

DIVISION S-8—NUTRIENT MANAGEMENT & SOIL & PLANT ANALYSIS

Nitrogen Dynamics of Decomposing Corn Residue Components Under Three Tillage Systems

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ABSTRACT

Corn (*Zea mays* L.) residues returned after grain-corn harvest are a heterogeneous mix of leaves, stems, husks, and cobs with a rather high overall C/N ratio. Considerable N immobilization has been reported from laboratory studies of decomposing corn residues, with less and variable N immobilization reported from field studies. The primary objectives of our study were to determine overall N dynamics for crop residues applied to land under corn grain production under three tillage systems in eastern Canadian conditions, and to see how constituent plant parts contribute to overall patterns of net N immobilization and release. Mesh litterbags (fiberglass screen) containing corn leaves, stems, cobs, or husks were buried or left on the soil surface in plots under no-till, reduced tillage, or conventional tillage, and retrieved over a 2-yr period. Residue N dynamics, including depth effects on residue N, differed greatly by residue type. Cobs, husks, and stems all immobilized N at some point. However, N immobilization was counterbalanced or exceeded by simultaneous N release from other residues, and no net N immobilization was observed for the residues overall (all types combined) for the sampling intervals included in our 2-yr study. Nitrogen dynamics were related to ease of residue decomposition, in turn influenced by residue physical and chemical characteristics as well as by placement depth. Thus cobs immobilized little or no N at any given time because of their slow decomposition, despite very low initial N content. Estimated differences in residue N content between overall tillage systems were relatively small.

GRAIN-CORN PRODUCTION returns large amounts of crop residues to the land at harvest. The residues are a highly heterogeneous mix of leaves, stems, husks, and cobs (unless the latter are removed, as for crib-stored grain), usually chopped or crushed to some degree by the harvester or subsequent field operations. The N content and other attributes of these different plant parts differ greatly, and the decomposition rates and N dynamics of such diverse residues decomposing together are probably different than would be found from a more homogeneous residue of similar average values for C/N ratio, lignin content, etc.

Grain-corn residues contain large amounts of N (e.g., 40–80 kg N ha⁻¹, depending on yield and N concentra-

tions), thus contributing to soil N pools as well as to soil humus formation. However, their C/N ratio is rather high (67 in the current study), and would therefore be expected to result in N immobilization by decomposer organisms at some point in the decomposition process. It is often stated that net N immobilization is likely to occur following addition of plant material with a C/N ratio above ~25 (Paul and Clark, 1989; Brady and Weil, 1996; Myrold, 1998), and some references have recommended supplemental N fertilizer additions for crops following grain corn (Aldrich et al., 1975; Association des Fabricants d'Engrais du Québec, 1994).

Residue N dynamics are influenced both by residue quality and by residue placement depth (e.g., surface vs. buried) and other environmental factors. Some studies report greater or more prolonged N immobilization in no-till soil (Rice and Smith, 1984) or surface residues (Cochran, 1991). Considerable N immobilization by corn residues has been reported from laboratory studies (Green and Blackmer, 1995; Recous et al., 1995). Reports of immobilization under field conditions have been variable, but generally involve smaller N amounts than those in laboratory studies (Parker, 1962; Zaboriski, 1995).

The objectives of this study were to determine: (i) overall N immobilization and release patterns for crop residues applied to land under grain-corn production under three tillage systems in eastern Canadian conditions; (ii) whether different corn residue types (leaf, stem, husk, cob) differ in their response to placement depth, relating N dynamics to initial residue characteristics and subsequent mass loss patterns; and (iii) how each residue type contributes to overall patterns of net N immobilization and release by pooled residues.

Mesh bags (litterbags) containing corn leaves, stems, husks, or cobs were left to decompose under field conditions for up to 2 yr, and retrieved for determination of residue mass and N content. It was expected that separate consideration of the different residue types would provide insights into overall residue N dynamics for pooled or mixed corn residues, facilitate comparison with studies that have involved different mixes (e.g., stems only, leaves + stems, leaves + stems + husks), and show how including or excluding particular plant parts might affect overall conclusions regarding residue

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Abbreviations: CDD, cumulative degree-days above 0°C; CT, conventional tillage grain corn; DD, degree-days above 0°C; NT, no-till grain corn; RT, reduced tillage grain corn.

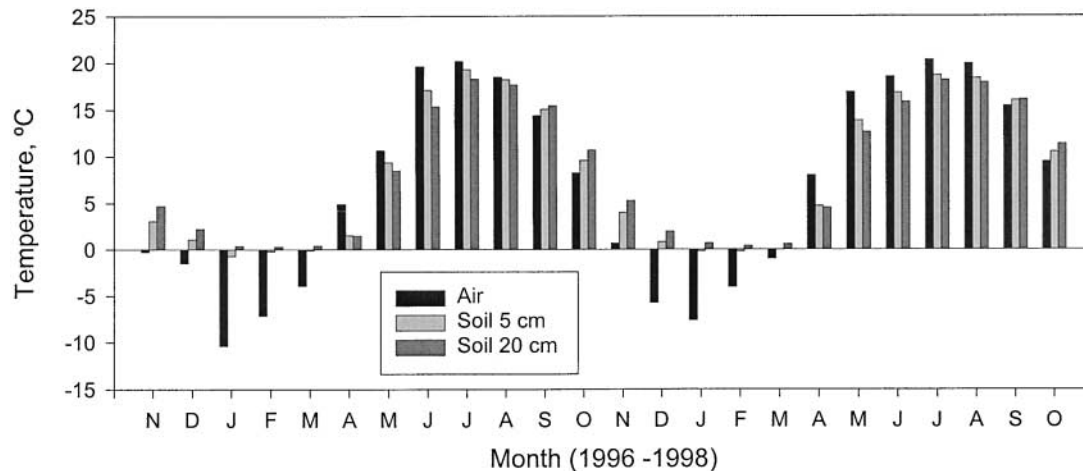


Fig. 1. Mean monthly temperatures during 1996–1998 study. Data from Ste-Anne-de-Bellevue weather station of Environment Canada.

