, nor do they specify if the credit is applied to a subsequent winter or spring crop. The objective of this study was to assess N release rates from residues of three peanut cultivars (NC V-11, GA 02-C, and ANorden) at two placements (surface and 10-cm deep) and two locations representing northern and southern extremes of U.S. commercial peanut production (North Carolina and Alabama). Litterbags containing the equivalent of 3.5 Mg ha^{-1} were placed in a completely randomized design at both locations with four replications and retrieved periodically up to 335 d after application. Results were fit to single or double exponential decay models. Based on empirical models, the N credit to a subsequent winter wheat (*Triticum aestivum* L.) crop was estimated at 14 to 19 kg N ha^{-1} when peanut residues were buried after harvest, and 19 to 24 kg N ha^{-1} when on the soil surface. When N credits were applied to a subsequent cotton (*Gossypium hirsutum* L.) crop, they were reduced to 2 to 9 kg N ha^{-1} (buried) and 6 to 10 kg N ha^{-1} (surface). Current recommendations are higher than the results obtained in this study suggest and warrant re-examination.

Core Ideas

- Recommendations of 22 to 67 kg N ha^{-1} credit after peanut are not substantiated.
- Decomposition of peanut residue in North Carolina and Alabama fit double exponential decay equations.
- Nitrogen credit to wheat was 14 to 24 kg N ha^{-1}, but to cotton was 2 to 10 kg N ha^{-1}.
- Nitrogen credits differ by location and placement of residue.
- Nitrogen credits should be specified to which crop they are applied.

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Peanut is an important agronomic crop in the southeastern United States. It is sometimes followed by winter wheat as a cover or cash crop, and commonly rotated with cotton the following spring as a peanut–winter fallow–cotton rotation. Double cropping winter wheat as a cash crop in a peanut–winter wheat–cotton rotation is not common because wheat harvest delays cotton planting. Conservation tillage of peanut is increasingly common in the region. The percent of residue remaining after planting peanut has increased from 3.9% in 1999, to 13.7% in 2004, and 16.7% in 2013 (USDA, 2016). Cultivation for weed control decreased from 65.4% of all planted peanut land area in the United States in 1999 to 34% in 2004. The trend toward reduced tillage is due to the adoption of conservation tillage practices among peanut producers. The percentage of total planted peanut land area under no-till and mulch-till in the United States increased from 4.4 to 19.9% from 1999 to 2004, and then to 25.3% in 2013 (USDA, 2016).

Availability of plant residue N to succeeding crops is dependent on synchrony of N release and N uptake by crops and therefore on residue N mineralization rates (Bruulsema and Christie, 1987). Throughout the U.S. peanut-growing region, University Extension recommends a N credit ranging from 22 to 67 kg N ha^{-1} to a subsequent crop following peanut (Caddel et al., 2006; Buntin et al., 2007; Mitchell and Phillips, 2010; Jones et al., 2011; Maguire and Heckendorn, 2011; Wright et al., 2011; VDCR, 2014; Crozier et al., 2016), but the synchronicity of N from peanut residues to subsequent crops is unknown. Furthermore, N credit recommendations following peanut typically do not specify if those credits should be applied to a subsequent winter or spring crop. A laboratory incubation study showed that minimal N from post-harvest peanut residue was available for a subsequent crop on Greenville fine sandy loam (Rhodic Kandiudults) and Tifton loamy sand (Plinthic Kandiudults) soils (Balkcom et al., 2004). Balkcom et al. (2007) found no difference in growth or N content of rye (*Secale cereale* L.) after peanut with or without peanut residue on a Dothan sandy loam (fine-loamy, kaolinitic, thermic Plinthic Kandiudult).

There are many factors that impact decomposition. Litter quality and environmental factors, such as moisture,

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Abbreviations: ADF, acid detergent fiber; NDF, neutral detergent fiber; SOC, soil organic carbon; UCP, Upper Coastal Plain Experiment Station, Rocky Mount, NC; WGS, Wiregrass Research and Extension Center, Headland, Henry County, AL.

temperature, and soil nutrient status, can have significant impacts decomposition (Berg and Staaf, 1980; Berg and Tamm, 1991; Vitousek et al., 1994). Litter quality can be affected by nutrient use efficiency, water use efficiency (Vitousek et al., 1994), soil nutrient status, and soil pH (Sanger et al., 1996). Isaac et al. (2004) found that the same species decomposed at different rates depending on environment. Tillage also impacts mineralization rates of crop residues. Incorporated residues decompose faster than surface-placed residues (Mulvaney et al., 2010) because of increased aerobic microbial activity (Doran, 1980), resulting in accelerated soil organic matter oxidation (Tisdall and Oades, 1982) and C and N mineralization (Doran, 1987; Franzluebbers et al., 1995; Franzluebbers and Arshad, 1997).

The N mineralization rates from peanut residue in the northern and southern peanut growing regions of the United States may be expected to differ. Information on N mineralization rates from peanut residue will provide information on availability to subsequent crops. The objective of this experiment was to assess mass loss and C and N mineralization rates from three peanut cultivars at two locations under simulated conservation and conventional tillage systems.

MATERIALS AND METHODS

A field decomposition study was set up at the Wiregrass Research and Extension Center (WGS), Henry County, Alabama (31°21′05″ N, 85°20′10″ W, 117 m elevation) on a Dothan fine sandy loam 0 to 2% slope (pH 6.1, 1.11% C, 0.054% N), and at the Upper Coastal Plain Experiment Station (UCP), Rocky Mount, Edgecombe County, North Carolina (35°56′07″ N, 77°46′31″ W, 34 m elevation) on a Norfolk loamy sand, 2 to 6% slope (fine-loamy, kaolinitic, thermic Typic Kandiudult, pH 6.4). Three peanut cultivars, ANorden (runner type) (Gorbet, 2007), NC V-11 (Virginia type) (Wynne et al., 1991), and GA 02-C (runner type) (Branch, 2003), were grown using best management practices at each research site to supply residue.

Peanut residues were subsampled and oven dried at 60°C for 48 h for dry matter determination, ground to pass through a 1 mm screen, and analyzed for neutral detergent fiber (NDF) and acid detergent fiber (ADF), permanganate lignin and acid-insoluble ash (Goering and Soest, 1970). Hemicellulose content was estimated by the difference between NDF and ADF. Cellulose was estimated by subtracting lignin and acid-insoluble ash from ADF.

