NOTES AND UNIQUE PHENOMENA

A HYDRAULIC CORING SYSTEM FOR SOIL–ROOT STUDIES

S. A. Prior,* G. B. Runion, H. A. Torbert, and D. C. Erbach

Abstract

Reliable sampling of belowground components in the field is essential to agroecosystem research. Factors such as hardpans and dry soil conditions often increase sampling time and impede adequate sampling. The objective was to design and construct a soil coring system for rapid field sampling that minimized such limitations. Cores were extracted using a custom-made telescoping hydraulic cylinder device assisted by a hydraulic post driver mounted to the front of a small tractor. The telescoping device inserted the core tube into the ground, and the post driver was activated only when insertion had been slowed or stopped. The tractor's hydraulics powered the telescoping device and the post driver; both were controlled by the tractor operator. Custom driving heads were constructed to fit the upper end of core tubes to collect large-diameter soil samples (25 cm diam. by 0.6 m deep) or small samples (3.8 cm diam. by 1.0 m deep). As many as 14 large cores or 24 small cores per hour could be collected with this system. The coring system has been successfully used on various soil types and to sample both agricultural and forest sites for a number of experimental objectives.

An important aspect of soil research is to obtain representative field samples. Mechanized devices that reduce time and labor have been developed to take soil cores (Bohm, 1979). There are commercially available hydraulic cylinder devices (mounted on trucks or tractors) used to insert and retrieve soil core tubes (e.g., Concord Inc., Fargo, ND; Giddings Machine Co., Fort Collins, CO).[1] However, reliance on vehicle weight to push core tubes into the ground often requires larger transport vehicles, especially when soil strength is an issue (e.g., dry soil conditions and hardpans). Some specialized hydraulic devices have been developed to overcome soil strength issues, but such systems require anchoring to the ground, which can prevent timely collection of samples due to setup time (e.g., Swallow et al., 1987). Use of larger vehicles can also restrict access to some locations, and in many cases, their weight cannot overcome soil strength constraints when soils are dry. This has led to the development of hand-operated power drivers (hammers) and core extraction systems (winches) that are portable and more maneuverable and can overcome access and soil strength problems (Prior and Rogers, 1992), but such systems require more labor.

Continued development of alternative soil-sampling methods is needed to successfully study belowground processes. Here we describe a coring system that combines positive attributes of previous approaches. This system, mounted to the front of a small tractor, employs both a hydraulic cylinder and a hydraulic hammer. This combination overcomes soil strength problems while minimizing weight requirements, improves plot accessibility, and is less labor intensive than hand-operated systems.

[1] Trade names and products are mentioned solely for information. No endorsement by the USDA is implied.

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Construction and Operation

The coring system was mounted to the front of a JD 950 (1639 kg, 20.4 kW; Deere & Co., Moline, IL; Fig. 1). A list of component parts and costs for the system is shown in Table 1, and detail specifications are discussed below and shown in Fig. 2 through 4. Initial testing was done at the soil bin facilities of the USDA-ARS National Soil Dynamics Laboratory, Auburn, AL (Batchelor, 1984), followed by several field tests.

The system inserted and extracted core tubes with a hammer-assisted telescoping device (hydraulic) (Fig. 1 and 2). The telescoping device pushed the core tube into the ground, and the post driver was activated only when insertion had been slowed or stopped. The driver was originally designed as a boom-mounted, heavy-duty signpost driver (Model H4876A; Fairmont Co., Fairmont, MN). The driver measured 787 mm (31 in) in height by 190 mm (7.5 in) in width and weighed 37.6 kg (83 lbs). Major components of the telescoping device included two black pipe sections (inner and outer), a tie-rod hydraulic cylinder [76 mm (3 in) bore by 1.5 m (60 in) stroke at 17.2 MPa (2500 psi); Model 306015TC; Bailey Int. Corp., Knoxville, TN], and a support structure (Fig. 2A, 2B, 2C, and 2E, respectively).