N dynamics. To our knowledge, this is the first field study to consider the respective roles of constituent plant parts in determining overall N dynamics of grain-corn residues, and the first litterbag study of corn residue N dynamics to have been done under Canadian conditions.

MATERIALS AND METHODS

Site Description and Management

The study was conducted at McGill University's research farm in Ste-Anne-de-Bellevue, in southwestern Quebec. Mean annual temperature is 6°C (16°C in May–Oct.), and precipitation averages 940 mm yr⁻¹ (Environment Canada, 1998). Mean monthly temperatures during the main study period are shown in Fig. 1. The soil, a Typic Endoaquent, was mostly of the St. Damase series (Lajoie and Baril, 1953), with sandy loam or loamy sand (mean thickness 28 cm) usually underlain by sand (mean thickness 18 cm), then clay starting at variable depths averaging 46 cm. Plots measured 18.5 by 80 m, and were drained by a subsurface drainage system.

The main study was conducted in 1996 to 1998 on nine grain-corn plots that had been managed since 1991 under three tillage systems: no-till (NT), reduced tillage (RT), or conventional tillage (CT), replicated three times in a randomized complete block design. A short-term study in spring 1999 involved NT plots only. Grain-corn plots were harvested with a multi-row combine-harvester that removed only the grain (25 Oct. 1996, 20 Oct. 1997, 9 Oct. 1998), leaving all residues on the plots. Some coarse chopping or crushing of aboveground residues occurred during harvest. No-till plots were not tilled at any time, RT plots were offset-disked 10 to 15 cm deep (31 Oct. 1996, 23 April and 26 Oct. 1998) and tandem-disked to 10 cm (22 May 1997, 28 Apr. 1998), and CT plots were moldboard-plowed to 20 cm (1–4 Nov. 1996, 22 Apr. and 26 Oct. 1998) and tandem-disked in spring as for RT.

Corn ('Funk 4120 hybrid') was planted in rows spaced 76 cm apart on 26 May 1997, 11 May 1998, and 6 May 1999. Each corn row had a wheel-tracked interrow on one side and an untracked interrow on the other. At seeding, (NH₄)₂HPO₄ was banded 5 cm below and 5 cm beside the seeds in the untracked interrows to provide 40 kg N ha⁻¹ and 43 kg P (102 kg P₂O₅) ha⁻¹. Two to 4 wk later (9–12 June 1997, 5 June 1998, 4 June 1999), NH₄NO₃ and KCl were applied (top-dressed) to the central portion of each wheel-tracked interrow to provide an additional 140 kg N ha⁻¹ and 123 kg K (148 kg K₂O) ha⁻¹.

Litterbag Preparation and Processing

Crop residues, defined here as aboveground plant parts excluding grain, were collected just before the 1995 harvest for use in the litterbag study. They were separated into four residue types: leaves; stems, cut into 10- to 15-cm lengths; husks; and cobs after grain removal, cut into pieces weighing ~5 g each. Leaves included approximately equal parts of leaf sheaths and leaf blades, and husks included a 3.25 to 1 ratio of husk leaves (the husk proper) to husk stems (stem attaching cob and husk to main stem). Residues were oven-dried at 60°C for up to 48 h in a forced-draft oven. They were then placed in mesh bags (litterbags) made from fiberglass screen (~1.0 by 1.3-mm openings). Sets were assembled joining together one bag of each of the four residue types, which were then placed and retrieved as a unit.

Litterbags for the main study were placed in early November 1996, at or just after time of tillage. Within each plot, sets were placed in two lines 76 cm apart. In spring, seed-rows were then positioned so that one line of bags would be located in a high-N wheel-tracked interrow, and the other in a low-N untracked interrow. Within each line, sets of bags were positioned at 1-m intervals. Placement depths were 0 cm (surface) and 5 cm in all plots, with an additional placement at 20 cm (plow-sole depth) in CT plots only. Buried sets were centered directly below surface sets at each location. For instance, in CT plots, the 20-cm sets were placed in the furrow at time of plowing (locations were recorded relative to fixed reference points), and 5- and 0-cm sets were then positioned directly above them. On each sampling date, a surface bag and underlying buried bags were retrieved from one location per line in each plot. Samples from both lines in each plot were processed and analyzed separately but results pooled prior to statistical analyses.

There were six sampling dates in 1997 (13 May, 26 June, 29 July, 26 August, 22 September, 15 October) and three dates in 1998 (stems and cobs only, 22 April and 20 July; all types, 2 October). The longer-term litterbags were briefly removed as necessary during intervening tillage operations and immediately replaced. Statistical analyses used the model Y equal to block depth-till, with three blocks and seven levels for the depth-till factor (0- and 5-cm placements in each of NT, RT and CT, and 20 cm in CT only). Analyses of variance were performed separately for each residue type and date, using the general linear models procedure (SAS Institute, 1987), and differences evaluated by preplanned contrasts. In a short-term study conducted in spring 1999, litterbags were placed on 2 May 1999 in NT plots only (single line per plot, 0- and

Table 1. Initial residue characteristics, residue mass, and N content at field scale.

