VERTICAL MULCHING OF TREES: EFFECTS ON ROOTS AND WATER STATUS

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Abstract. We examined the effect of vertical mulching on root growth and xylem water potential of large sugar maples (Acer saccharum) growing in pastures. Root mass in the 35-40 cm depth of undisturbed soil was about 50% that in the 5-10 cm depth, and root mass at the edge of the canopy (7.5 m from the trunk) was about 40% that found at 1/4 the distance to the edge of the canopy. After three growing seasons, the abundance of roots in perlite-filled vertical mulch channels (0.6 kg/m^3) was significantly ($P<0.0001$) less than in undisturbed soil 1-2 m away from mulch channels (4.4 kg/m^3) and in undisturbed soil immediately surrounding mulch channels (3.5 kg/m^3). Predawn and midday xylem water potentials, measured in late summer and used as indices of tree health, did not differ between mulched and non-mulched trees. Our results indicated that perlite-filled vertical mulch channels did not affect tree health, and, rather than being utilized as preferred pathways of growth, were avoided by tree roots.

Vertical mulching is used as therapy for low-vigor trees growing in heavy traffic areas. This technique involves drilling vertical channels, about 5-cm diameter and spaced about 100 cm apart throughout the root zone, to a depth of 45 cm; channels are back-filled with sand, perlite or other long-lasting porous material to prevent collapse. Conceptually, vertical mulching may benefit trees by improving the movement of water, air, nutrients, and roots within the soil. However, to the best of our knowledge, the assertion by Pirone et al. (6, p.51) that "no scientific research documents the benefits of this procedure" is still true today.

Tree roots tend to follow pre-existing channels or natural low-density pathways, especially when growing in compact soil, and to proliferate in microsites with increased water or nutrient availability (8). Given these two tendencies, the relative abundance of roots within vertical mulch channels versus within undisturbed soil would directly indicate whether vertical mulch channels provide a superior medium for root growth, and would be related to the extent to which a tree responds to mulching.

Xylem water potential is a convenient and conventional measure of the water status of a tree: pre-dawn potential is influenced by the volume of water in the root zone, and mid-day potential is influenced by transpiration and water uptake by roots. Xylem water potential has been shown to be related to a variety of indicators of tree health including rates of photosynthesis and growth, and susceptibility to insect and disease damage (3). It follows that any improvements in soil conditions and tree health brought about by vertical mulching, including increases in the surface area of absorbing roots, should be reflected in improvements in the water status of a mulched tree, and would be detected as a less negative xylem water potential.

Our study was performed in a situation where vertical mulching might realistically be recommended by a professional arborist: pastures with large and valuable trees (Table 1) under which cattle congregated. We addressed the fundamental question of the efficacy of vertical mulching by asking two related questions: 1) Do tree roots utilize vertical mulch channels? 2) Does vertical mulching improve a tree's water status? To answer these question we monitored root growth into mulch channels, and compared xylem water potentials of mulched and non-mulched trees.

Materials and Methods

Study Area. This study was performed at the Bluegrass Army Depot in the Outer Bluegrass physiographic region, Madison County, Kentucky. The climate is temperate, humid and continental with average annual precipitation of 122 cm, evenly distributed throughout the year; average monthly maximum and minimum temperatures, respectively, are 7.2°C and -2.2°C in January, the coldest month, and 30.0°C and 18.9°C in July, the warmest month (4).

The landscape is rolling karst on Ordovician limestones and calcareous shales. Soils used in this study were formed in calcareous residuum from this material and were classified as fine-loamy, mixed, mesic Typic Fragiudalfs (Nicholson series) (4). Soils were well-drained, with silt loam to silty clay loam textures and the following horizon sequence: A (0-20 cm) - Bt (argillic) (20-75 cm) - Bx (fragipan) (75-125 cm) - R (bedrock) (>125 cm).

