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Technical Note

A Technique for Estimating Riparian Root Production

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Abstract

Belowground plant biomass plays a critical role in the maintenance of riparian ecosystems and generally constitutes the majority of the total biomass on a site. Despite this importance, belowground dynamics of riparian plant species are not commonly investigated, in part because of difficulties of sampling in a belowground riparian environment. We investigated the field utility of a root-ingrowth sampling technique for measuring root production. We established four streamside sampling sites in southeastern Oregon, and randomly located four plots within each site. In each plot we established two 7.6-cm–diameter sand-filled ingrowth cores in September of 2004. In September of 2005 we harvested the cores with the use of a vacuum sampling technique in which a 5.1-cm–diameter camphored polyvinyl chloride casing was driven into the center of the root core and sand and root materials were suctioned out. Root-length density was determined by computer image analysis, and roots were dried and weighed to determine production by weight. Results indicate that root-length density averaged 7.2 (± 0.7) $\mathrm{cm \cdot cm^{-3}}$ across sites and root-production index was 356.7 (± 20.6) $\mathrm{g \cdot m^{-2}}$. Our index to root production by weight was consistent with previous estimates of annual root production reported in the literature. Our sampling technique proved to be a practical solution for root sampling in riparian environments, and helps overcome some of the difficulties in sequential coring of saturated soils. Use of any ingrowth core technique to index root production can potentially bias production estimates because of the artificial, root-free environment of the core. However, these biases should be consistent across sites, making ingrowth cores useful for determining differences between manipulative treatments.

Resumen

La biomasa subterránea de las plantas tiene papel crítico en el mantenimiento de ecosistemas rivereños y generalmente constituye la mayor parte de la biomasa total de un sitio. A pesar de esta importancia, las dinámicas debajo del suelo de las especies de plantas rivereñas, normalmente no se investigan, en parte por las dificultades de muestreo bajo el suelo en un ambiente rivereño. Investigamos la utilidad de campo de una técnica de muestreo de crecimiento de raíz para medir la producción de la misma. Establecimos cuatro sitios de muestreo a la orilla del torrente al sureste de Oregón, con cuatro parcelas al azar en cada sitio. En cada parcela establecimos dos núcleos de crecimiento de 7.6 cm de diámetro rellenos de arena en septiembre del 2004. En septiembre del 2005 cosechamos los núcleos utilizando una técnica de muestreo al vacio donde una cubierta de PVC de 5.1 cm de diámetro se introdujo en el centro de núcleo de la raíz, y la arena y los materiales de la raíz se succionaron hacia afuera. La densidad de la longitud de la raíz se determinó por análisis de imagen computacional. Además, las raíces se secaron y pesaron para determinar la producción por medio del peso. Los resultados indican que la densidad de la longitud de la raíz promedió 7.2 (± 0.7) $\mathrm{cm \cdot cm^{3}}$ a través de los sitios y el índice de producción de la raíz fue 356.7 (± 20.6) $\mathrm{g \cdot m^{2\cdot}}$ Nuestro índice de producción de raíz por peso fue consistente con previas estimaciones de producción anual de raíces reportadas en la literatura. Nuestra técnica de muestreo probó ser una solución práctica para muestreo de raíz en ambientes rivereños y ayudó a vencer algunas de las dificultades en secuencias básicas de suelos saturados. El uso de cualquier técnica de núcleo creciente para el índice de producción de raíz puede potencialmente perjudicar las estimaciones de producción debido al ambiente artificial libre de raíces del núcleo. Sin embargo, esas tendencias deben ser consistentes a través de los sitios, haciendo que los núcleos de crecimiento sean útiles para determinar las diferencias entre tratamientos manipulativos.

Key Words: belowground production, root-ingrowth core, root-length density

INTRODUCTION

Belowground plant biomass plays a critical role in the functioning of riparian ecosystems and may constitute the majority of site biomass (Manning et al. 1989). Roots and rhizomes serve not only to provide nutrients to plants, but also to anchor both the plants themselves and the rooting substrate (Smith 1976; Kleinfelder et al. 1992). Collectively, the roots of riparian plant communities (particularly sedges and woody plants) serve to buffer the structure of the stream channel and surrounding floodplain from the destabilizing energy of seasonal flooding (Beeson and Doyle 1995; Winward 2000).