Residue type	N concentration	C/N ratio	Solubles†	Lignin	Ash	% of total residue applied	Total mass applied	Total N in residue applied
	g kg ⁻¹		% by mass				Mg ha ⁻¹	kg N ha ⁻¹
Cobs, C	3.3	149	18	14	1	16	1.30	4.3
Stems, S	5.7	80	38	14	5	38	3.05	17.5
Leaves, L‡	10.3	42	31	9	10	32	2.57	26.4
Husks, H§	4.4	103	22	8	3	13	1.07	4.7
Pooled residues								
All residues	6.7	67	30	12	6	100	8.00	52.8
S,L,H only	7.3	61	33	11	7	na¶	6.70	48.6
S,L only	7.8	56	35	12	7	na	5.62	43.8

† Material soluble in neutral detergent.

‡ Ratio of leaf blades to leaf sheaths was 1:1.

§ Ratio of husk leaves to husk stems was 3.25:1.

¶ na, not applicable.

5-cm depths), and retrieved after 1, 2, 4, or 6 wk. The short-term study provided for separate data collection for leaf blades, leaf sheaths, husk leaves, and husk stems, as well as cobs and stems.

Upon retrieval, mesh bags were placed in coolers or cold storage (<4°C) and processed within 6 to 24 h. The residues were spray-rinsed to remove adhering soil, removed from the mesh bags, oven-dried in paper bags (48 h at 60°C), and weighed. Samples were ground (<1 mm) in a Cyclone sample mill (Udy Corp., Fort Collins, CO), placed in airtight specimen bottles, redried overnight, and kept capped until further processing. Total N was determined using an H₂SO₄-H₂O₂ digestion procedure (Allen, 1989). Ash content was determined for each sample (muffle furnace, 550°C overnight in Pyrex tubes (Corning Glassware, Science Products, Corning, NJ). This was used (together with ash content of initial residue and of soil) to correct for adhering soil, after Schuman and Belden (1991).

Initial Residue Quality

Initial chemical composition for each residue type was determined using the same material as was used in preparing the litterbags, oven-dried and ground as previously described. Organic C was determined by wet oxidation-redox titration (Tiessen and Moir, 1993). Analysis for lignin content and materials soluble in neutral detergent used the methods of Goering and van Soest (1970). For N, C, and ash, 12 to 15 samples of each initial residue were analyzed individually; for lignin, solubles, etc., these were composited into three mixed samples of each type. Separate analyses were done for leaf blades, leaf sheaths, husk leaves, and husk stems. These data were then combined using the appropriate ratios to obtain overall leaf and husk values. Values for totals including all or some of the component plant parts were calculated taking into account initial quantity and N content of each plant part in the field at harvest (Table 1).

Degree Days (Thermal Units)

Temperature data from the Ste-Anne-de-Bellevue weather station of Environment Canada, located <1 km from the site, were used to calculate daily degree days above 0°C (DD), after Gordon and Bootsma (1993):

$$DD = T_{\text{average}} - T_{\text{base}},$$

$$\text{where } T_{\text{average}} = (T_{\text{max}} + T_{\text{min}})/2 \text{ and } T_{\text{base}} = 0^\circ\text{C};$$

