EFFECT OF ORGANIC AND MINERAL MULCHES ON SOIL PROPERTIES AND GROWTH OF FAIRVIEW FLAME® RED MAPLE TREES

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Abstract. Five mineral mulches (crushed red brick, pea gravel, lava rock, carmel rock, and river rock) and 3 organic mulches (finely screened pine bark, pine wood chips, and shredded hardwood bark) were evaluated over 2 years to determine their influence on soil temperature, moisture, and pH, and to quantify their effect on growth of Fairview Flame® red maple (*Acer rubrum* L.). Soil temperatures were highest and moisture percentages lowest under the mineral mulches and nonmulched control. Soil pH readings were highest under shredded bark and wood chips, and lowest in the nonmulched control. Trees growing in river rock, crushed brick, pea gravel, and carmel rock had larger stem calipers than those growing in shredded bark plots. Crushed brick, pea gravel, and carmel rock treatments also resulted in greater leaf dry mass than did shredded bark. These results, however, should not be interpreted as an indictment of organic mulches. Because stem caliper and leaf dry mass measurements of trees growing in wood chips and any of the mineral mulches were not statistically different, blanket statements and generalizations regarding the performance of woody plants mulched with organic or mineral (rock) materials are unwise.

Key Words. Horticultural mulches; root-zone environment; growth measurements.

The benefits of using wood and bark byproducts as horticultural mulch over the root zones of landscape plants are well established (Watson 1988; Green and Watson 1989; Skroch et al. 1992; Greenly and Rakow 1995; Gleason and Iles 1998); however, several actual or perceived problems associated with organic mulches, such as unacceptable appearance (Rakow 1992), creation of a temporary soil nitrogen deficiency (Ashworth and Harrison 1983), potential fire hazard (Hickman and Perry 1996), and rapid decomposition (Rakow 1992), have led to increased use of mineral or rock mulches. But concerns that materials like rock, gravel, and crushed brick may promote potentially injurious high temperatures, both above and below the mulch layer, alkalinization of the soil, and mechanical injury to the stems of plants have caused many landscape and tree care professionals to reexamine their rationale for using mineral mulches as suitable ground-covering materials around woody and herbaceous plants. This experiment was designed to evaluate and compare the effects of 5 mineral and 3 organic mulches on 1) several soil properties, and 2) growth of Fairview Flame® red maple (*Acer rubrum* L.).

MATERIALS AND METHODS

Ninety bare-root, 1.6- to 2-cm (0.6- to 0.8-in.) caliper, 1.2- to 1.5-m (4- to 5-ft) tall, branched Fairview Flame® red maple trees were planted in a Nicollet fine sandy loam soil at the Iowa State University Horticulture Research Station, Gilbert, Iowa (USDA hardiness zone 5a; lat. 42°3'N), on April 22, 1996. The experimental design was a randomized complete block with 9 treatments, 5 blocks (replications), with treatments repeated twice in each replication. Trees were spaced 2 m (6.5 ft) apart in north-south oriented rows with 3 m (10 ft) between rows. Trees were hand watered once on the day of planting to facilitate establishment. Treatments consisted of 2.3-m^2 (25-ft^2) plots of 8 mulches:

- a 5-cm (2-in.) layer of 1.9-cm (0.75-in.) diameter crushed red brick,
- 0.9-cm (0.4-in.) diameter pea gravel,
- 1.3-cm (0.5-in.) diameter lava rock,
- 2.5-cm (1-in.) diameter carmel rock (chert),
- a 7.5-cm (3-in.) layer of 3.8-cm (1.5-in.) diameter river rock,
- a 10-cm (4-in.) layer of 4- to 6-cm (1.6- to 2.4 in.) long finely screened pine bark,
- 2- to 3-cm (0.8- to 1.2-in.) diameter pine wood chips,
- 4- to 5.5-cm (1.6- to 2.2-in.) long shredded hardwood bark (mostly oak),

and a nonmulched control maintained as bare ground. Organic mulches were placed directly on bare ground, while mineral mulches were underlaid with a woven polypropylene fabric (DeWitt Landscape Pro 5). Weeds and other unwanted vegetation within and between treatment plots, and along the east and west borders of the plots (15-cm [6 in.] wide) were controlled with glyphosate (1% v/v). Plots were not fertilized.

Soil moisture was recorded weekly during the growing season (June–August) in 1996 and 1997 with a Theta Probe (meter type HH1, sensor type ML1; Delta-T Devices Ltd., Cambridge, UK) soil moisture sensor at 6 cm (2.4 in.) below the soil surface. Soil temperature also was determined weekly using a portable Barnant 115 thermocouple thermometer (model 600-2810; Barrington, IL) at 10 cm (4 in.) below the soil surface. Both soil moisture and soil temperature readings were taken on the south side of the tree, approximately 0.6 m (2 ft) from the trunk.

