SOIL WATER NITRATE CONCENTRATIONS IN GIANT CANE AND FOREST RIPARIAN BUFFER ZONES

Jon E. Schoonover, Karl W.J. Williard, James J. Zaczek, Jean C. Mangun, and Andrew D. Carver[1]

ABSTRACT.—Soil water nitrate concentrations in giant cane and forest riparian buffer zones along Cypress Creek in southern Illinois were compared to determine if the riparian zones were sources or sinks for nitrogen in the rooting zone. Suction lysimeters were used to collect soil water samples from the lower rooting zone in each of the two vegetation types. The cane riparian zone had a significantly lower mean soil water nitrate-N concentration (0.45 mg L^{-1}) than the forest riparian buffer zone (4.29 mg L^{-1}). This was attributed to higher litter C/N ratios in the cane, which likely resulted in greater microbial immobilization of nitrogen within the rooting zone.

Forest and grass riparian buffer zones are being promoted throughout the United States and abroad to combat agricultural non-point source pollution. In Illinois, a leading agricultural state, nutrient and sediment inputs into streams are the States top water quality impairments. Excess nutrient export from the midwestern agricultural states, including Illinois, has been linked to the creation of hypoxic zones in the Gulf of Mexico (Alexander and others 2000).

Most of midwestern riparian zone research has focused on tile-drained agricultural systems in central Illinois and central Iowa (Osborne and Kovacic 1993, Schultz and others 1995, Lee and others 2000). However, the majority of agricultural land in the Midwest, including southern Illinois, is not tile-drained. Therefore, we are investigating the ability of native Illinois riparian cover types (cane and forest) to serve as sinks for nitrogen within the rooting zone of a non tile-drained system.

Historically, giant cane was an important component of the pre-European settlement landscape in southern Illinois (Flower 1822). There is significant interest among the state resource agencies responsible for riparian restoration in returning cane to the local landscape. There has been no research conducted to evaluate the nutrient attenuation capabilities of giant cane. The data collected from this research will supplement vegetation restoration and establishment guidelines for southern Illinois riparian zones.

MATERIALS AND METHODS

Study Location

The riparian research area was located in the Cypress Creek Watershed. Cypress Creek is a tributary of the Cache River in southern Illinois, and is one of the Illinois Department of Natural Resources (IDNR's) pilot watersheds (fig. 1). Field plots in two vegetation types (cane and forest) were established and monitored along Cypress Creek on a privately owned farm, Section 3, Township 13 South, Range 3 East (USGS 7.5 Topographic Map). The cane and forested plots were estimated to be 20-30 years old. The contributing agricultural field that drained into the buffers was 0.26 ha in size and had an average slope of 1 percent. The soil within the study area is classified as Haymond silt loam (Typic Udifluvent) and the underlying geology of the area is Ste. Genevieve (or Levias) and Warsaw limestones.

A no-till rotation between corn (*Zea mays* L.) and soybeans (*Glycine max* (L.) Merr.) had been practiced, with fertilizers added every other year (each corn year). Dry fertilizers, 0-0-60 and 18-

[1] Graduate Assistant (JES), Assistant Professor (KWJW), Assistant Professor (JJZ), Associate Professor (JCM), and Assistant Professor (ADC), Department of Forestry, Southern Illinois University, Carbondale, IL 62901-4411. KWJW is corresponding author: to contact, call (618) 453-7478 or e-mail at williard@siu.edu.

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46-0, were added to the soil surface at a rate of 223 kg ha^{-1}. Ammonia, at a rate of 167 kg ha^{-1} was knifed into the soil before planting. In the early spring, before planting, dense winter annuals covered the agricultural field, reducing the risk of erosion.

Field Methods

Water samples were collected between November 2000 and October 2001 at the study area. Soil suction or vacuum lysimeters were installed within the rooting zones of the vegetated buffer zones to sample soil water. The lysimeters were installed to a depth of 0.2 m in the cane buffer and 0.6 m deep in the forested buffer. The two depths represented the rooting depths of the two cover types. Within the two vegetation plots, 12 lysimeters were installed in three rows of four perpendicular to the field edge to try to account for the variability in soil water chemistry. The lysimeters were installed at 3.3 m intervals starting from the field edge. Row locations were randomly selected within the plot boundaries.

Soil lysimeters were composed of a 5 cm PVC tube, a porous ceramic cup, and a rubber cap. Lysimeters were installed on 2000 June 7. Sixty pounds of vacuum pressure was applied to the lysimeters using a hand pump to create pressure to extract water from the soil micropores. For the first 5 months after installation, the lysimeters were not sampled but flushed every 2 weeks to allow microbial activity to return to normal rates after the disturbance. Starting in November 2000, samples from the lysimeters were collected bi-monthly, and after significant storm events.