The inner pipe section measured 152 mm (6 in) in diameter and 2.1 m (7 ft) in length and housed the tie-rod hydraulic cylinder (Fig. 2). A flat bar piece [25 mm (1 in) by 57 mm (2.25 in) by 152 mm (6 in)] was welded to the inside of this pipe section [260 mm (10.25 in) from bottom] for attachment of the hydraulic cylinder's clevis. The inner pipe section was made stationary by mounting it to the bumper unit of the tractor (Fig. 1F and Fig. 3C) and to a vertical support structure (Fig. 1D and Fig. 2E). The bumper unit consisted of the tractor weight bracket bolted to an I-beam section [457 mm (18 in) by 152 mm (6 in)] with welded end plates [152 mm (6 in) by 152 mm (6in)] attached to the front end of the tractor. The support structure made from rectangular tubing [51 mm (2 in) by 102 mm (4 in) by 3.2 mm (0.125 in)] with flat bar weldment braces [76 mm (3 in) by 305 mm (12 in)] was welded onto the bumper unit (Fig. 1D). The top of the support structure had flat bar weldments [76 mm (3 in) by 76 mm (3 in)] for bolting [19 mm (0.75 in)] to the top of the inner pipe section (Fig. 3G). The inner pipe section had a 102-mm (4 in)-diam. hole (below

Fig. 1. Photograph of soil-coring system (fully extended position) getting ready to insert small-diameter core tube: (A) outer pipe section, (B) hydraulic post driver (ports visible at top right side of post driver), (C) slots in outer pipe section allowing passage of inner pipe mounting brackets, (D) support structure (with bottom braces) connected to the inner pipe section and bumper unit, (E) lock pin which holds driving head in bore of post driver, (F) inner pipe section (housing hydraulic cylinder) connected to bumper unit, (G) small-diameter core tube, (H) hoses for hydraulic cylinder passing through hole in inner pipe section, (I) insert showing system in fully retracted position (note that screwdriver has been inserted through core tube and driving head before extraction), (J) insert showing starting position for insertion of large core tube, and (K) insert showing extraction of large core tube.

weight bracket) to allow hose attachment to the hydraulic cylinder (Fig. 1H).

The outer pipe section was 203 mm (8 in) in diameter and 2.1 m (7 ft) in length and was capped at the top with the hydraulic post driver mechanically fastened near the bottom for maximum vertical displacement (Fig. 3). The post driver was fastened to the outer pipe section by top and bottom mounts (Fig. 3A and 3F). The top mount consisted of a flat bar pin receiver [76 mm (3 in) by 102 mm (4 in) by 19 mm (0.75 in)] bolted [13-mm (0.5 in) cap screws with 44-mm (1.75) spacers] to a flat bar piece [102 mm (4 in) by 32 mm (1.25 in) by 32 mm (1.25 in)] that was welded to the outer pipe section (Fig. 3A). The bottom mount consisted of a collar attached to a flat bar piece [102 mm (4 in) by 32 mm (1.25 in) by 32 mm (1.25 in)] that was welded to the outer pipe section (Fig. 3F). The tie-rod's clevis was removed, and the tie-rod of the hydraulic cylinder was attached to the top cap of the outer pipe section by means of a 32-mm (1.25 in) nut (see Fig. 3 for details). This enabled the outer pipe section to be extended 1.5 m (5 ft) or retracted over the inner section in a telescoping fashion; a sliding fit was created between the inner and outer pipe sections by welding machined shims to the inner pipe section at strategic locations. The side of the outer pipe section facing the tractor was slotted (Fig. 2G) along most of its length [44 mm (1.75 in) by 1.6 m (64 in)] to allow for clearance of the support structure (connected to the top of the inner pipe sec-

Table 1. Components list and cost of items for the hydraulic coring system.