Stem diameter at 15 cm (6 in.) above the soil surface and tree height from soil surface to the highest point in the crown were measured on September 19 and 20, 1997, respectively. Leaves were harvested from each tree on October 4 and 5, 1997, dried at 67°C (153°F) for 5 days, and weighed. Randomly chosen soil samples (1 from each treatment in each replication) taken at the soil surface immediately below the mulch treatment, were retrieved on December 1, 1997, and again on June 17, 1998, to determine pH. All data were subjected to analysis of variance and means separated by least significant difference ($P \leq 0.05$).

Table 1. Effect of 8 mulch treatments and a nonmulched control on soil temperature, percentage soil moisture, and soil pH.

Treatment	Temperature[z] (°C)	Moisture[y] (%)	pH[x] 1997	pH[x] 1998
Control	29.3[w] a[v]	19[u] d	6.03[t] d	5.86[s] d
Pea gravel	27.6 b	31 ab	6.44 b	6.14 bc
Crushed brick	26.2 c	30 bc	6.29 bc	6.04 cd
Carmel	26.2 c	29 c	6.29 bc	6.06 cd
River rock	25.2 d	29 c	6.47 b	6.33 b
Lava rock	24.5 d	30 bc	6.21 cd	5.82 d
Shredded bark	23.6 e	31 ab	6.82 a	6.81 a
Wood chip	23.3 e	32 a	6.81 a	6.37 b
Screened pine	23.2 e	32 a	6.13 cd	6.14 bc

[z]Soil temperature measured at 10 cm (4 in.) depth, between 2:00 and 4:00 P.M., CST.
[y]Soil moisture measured at 6 cm (2.4 in.) depth, between 2:00 and 4:00 P.M., CST.
[x]Soil samples for pH measurements collected at 0- to 10-cm (0- to 4-in.) depth.
[w]Data shown are means of 12 dates × 5 replications (n = 60) in 1997.
[v]Mean separation within columns by LSD, $P \leq 0.05$.
[u]Data shown are means of 12 dates × 5 replications (n = 60) in 1997.
[t]Data shown are means of 5 observations. Soil samples collected on December 1, 1997, for pH determination.
[s]Data shown are means of 5 observations. Soil samples collected on June 17, 1998, for pH determination.

RESULTS AND DISCUSSION

Effects on Soil Temperature and Moisture

In 1997 (data from 1996 are not presented because unseasonably cool, wet conditions caused a lack of statistical significance), highest soil temperatures were recorded in the nonmulched control plots, followed by pea gravel, crushed brick, and carmel rock treatments (Table 1). Plots covered by organic mulch treatments had significantly lower soil temperatures (mean = 23.4°C [74.1°F]) than plots treated with mineral mulches (mean = 25.9°C [78.6°F]). Loosely packed organic mulches insulate soils by intercepting and absorbing solar radiation instead of conducting heat energy downward (Waggoner et al. 1960; Montague et al. 1998).

Soil moisture content was highest under the 3 organic mulches and pea gravel; however, the shredded bark and pea gravel treatments were not different from lava rock or crushed brick (Table 1). Lowest moisture percentages were recorded in the nonmulched control. Soil moisture under mulch is increased through minimizing soil surface evaporation (Himelick and Watson 1990). In our study, organic mulches that meshed together, and fine-textured mineral mulches like pea gravel, presented a greater barrier to evaporation than coarser mulch materials or bare soil.

Effects on Soil Chemistry

Previous researchers report organic mulches cause no change in soil pH (Watson and Kupkowski 1991; Greenly and Rakow 1995) or reduce pH of the underlying soil (Billeaud and Zajicek 1989; Himelick and Watson 1990; Hild and Morgan 1993). Mulch-induced pH reduction results from the addition or retention of organic matter, with organic acids produced from decomposition of plant-derived materials accumulating or leaching into the soil (Himelick and Watson 1990). At the completion of our study (1997), soil pH was lowest in the nonmulched control plots and highest under shredded bark and wood chip mulches (Table 1). Elevated pH under these mulches could have resulted from the leaching of basic cations (NH_4^+) from decomposing organic matter (Tisdale et al. 1993). If so, we would expect the increase in pH from ammonification to be temporary because pH will decrease as ammonia is oxidized to nitrate by nitrifying bacteria in the soil. In 1998, soil pH readings again were highest under wood chip and shredded bark mulches. Lowest pH measurements were recorded in the lava rock treatment and in the unmulched control. While some mineral mulches could contribute to undesirably high soil pH, mineral mulches used in this study did not.