Nylon mesh bags measuring 20 by 10 cm with 50 to 60 μm openings were used to determine biomass decomposition and N release patterns of peanut residues in the field (Wieder and Lang, 1982; Vreeken-Buijs and Brussaard, 1996; Mulvaney et al., 2010). The use of micromesh litterbags excluded mesofauna (Bradford et al., 2002). Residue, consisting of leaves, stems, and very little root (approximately 5 cm of taproot as with typical commercial peanut digging operations), was collected post-harvest, air dried, and packed into the nylon mesh bags to represent 3.5 Mg ha^{-1} (7 g bag^{-1}). The samples of cultivar NC V-11 at UCP contained increased moisture due to recent rainfall and were therefore placed at a rate of 2.5 Mg ha^{-1} on an oven-dry basis, though efforts were made to air dry the samples as quickly as possible.

Litterbags containing residue were placed on the soil surface (to simulate conservation tillage) and buried at 10-cm depth (to simulate discing during conventional tillage). The treatments were arranged in a completely randomized design with four replicates. In total, 24 bags were retrieved from each location during each sampling period. Litterbags were deployed on 14 Oct. 2004 at UCP and on 5 Oct. 2004 at WGS. At WGS, litterbags were retrieved 0, 4, 8, 15, 29, 59, 114, 175, 225, and 339 d after application. At UCP, litterbags were retrieved 0, 4, 7, 14, 21, 49, 112, 175, 224, and 335 d after application. The content of each bag were dried at 60°C for 3 d, weighed for dry matter determination, ground to pass a 16 mesh sieve and analyzed for total C and N by dry combustion with a LECO TruSpec CN (Leco Corp, St. Joseph, MI). Sample contamination by soil was accounted for by converting all data to an ash-free dry weight basis by ashing 1.0 g of the samples in muffle furnace at 400°C for 12 h and determining the ash free dry weight (Cochran, 1991). Daily precipitation and temperature data at both locations are shown in Fig. 1.

Mass and nutrient loss data were described by double exponential decay equations of the form $Y = Ae^{-k_1 t} + Be^{-k_2 t}$, where Y = mass or nutrient loss, A = the labile portion, B = the recalcitrant portion, k_1 and k_2 are rate constants fitted to the data, and t = time in days after application (Wieder and Lang, 1982). Wieder and Lang (1982) define B as (1-A) with the implication that the amount contained within the labile pool is represented by A, and the recalcitrant pool by B. This conveniently allows an empirical calculation of the total amount (or, alternatively, the percentage) of biomass and nutrients contained with the labile (A) and recalcitrant (B) pools. When k_2 is not significant, the models collapse into single exponential decay equations.

The models were used to estimate C and N mineralization during subsequent cropping seasons. Although mineralization and mass loss estimates for any subsequent cropping system can be generated using the empirically derived equations described above, we have applied mineralization estimates to two crops that commonly follow peanut in the region, winter wheat (*Triticum aestivum* L.) and cotton, to exemplify mineralization during a subsequent winter and spring crop. Mineralization during a subsequent winter wheat season was calculated from 30 October to 15 June at UCP and from 30 October to 1 June at WGS (NASS, 1997). Mineralization estimates during a subsequent cotton crop (peanut–winter fallow–cotton) was calculated from 15 May to 15 October at UCP and from 7 May to 1 October at WGS.

Statistical significance of treatments was determined using PROC MIXED (SAS Institute, 2016) at the 95% confidence level. Full models and corresponding reduced models (e.g., analyses by location, depth, etc.) considered Location, Cultivar, Depth, and their interactions as fixed effects. Time(Location), Cultivar × Time(Location), and Depth × Time(Location) were also considered fixed effects. Replication and replication interactions with main effects were considered random effects. Repeated measures on Time specified an autoregressive Type I error structure. Because the cultivar NC V-11 at UCP was deployed at a lower rate than the other cultivars, this cultivar at this location was excluded from ANOVA analyses. Least squares estimates for nonlinear models were determined using four parameter double exponential decay models (Systat, 2008).

