DIVISION S-7—NOTES

MINIRHIZOTRON INSTALLATION IN SANDY, ROCKY SOILS WITH MINIMAL SOIL DISTURBANCE

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Abstract

We developed and demonstrated the utility of a technique for installing minirhizotron tubes in sandy, rocky soils where more traditional installation methods are inadequate. The method uses a pneumatic rock-drill alternately to drill and drive drill casing into the soil. Soil particles and drilling debris are removed from the casing as it is installed. The minirhizotron tube is inserted into the drill casing and the casing is withdrawn. A pneumatic screw-drive guide system powers the downward and upward movement of the rock-drill and controls the angle of installation. Working from a platform suspended from a center-pivot elevated catwalk minimized soil disturbance. Soil contact and root ingrowth around the minirhizotron tubes were very satisfactory. This method, while fairly labor intensive, allows minirhizotron studies of root dynamics in sandy, rocky soils where they would otherwise not be possible. Also, there is much less soil compaction and disturbance than traditional installation techniques entail.

Transparent glass or plastic minirhizotron tubes are widely used to study root dynamics in experimental and natural systems (e.g., Hendrick and Pregitzer, 1996a; Majdi and Kangas, 1997; Tingey et al., 1997). These tubes allow repeated observation of roots with specialized cameras (Hendrick and Pregitzer, 1996b), and provide a non-destructive means to track root production, growth, and turnover for extended periods of time (Majdi, 1996).

Use of minirhizotrons in natural, undisturbed ecosystems requires that they be installed in an intact soil profile. Furthermore, in order to minimize soil compaction and plant damage in the vicinity of the minirhizotron tube, trampling must be avoided during installation. This was particularly important on our study plots where a fragile cryptogamic crust fixes nitrogen and serves an important function in the nitrogen economy of desert ecosystems (Evans and Ehleringer, 1993; West and Skujins, 1978).

In typical minirhizotron installation techniques, either an auger (Kloeppel and Gower, 1995) or soil corer (Hummel et al., 1989) is used to make a hole into which the minirhizotron tube is inserted. However, gravel and cobbles in the soil at our study site prevented either augering or coring to a depth of 1 m, and the dry, sandy soil tended to collapse into the hole before the tube could be inserted. The purpose of this paper is to describe a method which we devised to install minirhizotron tubes in sandy, rocky soils while keeping soil disturbance to a minimum.

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Materials and Methods

Study Site

The Nevada Desert FACE (Free Air CO_2 Enrichment) Facility is located at 36°49′N, 115°55′ W in the Mojave Desert in southern Nevada at the U.S. Department of Energy's Nevada Test Site (Jordan et al., 1999). The study site is situated at ~960 m elevation in the middle of a broad bajada (alluvial fan) along the southern end of Frenchman Flat. The soil is an Aridosol derived from calcareous alluvium with textures of the <2 mm fraction ranging from loamy sands in the shallow A1 horizon (0–0.16 m) to coarse sands in the subsoil horizons. With the exception of the surface soil horizon, the <2-mm fraction is structureless. The rock content is variable but often quite high. The soil surface is a mosaic of plants and bare soil. In some areas, there is a "desert pavement" consisting of exposed rocks where the fine soil particles have been washed or blown away, and in other areas there is a well developed cryptogamic crust on the soil surface. The vegetation of the site is characteristic of the northern Mojave Desert and is dominated by the xerophytic shrubs *Larrea tridentata* (Sessé & Mocino ex DC.) Cov. (creosote bush) and *Ambrosia dumosa* (Gray) Payne (bur-sage).

Tube Installation

To minimize soil compaction and trampling of plants and the fragile cryptogamic soil crust, minirhizotron tube installation and all other research activities including minirhizotron video imaging in the FACE plots are conducted from platforms suspended above the ground (Fig. 1). These platforms are suspended from a center-pivot, rotating catwalk, which is approximately 2 m above the ground. The platform may be moved radially along the length of the catwalk to access the entire plot. The height of the platform is also adjustable in order to avoid damaging plants in its path.

