ORGANIC MULCH AND GRASS COMPETITION INFLUENCE TREE ROOT DEVELOPMENT

by Gary W. Watson

Abstract. Root density, soil moisture content and soil oxygen diffusion rate (ODR) were measured under three soil surface treatments—grass, organic mulch and bare soil. Seven tree species were tested, green ash, little-leaf linden, pin oak, red oak, sugar maple, red maple and Norway maple. All trees were approximately 20 years old. Elimination of the grass resulted in consistent increases in tree root density at the 0 - 7.5 cm depth, except for the oaks. Application of mulch increased root densities in the soil beneath it. The layer of decomposing organic mulch also provided additional medium for root growth. When compared to the grass treatment, total root surface area was increased up to 195 percent by the mulch treatment and up to 113 percent by the bare soil treatment. Soil moisture was significantly higher in the mulch and the soil beneath it and lowest in the grass treatment. ODR was unaffected by the treatments.

Résumé. La densité des racines, l'humidité du sol et le taux de diffusion de l'oxygène furent mesurés sous trois traitements du sol - présence de gazon, d'un paillis organique, et un sol à nu. Sept espèces d'arbres furent testées, le frêne rouge, le tilleul à petites feuilles, le chêne des marais, le chêne rouge, l'érable à sucre, l'érable rouge, et l'érable de Norvège. Tous les arbres étaient âgés d'environ 20 ans. Le développement racinaire fut augmenté lors de la présence d'un paillis et fut inhibé par la compétition due au gazon. L'élimination du gazon a résulté en des augmentations conséquentes de la densité du système racinaire dans les 7.5 premiers centimètres de sol, excepté pour les chênes. L'application d'un paillis a augmenté la densité racinaire de toutes les espèces. La couche de paillis composée de matières décomposées a aussi apporté un milieu additionnel favorable à la croissance de racines. Lorsque comparé au traitement avec du gazon, la densité racinaire fut augmentée de 195% lors de la présence d'un paillis et de 113% lors du traitement laissant le sol à nu. L'humidité du sol fut plus élevée dans le paillis et dans le sol sous-jacent pendant les périodes sèches et généralement plus basse lorsque du gazon était présent. Le taux de diffusion de l'oxygène ne fut pas affecté par les traitements.

Most tree species planted in urban areas originated in the forest where well developed soils have substantial humus and litter layers. Competition usually consists of other woody species and scattered non-aggressive herbaceous plants. In contrast, urban environments typically have compacted, disturbed soils with aggressive turfgrass competition over the entire root zone. Organic mulch seems to offer opportunities for substantial improvement of tree root environments in disturbed soils.

Turfgrass and mulch are known to greatly influence soil properties and processes (5, 7, 12). Organic mulch increases infiltration, reduces evaporation and increases soil organic matter, resulting in improved soil structure, water holding capacity and nutrient availability. Mulch acts as an insulator, buffering the soil from rapid temperature changes and extremes. Conversely, turfgrass competes for soil nitrogen and water (1, 11) and allows greater soil temperature extremes (2). Effects of bare soil are usually intermediate between turf and mulch.

Numerous studies have shown that grass competition reduces, and mulch increases, topgrowth of trees as compared to trees grown in bare soil (2, 6, 9, 10). Extra nitrogen and water sometimes reduce the negative effects of the grass on tree growth (1, 3, 5).

The specific effects of mulches and grass competition on root systems are not as well understood. Several reports have shown that tree root development is reduced by grass competition (1, 2). Whitcomb and Roberts (15) reported that grass root density was reduced when the tree roots were established first. Organic mulch usually increases overall root development, though reports on changes in soil penetration by roots under mulch have been conflicting. Stuckey (14) reported a decrease in rooting depth, and Kenworthy (8) reported increased root penetration into the soil. The purpose of this study is to investigate the long-term use of mulch to improve the tree root environment of many urban sites.

Methods

Seven tree cultivars were tested: Bowhall red maple (*Acer rubrum* 'Bowhall'), Emerald Queen Norway maple (*Acer platanoides* 'Emerald Queen'), Green Mountain sugar maple (*Acer saccharum* 'Green Mountain'), green ash *(Fraxinus pennsylvanica)*, little-leaf linden *(Tilia cordata)*, red oak *(Quercus rubra)*, and pin oak *(Quercus palustris)*. All trees were open grown, grouped by species, and approximately 20 years old at the time the study was begun. As far as could be determined from planting records and examination of the roots, all cultivars were growing on seedling root stock.