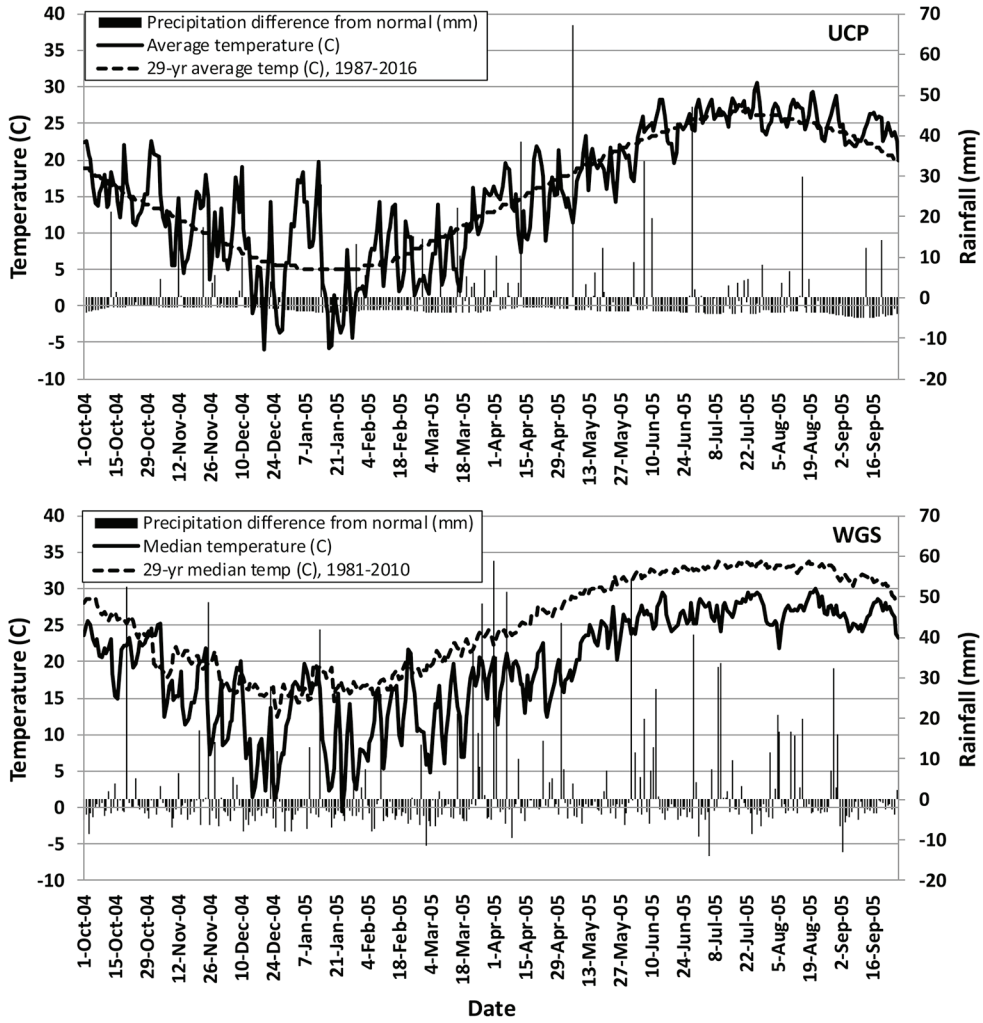

Fig. 1. Daily temperature and precipitation at the Wiregrass Research and Extension Center (WGS, bottom) in Henry County, Alabama and the Upper Coastal Plain Experiment Station (UCP, top), Rocky Mount, Edgecombe County, North Carolina during the study period. WGS temperatures are medians based on daily maximums and minimums; UCP temperatures are averages.

RESULTS AND DISCUSSION

Climate

During the study period, the climate at UCP was typically in the 29-yr normal range, while at WGS the study period was typically cooler than normal (Fig. 1) though still warmer than UCP. Heavy rainfall events were observed in late March and early April at WGS, with sporadic heavy rainfall being more characteristic of WGS than UCP.

Decay Rates

A note is warranted regarding analyses of decay rates. Decay rates may be placed on a normalized basis (that is, as a percentage of original mass, C, or N at Time 0) or on a mass per unit area basis. Although the two bases may appear similar, they are not the same and result in differing ANOVA (Table 1) and decay constants. For example, when the dependent variable N was placed on a normalized basis, cultivar was not significant ($P = 0.4212$) but when N was placed on a kg ha^{-1} basis, cultivar was significant ($P = 0.0056$). The differences are mainly explained by the fact that normalized data are forced to pass through the same intercept ($Y = 100\%$), but small variations in weight of samples at Time 0 result in large differences on a kg ha^{-1} basis. The reason there are small variations in sample weight at Time 0 is due to the fact that truly replicated Time 0 samples were deployed and retrieved immediately after deployment, instead of a "grab sample" taken from the bulk residue meant to serve as a proxy for truly replicated Time 0 samples. Variations in the Y intercept are consequential when conducting ANOVA and describing decay rates, particularly during the labile phase of decomposition. Therefore, normalized and mass per area data are described differently, and sometimes significantly so, though the data may appear similar at first observation. Reporting N on a normalized basis may be useful in cases where immobilization may be expected because values in excess of 100% clearly indicate net N immobilization (Tian et al., 1992, Balkcom et al., 2004). Because we were mainly interested in the amount of C and N mineralized from peanut residue during subsequent cropping seasons, only data on a mass per area basis are discussed here.

The highest order interactions (depth × location × cultivar) were not significant for any dependent variable and was removed from the model. In the reduced model, location was a significant factor for C and N mineralization (Table 1). Location × Cultivar interactions were not significant for any dependent variable. Location × Depth interactions were significant for all dependent variables except C/N ratio.

The use of micromesh litterbags has been shown to decrease rates of decomposition compared to litterbags with larger openings due to the effects of meso- and macro-fauna, including microarthropods (Vreeken-Buijs and Brussaard, 1996; Bradford et al., 2002). Since litterbags with 50 to 60 μm openings were used in this study, decomposition and mineralization rates presented here should be considered slower than would be represented under true field conditions. Wieder and Lang (1982) also noted that decomposition rates may be underestimated using litterbags compared to field conditions.

Mass Loss

Mass loss was significantly greater when residues were buried than when surface-placed at both locations (Fig. 2). Cultivars were not significantly different at either site when ANOVA were conducted by site ($P \geq 0.287$), keeping in mind that the NC V-11 at UCP was dropped from ANOVA analyses. When buried, residues typically lost 50% of their mass within 25 d regardless of location, but when surface-placed, residues lost approximately 50% of their original mass around 75 d after placement (Fig. 2). Tillage alteration of soil enzymatic and microbial activity due to changes in soil moisture, aeration, temperature regimes (Doran, 1980) play a role in reduced mineralization of surface compared to buried residues found in

Table 1. Analysis of variance for fixed effects on C, biomass, and N remaining on a mass area^{-1} and a % of initial applied bases. C/N ratio is unitless. DFn = numerator degrees of freedom; DFd = denominator degrees of freedom.

