Fine Root Turnover in Alfalfa During Stand Establishment

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Introduction

Fine root production and loss affect how ecosystems function because of plant nutrient and water uptake and subsequent release of assimilated C and nutrients to other organisms. Growth and decomposition in the fine root system occur simultaneously, and life spans of fine roots range from a few weeks to several years. Actual rates of fine root turnover (production, death, and decomposition) in the field are influenced by nutrient and water availability, cultural practices (like harvest), pathogen infestation, and soil faunal predation.

Recently, alfalfa germplasms with different root system architectures have been produced via divergent phenotypic selection. These germplasms are being developed to serve different agronomic and environmental goals, such as rapid root elongation into the subsoil to help remediate nitrate-contaminated soil or high root length densities in the topsoil to absorb nutrients applied in agricultural and food processing wastes.

Knowledge of root demographic characteristics associated with these germplasms is important because rapid root turnover could help alleviate N deficiencies in eroded soils or in neighboring plants, but also might exacerbate a nitrate contamination problem in soils subject to nitrate leaching. Our objective was to determine the extent and patterns of fine-diameter root production and loss of four contrasting alfalfas during the stand establishment year.

Materials and Methods

An underground room was built in a loamy sand Udorthentic Haploboroll at the University of Minnesota Sand Plain Research Farm, Becker, MN. Minirhizotrons, plastic tubes 1.8 m long, 57-mm o.d., and 51-mm i.d., were placed horizontally and perpendicular to the walls at depths of 10, 20, and 40 cm from the soil surface, under different plant rows. Soil was fertilized and limed according to University of Minnesota recommendations.

Four alfalfa germplasms were seeded by hand (31 May through 2 June) directly over the tubes and border areas in 8 rows spaced 15 cm apart. Germplasms included: effectively nodulated Agate (AGATE); Ineffective Agate, an ineffectively nodulated non-N_2-fixing near isoline of Agate (INEFF); an effective germplasm having a tap root with few fibrous roots (LFTAP); and an effective germplasm with many fibrous roots and a strongly branch-rooted architecture (HFBRH). All were inoculated with *Rhizobium meliloti*.

Seedlings were thinned to 200 plants/m^2, irrigated according to a modified "checkbook" method, and received five biweekly fertilizer applications of 22 kg N/ha. Herbage was harvested on 19 Aug. and 20 Oct. 1994. Root samples were collected between adjacent plants within a row in early November by removing 32-cm diam. soil cores. Washed roots were stained and scanned to determine length.

Video images of roots were obtained biweekly. For each root in the 1920 images, date records were kept for root appearance, secondary thickening, and death. Three root cohorts were defined as roots produced in early-season (between 22 June and 20 July), mid-season (between 3 and 17 August), and late-season (between 31 August and 15 September). All fine roots produced within each interval and still alive at the end of the interval were included in a given cohort. Fine roots that became secondarily thickened at a later date were excluded from cohort analysis. Survivorship curves were generated and cumulative loss of fine root length was calculated from average turnover rates for the 0- to 30- cm and 30- to 60-cm increments measured with minirhizotron observations and from washed root lengths from soil cores.

Results and Discussion

Yields of the effectively nodulated germplasms were typical for this site, and INEFF yields were smaller, due to N limitations. Root length densities measured after washing soil cores showed no differences among germplasms nor interactions of germplasm with depth, but length densities declined from 13.7 km/m^2 in the upper 10 cm to about 3.3 km/m^2 at depths below 20 cm. Root length densities in the topsoil were significantly higher than those found in most other reports but were similar to those of commercial alfalfa in the Central Valley of California.

For all germplasms, net fine root production at the 10- and 20-cm depths rapidly increased for the first two months after planting, declined during mid-season, and then leveled off or declined slowly until autumn. By late October, differences in root production among germplasms were evident at the 20- and 40-cm depths, but not at 10 cm. The HFBRH germplasm had 29% more fine roots than other germplasms at 20 cm. At the 40-cm depth, AGATE had fewer living fine roots than LFTAP and HFBRH, and both AGATE and INEFF had fewer total fine roots than HFBRH. LFTAP and HFBRH had similar numbers of fine roots at this depth, in contrast to 20 cm. About 7% of fine roots at each depth developed into secondarily thickened roots.

By the end of the first growing season, greatest fine root mortality had occurred at 10 cm (48%), and least occurred at 40 cm (36%). However, survival of contemporaneous root cohorts was not related to soil depth in a simple fashion. There was a pronounced loss (average 22%) of fine roots at the 10- and 20-cm depths in the 2-week period following herbage removal, confirming research in California, where fibrous root mass turnover was about 23% of that present before harvest in an established alfalfa crop.

Median fine root life spans at 10 and 20 cm ranged from 56 to 95 days for the early-season cohorts but only 42 to 69 days for the mid-season cohort. No estimates were possible for the 40-cm depth in the early-season cohorts or for any depths in the late-season cohorts. Lower herbage yield of the INEFF germplasm was not reflected in lower numbers of living or total fine roots produced by the end of the season. This confirms other results at this location, where total root mass, fine root mass, or fine root length was similar to ineffective and effective alfalfas, despite large differences in herbage yield.

Summary

Does root system architecture alter root demography? We did not find differences in total fine root turnover rates between the HFBRH and LFTAP germplasms, although our analysis of cohort survival demonstrated that a few temporal differences in root mortality rate occurred. Thus, although overall fine root survival during the stand establishment year was not influenced by root system architecture, the *patterns* of fine root mortality differed during the season. These mortality patterns will influence the timing of N release from decomposing roots. Based on a calculated loss of fine root length in the upper 60 cm of soil (totaling 274,000 km/ha) and an assumed N content of 0.22 mg N/m root, we estimate that fine root turnover in these alfalfa germplasms released about 60 kg N/ha during the stand establishment year.

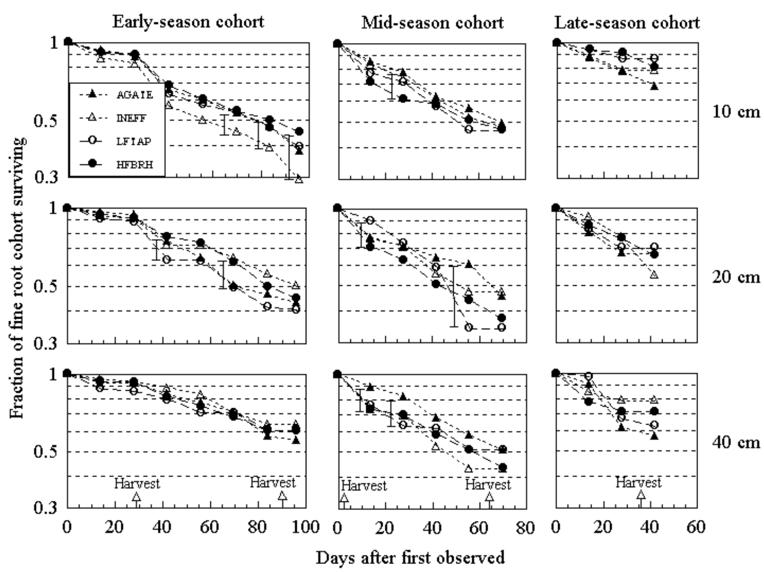

Figure 1. Fraction of surviving fine roots in three contemporaneous cohorts at three soil depths during alfalfa stand establishment. The period of observation extends to 26 Oct. 1994 in each case. For each date where significant differences were detected, the bar below the data points represents Fisher's protected LSD (P < 0.05) value.