At the beginning of the study, soil water samples were analyzed for ammonium, nitrate, and orthophosphate concentrations. After 3 months, samples were only analyzed for nitrate because ammonium and orthophosphate concentrations were always at or below the detection limit (0.05 mg L^{-1}). However, samples were randomly checked for ammonium and orthophosphate throughout the study period and none were detected. During the mid summer months, the soils became too dry for most of the lysimeters to extract water. During this period, measurable samples could be collected from only 1 or 2 lysimeters. Droughty conditions persisted at the site through September. In the wetter months, nearly all lysimeters accumulated sufficient water for sampling.

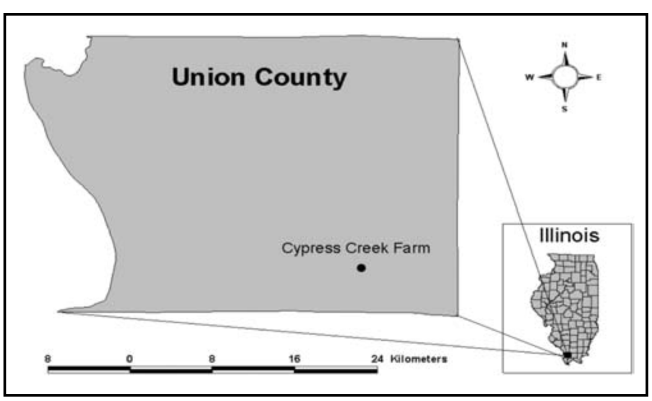

Figure 1.—*Study location along Cypress Creek in Union County, Illinois.*

The two vegetation communities were characterized by estimating the biomass and stems per acre for each site. To estimate cane biomass, 30 stems were randomly selected to represent the population of stems within the buffer. The leaves and the culms were separated and oven-dried to estimate their individual biomass. To estimate the number of stems per acre, a stratified random sample was used to locate 10 m^2 plots. Within each plot, each stem was counted and 10 random stems were measured for their diameter. In the forested site, all trees were identified and measured at diameter breast height (DBH). With published biomass equations, DBH was used to estimate the total aboveground biomass for each species in the forested cover type (Ter-Mikaelian and Korzukhin 1997).

Soil within the cane and forested buffers were analyzed for physical and chemical characteristics. The soil texture was analyzed using a hydrometer method outlined by Black and others (1965). Ten soil cores were collected at the soil surface, measured for volume and weighed. The cores were then oven dried and re-weighed to calculate the bulk density (Black and others 1965). The infiltration rates were also measured using ring infiltrometers (Black and others 1965). Five samples were taken at each site and the geometric mean was used to account for the variability in sampling locations.

Laboratory Methods

Soil water nitrate concentrations were analyzed using a Dionex 4000i ion chromatograph (Dionex Corporation, Smyrna, GA). Soil water ammonium and orthophosphate were analyzed with a Hach 4000v spectrophotometer via a nesslerization and absorbic acid method, respectively (Greenberg and others 1992). Total carbon to total nitrogen (C/N) ratios of the litter and the mineral soil were also determined for the two vegetation communities. First, the 4.5 m cores were collected with the help of Union County Natural Resources Conservation Service (NRCS) personnel. An NRCS soil scientist classified the soils.

The different horizons of the soil cores were individually analyzed for their C/N ratio. The soil was prepared for C/N determination by air drying, then sieving through a 2 mm (9 mesh) screen. Six mg of fine, dry soil was placed in 5 mm X 9 mm tin capsules along with an even scoop of vanadium pentoxide. Eighty-nine capsules containing mineral soil and litter samples were shipped to Fernow Experimental Forest Station in Parsons, WV, for total C and N analysis by combustion using an organic elemental analyzer (Baccanti and others 1993). The resulting total C and N values were reported on a percentage basis, mg of C or N per mg of soil. These total C and N percentages were converted to kg ha^{-1} of C and N by multiplying the percentages by the bulk density (g cm^{-3}) and the depth of the surface mineral soils, 15 cm.

Statistical Methods

Soil water nitrate-N was analyzed with SAS for Windows V8 (SAS Institute, Cary, NC). A mixed model with repeated measures procedure was used to analyze soil water nitrate-N differences between cover types and within cover types at varying distances. The LS MEANS mean separation procedure was used to identify differences between the sites. A T-test with unequal variances was used to analyze differences between the C/N ratios in soil cores.