Fixed effect	DFn	DFd	*F* value	*P* value	DFd	*F* value	*P* value
		mass area^{-1} basis			% of initial basis		
				C remaining			
Location	1	51.5	21.95	<0.0001	43.8	38.75	<0.0001
Cultivar	2	41.5	0.60	0.5557	7.4	1.37	0.3112
Location × Cultivar	1	50.0	0.52	0.4760	44.5	0.31	0.5802
Depth	1	11.9	18.42	0.0011	15.9	20.20	0.0004
Depth × Location	1	65.1	20.35	<0.0001	68.4	22.36	<0.0001
Depth × Cultivar	2	54.5	2.58	0.0853	57.0	2.53	0.0883
Time(Location)	18	45.9	24.91	<0.0001	38.7	24.17	<0.0001
Cultivar × Time(Location)	27	41.8	1.00	0.4944	36.8	1.05	0.4346
Depth × Time(Location)	18	55.5	6.92	<0.0001	58.3	6.52	<0.0001
				Biomass remaining			
Location	1	89.0	2.80	0.0978	87.2	25.25	<0.0001
Cultivar	2	79.4	0.08	0.9209	63.0	7.18	0.0016
Location × Cultivar	1	81.7	0.03	0.8682	81.4	1.49	0.2253
Depth	1	2.9	33.00	0.0120	14.4	44.41	<0.0001
Depth × Location	1	72.5	14.09	0.0003	76.7	19.46	<0.0001
Depth × Cultivar	2	68.3	3.12	0.0505	1.5	1.11	0.5050
Time(Location)	18	87.4	14.54	<0.0001	86.0	14.31	<0.0001
Cultivar × Time(Location)	27	77.3	1.03	0.4412	77.7	1.07	0.3905
Depth × Time(Location)	18	66.9	6.68	<0.0001	70.1	6.47	<0.0001
				N remaining			
Location	1	65.5	22.32	<0.0001	80.2	27.64	<0.0001
Cultivar	2	54.4	5.71	0.0056	53.1	0.88	0.4212
Location × Cultivar	1	94.8	0.23	0.6351	99.3	0.01	0.9113
Depth	1	62.2	4.31	0.0419	4.3	1.85	0.2400
Depth × Location	1	72.2	9.73	0.0026	84.7	10.05	0.0021
Depth × Cultivar	2	58.5	0.38	0.6882	57.0	0.34	0.7165
Time(Location)	18	55.6	12.59	<0.0001	61.2	12.24	<0.0001
Cultivar × Time(Location)	27	60.7	1.24	0.2407	60.3	1.01	0.4665
Depth × Time(Location)	18	61.5	4.90	<0.0001	63.8	4.95	<0.0001
			C/N ratio				
Location	1	5.9	1.45	0.2744			
Cultivar	2	3.0	39.40	0.0067			
Location × Cultivar	1	6.2	4.03	0.0895			
Depth	1	33.6	51.01	<0.0001			
Depth × Location	1	58.7	3.40	0.0703			
Depth × Cultivar	2	32.1	6.28	0.0050			
Time(Location)	18	4.0	11.07	0.0159			
Cultivar × Time(Location)	27	3.6	1.37	0.4311			
Depth × Time(Location)	18	33.4	2.18	0.0254			

this and other studies (Cochran, 1991; Mulvaney et al., 2010; Lynch et al., 2016).

Based on fitting double exponential decay equations to the data, the amount of peanut residue biomass at subsequent wheat planting was between 1.73 and 1.98 Mg ha^{-1} when buried and 2.51 and 2.94 Mg ha^{-1} when left on the surface, regardless of location when placed at 3.5 Mg ha^{-1} after harvest (Table 2). At subsequent cotton planting, peanut residue biomass was greater at UCP compared to WGS regardless of placement (averaging 44% more when buried and 29% more when surface applied), an expected result due to cooler climatic conditions at UCP compared to WGS. Double exponential decay models show that decay rates of recalcitrant portions (k_2) were lower than those of labile portions (k_1). Furthermore, the decay rate constant k_1 was affected to a greater extent by placement than was k_2, implying that the labile portion (A) of residues were more greatly impacted by placement than recalcitrant portions (B) (Table 2).

Carbon Mineralization

Carbon mineralization results closely mirrored those of mass loss, a result not surprising since mass, which is primarily C, is microbially decomposed and respired as CO_2, although cultivar differences were significant at WGS (P = 0.0396). When peanut residues after harvest were equivalent to 3.5 Mg ha^{-1}, peanut residue C mineralized during the wheat season was lower at UCP than at WGS: between 0.24 and 0.31 Mg C ha^{-1} at UCP compared to 0.41 and 0.42 Mg C ha^{-1} at WGS (Table 3). Similar trends were observed during the cotton season. Reduced C mineralization rates in UCP compared to WGS did not appear to be related to fiber quality differences between the two sites within a cultivar. Hemicellulose, lignin, and C/N ratios were similar among sites for a given cultivar (Fig. 3). Although ANorden had significantly lower ADF and acid insoluble ash (which may be considered relatively recalcitrant fractions) at UCP compared to WGS, it also had lower NDF (which may be considered relatively labile) at UCP compared to WGS. The ADF, acid insoluble ash, and NDF fractions were not significantly different between locations for the cultivar GA 02-C, although the cellulose content was significantly lower at WGS compared to UCP. The data suggest that the cooler climatic conditions in UCP compared to WGS were more likely responsible for reduced mineralization rates at UCP, rather than differences in fiber quality.

As with mass models, C decay rate constant values k_1 were larger for buried residue than with surface residue but the k_2 values were not. Residue labile C was more affected by burying residue than the recalcitrant C pool, as evidenced by a larger change in k_1 than k_2 when buried compared to surface-placed (Table 3). After 1 yr of decay, differences between surface and buried residues were <0.2 Mg C ha^{-1} yr^{-1} regardless of location (Fig. 4). Since this portion of the C pool is defined as recalcitrant, it may appear that this portion accumulates as soil organic matter. However, the significant k_2 values (Table 3) and extrapolation of the negative slopes (Fig. 4) for the recalcitrant C pool indicated that C mineralization was significant after 1 yr, and therefore long-term soil organic matter accumulation due to peanut residue addition seems unlikely regardless of placement. Studies conducted on Tifton and Greenville soils showed that both pre- and post-harvest peanut residue C was mineralized at the same rate regardless of soil type and found no differences in C turnover for pre- and post-harvest residue on either soil (Balkcom et al., 2004). Results of the current study in conjunction with previous studies suggest that peanut