We inserted 28 minirhizotron tubes at a 30° angle from vertical in each of the 9 FACE plots, to a vertical depth of 1 m. Angled minirhizotrons have been found to estimate root distribution better than vertical tubes (Bragg et al., 1983). The tubes were placed under *Larrea* and *Ambrosia* shrubs, as well as along transects across the plots to monitor other species present.

A pneumatic rock-drill (Gardner Denver S33, Quincy, IL) was mounted on a pneumatic screw-drive guide system attached to the suspended platform (Fig. 1 and 2). The rock-drill and the screw-drive were powered by a 250 cfm diesel air compressor. The screw-drive was adjustable so that the 30° angle from vertical could be maintained. A pipe driver

Abbreviations: FACE, Free Air CO_2 Enrichment; PVC, polyvinylchloride.

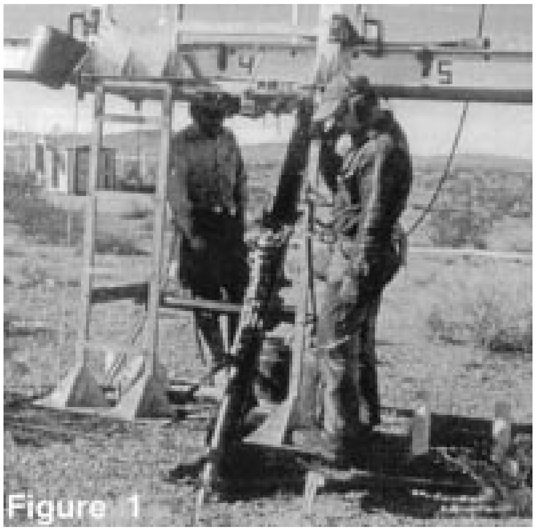

Fig. 1. Drill rig mounted on platform suspended from center-pivot catwalk, which is approximately 2 m from the ground.

was attached to the pneumatic rock-drill, which was used to drive a drill casing into the soil. We used steel drill casing (57-mm O.D., 49-mm I.D.) as a sleeve into which the polycarbonate minirhizotron tubes (44-mm O.D., 38-mm I.D., Bartz Technology Corp., Santa Barbara, CA) could be inserted. A hardened steel section of casing with beveled edges was screwed onto the end of the casing for cutting into the soil. When cobbles or gravel prevented the casing from penetrating any further, the pipe driver was removed from the rock-drill and a rock-drill bit (45-mm O.D., "star" bit) was inserted into the drill casing (Fig. 3). The rock-drill bit was used to break up the material inside the drill casing and approximately 1 to 2 cm beyond the end of the casing. During this operation, compressed air was blown down through the drill shaft and bit, which lofted soil and drilling debris up the casing. A vacuum attached to a side vent on the drill casing pulled the lofted material out of the drill casing (Fig. 3).

Once the drill casing was driven to the desired depth and the soil and rock debris was evacuated from the casing, the interior walls of the casing were cleaned with a cloth swab to prevent scratching the minirhizotron tube. The minirhizotron tube was also cleaned and then inserted into the casing. The minirhizotron tubes had a polyvinylchloride (PVC) plug glued in place on the bottom end. The PVC plug had a spade lug extending 4.5 cm from the plug to prevent rotation once the tube was installed in the soil. A wooden dowel was inserted into the minirhizotron tube to hold it down while the drill casing was pulled up around it. A strap was attached to the side vent of the casing and to the bottom of the rock-drill so that the pneumatic screw-drive could be used to pull the casing up.

A section of angle iron was driven into the ground along the bottom side of the minirhizotron tube to help stabilize it and to push it upward to ensure good soil contact along the upper surface of the minirhizotron tube where root images are taken. The tube was cut off 30 cm above the soil surface, and a light-tight, insulated PVC cap was placed over the opening to exclude foreign materials and minimize conduction of heat and light down the tube (Fig. 4).

During the drilling operation, we regulated the amount of compressed air used to loft the soil and rock debris for removal from the casing with the vacuum to prevent formation of cavities around the casing. To avoid this problem, we monitored the volume of soil removed by the vacuum to ensure

Fig. 2. Pneumatic rock-drill mounted on a pneumatic screw-drive guide system. The screw, which is seen behind the rock-drill, may be turned pneumatically in either direction, driving the rock-drill downward as drilling or pipe-driving proceeds, or upward to back the rock-drill off. The pipe driver is attached to the rock-drill in this photo, and is being used to drive the drill casing into the ground.

that it closely approximated the volume of the drill casing below ground. While there were numerous rocks in the soil, the texture of the <2-mm fraction was sandy and single grained, and good soil contact was made as the drill casing was withdrawn.