Effects on Tree Growth

Temperature, moisture, and chemical differences in root-zone environments brought about by the various mulch treatments did not translate into differences in tree height; however, trees growing in pea gravel, crushed brick, carmel, and river rock had larger stem calipers than those growing in shredded bark plots (Table 2). Stem calipers of trees in the 3 organic mulch treatments, lava rock, and in the nonmulched control were not different.

Crushed brick, pea gravel, and carmel rock treatments resulted in greater leaf dry mass than shredded bark plots. Leaf dry mass also was greater for trees in crushed brick and pea gravel than for trees mulched with screened pine. Dry mass of trees in the 3 organic mulch treatments, river rock, lava rock, and in the control were not different.

Differences in tree growth are most likely linked to temperature differences in the soil environment. Although we did not measure soil temperatures in April and May, based on summer readings it is logical to assume soil temperatures under organic mulches would be cooler and possibly more growth limiting (at least for the shredded bark and screened pine mulches) than warmer, growth-enhancing temperatures under the mineral mulches (particularly pea gravel, crushed brick, and carmel rock). Holloway (1992) reported similar results in Alaska, where 5 woody plant species grew best in stone mulch treatments. Elevated pH also might have contributed to poorer growth for trees in the shredded bark treatments.

Table 2. Effect of 8 mulch treatments and a nonmulched control on stem caliper, height, and leaf dry mass of *Acer rubrum* Fairview Flame®.

Treatment	Height[z] (cm)	Stem caliper[y] (cm)	Leaf dry mass[x] (g)
Lava rock	222[w] a[v]	4.1[u] ab	441[t] abc
Wood chip	222 a	4.1 ab	423 abc
Pea gravel	220 a	4.2 a	467 a
Crushed brick	219 a	4.2 a	478 a
Control	219 a	4.1 ab	419 abc
Carmel	218 a	4.2 a	463 ab
River rock	214 a	4.2 a	449 abc
Screened pine	214 a	4.0 ab	398 bc
Shredded bark	210 a	3.9 b	383 c

[z]Height measured from ground level to highest shoot apex on September 20, 1997.
[y]Stem caliper measured 15 cm (6 in.) above ground level on September 19, 1997.
[x]Leaves harvested October 4 and 5, 1997.
[w]Data shown are means of 10 observations.
[v]Mean separation within columns by LSD, $P \leq 0.05$.
[u]Data shown are means of 10 observations. Each observation is the average of measurements taken at 1) the widest point on the stem, and 2) rotated 90° clockwise from the first measurement.
[t]Data shown are means of 10 observations.

CONCLUSION

Our results indicate mineral mulches used in this study do not create growth-limiting soil environments. In fact, the capacity of crushed brick and pea gravel to conduct heat to soils below, particularly in early spring, may be responsible for the observed advantage in leaf dry mass for trees growing in these materials over those growing in soils kept relatively cool by insulating mulches such as shredded bark and screened pine. Mineral mulches used in this study also proved to be relatively inert, causing equal or smaller increases in pH than shredded bark or wood chips.

These results, however, should not be interpreted as an indictment of organic mulches. Because soils at the ISU Horticulture Research Station are fertile and well drained, the organic matter and nutrient contributions made by organic mulches may be of less consequence than if the study had been conducted on poor soils. Moreover, had conditions been drier and warmer during the years of the study (1996–1997), or if the experiment had been conducted in a warmer climate, organic mulches may have outperformed many of the mineral mulches. Finally, because stem caliper and dry leaf mass measurements of trees growing in wood chips and any of the mineral mulches were not statistically different, blanket statements and generalizations regarding the performance of woody plants mulched with organic or mineral (rock) materials are unwise.

The nursery and landscape industry is fortunate to have a wide variety of mulch materials to choose from, and each has its place in the landscape. But in the final analysis, cost and maintenance considerations dictate which mulch materials will be used.