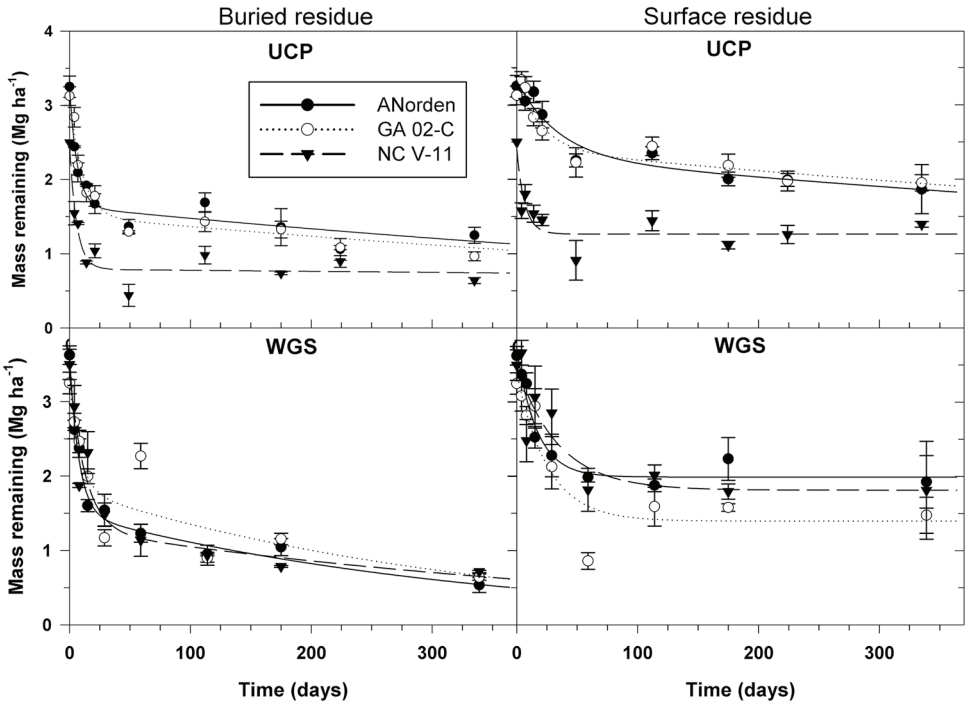

Fig. 2. Mass loss from three peanut residue cultivars at two locations under conservation and conventional tillage on a per area basis. Error bars represent standard errors of the mean. Bottom figures represent the Wiregrass Research and Extension Center (WGS), Alabama site and top figures represent the Upper Coastal Plain Experiment Station (UCP), North Carolina site. Left-hand figures represent buried residues and right-hand figures represent surface-placed residues.

Table 2. Equations regressed on time (days) for mass (Mg ha^{-1}) loss from three cultivars of peanut residue incubated in litter bags under field conditions. Double exponential decay equations are described as $Y = Ae^{-k_1 t} + Be^{-k_2 t}$, where Y = mass remaining, A = the labile portion, B = the recalcitrant portion, k_1 and k_2 are rate constants fitted to the data, and t = time in days after application. All residues were applied at 3.5 Mg ha^{-1} except NC V-11 at UCP, which was applied at 2.5 Mg ha^{-1}.

Parameter/Location/Cultivar	Equation	$P > F$†	$R^2_{adj.}$	S_{yx}‡	Mass remaining at planting of: Wheat	Cotton
Mass buried (Mg ha^{-1}) UCP						
ANorden	$Y = 1.59e^{-0.1560X} + 1.63e^{-0.0010X}$	0.0002	0.931	0.2	1.76	1.32
GA 02-C	$Y = 1.68e^{-0.0990X} + 1.51e^{-0.0010X}$	<0.0001	0.958	0.1	1.87	1.22
NCV-11	$Y = 1.68e^{-0.1660X} + 0.79e^{-0.0002X}$	0.0012	0.877	0.2	0.93	0.76
Mass surface (Mg ha^{-1}) UCP						
ANorden	$Y = 1.02e^{-0.029X} + 2.30e^{-0.0006X}$	0.0003	0.926	0.2	2.94	2.03
GA 02-C	$Y = 0.94e^{-0.048X} + 2.40e^{-0.0006X}$	0.0011	0.879	0.2	2.84	2.11
NCV-11	$Y = 1.14e^{-0.149X} + 1.26$	0.0201	0.676	0.2	1.38	1.26
Mass buried (Mg ha^{-1}) WGS						
ANorden	$Y = 2.10e^{-0.130X} + 1.50e^{-0.003X}$	<0.0001	0.977	0.1	1.73	0.81
GA 02-C	$Y = 1.47e^{-0.120X} + 1.82e^{-0.003X}$	0.0182	0.752	0.5	1.98	0.99
NCV-11	$Y = 2.13e^{-0.077X} + 1.28e^{-0.002X}$	0.0020	0.900	0.3	1.91	0.85
Mass surface (Mg ha^{-1}) WGS						
ANorden	$Y = 1.72e^{-0.06X} + 1.99$	0.0007	0.933	0.2	2.69	1.99
GA 02-C	$Y = 2.00e^{-0.039X} + 1.40$	0.0144	0.774	0.4	2.51	1.40
NCV-11	$Y = 1.68e^{-0.029X} + 1.81$	0.0267	0.710	0.4	2.90	1.81

† Significance of regression.

‡ Standard error of the estimate of Y on X.

Table 3. Equations regressed on time (days) for C (Mg ha^{-1}) mineralization from three cultivars of peanut residue incubated in litter bags under field conditions. Double exponential decay equations are described as $Y = Ae^{-k_1 t} + Be^{-k_2 t}$, where Y = carbon remaining, A = the labile portion, B = the recalcitrant portion, k_1 and k_2 are rate constants fitted to the data, and t = time in days after application. All residues were applied at 3.5 Mg ha^{-1} except NC V-11 at UCP, which was applied at 2.5 Mg ha^{-1}. For estimates of the amount of C mineralized during subsequent cropping seasons, peanut harvest was assumed to be 15 October at both locations. UCP wheat season was assumed to be 30 October to 15 June; UCP cotton was 15 May to 15 October. WGS wheat season was assumed to be 30 October to 1 June; WGS cotton was 7 May to 1 October.

