Biomass, carbon and nitrogen dynamics of multi-species riparian buffers within an agricultural watershed in Iowa, USA

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Abstract

This study was conducted to determine biomass dynamics, carbon sequestration and plant nitrogen immobilization in multispecies riparian buffers, cool-season grass buffers and adjacent crop fields in central Iowa. The seven-year-old multispecies buffers were composed of poplar (*Populus × euroamericana* 'Eugenei') and switchgrass (*Panicum virgatum* L.). The cool-season grass buffers were dominated by non-native forage grasses (*Bromus inermis* Leysser., *Phleum pratense* L. and *Poa pratensis* L). Crop fields were under an annual corn-soybean rotation. Aboveground non-woody live and dead biomass were determined by direct harvests throughout two growing seasons. The dynamics of fine (0–2 mm) and small roots (2–5 mm) were assessed by sequentially collecting 35 cm deep, 5.4 cm diameter cores (125 cm deep cores in the second year) from April through November. Biomass of poplar trees was estimated using allometric equations developed by destructive sampling of trees. Poplar had the greatest aboveground live biomass, N and C pools, while switchgrass had the highest mean aboveground dead biomass, C and N pools. Over the two-year sampling period, live fine root biomass and root C and N in the riparian buffers were significantly greater than in crop fields. Growing-season mean biomass, C and N pools were greater in the multispecies buffer than in either of the crop fields or cool-season grass buffers. Rates of C accumulation in plant and litter biomass in the planted poplar and switchgrass stands averaged 2960 and 820 kg C ha^{-1} y^{-1}, respectively. Nitrogen immobilization rates in the poplar stands and switchgrass sites averaged 37 and 16 kg N ha^{-1} y^{-1}, respectively. Planted riparian buffers containing native perennial species therefore have the potential to sequester C from the atmosphere, and to immobilize N in biomass, therefore slowing or preventing N losses to the atmosphere and to ground and surface waters.

Introduction

Natural and re-established riparian buffers reduce nonpoint-source pollutants derived from upland agricultural lands, and enhance terrestrial and aquatic habitat (Schultz et al. 1995). Their location between crop fields and streams places riparian buffers in a unique position to regulate the movement of materials in surface runoff and groundwater that flows from uplands to streams (Hill 1996; Schultz et al. 1995). Buffers placed between crop fields and streams can decrease nitrate levels within the soil solution, diminishing nitrate movement into streams. Mechanisms by which riparian buffers capture nitrate include plant immobilization, microbial immobilization and denitrification (Hill 1996).

Plants may immobilize more N than microbes during growing season (Groffman et al. 1992). Peterjohn and Correll (1984) estimated vegetation uptake of a riparian forest as 77 kg ha^{-1} y^{-1} for N, but potential N uptake rates may be much higher. Cole (1981) reported that poplar (*Populus nigra* L) assimilated 213 kg N ha^{-1} y^{-1} when fertilized with a nutrient-rich effluent at a rate of 400 kg N ha^{-1} y^{-1} for three years, but sites not receiving nutrient effluent assimilated only 16 kg N ha^{-1} y^{-1}. Fail et al. (1986) showed that

riparian forest sites that received runoff from cropland and a pig pen had higher rates of growth and plant nutrient concentrations than sites downslope from unused pasture. Storage of 51.8 kg N ha^{-1} y^{-1} in aboveground riparian forest biomass in Georgia considerably exceeded the subsurface groundwater nitrate input of 29 kg N ha^{-1} y^{-1} (Lowrance et al. 1984). O'Neill and Gordon (1994) reported that Carolina poplar (*Populus × canadensis* Moench.) trees were effective in lowering subsurface nitrate concentrations as the soil solution migrated through the rooting zones of trees. All these studies emphasize the importance of N immobilization by woody plants in riparian buffers, but further research is needed to evaluate the effectiveness of different types of riparian buffer plant communities on C and N cycling.

Understanding N dynamics in riparian buffer systems is essential to their proper management. Good understanding of N and C dynamics requires careful examination of both above- and belowground biomass dynamics, but few studies of above- and belowground biomass, and biomass C and N partitioning, have been conducted in riparian zones (Tufekcioglu et al. 1999; Fail et al. 1986). The primary objective of this study was to determine C sequestration and N immobilization in the biomass of planted multispecies riparian buffers, cool-season grass buffers and adjacent crop fields. This information provides insight into the potential benefits of riparian vegetation to act as sinks of C and N in agricultural regions.

Materials and methods

This comparative study was done on a private farm along Bear Creek, in Story County, Iowa, USA (42°11′ N, 93°30′ W). The study was conducted on a multi-species riparian buffer and a cool-season grass riparian buffer and in adjacent crop fields. Multi-species riparian buffers were established along Bear Creek in 1990 on soil that had been cultivated or grazed for more than 75 years. The basic design of the multi-species buffer includes five rows, at 1.2 × 1.8 m spacing, of hybrid poplar (*Populus × euroamericana* ' Eugenei') planted closest to and parallel to the creek. Upslope from the trees are a row of red osier dogwood (*Cornus sericea* L.) and a row of ninebark (*Physocarpus opulifolius* L.). A 7.3 m-wide strip of switchgrass (*Panicum virgatum* L.), a native warm-season (C$_4$) grass, is planted upslope from the shrubs at the interface with the cropped fields (Schultz et al.

