# TERRAVENT™: SOIL FRACTURE PATTERNS AND IMPACT ON BULK DENSITY

**by E. Thomas Smiley**

**Abstract.** Soil compaction is reported to be a limiting factor in many urban tree plantings. The Terravent™ was developed to decompact and aerate soil through the soil injection of high-pressure nitrogen gas. The purpose of this project was to determine the soil fracture patterns created by the Terravent and to determine if soil bulk density is reduced. Replicates of six fractures were made at three sites. Bulk density and the degree of fracturing were measured. No significant differences in soil bulk density were found between treated and nontreated areas. Fracture patterns were generally horizontal to convex shaped with a mean width up to 22.2 in. (56 cm), typically 9 in. (23 cm) below the soil surface. Other means of alleviating soil compaction are thought to be more effective.

**Key Words.** Bulk density; soil compaction; soil fracturing; air excavation; root growth.

Soil compaction is reported to be a limiting factor for growing trees in many urban environments. (Craul 1992; Day and Bassuk 1994; Randrup 1997; Jim 1998). Over the years, a number of machines have been developed that have claimed to provide rapid and relatively inexpensive alleviation of compaction problems (Smiley et al. 1990). One type of machine injects high-pressure air into the soil at a depth of 6 to 18 in. (15 to 45 cm). Fill material such as perlite or organic matter, intended to keep fractures open, or liquid solution, may be injected into the fracture created by the air. Previous research revealed that these machines did not significantly reduce soil compaction or significantly improve tree growth (Smiley et al. 1990; Rolf 1992; Smiley 1998).

The Terravent™ (Pinnacle Concepts Ltd., Cornwall, England) was introduced to the United States in 2000. This machine injects high-pressure nitrogen gas through a steel pipe previously driven into the soil. The pipe has ten holes in the sides to allow gas penetration into the soil. After fractures are created, liquid solution may be injected into the fractures.

The purpose of this project was to determine the soil fracture patterns created by the Terravent and to determine if the Terravent can reduce soil bulk density.

## MATERIALS AND METHODS

Three sites were selected at or near the Bartlett Tree Research Laboratories in Charlotte, North Carolina, U.S. The sites were an athletic field area with a fine sandy loam soil (Mecklenburg series B) with thick turf cover (Ball Field), a hilltop site with a sandy clay soil (Cecil B2) and sparse turf (Hilltop), and a field site with a sandy clay loam soil (Appling B) and moderate turf (Track).

The Terravent probe was driven into the ground to a depth of approximately 12 in. (30 cm) according to manufacturer's directions by Dr. Don Gardener, a Terravent representative. Nitrogen gas was then discharged through the probe at a pressure of 750 psi (50 bars). At least six replicated injections were made at each site. Injection sites were separated by at least 10 ft (3 m), a distance large enough that fractures created at one site would not influence adjacent fractures. Approximately 20 fl oz (0.6 L) of water solution containing blue dye (1 qt dye per 5 gal water) was injected into each site after the initial nitrogen gas discharge.

After treatments were applied, bulk density samples were taken 6 and 28 in. (15 and 70 cm) from the injection site. At the greater distance, there were no visual effects of the injection. Bulk density was determined by collecting undisturbed soil cores using a core sampler (AMS, American Falls, ID) from between approximately 2 and 5 in. (5 and 13 cm) below the soil surface. Samples were cut to 3 in. (7.5 cm) in length and dried at 190°F (88°C) until a constant weight was achieved. Bulk density was calculated by dividing soil volume by dry sample weight (Black 1965).

Six injection sites at each of two experimental sites (Hilltop and Track) were excavated to determine the pattern of fracturing in the soil. A backhoe removed soil to within 6 in. (15 cm) of the injection site, and deeper than the fractures. A smooth vertical cut was then made at the point of soil injection using a shovel. Measurements were made and a photograph was taken showing the horizontal movement of the dye solution. Scale drawings were made from the photographs. Soil above the largest horizontal fracture on the other half of the injection site was then removed. The radial movement of the dye within the fracture was measured and photographed.

Bulk densities within and outside of the fracture areas were compared using a T-test. Descriptive statistics were calculated for the soil fracture measurements.

**Table 1. Mean bulk densities at a depth of approximately 2 to 5 in. (5 to 13 cm), within 6 in. (15 cm) of the Terravent probe and from an adjacent, undisturbed area 28 in. (71 cm) from the probe, compared with a two-tailed T-test. Six samples were collected at each site.**

| | Mean bulk density (g/cc) Sample distance from probe | | | | T-test (*P*) |
|---|---|---|---|---|---|
| Site | 6 in. | Std. dev. | 28 in. | Std. dev. | Significance* |
| Hilltop | 1.46 | .126 | 1.43 | .084 | 0.78 |
| Track | 1.53 | .075 | 1.56 | .048 | 0.38 |
| Ball Field | 1.63 | .138 | 1.60 | .153 | 0.77 |

*Differences between means with $P \leq 0.05$ are considered significant. No values were in this range.