RESULTS AND DISCUSSION

The sand, silt, and clay content within both the cane and forested riparian buffer zones were 10, 70, and 20 percent, respectively. The bulk density of the cane site was 1.08 g cm^{-3} and the forested site was 1.19 g cm^{-3}. The infiltration rate of the cane site was 37.93 mm hr^{-1} and the forest was 26.78 mm hr^{-1}.

Soil water within the forested riparian buffer zone had a significantly (alpha = 0.05) higher nitrate-N concentration (4.29 mg L^{-1}) than within the cane buffer zone (0.45 mg L^{-1}) (fig. 2). It

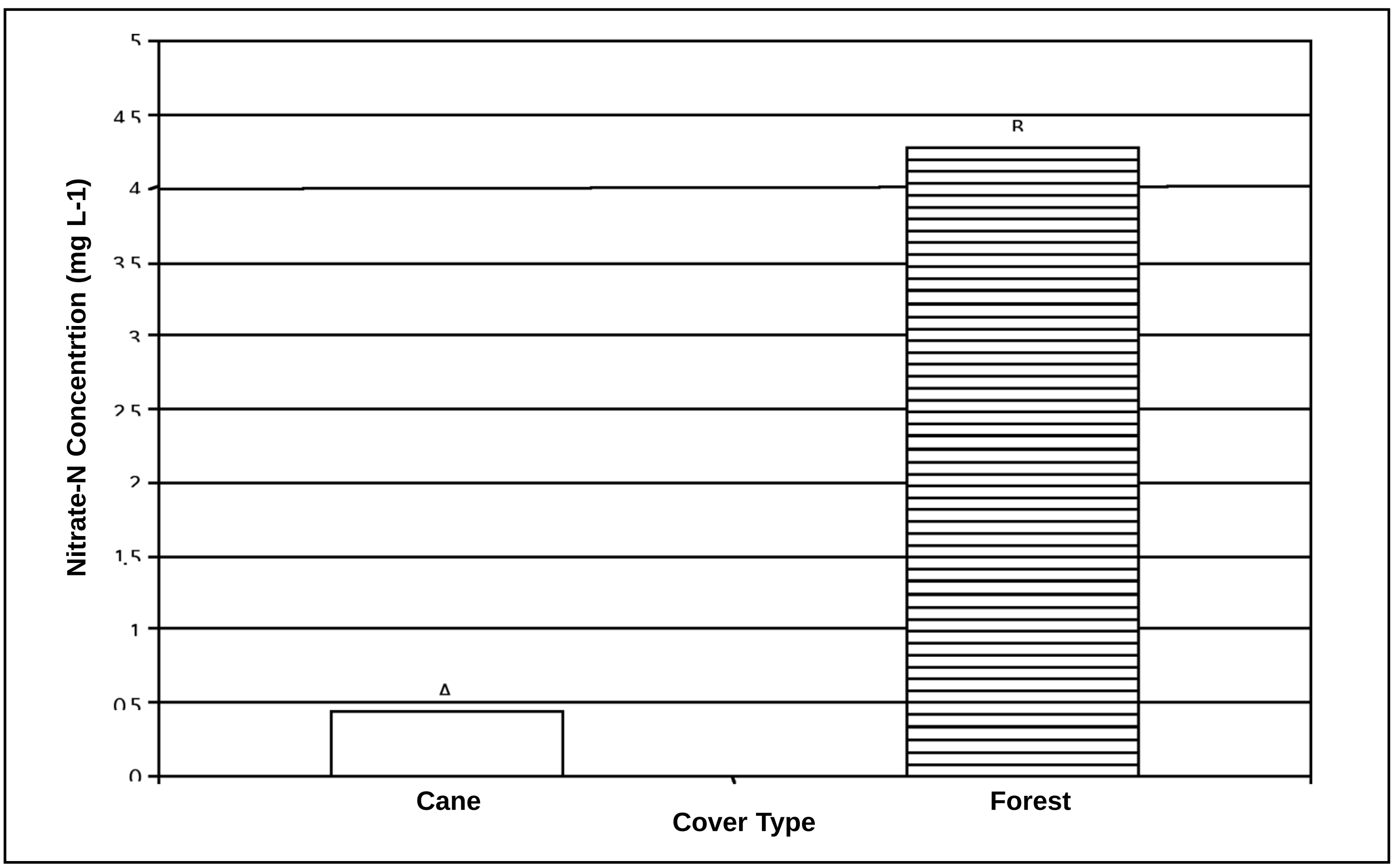

Figure 2.—*Mean nitrate-N concentrations in soil water beneath giant cane and forested cover types.*

is assumed that nitrogen inputs from the agricultural area into the two vegetation plots were similar because the plots drained the same field and were adjacent to one another. It is also significant to note that our soil horizons did not contain any shallow confining layers or fragipans. Therefore, we assumed that the majority of soil water sampled in the riparian zones originated from vertical percolation of overland flow within the riparian areas and not lateral interflow from the agricultural field.