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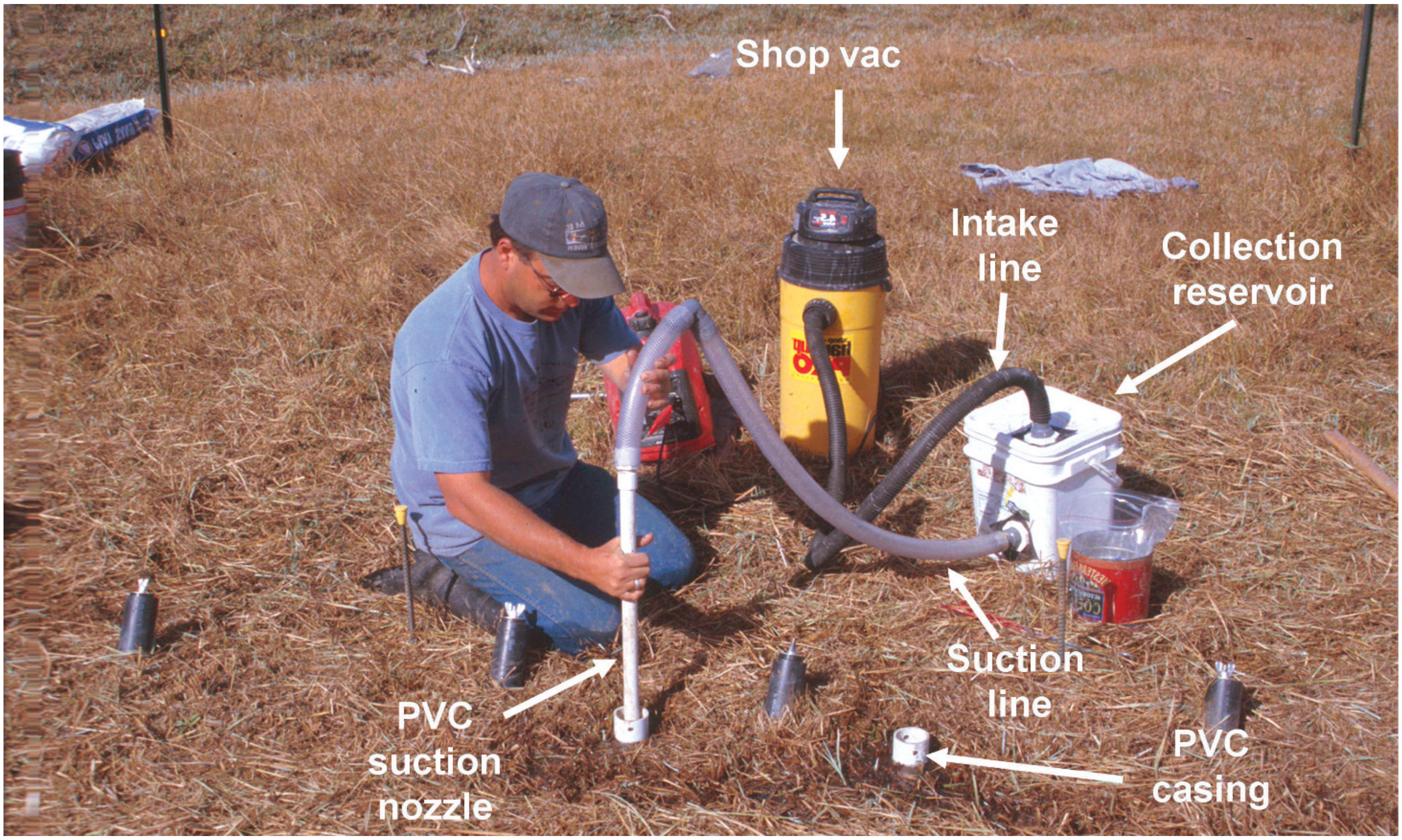

Figure 1. Overview of root-harvest technique. Ingrowth cores (7.6-cm diameter) were excavated to a 30-cm depth in streamside plots during the fall and filled with sand. Cores were harvested after 1 yr with the use of a shop vacuum modified with a polyvinyl chloride (PVC) suction attachment and collection reservoir.

Despite the importance of roots to the integrity of riparian areas, very little is known regarding the belowground production of riparian plants.