1995). Cool-season grass buffers were interspersed among the planted multispecies riparian buffers. The cool-season grass sites were part of a grazed riparian pasture prior to 1989 when grazing was stopped. Dominant grass species were smooth brome (*Bromus inermis* Leysser.), timothy (*Phleum pratense* L.), reed canary grass (*Phalaris arundinacea* L.) and Kentucky bluegrass (*Poa pratensis* L.). These same species also were found in the poplar understory. The crop fields were under an annual corn-soybean rotation. Corn (*Zea mays* L.) was usually planted in early May and harvested at the end of October and received an average of 130 kg N ha^{-1} added as urea in the spring. Soybean (*Glycine max* (L.) Merr.) was usually planted in mid-May and harvested in mid-September. Soybean fields didn't get any fertilizer application.

Six transects, three each bisecting different cool-season and multispecies buffers were established on both sides of a 0.8-km stretch of Bear Creek, perpendicular to the stream and extending into adjacent crop fields. In the multispecies buffer, biomass was measured in the poplar and switchgrass and in the adjacent crop fields. In cool-season buffers, biomass was measured in the cool-season grass plots and in the adjacent crop field plots. Overall, plot sizes varied from 7 × 10 m to 10 × 15 m.

Destructive sampling of the trees was used to develop allometric equations based on height and diameter at breast height (dbh) to estimate aboveground biomass of poplar. Ten trees were cut and dry weights of stems and branches were determined. The trees were harvested in winter, so leaf biomass was estimated from end-of-year leaf litter production. Live leaf C and N concentrations were determined on three independently collected samples of leaves collected in mid-summer in each poplar sites. Allometric equations were developed based on dbh and total height using total aboveground tree dry weight as the dependent variable. The derived regression:

$$\text{Tree mass (kg)} = 0.0147 \times (\text{dbh})^2 \times (\text{height}) - 0.157,$$
$$R^2 = 0.93$$

where dbh is in cm, height is in m. Branch biomass averaged 11% of tree woody biomass for the ten harvested trees. Nitrogen concentrations of branches and stems of poplar were determined from combined samples of discs taken at two-meter intervals on the main stem. Beavers (*Castor canadensis*) destroyed some of

the trees in one of our three planted poplar stands, so we selected plots in stands free of extensive beaver damage for study. Our data therefore reflect potential poplar biomass accumulation at these sites, under relatively beaver-free conditions.

In all sites, aboveground live biomass and litter of the herbaceous layer were determined approximately monthly by harvesting all aboveground live and dead plant material in five 25 × 25 cm quadrates (50 × 93 cm in crop fields) in each plot (n = 3 plots per vegetation type) during the growing seasons of 1996 and 1997. Five litter baskets were placed in each of the poplar plots to measure litterfall. Litter baskets were emptied monthly. Plant samples were oven-dried at 65 °C and were ground to pass through 1-mm mesh sieves and analyzed for C and N (Carlo-Erba NA1500 CNS analyzer, Carlo Erba Instruments, Milano, Italy).

Sequential coring was used to determine fine (0–2 mm) and small (2–5 mm) root biomass (Joslin and Henderson 1987). Soil cores of 5.4 cm diameter were removed approximately monthly from May to November during 1996 from the surface 0–35 cm of soil (5 cores per plots). During 1997, samples were taken in May, July and September from the 0–125 cm depth of soil. These sampling dates were based on root biomass dynamics observed in 1996.

Cores that could not be sorted immediately were placed into a cold room (4 °C) until they could be. Roots were separated from the soil by soaking in water and then gently washing them over a series of sieves with mesh sizes of 2.0 and 0.5 mm. Roots were sorted into diameter classes of 0–2 mm (fine root) and 2–5 mm (small root) and were then separated into live and dead fractions based on the elasticity of their tissues and the color of the cortex (Hayes and Seastedt 1987; Joslin and Henderson 1987). The roots from each size category were oven-dried at 65 °C, weighed, ground to pass through 1-mm mesh size sieves and analyzed for C and N (Carlo-Erba NA1500 CNS analyzer, Carlo Erba Instruments, Milano, Italy). Coarse root biomass data were obtained by directly measuring coarse roots in two 0.6 × 1.8 m soil pits dug to rooting depth in each plot, as reported in Tufekcioglu et al. (1999).

Statistical comparisons were made using the general linear models procedure of SAS. We used ANOVA to compare above- and belowground biomass, C and N among vegetation types and sampling dates using a repeated measures design. Differences between specific vegetation types and between sampling dates were determined with a least significant difference test at α = 0.05. Only the poplar plots contained trees, so tree and coarse root biomass were not included in the statistical comparisons.

Results

Aboveground biomass, C and N

Live aboveground non-woody biomass (Figure 1A) and biomass C differed significantly among vegetation types and months (P < 0.001). Over the entire growing season, switchgrass had significantly greater live aboveground biomass than did cool-season grass or soybean. Both buffer systems had significantly more live biomass than did the crop fields in late spring and early summer. However, live aboveground biomass was similar (soybean) or higher (corn) in crop fields than in cool-season grass sites in early fall. Aboveground live biomass in cool-season grass fluctuated over the growing season, but in crops and switchgrass it increased throughout the growing season.