$$\text{If } T_{\text{average}} < T_{\text{base}}, \text{ then } DD = 0.$$

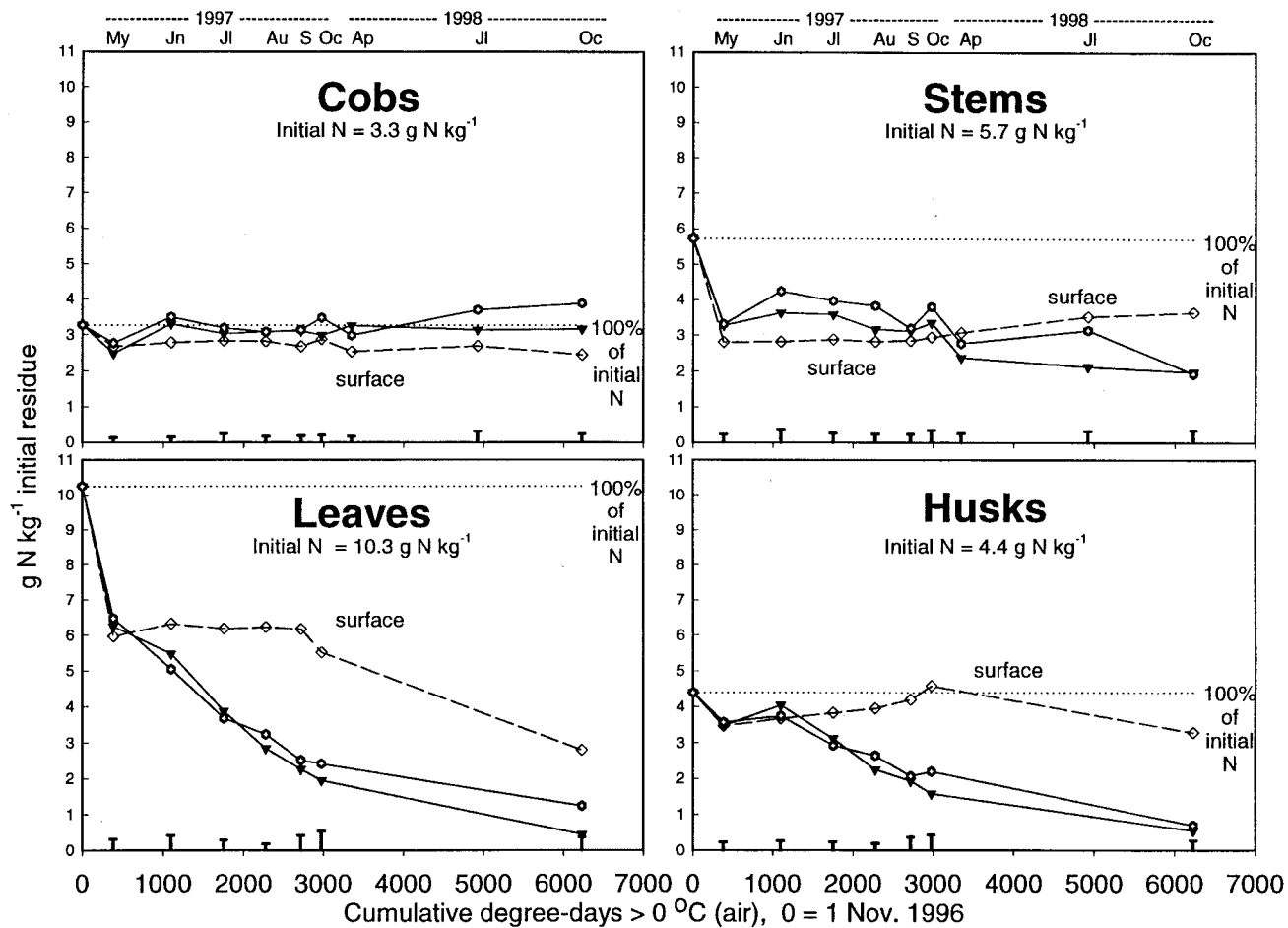
Daily DD were summed to give cumulative DD above 0°C (CDD) since time of residue placement.

RESULTS

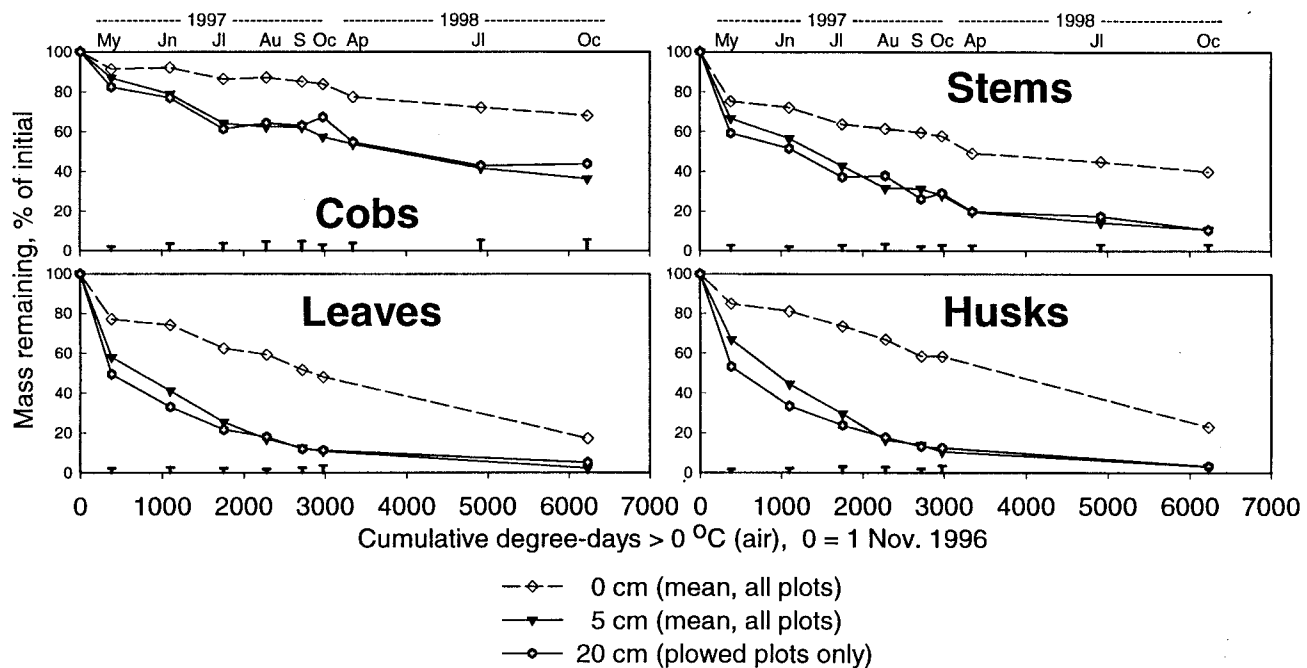
Figure 2a shows changes in residue N content across time by depth for each plant part or residue type, in grams of N recovered in residue per kilograms of residue applied. Within a particular depth, differences between tillage plots were generally not significant and are therefore not shown. The data are graphed using thermal units, i.e., CDD above 0°C since residue placement, as the time factor, facilitating comparisons with studies conducted under different temperature regimes (Honeycutt, 1999; Griffin and Honeycutt, 2000). Corresponding mass data are shown in Fig. 2b.