**Table 2. Descriptive statistics for the depth and horizontal spread of a dye solution in soil fractures created with a Terravent. Six samples were collected at each site.**

| | Mean depth of dye (in.) | | | Mean width of dye spread | |
|---|---|---|---|---|---|
| Site | Min. | Typical | Max. | In inches | Std. dev. |
| Hilltop | 7.0 | 9.0 | 14.5 | 22.2 | 4.1 |
| Track | 4.0 | 9.7 | 13.9 | 15.2 | 2.9 |

## RESULTS

Mean soil bulk densities in undisturbed areas adjacent to Terravent injection sites were 1.43, 1.56 and 1.60 g/cc for the Hilltop, Track and Ball Field sites, respectively (Table 1). Samples collected close to the Terravent injections had densities of 1.46, 1.53 and 1.63 g/cc, respectively, for the same sites (Table 1). At each site, there were no significant differences between the treatment means.

While the ports in the side of the Terravent injection probe were spaced along the probe to a depth of 12 in. (30 cm), the mean typical depth of fracturing was at 9 and 9.7 in. (22.8 and 24.6 cm) for the Hilltop and Track sites, respectively (Table 2). No fractures reached the soil surface. No fractures were found deeper than 16 in. (40.6 cm). The horizontal width of fractures ranged from 17 in. (43.2 cm) to a maximum of 25 in. (63.5 cm). The mean fracture width was 22.2 in. (56 cm) at the Hilltop site and 15.2 in. (39 cm) at the Track site.

Some vertical fractures were found near the injection probe (Figure 1). However, the majority of the fractures created by the Terravent discharge were horizontal to convex shaped. Typically, there was only one fracture layer at each site.

## DISCUSSION

The Terravent is similar in concept but slightly different in design from the Aero-Fertil Gun, Grow Gun, and Terralift. The Grow Gun and Terralift have previously been studied for both their soil-fracturing abilities and the subsequent growth response of trees in compacted soils treated with these machines (Smiley et al. 1990; Smiley 1998). The main differences among the tools are the number of ports on the probe and