Components	Cost
Hydraulic post driver (Model H4876A; Fairmont Co., Fairmont, MN)	$2000
Hydraulic cylinder (Model 306015TC; Bailey Int. Corp., Knoxville, TN)	$350
Standard hydraulic hoses and couplings	$250
Core tube (Model 51-505) with bit (Model 134) (Giddings Machine Co., Ft. Collins, CO)	$100
Custom large-diameter core tube	$50
Machined steel rod	$80
Black pipe	$100
Flat bar	$30
I-Beam	$20
Rectangular tubing	$50
Capscrews, lockwashers, hexnuts	$15
Chains and clevis	$15
TOTAL	$3060

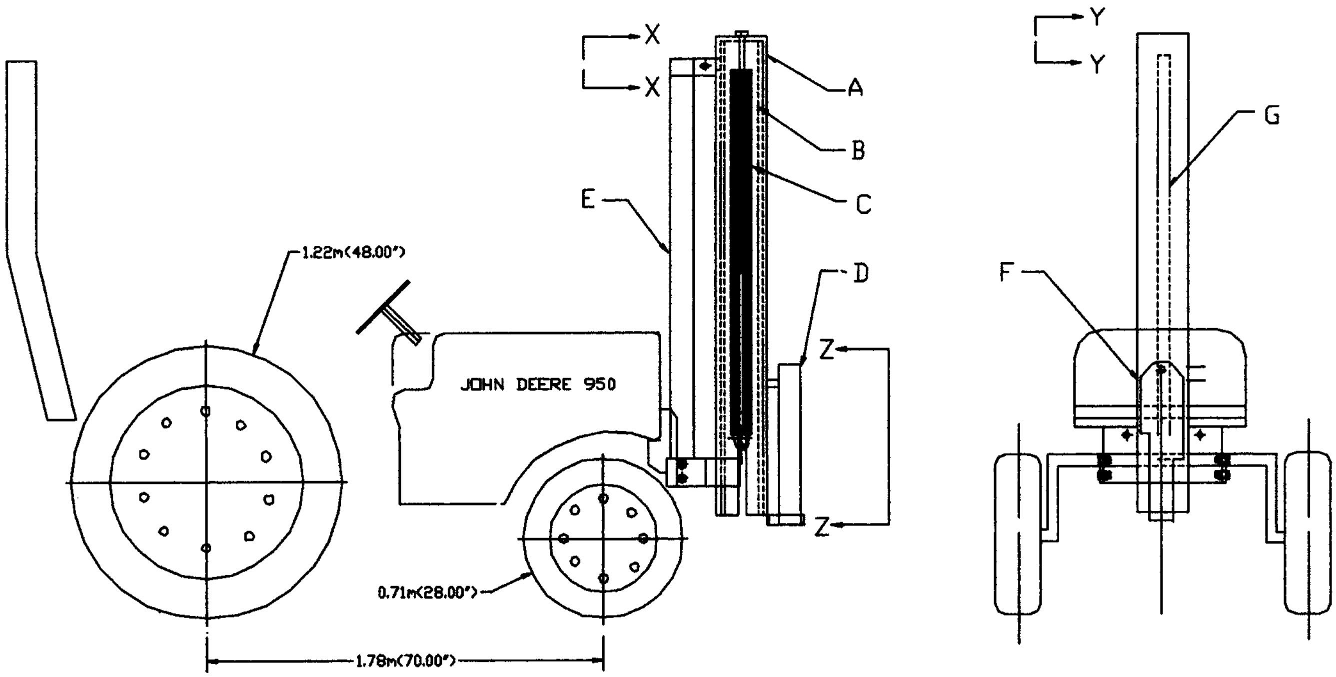

Fig. 2. Schematic of soil-coring system mounted to the front end of a small tractor: (A) outer pipe section, (B) inner pipe section, (C) hydraulic cylinder housed by inner pipe section, (D) post driver, (E) support structure, (F) post driver (front view), and (G) machined slot for operational clearance of support structure. Detailed views of X-X, Y-Y, and Z-Z are shown in Fig. 3.

tion; Fig. 2E and Fig. 3G) during extension or retraction. Additionally, the outer pipe section was slotted [both sides, perpendicular to the tractor; 38 mm (1.5 in) by 476 mm (18.75 in)], allowing it to slide past the bottom inner pipe mounting brackets (Fig. 1C).