Parameter/Location/Cultivar	Equation	$P > F$†	$R^2_{adj.}$	S_{yx}‡	Carbon mineralized during season: Wheat	Cotton
C buried (Mg ha^{-1}) UCP						
ANorden	$Y = 0.608e^{-0.1560X} + 0.698e^{-0.0020X}$	0.0016	0.862	0.1	0.31	0.13
GA 02-C	$Y = 0.663e^{-0.0970X} + 0.622e^{-0.0020X}$	0.0002	0.930	0.1	0.24	0.12
NCV-11	$Y = 0.717e^{-0.1500X} + 0.279e^{-0.0005X}$	0.0008	0.892	0.1	0.11	0.02
C surface (Mg ha^{-1}) UCP						
ANorden	$Y = 0.459e^{-0.0330X} + 0.904e^{-0.0020X}$	0.0009	0.889	0.1	0.60	0.17
GA 02-C	$Y = 0.339e^{-0.0560X} + 1.005e^{-0.0030X}$	0.0013	0.874	0.1	0.62	0.21
NCV-11	$Y = 0.558e^{-0.0860X} + 0.381e^{-0.0010X}$	0.0046	0.805	0.1	0.23	0.05
C buried (Mg ha^{-1}) WGS						
ANorden	$Y = 0.86e^{-0.103X} + 0.495e^{-0.003X}$	0.0004	0.947	0.1	0.41	0.10
GA 02-C	$Y = 0.69e^{-0.132X} + 0.597e^{-0.004X}$	0.0051	0.852	0.1	0.42	0.12
NCV-11	$Y = 0.81e^{-0.102X} + 0.527e^{-0.003X}$	0.0022	0.896	0.1	0.41	0.10
C surface (Mg ha^{-1}) WGS						
ANorden	$Y = 0.928e^{-0.0490X} + 0.542e^{-0.0030X}$	0.0007	0.895	0.2	0.69	0.10
GA 02-C	$Y = 1.055e^{-0.0330X} + 0.243e^{-0.0010X}$	0.0001	0.946	0.1	0.69	0.03
NCV-11	$Y = 0.909e^{-0.0290X} + 0.505e^{-0.0020X}$	0.0020	0.852	0.2	0.76	0.09

† Significance of regression.

‡ Standard error of the estimate of Y on X.

residue is not produced in sufficient quantities and is mineralized too quickly to significantly contribute to soil organic carbon (SOC).

Nitrogen Mineralization

Cultivar was a significant factor for N mineralization at WGS ($P = 0.0198$), but not at UCP ($P = 0.1647$) after removing NC V-11 at UCP from the analysis. Nitrogen mineralization data were more variable than mass loss or C mineralization data (Fig. 5), resulting in lower R^2_{adj} values for the associated double exponential decay equations (Table 4). Nitrogen mineralized from peanut residue during subsequent wheat and cotton growing seasons in Table 4 is based on these equations. Accepting only those equations with an R^2_{adj} value > 0.80, it can be estimated that the N mineralized from buried peanut residue in UCP to a subsequent winter wheat crop was approximately 19.3 kg N ha^{-1} (Table 4). Nitrogen mineralized during a subsequent cotton crop was approximately 8.9 kg N ha^{-1}. None of the models for surface residue at UCP met the criteria of R^2_{adj} value > 0.80, but N mineralized during wheat production at UCP was approximately 19 to 21 kg N ha^{-1} when placed at 3.5 Mg peanut residue ha^{-1}, and 10 to 11 kg N ha^{-1} to a subsequent cotton crop.

At WGS, using the same R^2_{adj} value > 0.80 criteria, the N mineralized during a subsequent wheat crop was approximately 14 kg N ha^{-1} when buried compared to 24 kg N ha^{-1} when surface-placed. Nitrogen mineralized during a subsequent cotton crop was 2.2 to 5.6 kg N ha^{-1} when buried and approximately 6 kg N ha^{-1} when surface-placed at WGS.

The initial amount of peanut residue load is important to consider when calculating N mineralization, as seen by the lower credits applied to residue from NC V-11 at UCP compared to ANorden and GA 02-C at the same site. In that case, NC V-11 was applied at 2.5 Mg ha^{-1} (1.0 Mg ha^{-1} less than the other residues), which resulted in lower N mineralization during subsequent crop production compared to residues applied at 3.5 Mg ha^{-1} (Table 4).

Based on the double exponential decay equations modeled in this study, a potential N credit to a subsequent wheat crop was estimated at 14 to 19 kg N ha^{-1} when peanut residues were buried after harvest, and 19 to 24 kg N ha^{-1} when left on the soil surface. When applied to a subsequent cotton crop (peanut–winter fallow–cotton), potential N credits were reduced to 2 to 9 kg N ha^{-1} (buried) and 6 to 10 kg N ha^{-1} (surface). Surface residues mineralized more N (on a kg ha^{-1} basis) over a subsequent cropping season compared to buried residues because there was more total N remaining in surface compared to buried residues, resulting in more total potentially mineralizable N over subsequent cropping seasons (Doran, 1987). It is important that Cooperative Extension recommendations regarding N credits to subsequent crops specify if those credits are applied to a subsequent winter crop or a subsequent spring crop–something that current recommendations typically do not clarify (Caddel et al., 2006; Buntin et al., 2007; Mitchell and Phillips, 2010; Maguire and Heckendorn, 2011; Wright et al., 2011; VDCR, 2014).

Data from the present study corroborate those previously reported in the literature (Mubarak et al., 2002; Balkcom et al., 2004, 2007; Meso et al., 2007) and suggest that the