This lack of knowledge of belowground riparian plant production may result from the fact that sampling in a belowground, seasonally flooded environment is logistically difficult. This difficulty is amplified by an extremely high standing crop of live and dead root material (Manning et al. 1989) that necessitates a large time investment for separating live or current year's production from previous years' production. One approach to estimating root production that minimizes some of these problems is to utilize a root-ingrowth technique (e.g., Kiley and Schneider 2005) that relies on root expansion into a root-free media. Here we report on a technique that employs root-ingrowth cores and a novel root-collection device for indexing root production in riparian systems.

MATERIALS AND METHODS

We established four 6 × 12 m sites along a Rosgen C channel (Rosgen 1994) stream in Harney County, Oregon. This area has historically been moderately utilized by cattle during the growing season and is dominated by Nebraska sedge (*Carex nebraskensis* Dewey) with lesser amounts of wooly sedge (*Carex lanuginosa* Michx.) and baltic rush (*Juncus balticus* Willd.). Electric fencing was used to exclude study sites from grazing for the duration of the study. At each site we measured water-table depth (relative to ground level) with the use of shallow polyvinyl chloride (PVC) wells from June through mid-September. We randomly selected locations for four 50 × 125 cm plots within each site. Plots were within 1 m of the stream edge and were within the streams' zone of hydrophytic influence under base flow conditions.

In each plot we located two ingrowth cores to a depth of 30 cm. Cores were excavated following plant senescence in September of 2004 with a 7.6-cm–diameter soil corer and immediately filled to ground level with commercially purchased sand (average particle size = 0.47 mm). Cores were harvested in late September of 2005 by driving a 35-cm length of 5.1-cm–diameter PVC casing (Fig. 1) into the center of the core. The edge of the PVC in contact with the soil was sharpened with a camphoring tool so that it would cut roots as the pipe was driven into the ground.

A 4.5-horsepower shop vacuum powered by a 1 000-watt generator was used to evacuate sand and root material from the PVC pipe. We attached the 3.8-cm (inside diameter) intake line for the shop vacuum to the detachable lid of an 18.9-L collection reservoir (Fig. 1). A 5.1-cm (inside diameter) suction line was attached 10 cm from the bottom of the collection reservoir; to facilitate ease of takedown we attached intake and suction lines by slipping them over PVC nipples. At the end of the suction line we used a threaded PVC reducer to attach a 1.9-cm (inside diameter) suction nozzle. We fitted a 90° elbow near the end of the suction line to facilitate holding the suction nozzle upright during harvest without dislodging its connection to the collection-reservoir nipple.

The two cores from each plot were combined for analyses. All material was bagged, drained of excess water, and frozen until analysis. Frozen root materials were thawed and washed in a root washer (Gillison's Variety Fabrications Inc., Benzonia, MI) through a 0.5-mm-mesh screen (rinse water was discarded following initial wash). Roots were then scanned (157.5 dots $\cdot$ cm^{-1}) on an Epson Expression 10,000XL digital scanner (Epson America, Inc., Long Beach, CA) and the WinRhizo analysis program (RHIZO-Regent Instruments, Quebec City, Quebec, Canada) was used to estimate root-length density (RLD) by size-class diameter (rhizomes = $>$ 3.5 mm, medium roots = 1–3.5 mm, fine roots = $<$ 1 mm) from scanned images. Root materials were then oven dried and weighed. All postharvest processing and analysis was conducted by the same person. Means for root-production index (estimated root production in g $\cdot$ m^{-2}) and root-length density are reported with their associated standard error.

RESULTS

Water-table depth was positive (i.e., standing water) from June through mid-July and then remained negative through mid-September, but never exceeded 20 cm from the soil surface. These values suggest that water was not a limiting factor for maintenance and growth of sedges during the time of our study (Castelli et al. 2000; Chambers et al. 2004).

We found total RLD (all size classes inclusive) averaged 7.2 ($\pm$ 0.7), and ranged from 5.8 ($\pm$ 0.5) to 9.4 ($\pm$ 2.1) cm $\cdot$ cm^{-3} across sites (Fig. 2A). These values varied dramatically between root-size classes, with fine roots averaging 88% of total RLD scores across sites (Fig. 2A). Rhizomes were least abundant (0.6% of total), and medium-diameter roots (1–3 mm) were intermediate (11.5% of total). Root-production index values varied across sites from 307.9 ($\pm$ 29.1) to 420.8 ($\pm$ 29.6) g $\cdot$ m^{-2}, averaging 359.7 ($\pm$ 20.6) g $\cdot$ m^{-2} (Fig. 2B).

