

A Comprehensive Review of the Effects of Mulching

The following is excerpted from “Impact of Mulches on Landscape Plants and the Environment—A Review,” by Linda Chalker-Scott (Washington State University, Puyallup Research and Extension Center, 7612 Pioneer Way E., Puyallup, WA 98371), *Journal of Environmental Horticulture* 25(4), December 2007, 239-249, published by the Horticultural Research Institute, 1000 Vermont Ave., N.W., Suite 300, Washington, DC 20005. There are nearly 150 references cited in the original article.

... The purpose of this review is to provide a comprehensive analysis of scientific research on the benefits and drawbacks of mulches used in ornamental and urban landscapes... Though landscape mulches were first reviewed in 1957, there have been no analyses summarizing the scientific research on landscape mulches.... such a summary is long overdue.

Comparative benefits of mulches

Improved soil moisture. Exposed to heat, wind, and compacting forces, bare soil loses water through evaporation and is less able to absorb rainfall or irrigation as it becomes increasingly compressed. Weeds can increase evapotranspiration of soil moisture by 25% in a summer day. In contrast, mulches will increase soil water by increasing percolation and retention, reducing evaporation, and reducing weeds. An early study demonstrated that a layer of straw only 1.5 inches thick reduced evaporation by about 35% compared to bare soil.... most mulched soil has greater water retention than bare soil, with the exception of competitive living mulches such as turf. What is less consistent is how different mulch types influence water movement. For instance, black plastic generally inhibits water movement between the soil and the above-ground environment, thus limiting recharge. Soil water recharge is dependent upon infiltration, which in turn is influenced by surface permeability. Activities and products that compact soils and/or create hydrophobic conditions will limit recharge while increasing runoff and erosion. Plastics, geotextiles, fine-textured organic mulches, sheet mulches, and mulches with waxy components are poor choices in this regard. Therefore, though these mulches may initially increase soil water retention since evaporation is reduced, over the long term they will create soils that are unnaturally dry.

In contrast, there is a wide variety of mulching materials that do not limit soil water infiltration and retention: their one similarity is that they are all permeable materials. Most comparative studies among mulch types indicate that organic mulches conserve water more effectively than inorganic; organic and inorganic are better conservers than synthetic; and all are better than bare soil. Mulches with demonstrated ability to retain water include gravel and stone, livestock manure, and a vast array of plant materials.... Cover crops are generally less effective than either organic or inorganic mulches as they must compete with other landscape plant materials for water.

From a practical standpoint, an appropriate mulch will significantly reduce the amount of irrigation needed for all landscapes, and in some cases can eliminate it altogether.

In addition to protecting soil reserves, coarse organic mulches will hold water much like a sponge, thereby capturing rainfall and irrigation water for later release and preventing runoff....

Reduced soil erosion and compaction. Mulch will protect soils from wind-, water-, and traffic-induced erosion and compaction, all of which contribute directly to root stress and poor plant health. Though living mulches are often the most effective in this regard, holding the soil matrix together even on the steepest slopes, they may not be the best practical or economic choice.... Adding even a thin organic mulch will protect soils ... a 0.6-inch layer of straw mulch reduced soil erosion by 86% [in one study]. Straw from rice ... and other grains ... in some cases can outperform living mulches such as legumes and grasses.... It is important to note that mulches cannot be used to “stabilize” slopes but only to reduce soil loss.

Slope stabilization requires an engineering solution, not a horticultural one.... Compaction is a common ailment of urban soils ... Adding organic mulch such as bark or jute disperses the direct impact of water droplets, feet, and tires, thus restoring soil aggregation and porosity. It is better to apply mulch before compaction occurs rather than after the fact. Research has demonstrated that proactive mulching will protect soil integrity, while the same mulch applied after compaction could not reverse bulk density changes after two years.

Maintenance of optimal soil temperatures. Mulches protect soils from extreme temperatures ... Temperature extremes will kill fine roots, and while rarely killing established plantings, they can induce a chronic stress as the plant expends energy to generate new fine roots. Temperature modification is especially important near the soil surface, where fine roots can be killed by freezing and frost heaving. Hot or cold surface soils can kill new transplants . Coarse mulches are more temperature-moderating than finely textured mulches of the same general category; for example, the soil under cobbles is cooler than that under gravel, and the soil under leaf mulch is cooler than that under compost. Likewise, thicker applications of organic mulches are more temperature-moderating than thin applications. Among mulch categories, living and organic mulches are more temperature-moderating than inorganic mulches.... Synthetic mulches, including asphalt, fabrics, and plastics, are poorest in this regard, routinely raising the underlying soil temperature as deep as 12 inches below the surface.... Black plastic mulches can either raise or lower soil temperatures, probably depending on how much light is absorbed by the plastic and whether heat is retained or reflected. Clear plastic mulches routinely raise soil temperatures since radiation (including infrared wavelengths) is transmitted through the plastic and heat is retained. While the impacts of mulches on soil temperature have