Mean carbon concentrations among all vegetation types ranged from 39–41%. Nitrogen concentrations in aboveground live biomass varied significantly among vegetation types, with highest N concentrations in soybean (3.6%) and lowest in switchgrass (1.3%). Based on least significant differences, N concentrations varied (P < 0.05) with soybean > cool-season grasses = poplar understory > corn > switchgrass. Based on these data and biomass harvests (above), the mean growing-season N content in aboveground live biomass (kg ha^{-1}) was similar among vegetation types, despite seasonal differences.

Aboveground litter mass (Figure 1B) and litter C also differed significantly among vegetation types (P < 0.001). Aboveground litter and litter C typically decreased from May to September (Figure 1B). Switchgrass had significantly greater aboveground litter and C than did any other vegetation type (P < 0.05). The decrease in switchgrass litter from May to the end of August averaged 23%, indicating a growing-season mass-loss (decay) rate of 9% mo^{-1}. In contrast, cool-season grass litter lost an average of 42% of its mass over the same period, which is equivalent to 18% mo^{-1}. Peak aboveground litter and litter C values were observed in October and November, following fall senescence of the vegetation (Figure 1B). Approximately 45% of the aboveground biomass of the crops was seed production and was removed
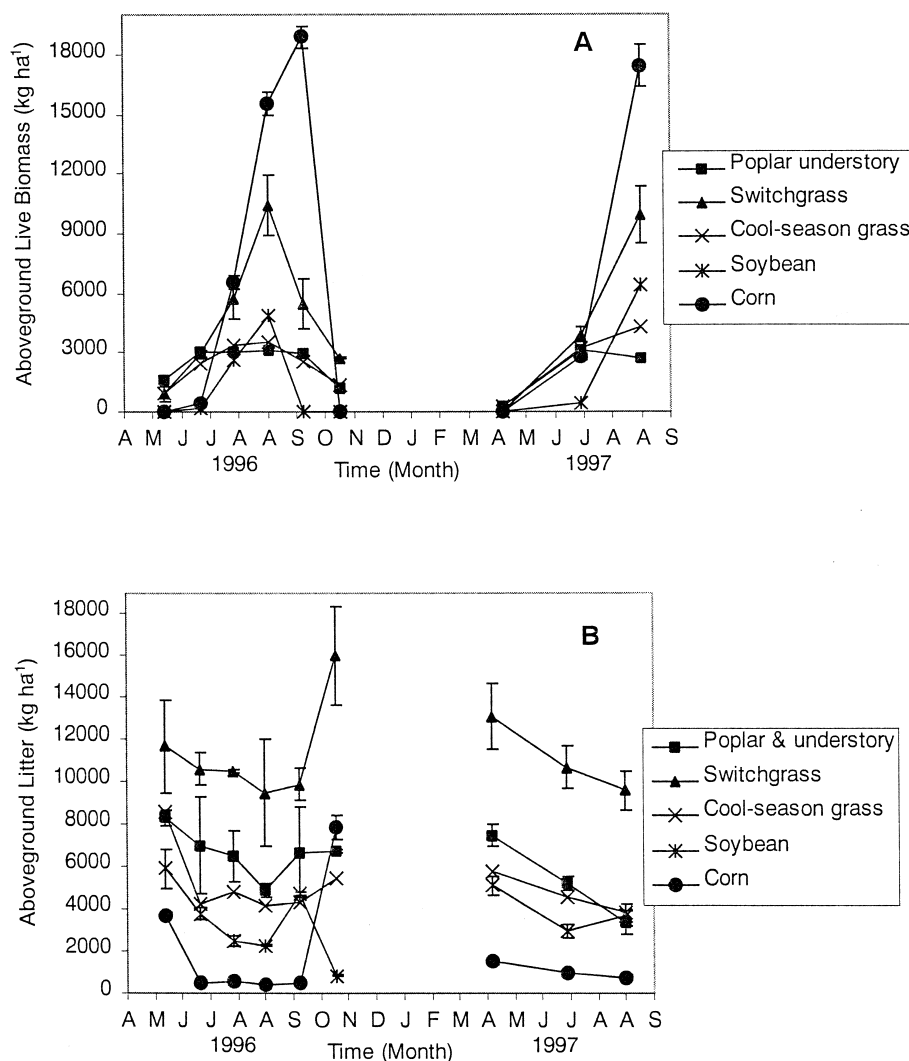
Figure 1. Aboveground live biomass (A) and litter (B) in buffers and adjacent crop fields along Bear Creek in central Iowa, USA. Shown are mean values ± 1 S.E. S.E. bars are not shown for some vegetation types to improve the clarity of the figure.

by harvest during the fall. All other crop residues were returned to the fields.

Nitrogen concentrations in aboveground litter were significantly higher in the cool-season grasses and poplar understory (1.2%) than in all other sites, and N concentrations in litter in the soybean fields (0.5%) were significantly lower than those in any other sites. This appears to contradict our finding that soybean had the highest live biomass N concentrations, but the litter in the soybean fields was old corn residue left from the previous growing season due to corn-soybean rotation. Over the study period, litter N (kg ha^{-1}) varied significantly among vegetation types ($P < 0.001$) (Figure 2B). Detrital N pools were signifi-

cantly greater in the buffers than in cropped fields in spring and summer (Figure 2B).