The Bluegrass Army Depot is a munitions storage facility. Our research was performed on a portion of the Depot that is also used as pasture for beef cattle. In this area trees, primarily sugar maple (*Acer saccharum*), oaks (*Quercus* spp.), hackberry (*Celtis occidentalis*), black cherry (*Prunus serotina*), and sycamore (*Platanus occidentalis*) occur as scattered individuals, in small patches, and along fencerows and streams.

Field Methods - Root Study. Five large sugar maples were used in the portion of the study dealing with root growth (Table 1). The five trees were scattered within an area of 300 ha, and were separated from one another by distances ≥750 m. During the winter of 1988-89, in each quadrant under each tree, 5-cm diameter vertical mulch channels were drilled to a depth of 45 cm at distances of 1/4, 1/2, 3/4 and 4/4 from the trunk to the edge of the crown, for a total of 16 channels per tree. The mulch channels were back-filled with perlite. At the same time, points were randomly marked at the same distance from the trunk and 1-2 m to either side of the mulch channels to serve as control soil sample areas.

During the winter, 1991-92, after three growing seasons, one location at each distance from the trunk was randomly selected under each tree for sampling. Samples of the 5-10, 15-20, and 35-40 cm depths were collected from vertical mulch channels and control soil areas using an iron core-sampler 12.5-cm inside diameter and 5-cm thick. When sampling mulch channels, the core-sampler was centered over the mulch channel, and the 12.5-cm diameter sample that was collected was subdivided into the 5-cm diameter perlite-filled mulch channel and the annulus of soil surrounding the mulch channel. Five sample trees, four distances from the tree trunk, three depths, and three treatments (control, mulch channel, mulch annulus) provided 180 samples which were returned to the lab for separation of roots from the soil.

Field Methods - Xylem Water Potential. Three pairs of trees on a single site were used in the portion of the study dealing with xylem water potentials (Table 1). The three pairs occurred within an area of 3 ha, and pair members were, on average, 40 m apart. During the winter of 1988-89 perlite-filled mulch channels as described above were installed at a spacing of 1 m beneath the crowns of one randomly-selected tree from each of the three pairs. This spacing was equivalent to about 250 mulch channels per tree.

Xylem water potentials of mulched and non-mulched trees were measured on September 25, 1990; September 20, 1991; and September 25, 1992. This was done late in each growing season to ensure that soil water reserves were low and

Table 1. Characteristics of sugar maples (*Acer saccharum*) used for studies of effects of vertical mulching on root density (n = 5 trees) and xylem water potential (n = 3 pairs of trees).

Characteristic	Mean	Minimum	Maximum
		Root density study	
DBH - cm (in)	73.6(29.0)	50.8(20.0)	103.6(40.8)
Crown width - m(ft)	15.0(49.5)	11.5(37.9)	20.0(66.0)
		Xylem water potential study (mulched trees)	
DBH - cm(in)	84.1(33.1)	74.2(29.2)	90.7(35.7)
Crown width m(ft)	16.2(53.5)	16.0(52.8)	16.4(54.1)
		Xylem water potential study (non-mulched trees)	
DBH - cm(in)	84.8(33.4)	74.7(29.4)	101.6(40.0)
Crown width - m(ft)	19.0(62.7)	16.8(55.4)	21.2(70.0)

that any beneficial effects of vertical mulching would be readily detected as less negative xylem water potentials. Sampling dates were scheduled to avoid the presence of dew on the leaves. On each sampling date, xylem pressure potentials were determined at pre-dawn hours (0500 - 0700 hr) and mid-day hours (1300 - 1400). Shoots of the current year were collected from first or second internodes located around the entire circumference of the crown. Shoots approximately 2-in long were excised with a razor and placed in a pressure bomb within 1 min of removal. Xylem pressure potential was recorded to the nearest 0.01 MPa; intra-tree repeatability of 0.05 MPa was obtained by sampling 3 or 4 shoots per tree.

Field Methods - General. An aluminum neutron probe access tube was installed to a depth of 75 cm at one location beneath the crown of each of the 11 trees used in this study. Volumetric water concentrations were recorded with a Troxler neutron probe at depths of 30 and 60 cm at least once a month from January through December, 1990, in order to monitor patterns of soil wetting and drying on the study area.