been well documented, there is also an effect of mulch type on surface temperature. There are far fewer studies on this phenomenon, but it is clear that some mulches heat the soil as a function of solar radiation absorption more than bare soils and living mulches....Living mulches such as turf release water vapor through evapotranspiration and reduce surface temperatures by evaporative cooling, though they use more soil water than nonliving mulches. Interestingly, the soil temperature beneath turf was shown to be higher than that below mulch, perhaps because soil beneath turf was drier and thus less protected against high temperatures....

Increased soil nutrition. Living and organic mulches can increase, decrease, or have no effect upon nutrient levels, depending upon mulch type, soil chemistry, and particular nutrients of interest. As living and organic mulches decompose under appropriate water and temperature levels,,nutrients are released into the soil and become available for root uptake or microbial use. Generally, green and animal manures used as mulch supply nutrients at higher rates than other mulch choices (such as straw, bark, and wood chips) and often perform better than inorganic fertilizers. While immediately available nutrients are sometimes desirable for a landscape, it is important to note that overapplication of these materials can lead to excess mineral availability, causing damage to plants, soil organisms, and nearby watersheds. Therefore, nutrient-rich mulches should be applied sparingly and may be most effective as part of a mulch layer. While living mulches often compete for nutrients as well as water, this characteristic can be valuable on landscapes where fertility is too high. Fast-growing plant materials will reduce soil nutrient levels, as can microbial activity in low fertility organic mulches. This has been helpful in restoration of ecosystems with naturally low fertility, allowing native plants to compete more effectively with invasive species. Low-nutrient mulches such as uncomposted bark or straw were found to decrease nitrogen levels of soil water while not impacting plant nutrition, thus reducing watershed pollution. While mulches with relatively high nitrogen content often result in higher yields, low-nitrogen mulches can also increase soil fertility and plant nutrition. For example, straw, sawdust, and bark mulches have been shown to increase nutrient levels in soil and/or foliage....

Reduction of salt and pesticide contamination. Many landscapes experience salinity stress besides those found near marine coastlines. Arid landscapes in particular are often highly saline as evaporating water leaves behind salt crusts. Irrigation water in arid environments and improperly treated graywater (domestic, non-sewage waste water) can also contain high levels of salts from fertilizers, detergents, and other chemical sources. Container plants that are over-fertilized will likewise experience increasing levels of salts. Because mulches reduce evaporation, more water is left in the soil and salts are diluted. Furthermore, organic mulches can reduce the effect of salt toxicity on plant growth. Plastic mulches are not effective in this regard, probably because

they are not able to bind ions as organic materials can. Organic mulches can also help degrade pesticides and other contaminants, presumably by providing increasing microbial populations that degrade pesticides.

Increased binding of heavy metals. Organic as well as living mulches can be effective in removing heavy metals from landscape and garden soils. Common urban contaminants such as lead and cadmium can be removed from the soil solution by mulched leaves of eucalyptus (***Eucalyptus*** spp.), pine, poplar (***Populus*** spp.), and arborvitae (***Thuja*** spp.). Likewise, a mixture of compost and woodchips was found to decontaminate forest soils by complexing copper into a less toxic form.

Improved plant establishment and growth. Mulches are used globally to enhance establishment of many woody and herbaceous species. There are hundreds of controlled studies demonstrating that mulches improve seed germination and seedling survival, enhance root establishment and transplant survival, and increase overall plant performance when compared to unmulched controls....

Improved seed germination and seedling survival....

Seedling emergence and survival presents a management conundrum: we want to encourage desirable plants yet prevent weeds from establishing. Unfortunately, mulches do not distinguish between weeds and desirable plants. For this reason, many mulches are not appropriate for annual flower beds and vegetable gardens. On the other hand, these same mulches are excellent choices for repelling weed colonization. Success in this respect may be determined by mulch depth and/or seedling maturity. Deeper mulches are associated with improved weed control and are not the best choices for areas that are to be seeded rather than planted, especially if the species of interest have small seeds. Broadcast seeding on a restoration site was successful when a thin mulch layer was applied post-seeding, but significantly reduced when the mulch depth was doubled or when mulch was applied before seeding. Organic mulch may be a better choice for seed germination than gravel, which in deeper layers can prevent seedling emergence....