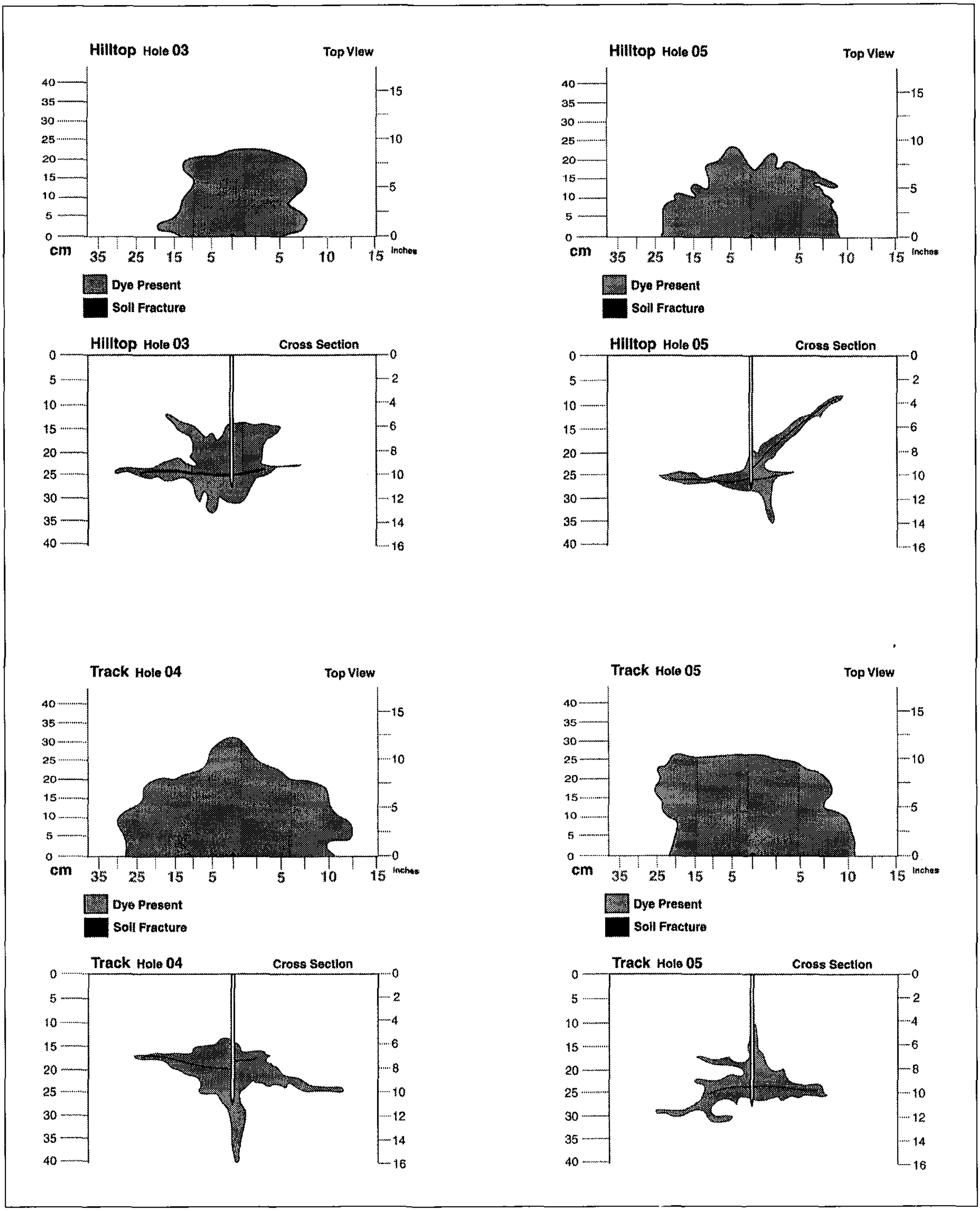


**Figure 1. Soil fracture patterns produced in sandy clay (Hilltop) and sandy clay loam (Track) soil by injecting dye into the soil with the Terravent.**

how the probe is inserted into the soil. With the Grow Gun and Terralift probes, four ports on each were located near the tip. The Terravent has ports distributed along the probe. The hole for insertion of the Grow Gun's probe was drilled with an earth auger. The Terralift was driven into the soil with pneumatic pressure. The Terravent is manually driven into the soil with a slide hammer assembly.

The average maximum spread of dye injected through the Terravent was less than a quarter of that produced by the Terralift and less than half that produced by the Grow Gun (Smiley et al. 1990). In previous studies, there were no significant reductions in bulk density with either the Grow Gun or Terralift. There was no reduction in bulk density (soil compaction) with the Terravent, either.

The growth response of trees in compacted sites treated with the Grow Gun and Terralift was not significant (Smiley 1997b, 1998). The growth response of trees to the Terravent was not tested in this study. Given the lower levels of soil fracturing found with the Terravent, it is expected that tree growth response would not be significant with the Terravent. Lack of efficacy with soil injection devices is probably due to the inability of these machines to affect a large enough volume of soil. With the Terravent, there is no mechanism for introducing fill materials such as perlite or organic matter that will keep soil from recompacting.

While soil fracturing with compressed gases appears to be a good theory, results to date have not proved that it is a cost-effective means of treating soil compaction. More effective treatments for soil compaction include rototilling or mechanically breaking up of soil in areas in advance of root growth (Rolf 1992; Craul 1994; Day and Bassuk 1994; Smiley 1997a, 1997b), radial trenching (Watson et al. 1996; Smiley 1997a, 1997b), and air excavation (Smiley 1999).

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**Résumé.** La compaction du sol est rapportée comme étant un facteur limitatif dans plusieurs sites de plantation d'arbres. Le Terravent™ a été développé pour décompacter et aérer le sol au moyen d'une injection dans le sol d'azote gazeux à haute pression. Le but de ce projet était de déterminer le patron de fracturation du sol créé par le Terravent et de déterminer la diminution de densité du sol obtenue. Des reproductions de six essais de fracturation ont été effectués sur trois sites différents. La densité du sol et le degré de fracturation ont été mesurés. Aucune différence significative dans la densité du sol n'a été observée entre les sites traités et non traités. Les patrons de fractures étaient généralement horizontaux à convexes avec une largeur allant jusqu'à 56 cm (22,2 po.), et ce à une profondeur de 22 cm (9 po.) sous la surface du sol généralement. Les autres méthodes d'allègement du sol sont considérées comme plus efficaces.

**Zusammenfassung.** Als limitierender Faktor für Baumpflanzungen in Städten wird häufig Bodenverdichtungen genannt. Der Terravent™ wurde entwickelt, um den Boden durch die Injektion von Hochdruck-Stickstoff zu belüften und zu lockern. Der Sinn dieses Projekts war, die Bodenstruktur, die der Terravent hinterlässt, zu bestimmen und zu ermitteln, ob die Dichte des Bodenkörpers sich geändert hat. Von drei Standorten wurden Repliken von sechs Frakturen angefertigt. Es wurden keine signifikanten Unterschiede zwischen behandelten und unbehandelten Bodenbereichen gefunden. Die Frakturverläufe waren hauptsächlich horizontal bis konvex mit einer mittleren Breite von 56 cm, typischerweise 23 cm unter der Oberfläche. Andere Methoden zur Auflockerung von Bodenverdichtungen schienen effektiver.

**Resumen.** Se ha reportado a la compactación del suelo como un factor limitante en muchas plantaciones de árboles urbanos. Se empleó Terravent™ para descompactar y airear el suelo a través de inyecciones a alta presión con gas nitrógeno. El propósito de este estudio fue determinar los patrones de ruptura del suelo creados por el Terravent y determinar si la densidad aparente es reducida. Se efectuaron réplicas de seis fracturas en tres sitios. Fueron medidos la densidad aparente y el grado de fractura. No se encontraron diferencias significativas en densidad aparente entre áreas tratadas y no tratadas. Los patrones de fractura fueron generalmente de formas horizontales a convexas, con una anchura media superior a 56 cm, típicamente a 23 cm debajo de la superficie.