The lower average nitrate concentration in the cane could be explained by differences in root uptake rates and/or microbial nitrogen cycling rates between cane and forest. The cane could have greater uptake rates of nitrate due to an observed dense rooting network in the shallow soil horizons. While root biomass was not estimated for the two cover types, the aboveground biomass was calculated. The forest had significantly (alpha = 0.05) greater aboveground biomass (463,717 kg ha^{-1}) than the cane (36,321 kg ha^{-1}), which does not support our results assuming aboveground biomass is an adequate index to root biomass.

The soil nitrogen cycling characteristics of the two cover types was investigated by measuring the C/N ratios in the soil at rooting depth. At C/N ratios >30, net N immobilization generally occurs while at C/N ratios <20, net N mineralization occurs (Alexander 1977). This is due to the competition for N between nitrifying (autotrophic) and immobilizing (heterotropic) bacteria in the soil. It has been shown that heterotrophic bacteria can out compete nitrifiers for available ammonium (Riha and others 1986). Thus, at lower C/N ratios, the heterotrophic demand for ammonium is satisfied and more N is available for nitrifying bacteria, allowing for greater net nitrate production. The cane litter had a significantly greater mean C/N ratio (20.47) than the forest (17.12) (table 1), indicating a greater likelihood of net N immobilization rather than net mineralization. C/N ratios of litter have been found to be a strong indicator of the potential for nitrate leaching in forest soils in a broad survey of European forests (Gunderson and others 1998).

Increased N immobilization in the cane site may also be due to a more uniform addition of labile carbon to the litter layer via year-round leaf-fall. During forest leaf-fall in mid- to late-October, a flush of carbon would be added to the system, but throughout the remainder of the year the litter would likely be left containing more recalcitrant carbon forms (Paul and Clark 1996).

C/N ratios in mineral soil were higher in the forest soil (13.61) than the cane soils (10.96) (table 1), which is opposite of the relationship in the litter layer of the two sites. If carbon was in an available form in the mineral soil, one would expect more net nitrogen immobilization in the forest soils. However, tree leaves, bark, and stems contain substantial amounts of carbon that is in recalcitrant forms, such as lignin (Paul and Clark 1996), while grasses have fewer recalcitrant types of carbonaceous compounds within their tissues (Paul and Clark 1996). Therefore, the cane may still exhibit greater net N immobilization than the forested site, because its carbon is found in more available forms that are rapidly assimilated. The rapid assimilation of the carbon could result in the lower observed C/N ratios within the mineral soil of the cane.

Microbial denitrification within the soils is another possible source of nitrate loss within the rooting zone. However, at our study site, denitrification was assumed to be negligible because of the presence of a relatively well-drained riparian soil, and a water table that remained well below the rooting zone throughout the study.

Table 1.—*Carbon to nitrogen ratios (C/N) of mineral soil and litter in forest and giant cane riparian buffer zones*

Site	Location of core (m)	Mineral soil C/N	Litter C/N	Total N content of surface soil kg ha^{-1}
Cane	Field edge	12.48	21.74	1,177
Cane	3.3	10.50	21.28	1,308
Cane	6.6	10.75	21.26	2,452
Cane	10.0	10.11	17.60	2,779
Forest	Field edge	14.38	16.85	1,805
Forest	3.3	14.92	17.15	3,203
Forest	6.6.	15.19	16.87	2,690
Forest	10.0	9.97	17.61	2,655

CONCLUSIONS

Giant cane appeared to be a greater sink for nitrogen than deciduous forest. High litter C/N ratios of cane likely contributed to the low soil water nitrate-N concentrations by stimulating microbial nitrogen immobilization. The year-round inputs of fresh litter by cane supplied significant amounts of labile carbon to riparian soils, likely resulting in substantial microbial nitrogen immobilization. Giant cane's ability to serve as a sink for nitrogen in the rooting zone provides further evidence why it should be included in a multi-species riparian zone restoration design.

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