The first 10 cm (depth after settling) of mulch was applied prior to the 1980 growing season. Another 10 cm of mulch was applied over the original layer in the fall of 1982 and the last 10 cm in the fall of 1984. The material used was partially composted wood chips and/or leaves. By the July 1986 sampling time, the 30 cm of mulch that was applied had become a well-composted layer approximately 10-12 cm thick.

Three trees of each species were used. Plots of approximately 1 square meter were created on opposite sides of each tree, centered approximately two meters from the trunk. A similar sized area to the side of each mulch plot, the same distance from the trunk, was maintained as a turf treatment. In May 1986, a third treatment area of bare soil was created on the other side of the mulch, using glyphosate herbicide. To avoid disturbing the surface roots of the trees, no attempt was made to remove the dead plants or cultivate the soil. Though this area was considered as bare soil, the small amount of plant residue may have served as a slight mulch, reducing evaporation and shielding the soil from the sun.

Root density, moisture content (MC) and soil oxygen diffusion rate (ODR) sampling was done in the summer of 1986. Root samples were taken in mid-July. MC and ODR measurements were both taken when treatment differences in soil aeration would be most meaningful. MC samples were taken in August, when the soil was dry. ODR measurements were taken in late September after soil moisture was restored. Both moisture content and ODR measurements were taken at similar locations as the root samples. Fine root ($<$ 3 mm diameter) densities (cm^2 surface area/300 cm^3 soil) were determined by subdividing 7 cm diameter soil cores into mulch layer (thickness was measured to nearest cm), 0-7.5 and 7.5-15 cm deep soil layers. Tree roots were washed free of soil and separated from grass roots before measuring surface area.

Statistical procedures were performed using SPSS/PC+ Version 1.1. One-way analysis of variance was used to study the effect of soil surface treatments. Separation of means was by the Student-Newman-Keuls procedure with significance at 5 percent (0.05).

Results and Discussion

Tree root densities were generally higher in the mulch and the 0-7.5 cm soil layer below the mulch (Table 1). The differences were significant for red maples. Though the differences for many other species were substantial (as much as 4-fold), statistical significance was not achieved due to

Table 1. Root density (cm^2 surface area/300 cc soil or mulch)

	Bare soil		*Organic mulch*			*Grass*	
Depth (cm)	*0-7.5*	*7.5-15*	*Mulch*	*0-7.5*	*7.5-15*	*0-7.5*	*7.5-15*
Red maple	40.3^b	25.5^b	64.8^{ab}	77.5^a	36.5^b	32.2^b	33.3^b
Norway maple	61.2	64.3	88.5	75.8	73.3	52.3	56.0
Sugar maple	13.2	14.5	17.7	15.5	11.1	4.4	8.6
Green ash	32.3	27.5	56.4	28.7	32.3	25.1	18.1
Pin oak	14.9	20.2	7.9	25.0	21.6	18.9	14.6
Red oak	4.8	6.5	1.0	7.2	5.0	4.2	8.0
Linden	24.4	17.7	42.2	21.4	19.8	12.7	18.3

Data on the same line bearing the same letter were not significantly different (5% level) using one-way analysis of variance with separation of means using the Student-Newman-Keuls procedure. Treatment effects were non significant in lines without letters.

the large variation that is characteristic of root density sample measurements. Elimination of the grass, even without addition of mulch, resulted in a non-significant increase in root development at both the 0-7.5 and 7.5-15 cm depths for most species. The mulch itself provided additional volume of material that could be utilized for root development.

Moisture content of the mulch was significantly higher than all soils (Table 2). The 7.5 cm soil layer below it had higher soil moisture than any of the other soil samples. Moisture content of the 7.5-15 cm depth under the turfgrass was the lowest. The grass may have been depleting the soil moisture at this depth without being replenished by light summer rains which often wet only the top few centimeters of soil. It is likely that these differences in moisture content are at least partially responsible for the variations in root density observed.

Soil ODR measurements were taken when the soil was at or near field capacity because this is the time when aeration is at a minimum level (other than when saturated). ODR was highest in the mulch layer and there were no significant differences between treatments at comparable soil depth. None of the measurements was below the 0.2 $\mu g/cm^2$ min. level which is considered to be restrictive of root growth (13).