All residue types decreased in N content between placement in November 1996 and first sampling in May 1997. Surface-placed and buried residues had similar N contents on the first sampling date, despite faster mass loss for buried residues. From June onwards, however, N contents of surface and buried residues generally differed significantly, and there were sometimes also differences between 5- and 20-cm placements in CT plots. As indicated in Fig. 2a, the nature and magnitude of these differences differed greatly from one residue type to another. In the case of leaves and husks, residues held N longer if left on the surface than if buried. Between May and October 1997, the N content of surface leaves remained almost unchanged, and that of surface husks increased by 25% (1.1 g N kg⁻¹ initial residue), while buried leaves and husks each lost a large portion of their N (42% at 5 cm). In contrast, surface stems neither released nor immobilized N (net amounts) over the first growing season, but increased in N content in the second year, while buried stems increased in N content at the start of the first summer, then generally decreased in an irregular manner. Unlike most other residues, cobs usually held more N if buried than if left on the surface. By the end of the second year, surface-placed cobs had lost 25% of their initial N (0.8 g N kg⁻¹ initial residue), while buried residues held the same quantity as at placement (5-cm cobs) or more (19% increase at 20 cm). Increases in N content of buried cobs, husks, and stems between May and June 1997 seemed partly related to the fertilizer application of 12 June, as indicated by comparing residue N in high-N vs. low-N interrows. (In high-N interrows, these residues gained ~1 g N kg⁻¹

---- (a) N in residues ----

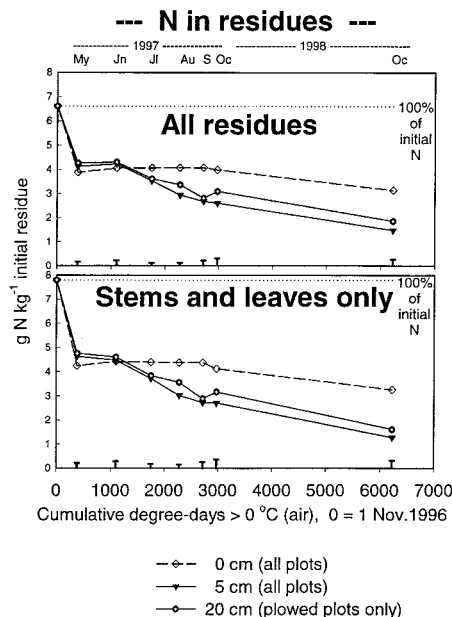


----- (b) Residue mass -----



(Vertical bars = standard errors of means of the seven depth-tillage combinations.)

Fig. 2. (a) Litterbag residue-N content and (b) mass versus degree-days above 0°C since placement, Nov. 1996 through Oct. 1998, averaged by depth.



(Vertical bars = standard errors of means of the seven depth-tillage combinations.)

Fig. 3. Pooled litterbag residue-N content versus degree-days above 0°C since placement, Nov. 1996 through Oct. 1998, averaged by depth.

initial residue, whereas in the low-N interrows, there was little or no increase in N content.)

Pooling of data from all residues combined indicated that overall N release was slower from surface residues than from buried residues from the second sampling date onward (Fig. 3 top). By the end of the 2-yr study, all surface residues together had released 53% of their initial N (3.5 g N released kg⁻¹ initial residue), while buried residues released between 70 and 80% of initial N. Similar trends were found if pooled totals were calculated including stems and leaves only (Fig. 3 bottom), or including stems, leaves and husks but not cobs (not shown).

When expressed on a DD basis, residues placed in spring 1999 had mass loss patterns (not shown) similar to those of residues placed in fall 1996, but N contents of surface stems and leaves were greater in the short-term study (compare Fig. 4 and Fig. 2a). Nitrogen immobilization by husks was shown to be because of N increases in the husk-leaves, which had low initial N contents (3.6 g N kg⁻¹ residue), not in the husk-stems (initially 6.8 g N kg⁻¹ residue).

DISCUSSION

Nitrogen Immobilization by Residues

All the residues with low initial N concentrations immobilized N at some point in their decomposition, either relative to initial amount present (cobs and husks) or relative to quantity held on an earlier sampling date (stems). However, total quantity of N held by all types together never exceeded initial residue N for the sampling dates included in our study. Immobilization by even our low-N residues was much smaller than values reported from laboratory studies with ground or finely

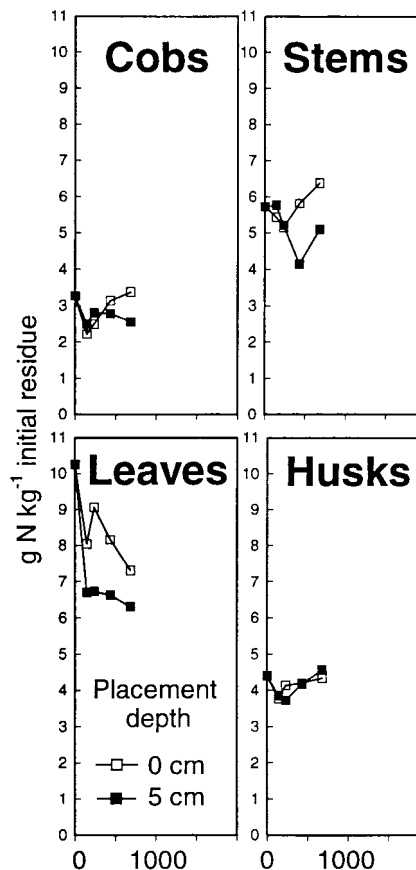


Fig. 4. Spring 1999 study: N content of litterbag residues versus degree-days. Placed 2 May 1999 (no-till plots), and retrieved 10, 17, 30 May and 11 June.

chopped corn residue (with a C/N ratio of 45–130), where soil inorganic N quickly fell by 10 g for every kilogram of residue added (Green and Blackmer, 1995; Recous et al., 1995). This probably reflects different experimental conditions, e.g., soil moisture and temperature, microbial access to soluble substrate because of particle size, and perhaps measurement techniques.