Tractor hydraulics were used to power the post driver and telescoping device; both were controlled by the tractor operator. Standard hydraulic hoses and couplings were used (Table 1). Custom driving heads were machined from a steel rod (Fig. 4A) to fit on one end to the hydraulic post driver and to the other end of small-diameter soil core tubes [38 mm (1.5 in) diam. by 1.0 m (3.3 ft) deep; Fig. 4E]. In addition, this driving head had a milled out section to allow passage of a lock pin to hold the driving head in the hammer. The small-diameter soil core tubes are commercially available molychrome steel soil core tubes (Giddings Machine Co., Fort Collins, CO)

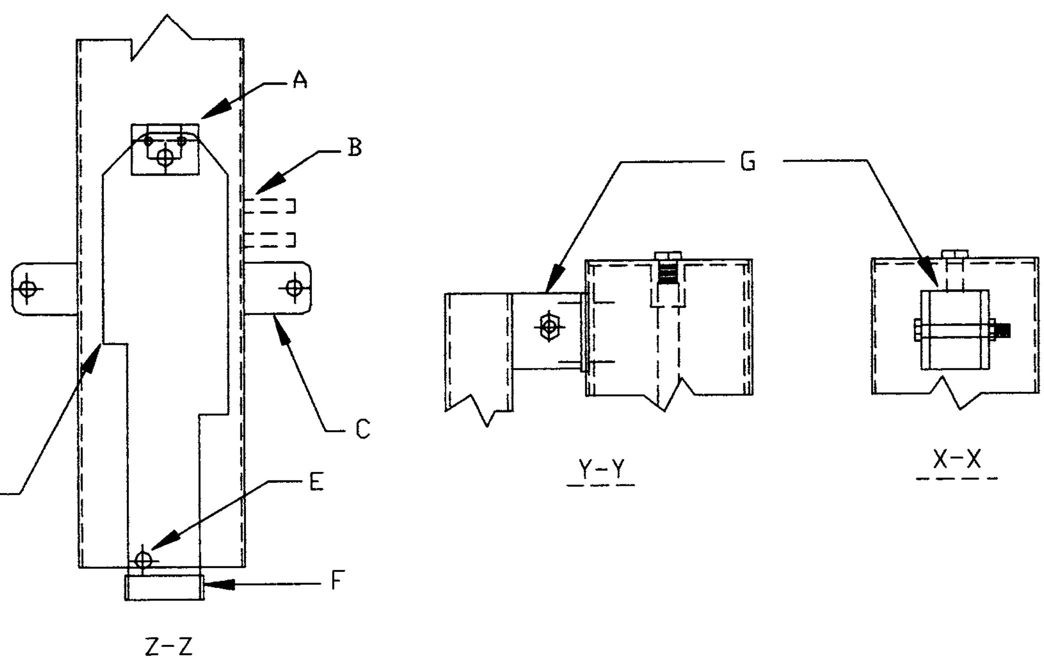

Fig. 3. Schematics of detailed views referenced in Fig. 2. Component parts are (A) post driver top mount, (B) hydraulic ports (fitted to universal agricultural quick couplers), (C) inner pipe mounting bracket (flat bar parts welded to inner pipe section and bolted to tractor bumper unit), (D) post driver (front view), (E) detent for drive adaptor lock pin, (F) post driver bottom mount, and (G) upper mount connecting inner pipe section to support structure.