Laboratory Methods. Sample cores were hand-sorted to remove large roots, then dispersed in Na-hexametaphosphate and poured through nested 2-mm and 1-mm sieves. Prior to drying, root lengths were determined for a random subsample of 45 (15 samples from each treatment) using the line intersect method of Tennant (10) as described by Kalisz et al. (2). Roots removed from all 180 samples were then dried at 60 C and ignited in a muffle furnace at 450°C, and ash-free oven-dry masses were calculated.

Statistical Methods. Root lengths and masses from the subsample of 45 cores were used to develop the following regression equation predicting root length (L) as a function of root mass (M): $L = 7916 + 7291(M)$; $r^2 = 0.78$. Root lengths predicted by this equation were not statistically analyzed, but were useful in interpreting the results of our study. For each of the five trees, root masses were averaged over all sample depths and distances from the tree trunk, and were then compared among the three treatments using ANOVA (n=5 replicates) and Scheffe's mean separation technique. Predawn and midday xylem water potentials were compared each year between mulched and non-mulched trees using Wilcoxon two-sample tests. The significance of all statistical tests was evaluated at $P \leq 0.05$.

Results

Water Concentration. Volumetric water concentrations were similar beneath all 11 trees used in this study. Concentrations ranged from 35 to 50% by volume during the period November through May, and from 20 to 35% during the rest of the year. Lowest soil water levels occurred from August to October. The soil was never water-saturated during the growing season, and water concentrations were similar at depths of 30 and 60 cm.

Root Mass. The average mass of roots in perlite-filled mulch channels was significantly lower than in undisturbed soils (control) and in soils surrounding mulch channels (annulus) (Table 2). Based on the regression equation relating root mass to root length, there were 30,000 to 40,000 m/m^3 (equivalent to 15 to 20 $miles/yd^3$) of roots in the control and annulus samples. This is similar to root lengths found in A horizons under mixed hardwood forests in eastern Kentucky (2), and illustrates the impressive amount of tree roots that may occur in good soils.

Xylem Water Potential. Mean xylem pressure potential ranged from -0.26 to -0.45 MPa at pre-dawn, and from -1.23 to -1.79 MPa at mid-day (Table 3). Xylem pressure potentials did not differ significantly between mulched and non-mulched trees during the three years of measurement.

Table 2. Mean measured root masses (ash-free, oven-dry) for three treatments resulting from vertical mulching under sugar maples (*Acer saccharum*) (60 samples per treatment).

Treatment	Mass (kg/m^3)
Control core	4.4 a*
Perlite annulus	3.5 a
Perlite core	0.6 b

*Means marked with different letters differed significantly at P < 0.0001.

Table 3. Mean mid-day and pre-dawn xylem water potentials of vertically mulched and non-mulched sugar maples (Acer saccharum) measured in late summer of 1990, 1991, and 1992 (N = 3 pairs of trees).

Treatment	Year 1990	1991	1992
	Pre-dawn (MPa)		
Mulched	-0.30a*	-0.45a	-0.26a
Non-mulched	-0.29a	-0.34a	-0.26a
	Mid-day (MPa)		
Mulched	-1.23a	-1.34a	-1.79a
Non-mulched	-1.37a	-1.31a	-2.03a

*Within years and daily measurement periods, there were no differences between mulched and non-mulched trees at P = 0.05.

Discussion

Under the experimental conditions described above, roots did not effectively colonize vertical mulch channels and trees did not seem to benefit from the procedure. This is likely due to the discrepancy in the pore size of the filled channels compared to the surrounding undisturbed soil, with the result that mulch channels function as coarse-textured soil layers that are by-passed by the wetting front under conditions of unsaturated flow of soil water (9). This effect has been described for "fossil" animal burrows that have naturally back-filled by grains derived from the surrounding soil (11), and would be even more striking in the case of vertical mulching where channels are filled with porous media that have physical properties very different from those of the soil matrix. Compared to sand and loam, perlite has a relatively large pore size, and a low hydraulic conductivity and available water capacity (1,5,12). Under conditions of unsaturated flow, water percolating through the soil would not cross the boundary separating the finer soil matrix from the coarser mulch channel, and the perlite-filled channel would therefore be dryer than the surrounding soil. This likely accounts for the relatively low root density that we found in perlite under trees in the present study, and for the low root densities that have been reported in perlite under grasses (7) and legumes (1).