The short-term study confirmed that rapid early N immobilization (preceded by initial N loss) was indeed possible for stem, cob, and husk residues. However it is not known to what extent results from spring-placed residues are applicable to fall-placed residue conditions.

Many studies have reported greater or delayed N immobilization, or slower N release, by surface residues as compared with buried residues (Christensen, 1986; Cochran, 1991; Schomberg et al., 1994). Earlier N release by buried residues was indeed evident for our faster-decomposing residues, i.e., leaves and husks. With stems and cobs, buried residues held more N than surface residues on at least some of the sampling dates. With cobs, depth differences during most of the study were <1 g N kg⁻¹ of added residue, and seemed related to the larger increase in buried-cob N in high-N interrows after the June 1997 fertilizer application.

Residue Nitrogen Content and Mass-Loss Phase

Residues appeared to go through several phases in their decomposition, with N dynamics related to stage

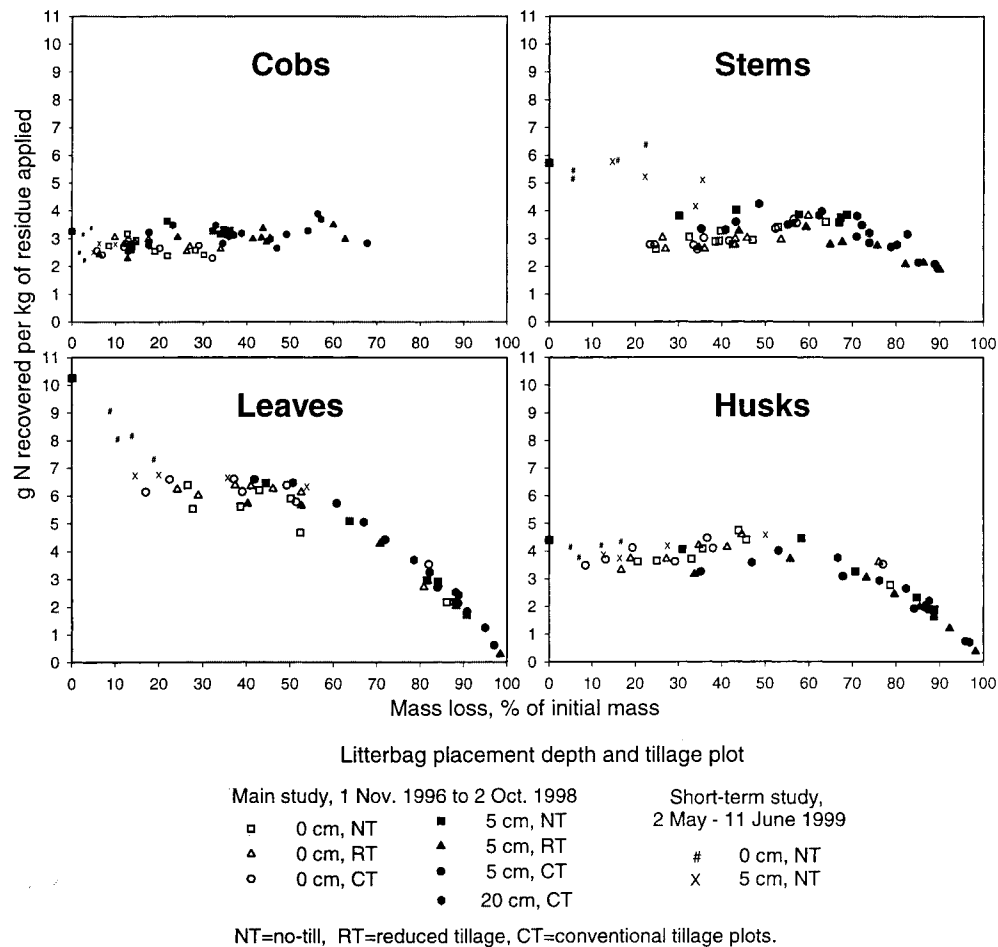


Fig. 5. Relationship between litterbag residue mass loss and N quantity recovered in residues.

or extent of mass loss. Even low-N residues appeared to have at least a brief initial period of N loss after placement, in common with data presented in other studies (Staaf and Berg, 1982; Christensen, 1986; Schomberg et al., 1994). Since a certain fraction of initial residue components is water-soluble, some initial N (and C) losses can occur because of leaching (Christensen, 1986; Parsons et al., 1990), if the water-soluble portion is exposed to sufficient precipitation or soil water movement. Tenney and Waksman (1929) reported that for corn leaves and stems near maturity, 38% of total N was soluble in cold water; Parker et al. (1957) reported a similar figure for N in mature cornstalks. However, under field conditions with intact rather than ground residue, not all such material is necessarily available for leaching (e.g., Havis and Alberts, 1993).