Only the poplar stands contained woody plants. Based on our inventories of all trees in the poplar stands not decimated by beavers, the mean pool sizes of wood biomass, wood C, and wood N averaged 38,000, 17,000 and 135 kg ha^{-1}, respectively. Poplar leaf biomass, C and N averaged 1500, 299 and 17 kg ha^{-1}, respectively, during the summer growing season.
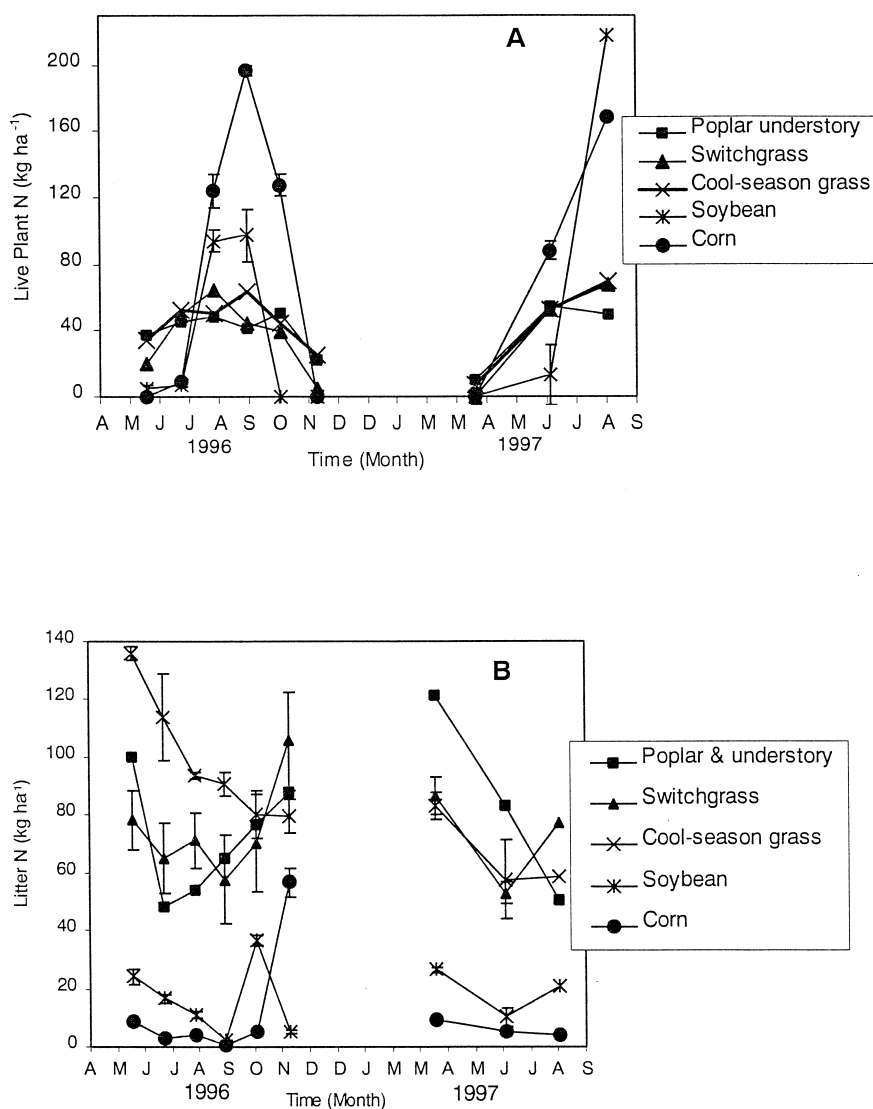
Figure 2. Aboveground live plant N (A) and litter N (B) in buffers and adjacent crop fields along Bear Creek in central Iowa, USA. Shown are mean values ± 1 S.E. S.E. bars are not shown for some vegetation types to improve the clarity of the figure.

Belowground biomass, C and N pools

Belowground biomass was assessed in terms of fine (<2 mm), small (2–5 mm) and coarse (>5 mm) roots. Coarse root data were published previously (Tufek-cioglu et al. 1999); therefore we focus on fine and small roots in this paper.

Live fine root biomass and C differed significantly among vegetation types ($P < 0.005$) (Figure 3A). Buffers had significantly higher live fine root biomass and C than did crop fields. Switchgrass had significantly greater live fine root biomass than did any other vegetation type ($P < 0.05$). Live fine root bio-

mass in the crop fields increased from May to the end of August and then declined (Figure 3A). Switchgrass live fine root biomass increased throughout the growing season, but declined over winter (Figure 3A). Poplar and cool-season grass had peak live fine root biomass in the early summer, with a second maximum in late fall of our first year of sampling (Figure 3A).