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Résumé. Cinq paillis de type minéral (brique de terre cuite concassée, petit gravier, pierre volcanique, pierre de granite, galet de rivière) et trois de type organique (écorces fines de pin, copeaux de bois de pin, écorce de bois durs déchiquetée) ont été évalués sur deux ans afin de déterminer leur influence sur la température du sol, l'humidité et le pH, et aussi pour quantifier leur effet sur la croissance de l'érable rouge Fairview Flame® (*Acer rubrum* L.). Les couches de paillis ont été appliqués de façon aléatoire autour des arbres selon cinq blocs. Les paillis organiques ont été appliqués directement sur le sol nu alors que les paillis minéraux ont été placés sur une membrane de polypropylène. Sous les paillis minéraux ou à l'absence de paillis, les températures de sol étaient les plus élevées et les pourcentages d'humidité les plus faibles. Les lectures de pH du sol étaient les plus élevées sous l'écorce déchiquetée et les copeaux de bois et les plus faibles en l'absence de paillis. Malgré ces différences au niveau de l'environnement racinaire, il n'y avait pas de différence significative au niveau de la hauteur des arbres. Les arbres avec un paillis de galet de rivière, brique concassée, petit gravier ou pierre de granite avaient néanmoins une tige plus grosse que ceux poussant dans les unités d'écorce déchiquetée. Les paillis de brique concassée, petit gravier ou pierre de granite ont aussi produit une masse foliaire sèche plus élevée que l'écorce déchiquetée. La masse foliaire sèche était aussi plus élevée pour les arbres avec un paillis de brique concassée ou de petit gravier que ceux avec de l'écorce fine de pin. Nos résultats indiquent que les paillis minéraux utilisés dans cette étude ne créent pas de limitation à la croissance au niveau de l'environnement du sol.

Zusammenfassung. Fünf mineralische Mulchmaterialien (gemahlene Ziegelsteine, Split, Lavagestein, carmel rock und Flußkies) und drei organische Mulche (feine Kiefernrinde, Kiefernholzschnitzeln und geschredderte Hartholzrinde) wurden über zwei Jahre bewertet, um ihren Einfluß auf Bodentemperatur, Feuchtigkeit und pH zu bestimmen und um ihren Effekt auf das Wachstum von Fairview Flame® (Rotahorn) zu quantifizieren. Die Mulchbehandlungen (2,3 m2 Flächen mit 8 Mulchen und einer Kontrollfläche) wurdne unwillkürlich in fünf Blöcken auf die Bäume verteilt. Die organischen Mulche wurden direkt aufgebracht, während die mineralischen mit einer Polypropylengewebeschicht unterlegt wurden. Unter den mineralischen Mulchen und dem Kontrollversuch ohne Mulch war die Bodentemperatur am höchsten und die Bodenfeuchtigkeit am niedrigsten. Der Boden-pH war unter der geschredderten Rinde und unter den Holzschnitzeln am höchsten und unter der Kontrollfläche am niedrigsten. Abgesehen von den Differenzen in der Wurzelzone gab es keine signifikanten Unterschiede in der Baumhöhe. Bäume, die in Flußkies, gemahlenen Ziegeln, Split oder in carmel rock standen, hatten größere Stammumfänge als solche, die in geschredderter Rinde wuchsen. Ziegelgrus, Split und carmel rock Behandlungen führten auch zu einer größeren Blatt-Trockenmasse als bei Rindenmulch. Die Blatt-Trockenmasse bei Bäumen, die in Ziegelgrus und Split wuchsen, war auch höher als bei geschredderter Kiefer. Unsere Resultate zeigen, daß mineralische Mulche kein wachstumbegrenzendes Bodenumfeld schaffen.

Resumen. Cinco mulches minerales (ladrillo rojo quebrado, grava chícharo, roca lava, roca carmel y piedra de río) y tres mulches orgánicos (corteza de pino finamente tamizada, astillas de madera de pino y corteza de madera dura desmenuzada) fueron evaluados durante dos años para determinar su influencia sobre la temperatura, la humedad y el pH del suelo, y para cuantificar su efecto sobre el crecimiento del arce de Virginia, Fairview Flame® (*Acer rubrum* L.). Los tratamientos con mulch fueron aplicados a los árboles en cinco bloques al azar. Los mulches orgánicos fueron colocados directamente sobre la tierra desnuda, mientras que los mulches minerales fueron tendidos sobre un tejido de polipropileno. Bajo los mulches minerales y los de control no mulcheados las temperaturas del suelo fueron las más altas y los porcentajes de humedad del suelo los más bajos. Las lecturas del pH del suelo fueron las más altas bajo la corteza desmenuzada y las astillas de madera, y las menores en el control no mulcheado. A pesar de estas diferencias en los ambientes de la zona de raíces, no hay diferencias significativas en la altura del árbol. Sin embargo, los árboles que crecen con piedra de río, ladrillo quebrado, grava chícharo y roca carmel, tuvieron mayor calibre en sus troncos que aquéllos que crecieron en parcelas con corteza desmenuzada. Los tratamientos con ladrillo quebrado, grava chícharo y roca carmel también resultaron en mayor masa foliar seca que con la corteza desmenuzada. La masa foliar seca también fue mayor para árboles con ladrillo quebrado y grava chícharo que con pino tamizado. Nuestros resultados indican que los mulches minerales usados en este estudio no crean ambientes en el suelo que limiten el crecimiento.