Results and Discussion

We successfully installed 294 minirhizotron tubes using these procedures from 11 July to 10 Sept. 1997. The time needed to install ranged from approximately 20 min to 2 h depending on the amount of cobbles and gravel at that spot. Surface disturbance was minimal at the installation sites (Fig. 1, 3, and 4). Immediately after tube installation, there was a zone 25 to 30 cm in diameter which appeared somewhat disturbed by dust and possibly vibration from the drilling. However, after just a few months, little evidence remained of surface disturbance (Fig. 4). Thus, the fragile cryptogamic crust was preserved and there was no compaction from foot and machinery traffic which could damage plants and alter water infiltration rates.

We waited 3 to 5 mo after tube installation before collecting video images to allow the soil to settle and for root ingrowth to occur in the disturbed area immediately around the tubes. Analysis of video images recorded at that time (16–18 Dec. 1997) in all the tubes in 6 plots by MSU-ROOTs software (Enslin et al., 1994) showed 94% soil contact in the top 25 cm, 85% contact below 25 cm, and 11% of the video images (~10 by 14 mm) to a depth of 1 m contained roots (Fig. 5). By May, the proportion of images containing roots increased to 50%

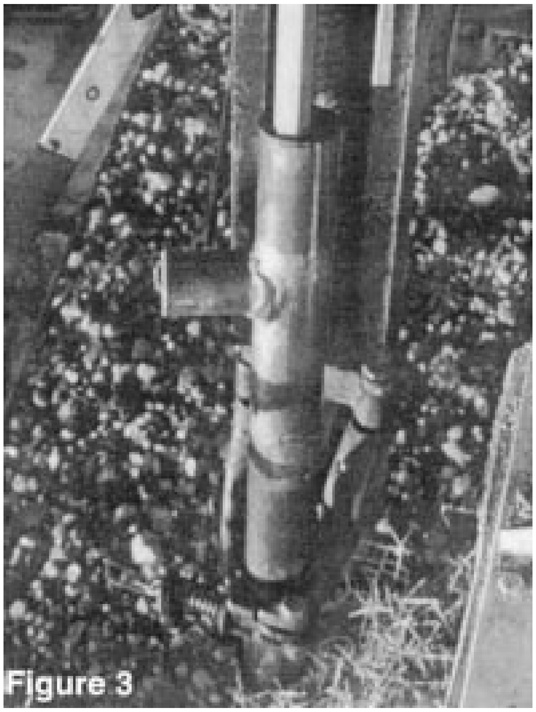

Fig. 3. The drill casing has been driven > 1 m into the ground with the pipe driver. The drill shaft with its attached drill bit is extending down into the casing to drill just beyond the end of the casing. Soil and rock debris lofted by compressed air blown through the drill shaft and bit are removed by a vacuum hose which attaches to the side vent seen on the top of the drill casing. The screw-drive can be seen behind the drill shaft and between the two rails. Note the rocky "desert pavement" on the soil surface.

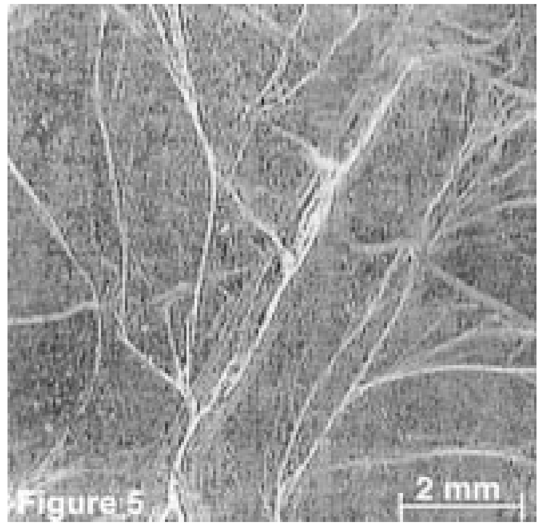

Fig. 5. Video image in December, 1997, 3 to 5 mo after tube installation, showing a high degree of root ingrowth into the area around the tube.