Nitrogen concentrations in live fine roots were significantly greater in corn (1.3%) and soybean (1.7%) than in buffer vegetation. Nitrogen concentrations in live fine roots were significantly lower in switchgrass (0.7%) than in poplar (1.0%) or cool-season grass
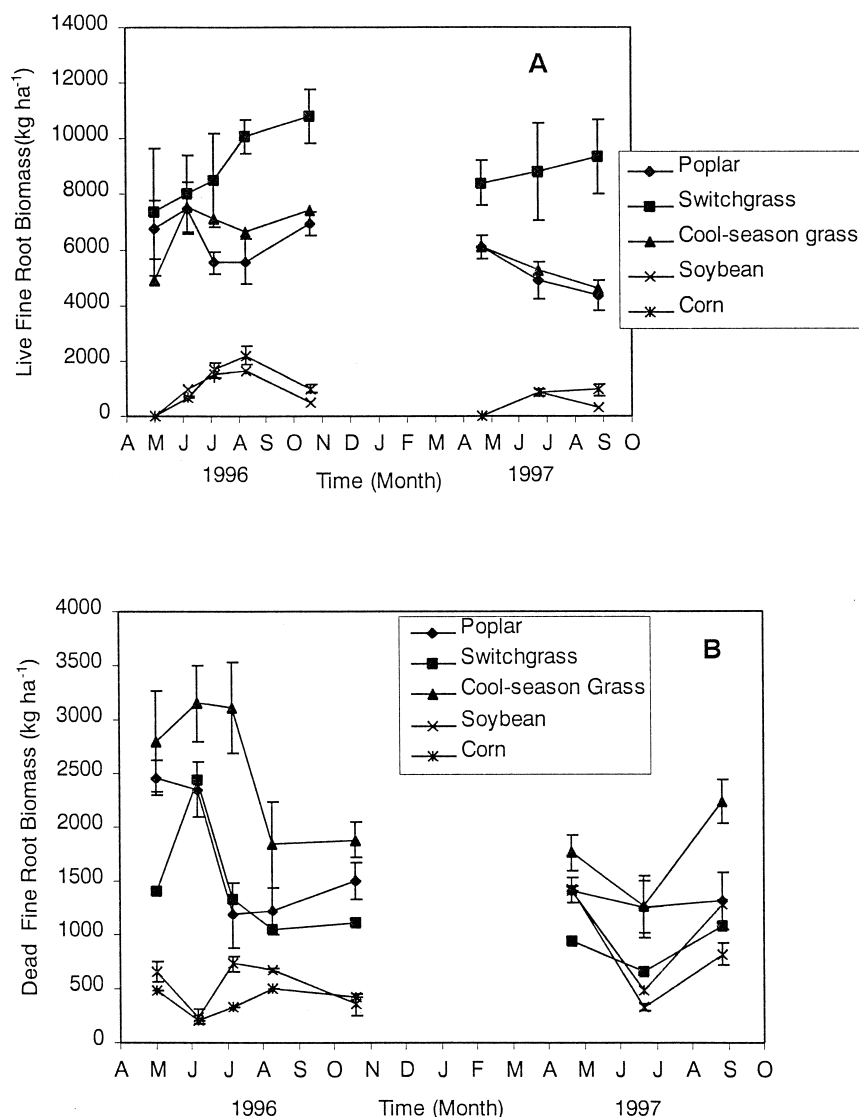
Figure 3. Live (A) and dead (B) fine root (0–2 mm) biomass in buffers and adjacent crop fields at 0–35 cm soil depth along Bear Creek in central Iowa, USA. S.E. bars are not shown for some vegetation types to improve the clarity of the figure.

(0.9%) ($P < 0.05$). Live fine root N pools (Figure 4A) varied significantly among vegetation types ($P < 0.001$) and sampling dates ($P < 0.03$). Over the growing season the crop fields had significantly lower live fine root N pools than did any other vegetation types. Switchgrass had significantly greater ($P < 0.05$) live fine root N pools than did any other vegetation type (Figure 4A).

Dead root biomass was substantially less than live root biomass in the buffers. In the crop fields all roots present at the end of the growing season (Figure 3B) contributed to the dead root pool during the winter.

Dead fine root biomass and C differed significantly among vegetation types ($P < 0.001$), with cool-season grasses having significantly greater dead fine root biomass and C than any other vegetation type ($P < 0.05$). Dead fine root biomass and C were significantly lower in the crop fields than in the buffers, except in September 1997. Peak dead root biomass varied across the growing season in all sites (Figure 3B).

N contents of dead fine roots were significantly higher in corn (1.6%) and soybean (1.6%) than in cool-season grasses (1.2%), poplar (1.2%) or switchgrass (1.0%) ($P < 0.05$). Dead fine root N pools (Fig-
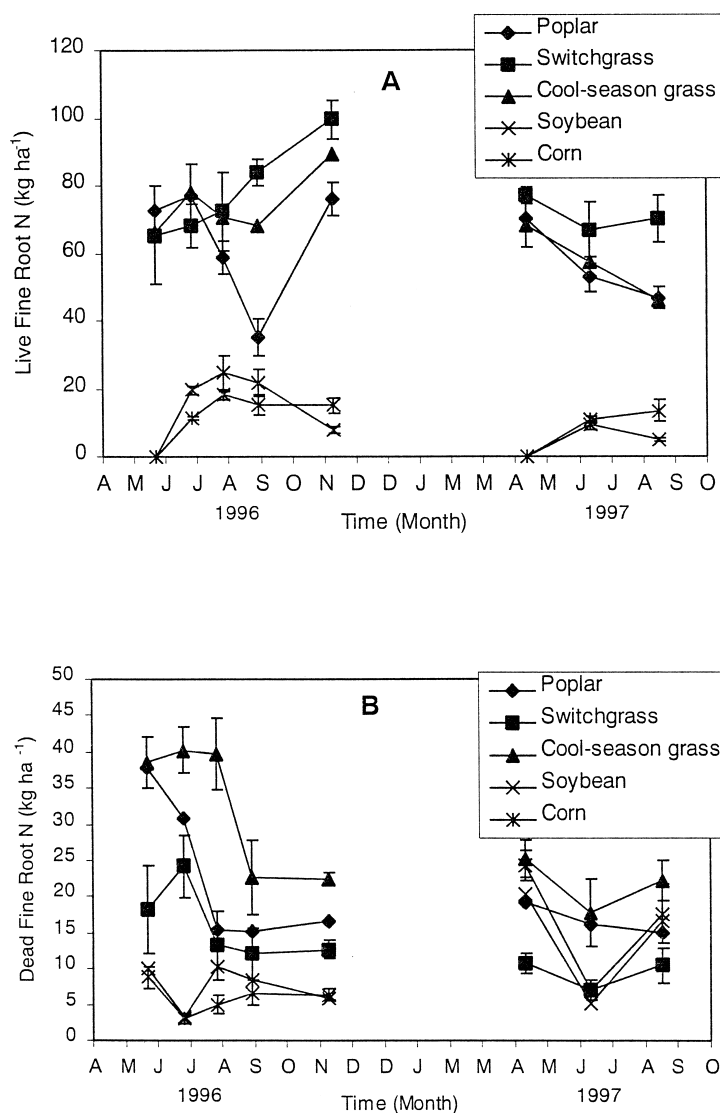
Figure 4. Live (A) and dead (B) fine root (0–2 mm) N in buffers and adjacent crop fields at 0–35 cm soil depth along Bear Creek in central Iowa, USA. S.E. bars are not shown for some vegetation types to improve the clarity of the figure.