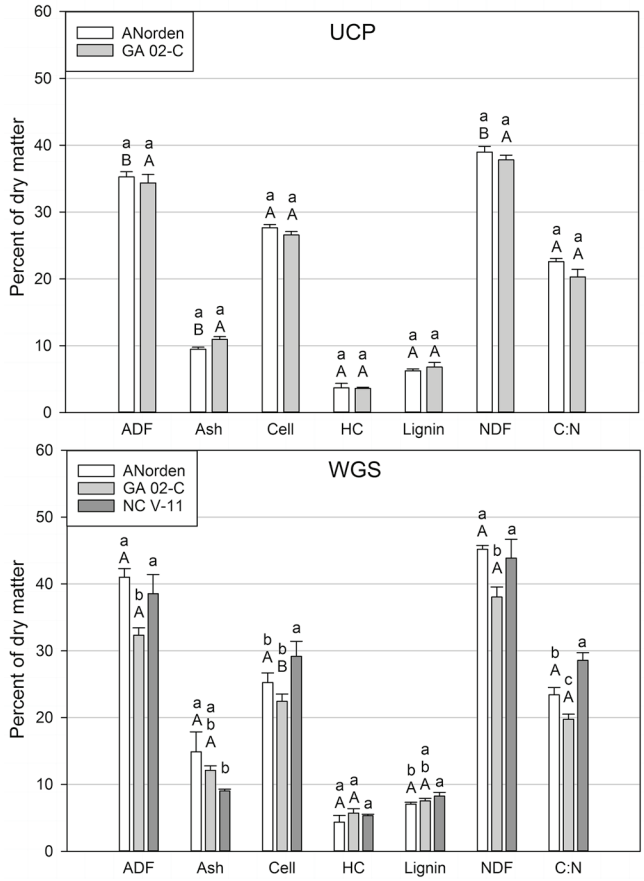

Fig. 3. Fiber analysis of peanut cultivars grown and decomposed at the Wiregrass Research and Extension Center (WGS, bottom) in Headland, AL, and at the Upper Coastal Plain Experiment Station (UCP, top), Rocky Mount, Edgecombe County, North Carolina. Error bars represent standard errors of the mean. Within location and fiber component, different lowercase letters represent significantly different cultivar effects at $P < 0.05$ (LSD). Within cultivar and fiber component, different uppercase letters represent significantly different location effects ($P < 0.05$, LSD). ADF = acid detergent fiber; Ash = acid insoluble ash; Cell = cellulose; HC = hemicellulose; Lignin is permanganate lignin; NDF = neutral detergent fiber. C/N data are ratios, and are not shown as a concentration of dry matter. Data for NC V-11 at UCP were not available.

current Extension recommendations for N credits of 22 to 67 kg N ha^{-1} following peanut (Caddel et al., 2006; Buntin et al., 2007; Mitchell and Phillips, 2010; Jones et al., 2011; Maguire and Heckendorn, 2011; Wright et al., 2011; VDCR, 2014; Crozier et al., 2016) are overestimated. In addition, not all of the N released from peanut residue would be available to subsequent crops because of N cycling mechanisms, including immobilization and leaching (Knops et al., 2002), particularly on typical peanut-producing sandy soils with low cation exchange capacity. Also, the exclusion of mesofauna by litterbags used in this study implies that mineralization rates found in this study underestimated mineralization rates that would be observed under typical field conditions (Vreeken-Buijs and Brussaard, 1996; Bradford et al., 2002). That is, the rapid mineralization of labile residue N was underestimated compared to field conditions, such that recalcitrant N mineralized during subsequent cropping seasons would likely be less than that reported here. Therefore, the potential N credits

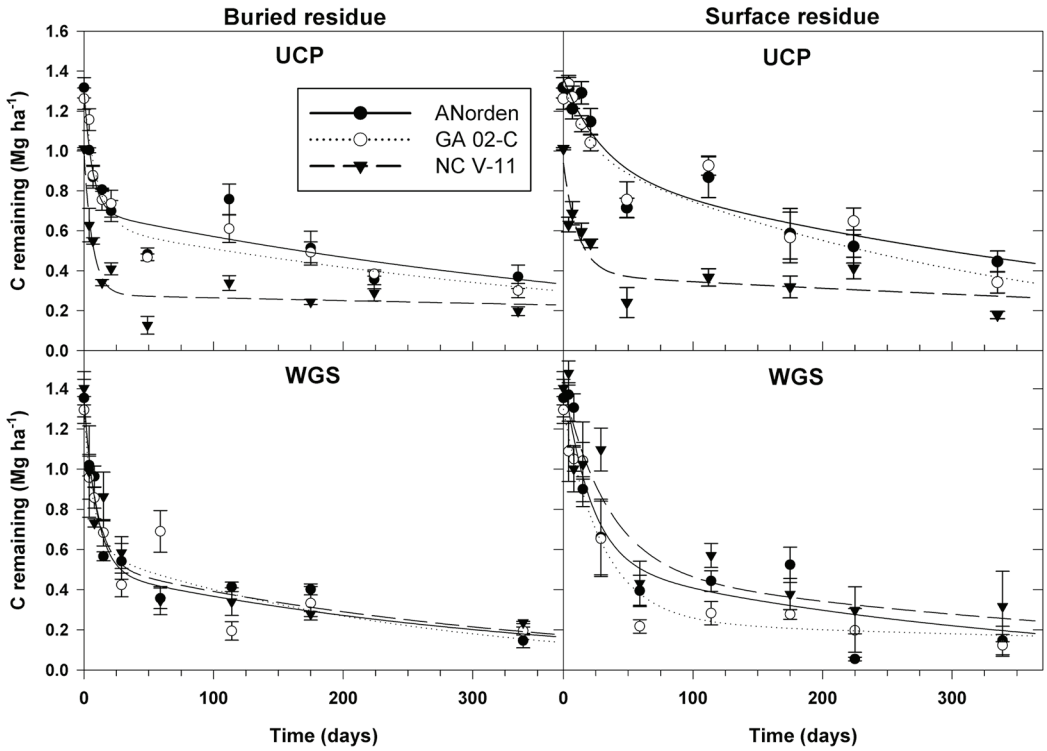

Fig. 4. Carbon loss from three peanut residue cultivars at two locations under conservation and conventional tillage on a per area basis. Error bars represent standard errors of the mean. Bottom figures represent the Wiregrass Research and Extension Center (WGS), Alabama site and top figures represent the Upper Coastal Plain Experiment Station (UCP), North Carolina site. Left-hand figures represent buried residues and right-hand figures represent surface-placed residues.