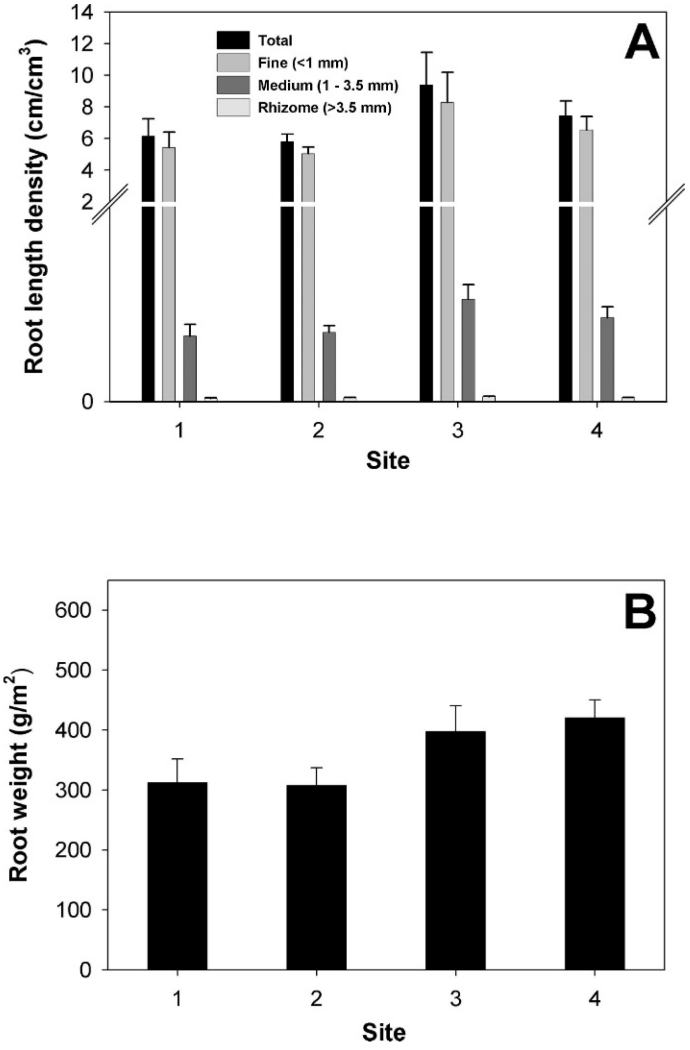

Figure 2. Root-production index measured with the use of root-length density by root-size class (**A**) and weight (**B**) for sedge-dominated riparian plots in eastern Oregon. Values represent mean scores within a site ± standard error.

DISCUSSION

Root production of sedges is seldom reported, but our values are within the range of values for annual production reported in the literature. Season-long fine-root production (to 15-cm depth) for sedge-dominated (*Carex scopulorum* T. Holm) wet meadows in Colorado was 364 g $\cdot$ m^{-2} (Fisk et al. 1998). Fine-root production for sedge (*Eriophorum vaginatum* L.) tundra was 150 g $\cdot$ m^{-2} in the upper 40 cm of the soil profile (Sullivan et al. 2007). Kiley and Schneider (2005) found production values (to 30-cm depth) of approximately 500 g $\cdot$ m^{-2} for mixed sedge (*Carex* spp.) communities in a riparian system in New York. We were not able to find published references to production of sedges as a function of RLD. However, given that root length may relate strongly to erosion control (Manning et al. 1989), RLD may be an important indicator of stability for streamside sedge communities. Manning et al. (1989) reported RLDs of 95.6 and 33.6 cm $\cdot$ cm^{-3} for Nebraska sedge and Baltic rush communities, respectively. These values are probably higher than our RLD estimates because they represent standing crop of live roots, which incorporates multiple years of root production.

The central concept behind our technique was the use of suction to harvest root-ingrowth cores after the roots have been severed with a camphored PVC casing. Harvest of ingrowth cores by a coring technique has been used in sedge communities (e.g., Kiley and Schneider 2005). However, the high water table in our plots often made this coring technique difficult, as water-saturated soils generally fell out of the bottom of the coring device when extraction was attempted. In fact, the most difficult step in our field technique was extracting the initial core to be filled with sand. We found the suction technique to be effective at evacuating sand and root material from the ingrowth core, even in plots where the core was completely submerged. Ease of harvest with our suction technique was partly facilitated by the use of sand as an ingrowth media. Sand flowed easily through the suction nozzle, but the vacuum pressure was not sufficient to suction the loamy, root-laden soils at the bottom of the core, thus preventing root materials from outside the ingrowth core from entering the sample.