The initial period of N loss was followed in many cases by a period of increasing or relatively unchanging (albeit variable) residue N content. Fluctuating N levels, including several peaks and dips in residue N content over time, have been observed in studies with forest leaf litter (Blair and Crossley, 1988). A more sustained period of N loss eventually followed. This seemed to generally begin only after at least 50 to 60% of initial residue mass had been lost (Fig. 5), which occurred later for surface-placed than for buried residue, and later for

the residues with more recalcitrant and less accessible components, i.e., cobs and stems.

The timing of the start of sustained N loss is consistent with results of other studies with various residues. Schomberg et al. (1994) also reported net N release by low-N residues (sorghum [*Sorghum bicolor* L.], wheat [*Triticum aestivum* L.]) after 50 to 60% mass loss, with maximum immobilization occurring slightly earlier (45–55% mass loss); N content of barley straw apparently peaked and then declined at 30 to 50% mass loss (Christensen, 1986; Cochran, 1991). It seems that the apparently disparate patterns exhibited by our different residue types may largely reflect the differing amount of time needed for each type-depth combination to reach a particular decomposition stage. Some variations in N dynamics by depth within a particular residue type could occur because of placement effects on external N availability (i.e., from soil) and on the decomposer community, including a greater relative importance of fungi vs. bacteria in surface-placed residues (Hendrix et al., 1986; Holland and Coleman, 1987).

Nitrogen Concentrations versus Mass Loss

The relationship between N concentration and mass loss (or mass) appeared to be slightly curvilinear, espe-

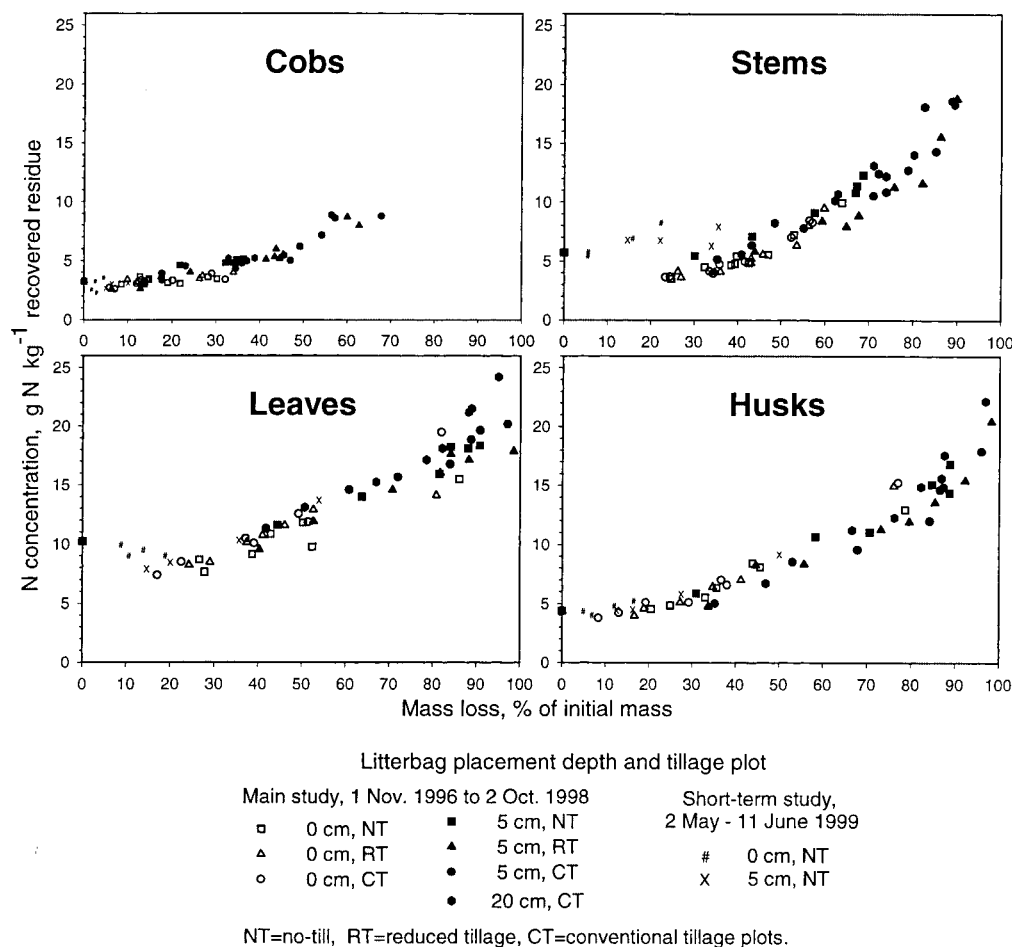


Fig. 6. Nitrogen concentration versus mass loss of litterbag residues.

cially if data from all depths were included (Fig. 6). Some authors (Aber and Melillo, 1982; Schomberg et al., 1994) have used relationships between mass and N concentration (calculated separately for each depth, and assumed to be linear) to predict maximum N immobilization (timing and quantity) from mass and concentration data. However, such calculations may be of limited predictive applicability if maximum N immobilization occurs before or after (or between) sampling dates and is not indicated by the data collected.