Enhanced root establishment and transplant survival.

Numerous studies have demonstrated that improved water retention and reduced weed growth are correlated with increased root growth and exploration by desirable plants. Mulches allow roots of trees and shrubs to extend and establish far beyond the trunk compared to bare soil and thus become increasingly stabilized. Mulch choice is important in determining how well roots will explore the underlying soil. Root development and density [in various studies] were greatest under organic mulches compared to ... plastic, bare soil, or living mulches. In contrast, sheet and film mulches that act as barriers to water and air movement will encourage root growth on top of the mulch, which can eventually injure desirable plants when and if the sheet mulch is removed.. Roots tend to

grow into organic mulch layers, but by and large these are fine roots whose presence is transient. Generally, these roots exploit water and nutrient resources in mulch until conditions become unfavorable (e.g., when mulch begins to dry in the summer). These roots die back and new feeder roots appear where resources are more available. In any case, it does not appear to injure the plant to have roots exploring the mulch layer. However, roots will also colonize landscape fabrics, and if these materials are eventually removed, they could cause extensive damage to fine root systems. This is one reason not to use landscape fabrics around woody plants....

Increased overall plant growth performance.

As early as 1942, researchers found that mulched trees grew 67% better than those grown on bare soil. Many others since then have shown similar improvements in growth of trees, shrubs, and other plant materials in field and nursery conditions. ..The best mulches for overall plant performance are organic materials, consistently rated as the best or second best in comparative field trials.... in annual crop production, ... slow decomposers such as bark can create nutritional problems for fast-growing species with limited root mass. Gravel and stone are generally not as effective as organic mulches in optimizing plant performance. Sheet mulches can also produce disappointing results. Not surprisingly, competitive ground covers such as turf grasses result in reduced growth, even compared to bare soil conditions.

Reduction of disease.

Physically, mulches will reduce splashing of rain or irrigation water, which can carry spores of disease organisms up to the stems or leaves of susceptible species. Additionally, the populations of beneficial microbes that colonize many mulch materials can reduce soil pathogens either through direct competition for resources or through chemical inhibition. Regardless of the mechanism involved, disease reduction is an important benefit of many mulches....

Reduction of weeds.

Mulching as a means for landscape weed control is highly effective, though the mechanism(s) responsible for control are not completely understood for all mulch types.... Nearly all mulches reduce light, which will stress existing weeds and prevent the germination of many weed species, especially those with small seeds. A comparison of 15 mulch types showed that all significantly reduced weed growth as compared to bare soil, but there were no differences between types tested. The physical barrier emerging, though this effect is temporary and disappears as mulches decompose. Certain organic mulches, especially woodchips, may control weeds chemically through the leaching of allelopathic chemicals naturally occurring in the wood. Additionally, the protected soil habitat created by the use of mulches can increase beneficial organisms that prey upon weeds or eat their seeds. Living mulches can reduce weed problems through both competition for resources and allelopathy. Ideally, cover crops and ground

covers suppress weed seed germination and [seedling] establishment while having little effect on desirable plants. This ideal is realized in situations where ground covers occupy a different niche than the desirable plants (e.g., trees and large shrubs whose roots are typically deeper than ground covers). If ground covers are too much like other plants in the landscape, such as low-growing herbaceous perennials, then they may compete more directly for limited resources like water, nutrients, and sunlight. Although they can be highly effective in immediately eliminating weeds, plastic films and landscape fabrics should not be used as a long-term approach of weed control in landscapes. White and green plastics do not eliminate photosynthetic radiation, thus allowing weeds to continue to grow underneath; darker mulch colors will eliminate these wavelengths and prevent weed growth. Regardless of mulch color, eventually weeds will colonize soil above these mulches, and some weeds can pierce and grow through plastic films. Replacement of plastics and fabrics is not only time-consuming and expensive but damages the roots of desirable plants that invariably will grow through these mulches. In general, inorganic and organic mulches are most effective in weed control when applied at sufficient depth and are least susceptible to compaction. Inorganic mulches such as gravel will prevent weed growth if the layers are at least 1.5 inches deep....