ure 4B) varied significantly among vegetation types and sampling dates ($P < 0.001$). Cool-season grass had significantly greater dead fine root N than did any other vegetation types ($P < 0.05$). Poplar had significantly higher dead fine root N than did switchgrass or crops.

Live small root (2–5 mm) biomass, C and N were substantially less than live fine root (0–2 mm) biomass (Table 1), C and N. Live small root biomass, C and N differed significantly among vegetation types and sampling dates ($P < 0.003$). Switchgrass had significantly greater live small root biomass, C and N than did any other vegetation type. Live small root

biomass in poplar was significantly greater than in corn and soybean. There were no significant differences in dead small root biomass and C and N among vegetation types.

Root biomass decreased with increasing soil depth (Table 1). Across all sites, more than 73% of the total root biomass (0–125 cm) was in the surface 0–35 cm soil depth. Buffers had significantly higher root biomass in both soil depths than did crops (Table 1). Root biomass in the 35–125 cm depth accounted for 17 to 27% of total belowground biomass with switchgrass having the highest values.

Table 1. Belowground biomass distribution with soil depth averaged over sampling times in buffers and adjacent crop fields along Bear Creek in Central Iowa, USA

0–35 cm depth	Poplar (kg ha^{-1})	Switchgrass (kg ha^{-1})	Cool-season grass (kg ha^{-1})	Soybean (kg ha^{-1})	Corn (kg ha^{-1})
Live Fine Root (0–2 mm)	5822 (207)	8880 (543)	6455 (341)	683 (33)	917 (21)
Dead Fine Root (0–2 mm)	1549 (72)	1248 (69)	1943 (30)	675 (74)	623 (14)
Live Small Root (2–5 mm)	561 (77)	1899(211)	364 (156)	199 (55)	114 (12)
Dead Small Root (2–5 mm)	123 (48)	225 (100)	96 (3)	74 (26)	64 (21)
Coarse Root (>5 mm)	3119	0	0	305	1124
Total	11273	12222	9016	1943	2856
35–125 cm depth					
Live Fine Root (0–2 mm)	1798 (423)	4607 (799)	1722 (227)	211 (42)	292 (38)
Dead Fine Root (0–2 mm)	305 (96)	163 (57)	220 (54)	186 (28)	177 (13)
Live Small Root (2–5 mm)	287 (118)	19 (19)	63 (43)	0	4 (4)
Dead Small Root (2–5 mm)	44 (20)	0	1 (1)	0	1 (1)
Coarse Root (>5 mm)	813	0	0	0	0
Total	2986	4600	1858	465	557
0–125 cm depth					
Overall Total	14259	16822	10874	2408	3413
% in 0–35 cm	79	73	83	81	84
% in 35–125 cm	21	27	17	19	16

Note: Standard errors in parenthesis.

C-N ratios and biomass partitioning

Live aboveground tissues had higher C-N ratios than did aboveground litter. In contrast, C-N ratios of dead fine roots were higher than those of live fine roots, except for soybeans. Crop roots had significantly lower C-N ratios than did buffer-vegetation roots. Switchgrass had the highest C-N ratios in both above- and belowground tissues; soybean had the lowest. Root C-N ratios differed significantly with soil depth. Roots in the surface 0–35 cm had lower C-N ratios than did roots at 35–125 cm.

Biomass, carbon and nitrogen accumulations in above- and belowground components varied among vegetation types (Figure 5). Total aboveground standing live biomass, C and N were greatest in the poplar sites due to the contribution of the trees. Poplar had the greatest aboveground biomass, while switchgrass had the greatest belowground biomass. Because 1/3 of poplar stands were destroyed by beavers, these data reflect potential accumulations by poplar in sites relatively free of beaver damage. Poplar, soybean and corn accumulated more than 64% of their total C and N aboveground, while switchgrass and cool-season grasses incorporated less than 52 and 48%, respectively.

However, as a percentage of total biomass, belowground accumulation was the greatest under cool-season grass. Crops had the lowest mean belowground carbon and nitrogen pools. Total C and N accumulations were greatest in poplar, followed by switchgrass, cool-season grass, corn and soybean.