Effects of Cobs and Husks

With older harvesting techniques, cobs as well as grain were removed from the field during grain-corn harvest, unlike with modern combine-harvesters which leave cobs in the field. Previous studies of corn residue N dynamics have generally involved leaves and stems, occasionally including husks, but not cobs. One objective of our collecting data separately for each residue type was to facilitate comparisons with situations or studies that excluded one or more plant parts. Specifically, we wanted to see whether inclusion of cobs and husks, with their high C/N ratios, might increase N immobilization estimates compared with totals that considered only leaves and stems.

Calculated totals that excluded either cobs alone or

both cobs and husks had higher initial N concentrations, but lower initial residue-N amounts on a per-hectare basis, assuming leaf and stem applications were unchanged. Overall N-loss patterns were essentially the same with and without the cob and husk data, but with slightly faster N loss on a percentage basis when cobs and husks were excluded (Fig. 3). Returning cobs (and husks) to the field rather than removing them thus seems to have a minimal impact on overall residue N content, partly because of the small quantities of such residues as a percentage of the total residue returned.

Comparison with Other Field Studies with Corn

In general, overwinter N losses (pooled residues) were similar to those reported for corn stalks and leaves on a tilled-planted site in Iowa (Alberts and Shrader, 1980). Alberts and Shrader (1980) supposed that most of this was probably because of leaf decomposition. Our data indicate that about half of our overwinter decrease ($10\text{--}12\text{ kg N ha}^{-1}$) was because of N loss from leaves, with stems accounting for another 40% of the total decrease ($7\text{--}10\text{ kg N ha}^{-1}$), and cobs and husks the remainder.

Our N-content values were lower than those reported by Parker (1962) for corn residue in Iowa, perhaps be-

cause the latter placed the residue in spring rather than fall, exposing them to different soil N and moisture conditions. Also, Parker's maximum N values (120% of initial N, or 2 g N immobilized per kilogram initial residue) occurred for buried residue at the 20% mass-loss stage, earlier than our first sampling date. Fall-placed surface corn residues in Ohio (Zaborski, 1995) also increased in N content at this mass-loss stage (preceded by a period of N loss), as did surface residues in our short-term study. However, the 20% figure does not necessarily hold for all conditions: there was no corresponding peak for buried residues in our short-term study, nor for surface residues in our main study (although net N release did stop).

Unlike results from studies by Parker (1962) and Zaborski (1995), our main-study litterbag data (pooled residues) showed no net increase in total residue N content between sampling dates, other than the very slight increase in June 1997 for buried residues. Earlier monitoring (e.g., fall, spring), and use of alternative techniques to determine fate of N and C lost from the residue, would be useful given the substantial mass losses observed between November and May. It is not known, for instance, whether residue-N released in this period would contribute to overwinter NO_3^- leaching losses or be retained in the soil profile, or both. It is also not known whether N immobilization by low-N residue components occurred at some point between fall placement and spring sampling, which could help reduce overwinter N losses from the soil system as suggested by Powlson et al. (1985) in a UK study with wheat straw (C/N ratio of 73).

Differences Between Tillage Systems at Field Scale

Residue N dynamics at field scale under different tillage systems would reflect the residue depth distribution characteristic of each tillage system. Using litterbag N data from the appropriate depth(s) and tillage plots, residue N content in kilograms of N per hectare was calculated assuming that all residues remained on the surface in NT plots, two-thirds were buried in RT plots, and 95% were buried in CT plots. These calculations estimated that the amount of N held by the residues placed in fall 1996 was similar in all three tillage systems on the first three sampling dates (13 May–30 July 1997), and amounts held by RT and CT were nearly identical throughout the study. From August 1997 onward, RT and CT residues held somewhat less N than NT residues, which lost both N and mass more slowly. The maximum calculated difference between NT and CT was 10 kg N ha^{-1} (September 1997). Possible effects of such differences on soil N availability (e.g., levels of soil NO_3^- or NH_4^+) would probably not be detectable against the high background variability in inorganic soil N levels. In addition, soil N availability would be influenced by residue additions from previous years, as well as possible effects of tillage or long-term residue additions on soil organic matter, N mineralization, nitrification, etc.

Decomposition of surface leaves and husks, and per-

haps stems and cobs, probably proceeds faster than was indicated by litterbag data, at least in the first year, because of greater exposure to physical forces of fragmentation (e.g., raindrop impact, tractor traffic). Also, some NT residue is in fact buried each year through seeding operations, earthworm (e.g., *Lumbricus terrestris*) activity, etc., further accelerating its breakdown. It is therefore possible that N immobilization by surface-placed husks and stems, and perhaps N release by surface-placed leaves, would occur sooner under no-till conditions. These effects might cancel each other out, or could result in an earlier release of residue N in NT than indicated above. This could lead to even smaller differences between NT and RT or CT systems overall, at least where these systems have been in place for several years.

CONCLUSIONS

Low-N residues (cobs, husks, and stems) all immobilized N at some point in their decomposition. However, for the sampling dates included in the 2-yr study, any such immobilization was always counterbalanced or exceeded by N release by other residues. Therefore no net N immobilization was observed when all residues were considered together, and differences between overall tillage-system estimates were relatively small.

Nitrogen dynamics were related to ease of residue decomposition as well as initial N content, and were thus influenced by residue physical and chemical characteristics as well as by environmental conditions. For instance while cobs had very low initial N content (C/N ratio of 149), their slow decomposition appeared to limit microbial N needs at any given time, so that net amounts of N immobilized during the study were small. Physical as well as chemical characteristics may also have influenced residue N response to placement depth.

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