Organic mulches are variable in their weed-controlling abilities. Nutrient-rich, finely textured materials like compost are not satisfactory mulches for weed control. Instead, they act as a fertile base and potential seed bank for establishment of new weeds or enhancement of perennial weeds. Weed seeds that settle on top of organic mulches are more likely to germinate, especially if the mulch layers are thin (meaning seedling roots can more quickly reach the underlying soil). Applying two rather than one organic mulch layer results in significantly less seed germination. Organic mulches that are coarse, applied in thicker layers, and/or less nutrient-rich are more effective in controlling weeds—sometimes even better than herbicides. Locally derived residues from crops and forest products have all proved effective in reducing weed success in a variety of agricultural and landscape situations, especially in uncomposted form. While some studies recommend the use of sawdust ..., others have noted that thick layers of sawdust can be impermeable to gas and water movement. This material might best be used in situations where soils are less frequently compacted by vehicular or foot traffic: not urban landscapes.

Reduced pesticide use.

Mulches reduce plant stress and susceptibility to pests. This important function means that plants will be more resistant to weed invasion and opportunistic pests and pathogens, which leads to reduced use of herbicides, insecticides, and fungicides....

Aesthetic improvement.

Mulches can be beautiful as well as functional ... Visually distinctive mulches can be used to control foot traffic by directing pedestrians through a landscape, which

both protects sensitive root zones and adds a design element. Some mulches add other sensory elements in addition to visual interest ... The aesthetic appeal of mulches is critical to their acceptance by consumers, who may otherwise perceive mulches as “messy” and prefer the appearance of bare soil.

Economic value.

For any landscape management practice to become widely adopted, its economic viability must be established. Many decades of research have demonstrated that mulching improves crop production. Far fewer studies have addressed the economic impacts in urban landscapes, and so it is difficult to make detailed economic arguments based on tangible costs and benefits.... Not all mulches result in defensible cost : benefit ratios. Paper, plastic discs, and black polyethylene mulches all failed to improve survival and growth for several tree species, causing the researcher to recommend against their use for economic reasons. Furthermore, the synthetic mats and films tend to be the most expensive choice....

Acidification.

Organic mulches such as woodchips and bark are thought by some to be soil acidifiers. No scientific research supports this, and in fact studies refute this perception. One study found neither pine bark nor pine needles had any effect on soil pH. A second report found bare soil to be more acidic than soil covered by inorganic mulch, and that shredded bark and wood chips were least acidifying of all treatments. Similarly, a year-long study found that the soils under organic mulches were either more alkaline or not affected by mulch treatment. It's likely that in artificial conditions, such as nursery production, woody materials do have an acidifying effect when they are used as part of a potting medium. Release of phenolic acids is one stage of the decomposition of woody material, and if this material comprises the bulk of the medium then acidification is likely to occur. In a field situation, however, where the woody material is used as a mulch (and not worked into the soil), any acidification will be localized within the mulch layer and have little effect on the vast underlying soil environment ...

Allelopathy.

Allelopathy is the inhibition of seed germination and growth of plants through the release of chemicals and apparently plays a large part in the weed-controlling behavior of many organic and living mulches. A few growth-inhibiting substances have been isolated and identified, including the classic example of juglone (and juglonic acid) which is produced in all parts of black walnut (***Juglans nigra***). Juglone can kill or injure seedlings and shallowly rooted plants, although it apparently has little effect on established plants. In laboratory tests, allelopathic activity is usually confirmed by inhibition of seed germination rather than how it affects mature plant materials....Seeds and seedlings, whether weeds or desirable species, are most sensitive to mulch suppression, as they do not have

the extensive root systems of established plants. Mulches made of pine (**Pinus** spp.), eucalyptus, and acacia (**Acacia** spp.) were able to suppress germination of several common weed species, as were water extracts of these materials, supporting an allelopathic function. Grasses may be less affected than dicot weed species ...It is unlikely that any properly applied landscape mulch will have allelopathic effects on established landscape plants, but is most likely to injure newly planted or shallowly rooted plants in the landscape. For such plantings, a short period of composting and correct application of woody mulch will prevent damage.

Competition.

As mentioned earlier, living mulches can be competitive with landscape plants for water, nutrients, and space.... Turf and other grasses are very competitive, especially during plant establishment. Thus, turf grass must be kept away from newly installed shrubs and trees and can easily be replaced with an organic mulch. These “tree skirts” allow rapid root establishment without competition from turf roots.

Chemical contamination.

As with composts, woody mulch quality is influenced by the source of materials. Mulches created from branches and tree trimmings often contain a diversity of leaves, wood, and bark, which contributes to a highly functional mulch. In contrast, woody mulch made from wood recovered from construction and demolition debris can contain pressure-treated lumber. In one Florida study, 18 of 22 samples collected from debris processing facilities contained arsenic (from chromated copper arsenate-treated wood) at concentrations greater than the state’s allowable levels....