Discussion and conclusions

Aboveground biomass, C and N mass

Maximum aboveground biomass estimates for corn (19,380 kg ha^{-1}) in this study correspond well with data reported in the literature; Liang and MacKenzie (1994) reported values between 11,700 and 20,500 kg ha^{-1}. Our maximum aboveground biomass estimates for soybean (10,050 kg ha^{-1}) were greater than the four-year mean of 8330 kg ha^{-1} reported from Missouri (Buyanovsky and Wagner 1997). Our sites were located in riparian areas that probably were richer in soil nutrients and water than were the upland sites of Buyanovsky and Wagner. The growing season total (live + dead) aboveground biomass values for switchgrass (13,100–19,900 kg ha^{-1}) were higher than those reported for switchgrass by Stout
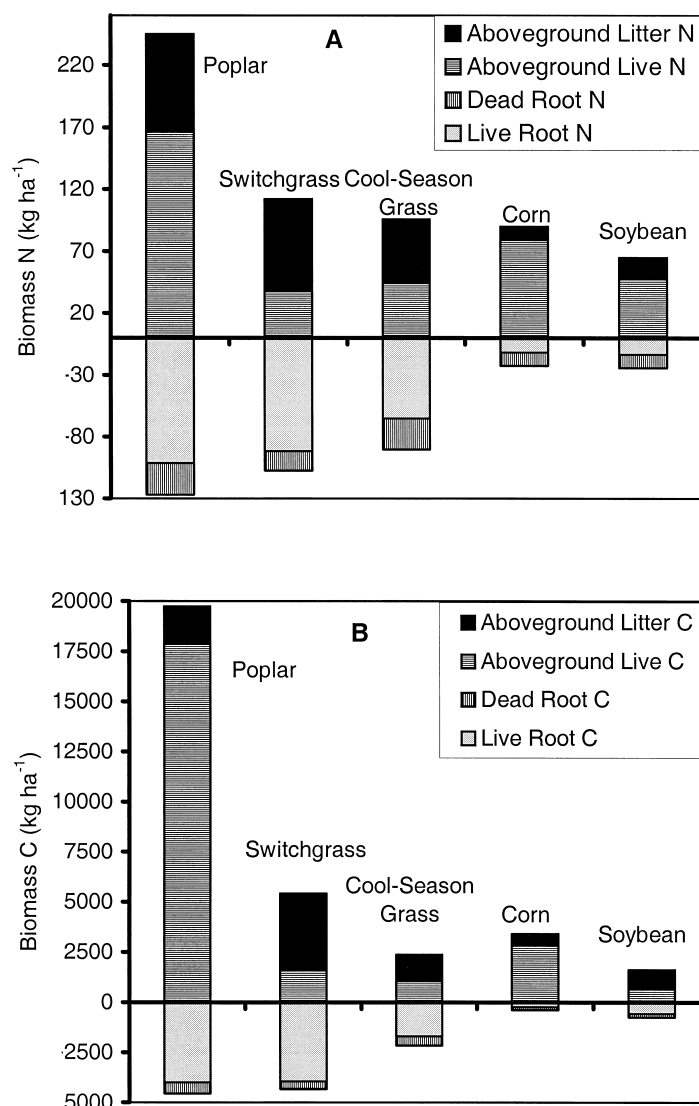
Figure 5. Nitrogen (A) and carbon (B) partitioning in buffers and adjacent crop fields averaged over all sampling dates along Bear Creek in central Iowa, USA.

and Jung (1995). Poplar aboveground biomass (38,000 kg ha^{-1}) after seven years was higher than that reported by Zavitkovski (1981) for five year-old, 1.2 × 1.2 m spaced poplar plantings in Canada.

Switchgrass and corn produced more live aboveground biomass with higher C-N ratios than did cool-season grasses and soybean. This indicates higher N use efficiency in switchgrass and corn compared to cool-season grass and soybean. Christie (1979) also found that total aboveground N pools were greater in C$_4$ than in C$_3$ grass communities. Low C:N ratios in soybean could be due to its nitrogen-fixing ability. It should be noted that corn was fertilized annually but

there was no fertilization in the buffers or soybean fields. The poplar sites had the highest overall aboveground biomass and C:N.

The crop fields had virtually no live biomass between November and May. Therefore, plant uptake of nitrogen in the crop fields was non-existent at those times. Keeney and Deluca (1993) observed maximum nitrate-N concentrations in the Des Moines River in April, May and early June from 1980 to 1991. Thus, there is no plant uptake of nitrogen by crops early in the year, when nitrate availability is high. At the same time, cool-season grass, switchgrass and poplar had

more than 4,000 kg ha^{-1} of live fine root biomass potentially able to absorb nutrients.

Switchgrass plots contained more aboveground detritus year-round than did any other sites, and contained the highest C-N ratios in their detritus. Based on summertime losses of litter mass, cool-grass litter decayed almost twice as fast as did that of switchgrass. The production of large amounts of high C:N litter by switchgrass may promote N immobilization in the switchgrass sites. Aboveground litter, and litter C and N were significantly higher in switchgrass sites. Wedin (1995) reported that low-quality litter from the prairie grass *Schizachyrium scoparium* (Michx.) Nash., a C$_4$ species, decomposed slowly and immobilized large amounts of N, whereas litter from the C$_3$ grass *Agropyron repens* (L.) Beauv. decomposed faster and showed no net N immobilization. Existence of substantial amounts of dead material on the soil surface in switchgrass sites provides relatively good conditions for nutrient and sediment removal from surface runoff.