following a very wet El Nino winter and spring with profuse growth of annuals. In comparison, Tingey et al. (1997) found 5 to 25% of minirhizotron frames with roots in a study of ponderosa pine under various CO_2 and N fertilization treatments. This demonstrates that after a stabilization period of a few months, roots were readily able to grow into the areas surrounding the minirhizotron tubes installed in this manner. Joslin and Wolfe (1999) suggested that root growth near the surface in the first growing season after minirhizotron installation is often stimulated because of soil disturbance of organic rich surface horizons accelerating decomposition and N mineralization, thus creating N-rich microsites. Such an effect may be reflected in our early images of root growth, although the very low organic content of the desert soil may minimize this.

Several of the minirhizotron tubes outside the FACE plots were excavated 1 yr after installation. Soil contact was generally good (Fig. 6), although there were some areas devoid of fine soil particles in the immediate vicinity of larger rocks. Figure 6 also shows the rockiness of the soil in which the tubes were successfully installed, and the growth of fine roots down to and around the tubes.

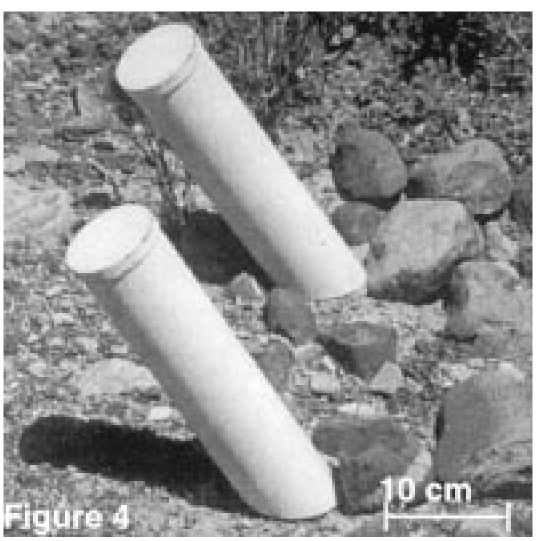

Fig. 4. PVC minirhizotron tube caps. These caps are insulated with pipe insulation and painted to protect the PVC from UV damage and for light-tightness. Note the minimal surface disturbance where the tubes were installed and the rockiness of the substrate.

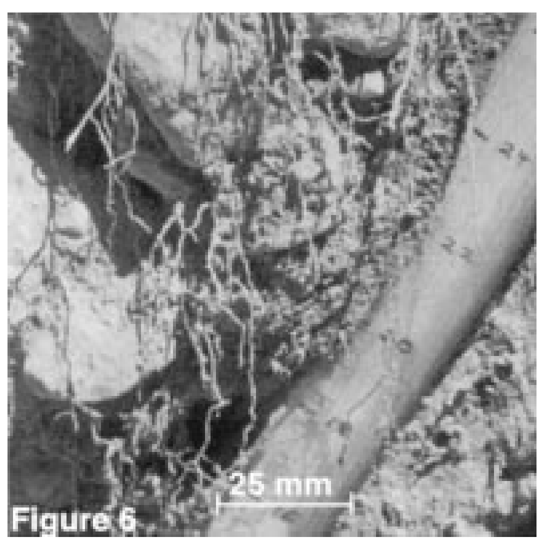

Fig. 6. Minirhizotron tube excavated 1 yr after installation. Note the generally good soil contact, the rockiness of the soil, and the ingrowth of roots around the tube. A white PVC pipe with numbered camera image positions has been inserted in the tube in this photo.

This procedure should be applicable to other sites where traditional coring or augering installation methods do not work. In sandy soils without many rock fragments, the pipe driver may be sufficient to drive the casing to the desired depth. The rock-drill bit is only required when rocks prevent further penetration. This would speed up the process, since changing back and forth is time consuming, and rock-drilling is the slowest part of the procedure. However, without the compressed air which is blown through the drill bit to loft the soil and rock debris for removal by the vacuum, a vacuum hose may need to be inserted down the casing to remove the soil.

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