Disease.

Mulches made from diseased plant materials contain those pathogens. For this reason, many mulches are composted or otherwise treated at temperatures that kill the pathogens along with other harmless or beneficial organisms. Therefore, many commercially available organic mulches are relatively sterile. While mulches made from diseased wood can contain viable populations of pathogens ..., few examples of disease transference exist in the literature.... The pathogen of interest must be present in such a way as to fit the epidemiology of the disease cycle; simply existing in a mulch source is not enough. While disease transmission from mulch to tree is unlikely, there is greater probability of infection if backfill soil is amended with woodchips....

Flammability.

Though there are documented incidences of spontaneous combustion of yard wastes, in general wood based mulches are not flammable. A recent comparison of 13 landscape mulches found rubber mulch to be the most flammable, followed by fine-textured organic mulches (dried pine needles, straw, shredded bark), coarse-textured organic mulches (chipped wood, bark nuggets, cocoa shells),

mulches with higher water content (composted yard waste and sod), and finally brick chips (which never ignited). These comparisons should be carefully considered when mulching in regions where there is significant fire danger.

Nitrogen deficiency.

A common misconception about woody mulches is that they impose a nutrient deficiency upon plant materials. This is based on the fact that woody mulches have a high carbon:nitrogen (C:N) ratio and nitrogen will be “tied up” by microbes during the decomposition process. Furthermore, woody materials that are used as amendments incorporated into soil or potting mixes will create zones of nitrogen deficiency, which is visualized by spindly, chlorotic growth of plants in these zones. Experimental research reveals that neither nitrogen immobilization nor growth suppression occurs as a result of using woody materials for mulch. To the contrary, many studies have demonstrated that woody mulch materials actually increase nutrient levels in soils and/or associated plant foliage. A zone of nitrogen deficiency exists at the mulch/soil interface (Chalker-Scott, unpublished data), possibly inhibiting weed seed germination while having no influence upon established plant roots below the soil surface. For this reason, it is inadvisable to use high C:N mulches in annual beds or vegetable gardens where the plants of interest do not have deep root systems.

Pests.

Many organic mulches, especially those based on wood products, have an undeserved reputation as “pest magnets.” In fact, many of these wood-based mulches are not attractive to pest insects but are actually insect-repellent. **Salvia** spp., pine needles, and cedar shavings were found to repel fire ants (***Solenopsis invicta***) under laboratory conditions. **Thuja** species have developed a number of chemical weapons against pests, including thujone, one of several essential oils found in arborvitae foliage and that of [some] other non-**Thuja** species....A common concern is whether wood-based mulches are attractive to termites.... [one] study ... found that termites preferred mulches with higher nitrogen and phosphorus content.... in regions where subterranean termites are potential pests, organic mulches should be selected that are low in nutrients. Research upon the ability of mulch to exacerbate or control other pest insects and nematodes is sparser and more variable, so it is not easy to draw generalizations. Dry-surfaced mulches, such as gravel and woodchips, are recommended as deterrents to ticks (***Ixodes scapularis***) that carry Lyme disease; other insects (beneficial or otherwise) may likewise be discouraged. Black plastic and landscape fabric may reduce certain pest species in the short term, but their long-term negative impacts on soil and plant health are so significant that their perpetual use in a landscape cannot be recommended. In general, any mulch which increases the general health of the soil environment will undoubtedly enhance the diversity of beneficial microbes and insects in the landscape. Mulches are variable in their ability to attract or repel mammalian pests as well. Some materials may naturally repel herbivorous mammals by virtue of their thorns or odors or texture, while others may attract

undesirable pests, especially rodents, who can use dense ground covers or sheet type mulches for shelter.

Weed contamination.

Mulches lacking pedigrees can be carriers of weed seeds and other undesirable plant parts. While controlled research on this problem is lacking, anecdotal evidence suggests that improperly treated crop residues and composts, as well as bark mulches, are often carriers of weed seed. Woody mulches may contain invasive species associated with tree materials that are chipped.... If it is not possible to document the mulch source, it might be prudent to use it on a small area of the landscape and monitor it for problems before using it more widely....

Other considerations.

In addition to the objective science that should be used to guide landscape management decisions, there are other factors to consider. Perhaps the most important are those that affect the sustainability of not only the local landscape but global ecosystems as well.... Such issues as environmental degradation associated with acquisition of some mulching materials, use of invasive species as ground covers, nutrient overload from overuse of organic mulches, and toxic leachates from some synthetic mulches must also be considered.