Belowground biomass, carbon and nitrogen

Belowground biomass values found in this study for switchgrass were higher than those reported by Bransby et al. (1998), but lower than those reported by Ma et al. (2000). Dead and live fine root biomass in cool-season grasses were similar to those reported by Hayes and Seastedt (1987) in Kansas tallgrass prairie. In that site, live fine root biomass varied from 3200 to 6200 kg ha^{-1} and dead fine root biomass changed between 2800 to 5600 kg ha^{-1}. Our maximum root biomass values for corn (2850 kg ha^{-1}) and soybean (1940 kg ha^{-1}) were higher than those reported by Mengel and Barber (1974) for corn (1600 kg ha^{-1}) and by Sivakumar et al. (1977) for soybean (580 kg ha^{-1}) in the USA.

Switchgrass had the greatest amount of belowground biomass, C and N, but a relatively small dead root biomass. This might be due to the production of long-lived rhizomes. Hartnett (1989) reported that switchgrass maintained intact rhizome interconnections among stems up to 10 years and that it had long-lived rhizomes that function as sites of carbon and nitrogen storage. Wedin and Tilman (1990) found more than two-fold higher belowground biomass under C$_4$ grasses compared to C$_3$ grasses in the monocultures of five perennial grasses. Derner et al. (1997) suggested the possibility that accumulation of resources in C$_4$-grass rhizomes, rather than soils, helped to maintain C$_4$-grass dominance in the tallgrass community. The C$_4$ physiology of switchgrass may give it some advantages in producing more roots using relatively less nitrogen compared to cool-season grasses. Hence, we suggest that switchgrass may have a greater nitrate immobilization potential than do cool-season grasses.

Switchgrass had the lowest root and shoot N concentrations but the greatest root biomass. Tilman and Wedin (1991) observed that the species with the greatest root biomass and the lowest root and shoot N concentrations reduced soil ammonium and nitrate to a lower level than did other species grown in monocultures along an experimental nitrogen gradient. Thus, switchgrass may reduce soil solution and groundwater nitrate levels more than do cool-season grasses.

Cool-season grasses had the greatest dead belowground biomass, C, and N and the greatest percentage of belowground biomass accumulation. Several reasons could account for the relatively higher dead root biomass in cool-season grass sites. First, the fine roots of the cool-season grasses were concentrated in the surface soil (Tufekcioglu et al. 1999), where they were subject to dessication. Hayes and Seastedt (1987) found that extremely high root turnover rates in the 0–10 cm soil depth reflected by a cycle of pulses of root growth after a rain followed by rapid dieback as the soil dried out. Large amounts of surface litter in the switchgrass sites seemed to maintain higher soil moisture levels (Tufekcioglu et al. 2001).

In other studies conducted in the same area as our own, Marquez et al. (1999) reported higher soil organic C under cool-season grasses than under switchgrass, Pickle (2000) found greater microbial biomass under cool-season grasses than under switchgrass, and Tufekcioglu et al. (2001) observed greater rates of soil respiration in cool-season grasses than in switchgrass. The higher soil organic C accumulations and greater soil biological activity in cool-season grasses than in switchgrass might be driven by root biomass inputs having relatively low C:N ratios. That is, the production of high quality detritus by cool-season grasses may stimulate soil heterotrophic activity and promote the accumulation of microbial by-products that remain in the soil organic matter pool.

C-N ratios and biomass partitioning

In this study, root biomass represented from 19 to 57% of the total biomass of our sites. It decreased

with increasing soil depth. More than 73% of root biomass was in the surface 0–35 cm depth. Buyanovsky et al. (1987) found that approximately 81 to 87% of roots were in the surface 0–25 cm depth of soil in a prairie ecosystem, in Missouri, USA. Switchgrass had the highest root biomass in both 0–35 and 35–125 cm soil depths. Ma et al. (2000) found that switchgrass had a very deep root system, with roots extending up to 330 cm below the soil surface, implying that it can be useful in preventing losses of nutrients associated with non-point source pollution.

C-N ratios of roots differed with vegetation type and soil depth. Crops had lower C-N ratios compared to buffer vegetation. This could be due to fertilization in corn fields and N_2-fixation by soybean. Liang and MacKenzie (1994) found a linear relationship between N concentrations of corn and N fertilizer rate. Roots in 0–35 cm depth had lower C-N ratios than did roots in 35–125 cm depth. Surface horizons are generally rich in nutrients due to higher organic matter content and biological activity compared to subsurface horizons. This might be the reason for lower root C-N ratios in 35–125 cm soil depth.

After seven years of growth, the planted poplar and switchgrass plots had accumulated more biomass C and N than did the adjacent cool-season grass buffer (Figure 5). Over this period, rates of C accumulation in the poplar and switchgrass sites averaged 3000 and 800 kg ha^{-1} yr^{-1}, respectively. Rates of N immobilization in live and dead plant biomass averaged 37 and 16 kg ha^{-1} yr^{-1}, respectively. These values reflect the potential for planted, native-species perennial buffer vegetation to immobilize C and N on site during their early years, in central Iowa. Nitrogen immobilized by plants is not available for leaching to surface or ground waters, so planted riparian buffers can be used to help diminish the negative impacts of excess N in agricultural regions.

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