Others have constructed ingrowth cores for sedges with the use of soil-filled fiberglass (Nadelhoffer et al. 2002) or nylon mesh cylinders (Sullivan et al. 2007). This technique is predicated on the assumption that roots extending into the ingrowth core will break cleanly when the core is extracted (as opposed to being pulled out of the core as it is extracted). We initially experimented with wire-mesh cylinders and found that this assumption does not necessarily hold, particularly for larger-diameter roots. An alternative is to recore the mesh cylinders with the use of a coring device with a diameter slightly larger than the cylinder and then cut the roots flush with the mesh with a razor blade. However, this does not solve the problem of waterlogged soils falling out of the coring device during extraction.

Variable physical and nutrient characteristics of rooting media can cause between-site variation in production as measured by root ingrowth (Fisk et al. 1998; Milchunas et al. 2005). Our use of sand as an ingrowth media is somewhat artificial, given the loamy soil texture (within the depth range of the ingrowth cores) of native soils at our sites; thus our use of the term "root-production *index*." Using root-free sand could result in overestimates of root production because of relative ease of roots passing through sand as compared to native soil and the competition-free environment of the core (Fisk et al. 1998). Alternatively, estimates could be negatively biased because of a low nutrient supply rate associated within the sand media (James and Richards 2006). However, any quantitative biases associated with competition, particle size distribution, or nutrient supply rate should be consistent across sites, which would not undermine the utility of our technique for estimating qualitative differences in root production between manipulative treatments. If the artificiality of using sand is of concern, practitioners of our technique could use sieved native soils to fill ingrowth cores, but a more powerful vacuum may be necessary to extricate this media.

For our sites, the diameter of the initial hole for the sand-filled core needed to be larger than the intended final core diameter. Our initial core holes were extracted to 7.6-cm diameter, but shrunk to approximately 6.4-cm diameter following removal of the coring device because of the sponge-like properties of the root-laden, wet riparian soils. The resulting 6.4-cm–diameter hole was slightly larger than the 5.1-cm–diameter core that was harvested, which helped to prevent driving the PVC casing used at harvest into the native soils surrounding the core (Kiley and Schneider 2005). The differential texture between the sand-filled core and the "tighter" textured native soils also helped to guide the PVC casing as it was pushed into the ground at final extraction.

Attaching the intake line to the lid of the collection reservoir (Fig. 1) allowed for collection of roots without having them sucked into the shop vacuum. Collecting roots in the shop vacuum itself would simplify our collection system. However, in preliminary field work we found that roots tended to collect on and around the vacuum filter and in crevices within the machine, making full recovery of harvest materials uncertain. With the collection reservoir installed we did not observe any root matter within the shop vacuum.

Additional considerations when developing a field protocol for using ingrowth cores include duration of ingrowth period and potential impacts of freezing samples prior to processing. Although we are aware of no published references indicating this to be the case, it is possible that postharvest freeze/thaw cycles could fracture roots and decrease accuracy of production estimates. In our study the decision to freeze samples prior to processing was pragmatic: Not freezing samples would have increased likelihood of decomposition because of the time necessary to wash root samples and prepare them for analysis. Use of a 12-mo ingrowth period may alter root-production estimates because of death and decomposition of roots. We installed cores in the fall because flooding during spring would have prevented installing them at that time, and installation during summer would miss the spring growth window. If increased accuracy of production estimates is required, multiple cores should be installed in each experimental unit and harvested sequentially throughout the growing season.

IMPLICATIONS

In many sedge-dominated plant communities the majority of the biomass pool is below ground (Manning et al. 1989). In spite of the importance of belowground biomass, there are relatively few studies on the topic. Sand-filled ingrowth cores combined with vacuum sampling proved to be a practical solution for overcoming difficulties associated with sampling root production in riparian environments. Our data suggest this technique will provide production estimates (based on weight) similar to those reported for other sedge communities. The artificial environment of root-free sand cores could quantitatively bias production estimates, but these biases would not reduce the value of the technique for estimating qualitative impacts of treatments or trends in production over time. The major disadvantage of our technique is logistical, given the broad array of equipment required for sampling. A wheeled cart or, where permissible, all-terrain vehicle, for equipment transport would increase the logistical feasibility of the technique.

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