Considered as an arboricultural tool, vertical mulching could most responsibly be prescribed for use in soils with relatively shallow hardpans or other types of soil layers that perch water. In such soils, water ponded during wet weather would develop sufficient hydraulic pressure to enter and drain through vertical mulch channels that are open to the surface and extend below the restrictive layer. The rationale for recommending vertical mulching is less clear in the case of soils that do not pond water, or that have restrictive layers that extend below the depth of the mulch channels. If used in the latter situations, however, vertical mulching would more likely be effective in providing pathways for root growth if the pore size characteristics of the medium used as fill in the mulch channels are similar to those of the surrounding soil.

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Résumé. Nous avons examiné les effets du paillage vertical sur la croissance des racines et sur le potentiel en eau du xylème sur de gros érables à sucre (*Acer saccharum*). La masse de racines à une profondeur de 35 - 40 cm était de 50% inférieure à celle à une profondeur de 5-10 cm pour un sol non perturbé, et la masse de racines en bordure de la couronne (7.5 m de distance du tronc) était de 40% à celle retrouvée à 14 fois la distance de la couronne. Après trois saisons de croissance, l'abondance en racines des trous remplis de perlite (0.6 kg/m^3) était significativement moindre ($P \leq 0.0001$) que pour la zone de sol non perturbé (4.4 kg/m^3) située un à deux mètres plus loin que les trous remplis de paillis (4.4 kg/m^3) et que pour le sol non perturbé à proximité immédiate des trous remplis de paillis (3.5 kg/m^3). Les mesures de potentiel en eau, avant l'aube et au milieu de la journée, ont été prises à la fin de l'été et employées comme indice de la santé de l'arbre; elles ne présentaient alors aucune différence entre les arbres avec paillis ou ceux sans paillis. Nos résultats indiquaient donc que les trous remplis de perlite n'affectent pas la santé des arbres et qu'ils ne sont pas privilégiés pour la croissance des racines, mais bien plutôt évités.

Zusammenfassung. Wir untersuchten den Effekt von vertikalem Mulchen bezüglich des Wurzelwachstums und Xylem-Wasserpotential bei großen Zuckerahornen (*Acer saccharum*). Die Wurzelmasse in 35-40 cm Tiefe in ungestörtem Boden war etwa 50% vom dem in 5-10 cm Tiefe, und die Wurzelmasse am Rande des Kronenmantels (7.5 m vom Stamm) betrug etwa 40% von dem, was bei einer Distanz von 14 m gefunden wurde, die Distanz zum Rande des Kronenmantels. Nach drei Wachstumsperioden war die Menge der Wurzeln in perlit-gefüllten vertikalen Mulchkanälen (0.6 kg/m^3) signifikant ($P \leq 0.0001$) weniger als in ungestörtem Boden in 1 - 2 m Entfernung von Mulchkanälen (4.4 kg/m^3) und in ungestörtem Boden direkt um Mulchkanäle (3.5 kg/m^3) herum. Die Xylem-Wasserpotentiale vor der Morgendämmerung und um Mittag, gemessen im Spätsommer und benutzt als Indikator für Baumgesundheit, differierten nicht zwischen gemulchten und ungemulchten Bäumen. Unsere Ergebnisse zeigten, das perlit-gefüllte vertikale Mulchkanäle keinen Einfluß auf Baumgesundheit hatten und daß, anstatt als Wachstumspfad mehr bevorzugt zu sein, sie von Baumwurzeln eher gemieden wurden.