Very few of the tree species commonly planted in urban areas compete with grass plants for rooting space in their natural habitat. The results of this study indicate that the presence of grass competition and the absence of the humus layer on the surface of the soil in the root zone of trees inhibits fine root (< 3 mm diameter) development of the trees. A tree with a poorly developed fine root system would have reduced ability to absorb moisture and nutrients from the soil, especially when in limited supply. The consequences are likely to be a reduced water and nutrient absorption. Drought stress could be increased and nutrient deficiencies may develop (11). This supports the many literature reports of reduced tree growth and chlorosis in the presence of grass competition. Addition of water and nutrients to the soil may help by making them more available to the root system, but does not address the real problem.

Sequence of establishment may be a factor. Whitcomb and Roberts (15) reported that tree root systems were unaffected by grass competition when established first. This was in a container experiment with a peat/sand medium which would offer little resistance to any type of root system. Clayey urban soils have entirely different characteristics and these results may not apply to the urban situation.

In Table 3, the enhancement of the fine root system as a result of the treatments is expressed as percent increase of root surface area as compared to the grass treatment. Four of the seven species more than doubled the amount of fine roots as a result of the mulch treatment. The increase was significant for all species tested except the two oaks. Only red oak did not increase at least 50 percent. Elimination of grass alone, without addition of mulch, resulted in a significant root surface area increase (113%) in sugar maple roots and increases of over 30 percent in linden and green ash roots. Sugar maple was apparently the most affected by grass competition, since the largest increases in root density were recorded for this species in both the bare soil and mulch treatments. It should be remembered that this change occurred in only two months. Increases might have been greater if a longer time had been allowed before sampling.

Table 2. Moisture Content (% water) and ODR (ug/cm^2 min) of mulch and soil.

	Bare soil		*Organic mulch*			*Grass*	
Depth (cm)	*0-7.5*	*7.5-15*	*Mulch*	*0-7.5*	*7.5-15*	*0-7.5*	*7.5-15*
Moisture Content	16.5^c	15.6^c	20.9^a	18.0^b	15.4^c	15.7^c	14.3^d
ODR	0.33^b	0.25^c	0.41^a	0.32^b	0.26^c	0.35^b	0.26^c

Data on the same line bearing the same letter were not significantly different (5% level) using one-way analysis of variance with separation of means using the Student-Newman-Keuls procedure.

Table 3. Percent increase of fine roots above 15 cm depth (including mulch) compared to grass treatment.

Species	*Bare soil*	*Mulch*
Red maple	0	172*
Norway maple	16	90*
Sugar maple	113*	195*
Green ash	38	128*
Pin oak	2	51
Red oak	-8	6
Linden	34	127*

*Significant increase (5% level) in tree root density over grass treatment using one-way analysis of variance with separation of means using the Student-Newman-Keuls procedure.

Mulch has occasionally been reported to have negative effects on plant root systems. Gouin (4) reported that consecutive applications of mulch can reduce oxygen supply to plant roots. In this study, the mulch layer was well aerated. The soil beneath the mulch was also well aerated. There was no significant difference in ODR between treatments and no reduction of root density. Stuckey (14) reported that mulch caused a more shallow root system, which might be more prone to drought damage. Data from this study show no such decrease in rooting depth. Kenworthy (8) reported that hay mulch actually promoted soil penetration by the roots. This may have been due to improved soil structure resulting from the mulch application. Care must be taken to choose porous material and apply it in moderate amounts. Gouin (4) also reported that the temperature of dry mulch could drop rapidly to temperatures that could kill fine roots. While this might be possible in unusual situations, data from this study show that the mulch layer holds moisture extremely well, and this is not likely to happen. The mulch should be kept away from the trunks of plants to prevent disease and rodent damage.

The root systems of trees are quite shallow and spread well beyond the dripline when unrestricted. Urban situations usually restrict lateral root spread with foundations and pavements. Poor aeration and drainage of clayey soils prevents root development in deeper soil layers. Reduction of tree fine roots in the shallow soil by competing turfgrass further compounds the problem. If two plants are present, each will have less rooting space and soil resources will have to be divided. Recycling of organic matter and nutrients is almost nonexistent in soils with well-kept lawns. If we are to expect our urban trees to grow vigorously and live long, the rooting environment must be improved. Use of organic mulches is an excellent means of accomplishing this. The soil is improved, competition is minimized, organic matter is recycled and fine root development is enhanced.

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