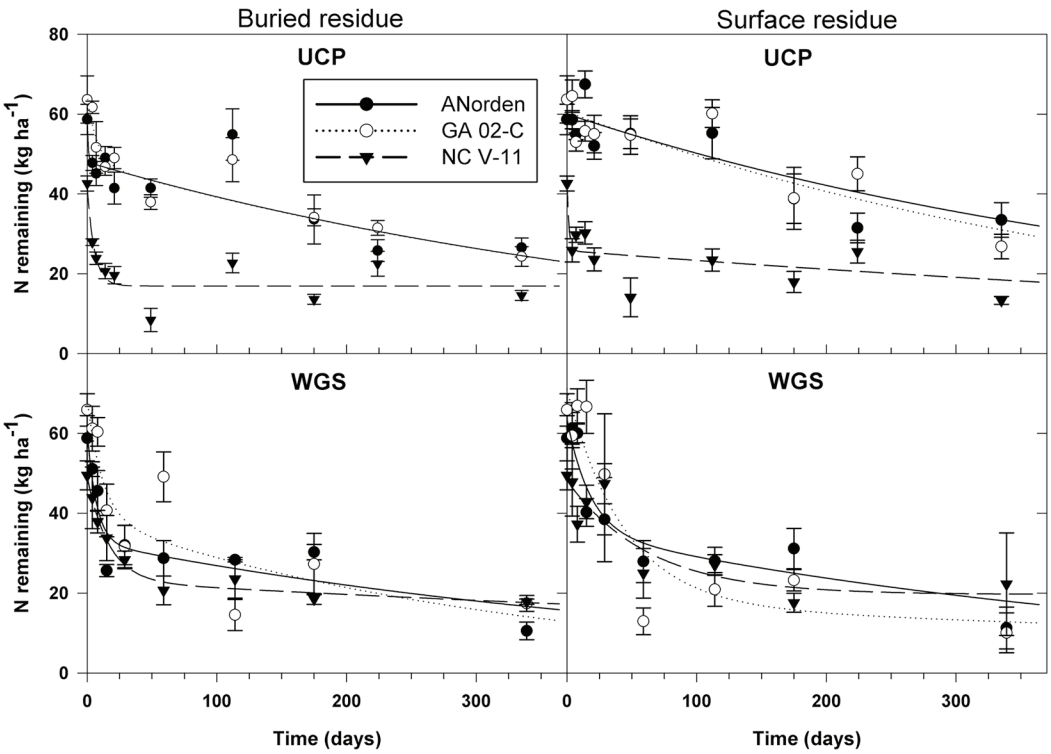

Fig. 5. Nitrogen loss from three peanut residue cultivars at two locations under conservation and conventional tillage on a per area basis. Error bars represent standard errors of the mean. Bottom figures represent the Wiregrass Research and Extension Center (WGS), Alabama, site and top figures represent the Upper Coastal Plain Experiment Station (UCP), North Carolina site. Left-hand figures represent buried residues and right-hand figures represent surface-placed residues.

Table 4. Equations regressed on time (days) for N (kg ha^{-1}) mineralization from three cultivars of peanut residue incubated in litter bags under field conditions. Double exponential decay equations are described as $Y = Ae^{-k_1 t} + Be^{-k_2 t}$, where Y = nitrogen remaining, A = the labile portion, B = the recalcitrant portion, k_1 and k_2 are rate constants fitted to the data, and t = time in days after application. All residues were applied at 3.5 Mg ha^{-1} except NC V-11 at UCP, which was applied at 2.5 Mg ha^{-1}. For estimates of the amount of C mineralized during subsequent cropping seasons, peanut harvest was assumed to be 15 October at both locations. UCP wheat season was assumed to be 30 October to 15 June; UCP cotton was 15 May to 15 October. WGS wheat season was assumed to be 30 October to 1 June; WGS cotton was 7 May to 1 October.

Parameter/Location/Cultivar	Equation	$P > F$†	$R^2_{adj.}$	S_{yx}‡	Nitrogen mineralized during season: Wheat	Cotton
N buried (kg ha^{-1}) UCP						
ANorden	$Y = 10.7e^{-1.3200X} + 48.0e^{-0.0020X}$	0.0491	0.559	7.4	17.1	9.0
GA 02-C	$Y = 17.1e^{-0.1330X} + 47.8e^{-0.0020X}$	0.0028	0.835	5.2	19.3	8.9
NCV-11	$Y = 25.2e^{-0.1800X} + 16.9$	0.0184	0.686	5.2	1.7	0.0
N surface (kg ha^{-1}) UCP						
ANorden	$Y = 54.2e^{-0.0020X} + 5.8$	0.0158	0.702	6.5	19.3	10.1
GA 02-C	$Y = 29.0e^{-0.0020X} + 31.6e^{-0.0020X}$	0.0272	0.641	7.0	21.5	11.3
NCV-11	$Y = 16.8e^{-0.6380X} + 25.8e^{-0.0010X}$	0.0541	0.544	5.8	5.2	3.2
N buried (kg ha^{-1}) WGS						
ANorden	$Y = 27.7e^{-0.1400X} + 32.8e^{-0.0020X}$	0.0104	0.803	0.2	14.5	5.6
GA 02-C	$Y = 29.6e^{-0.0840X} + 39.0e^{-0.0030X}$	0.0327	0.684	0.1	26.1	7.5
NCV-11	$Y = 26.3e^{-0.0600X} + 23.0e^{-0.0008X}$	<0.0001	0.976	0.2	14.3	2.2
N surface (kg ha^{-1}) WGS						
ANorden	$Y = 28.1e^{-0.0560X} + 35.5e^{-0.0020X}$	0.0053	0.850	6.7	24.1	6.0
GA 02-C	$Y = 53.7e^{-0.0230X} + 17.3e^{-0.0009X}$	0.0117	0.793	11.2	40.7	2.3
NCV-11	$Y = 28.6e^{-0.0160X} + 19.7$	0.0254	0.715	6.6	21.8	1.0

† Significance of regression.

‡ Standard error of the estimate of Y on X.

estimated in the current study may be higher than those represented under actual farming conditions, but are still lower than those recommended in the Extension literature. One year after residue placement, the difference in N content between surface and buried peanut residue was negligible, approximately 0 kg N ha^{-1} yr^{-1} at WGS and 5 kg N ha^{-1} yr^{-1} at UCP (Fig. 5). Similar conclusions were drawn by Meso et al. (2007) in a peanut–cotton rotation in Alabama, by Mubarak et al. (2002) in Malaysia, and by Balkcom et al. (2004) in Georgia.

CONCLUSIONS

Peanut residue decomposition occurred quickly regardless of placement and location. Conservation tillage peanut did not increase N credits compared to conventional tillage at locations representing the northern and southern limits of U.S. peanut production. The U.S. Cooperative Extension recommendations for N credits following peanut do not specify to which crop, winter or spring, those credits should be applied. This study estimated a potential N credit to a subsequent winter wheat crop at 14 to 19 kg N ha^{-1} when peanut residues were buried after harvest, and 19 to 24 kg N ha^{-1} when left on the soil surface. When potential N credits were applied to a subsequent cotton crop (peanut–winter fallow–cotton), they were reduced to 2 to 9 kg N ha^{-1} (buried) and 6 to 10 kg N ha^{-1} (surface). Surface residues mineralized more N (on a kg ha^{-1} basis) over a subsequent cropping season compared to buried residues because there was more total N remaining in surface compared to buried residues, resulting in more total potentially mineralizable N over subsequent cropping seasons. Current extension recommendations are generally higher than the results obtained in this study suggest and warrant re-examination.

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