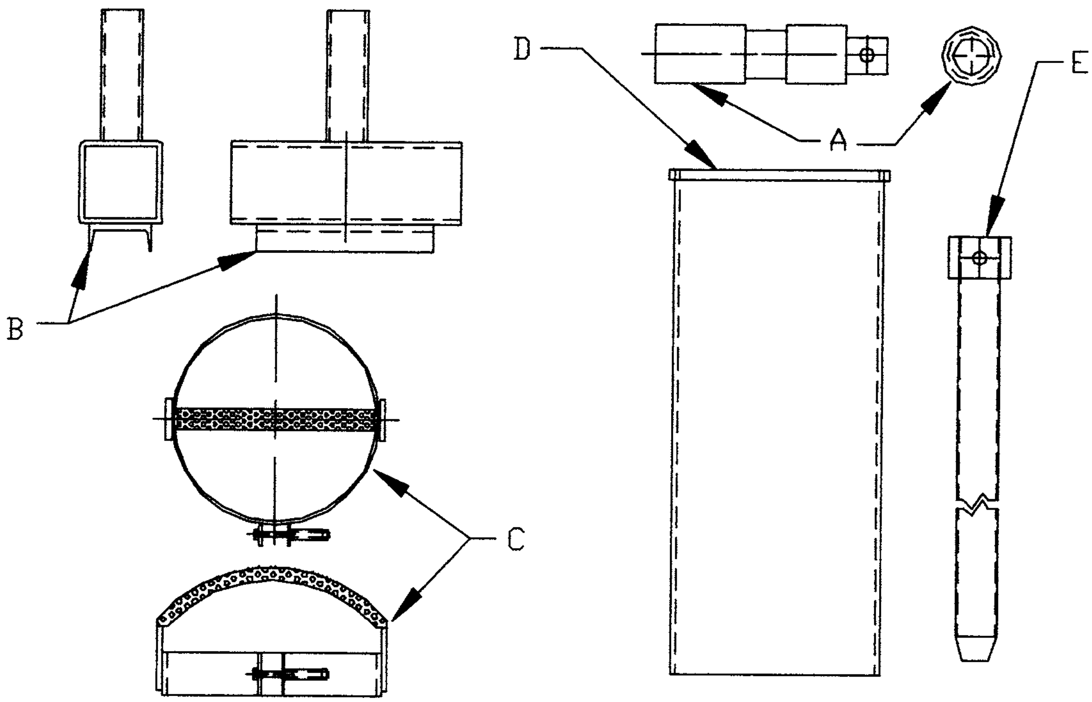

Fig. 4. Schematics of driving head, core tubes, and extractor collar: (A) driving head used for small core tubes and with Extension B for large core tubes, (B) driving head extension for large core tube, (C) collar with chain for extracting large core tubes, (D) large core tube, and (E) small core tube.

with reinforced steel collars (Model 51-505) and were fitted with 51-mm (2 in) heavy-duty quick-relief coring bits (Model 134) as described in detail by Prior and Rogers (1992). The driving head was held in place by insertion of a lock pin (Fig. 1E) into a detent in the hydraulic post driver (Fig. 3E); removal of this pin allowed the driving head to be removed during transport. Pre-existing drill holes (core tube and collar; Fig. 4E) matched a hole in the driving head so that a blunt-tip screwdriver could be inserted for tube extraction (Fig. 1I). This driving head (Fig. 4A) could also be used in combination with a custom extension (Fig. 4B) constructed to fit the upper end of large soil core tubes [254 mm (10 in) diam. by 0.6 m (2 ft) deep; Fig. 4D). In this case, once the large tube had been driven into the ground (Fig. 1J), the driving head was removed, and an extraction collar (with chain) was attached (Fig. 4C) and connected to a chain for tube extraction (Fig. 1K).

Discussion

This system, mounted to the front end of a small tractor, employs both a hydraulic cylinder and a hydraulic hammer. The system was used to insert and extract small- and large-diameter soil core tubes. The hydraulically driven telescoping device inserted the core tube into the ground, and the post driver was activated only when insertion had been slowed or stopped. This combination overcomes soil strength problems. Occasionally, core bits needed replacement due to damage caused by rocks within the profile; however, this problem is also common to other soil-coring systems. The use of a small tractor minimized weight requirements, improved plot accessibility, and was less labor intensive than hand-operated systems. Furthermore, as in our case, scheduling the use of a small tractor (vs. larger tractors) can be easier since larger tractors are generally in greater demand, especially at the beginning and/or end of growing seasons. Smaller tractors are also easier to move or transport to different field locations. It is important to note that our system is best suited for early in the season before crop height prohibits access or at season's end after biomass data have been collected and, consequently, crop damage is not a major consideration.

In repeated field tests, the coring system has performed efficiently and reliably on different soil types (i.e., fine sandy loam, loamy sand, sandy loam, and clay loam).The system has been used to collect over 750 cores (250 large, 500 small) and can collect as many as 14 large cores or 24 small cores per hour. It has been used to sample both agricultural and forest sites for a number of experimental objectives.

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