MEMORANDUM

TO: TACO Board 7/11/2023
FROM: TACO Landscape Committee
SUBJECT: Turf Fertilization and Weed Treatment

Executive Summary

Over the past few weeks, the TACO Landscape Committee (LSC) has received input from a contractor who has proposed an alternative method of weed control at Tamarron. The contractor explained the alternative method and presented the committee with examples of the use of the method in various locations in the community. The committee has made a visual inspection of these areas and has determined that the proposed alternative does not yield results acceptable in a residential community such as Tamarron. Further study by the committee has also revealed that the use of the recommended "compost tea" has the potential to introduce dangerous pathogens at Tamarron. In addition, the committee found that the amount of "bio-char" that would be necessary to achieve the desired end of the alternative method would create an untenable house-keeping problem for Tamarron residents. Therefore, the LSC recommends that Tamarron continue its current program of weed control but change to a granular form of the weed control agent and use an over-the-counter product (such as Weed-Be-Gone) to address aggressive pockets of weed growth while, at the same time, continuing research into other alternatives.

Mission … To develop and periodically update a comprehensive Plan for approval by the TACO Executive Board to upgrade and maintain the community's grounds and landscaping to a level that is pleasing to Tamarron owners and guests. The Plan will equally consider the ongoing sustainability of landscaping while addressing the challenges of the mountain environment, water and irrigation requirements, safety, and limited landscaping staff according to the Priorities listed, and Action Items described, in the Plan.

Landscape Committee Plan for 2023 Turf Treatment … After the Spring contractor weed treatment, selectively spot treat broadleaf using the product Alligare-Prescott according to the Plan provided by La Plata County[1].

1. Summary

Earlier this year several owners expressed health concerns over the use of Scott's weed and feed application as described in the 2023 Landscape Committee Plan. Scott's application was halted, the LSC received a proposal[2] and presentation from a local firm, Bee Happy Lands, on an alternate use of Compost Tea and Bio-Char for turf treatment. The LSC was struck by the lack of specificity provided, expecting to see a more quantitative presentation providing a seasonal calendar telling when supplements will be applied and the quantities that will be applied. It was made clear that Happy Bee Lands applies no product that kills weeds. Further, the control of weeds only takes place through cutting/mowing, overseeding, mulching and organic applications. Because we mow regularly, it appears there would be no opportunity for seed gathering. The other elements of weed control would only come into play at some unspecified time in the future depending on the success of soil regeneration. The LSC has evaluated both the historic turf treatment using commercial fertilizer and weed control and the alternate use of Compost Tea and Biochar; doing so guided by the Committee's Mission. We further find that Happy Bee's stated goal of making our lawns look as close as possible

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[1] Attachment A
[2] Attachment B

to the way they look now to conflict with the LSC mission. In summary, without further information, the LSC recommends it the best interest of Tamarron not to deviate from the 2023 LSC Plan next year with modification proposed in the Conclusion below.

2. Aesthetics

The LSC believes that the "bottom line" is that TACO maintain a landscape that is aesthetically pleasing to owners and guests per the Mission. Healthy turf is part of that. The representative of Bee Happy Lands provided locations in Durango where their firm treats turf using Compost Tea and Bio-Char to including: 1. Durango's Rotary Park, 2. Durango's Brookside Park and 3. Sunshine Garden Condominiums. The LSC visited and photographed[3] the turf conditions at these locations. While the LSC understand that aesthetics is a subjective measure, and while this approach may well be successful in open acreage, the LSC found none of the lawn areas in these examples to be up to the standard of current Tamarron landscaping as stated in the LSC Mission. The photos in Attachment C show that the turf was very thin from the lack of nutrition, likely nitrogen deficiency, and weeds were present in quantities that greatly exceeded our Tamarron lawns. With that, the LSC concludes that Compost Tea and Bio-Char alone, as proposed by Bee Happy Lands, would not be an aesthetically acceptable turf treatment at Tamarron.

3. Compost Tea

Compost Tea is the leachate created by leaching compost with water. It is a beneficial liquid fertilizer that contains the microbial population resident in the compost. At issue is that it is hard to get even approximate values for nutrient content as each batch varies due in part to the materials used to make the compost. Hence, unlike commercial fertilizer with guaranteed concentrations, there is a question of the nitrogen content which is necessary for healthy turfgrass. Based on LSC observations of the examples described in 2 above, Compose Tea is lacking in nitrogen content, and that additional nitrogen fertilizer would be necessary to supplement the Compost Tea application. This would come at a secondary cost above that of the Compost Tea treatment.

Compost Tea application at Tamarron presents a more serious consideration that the LSC has learned of. According to the University of Arizona[4] … "The nutrient-rich condition shared by all compost teas, while providing benefits to soils and plants, is also the primary reason why compost tea can be a potential problem, as the addition of nutrient additives and water can cause pathogen proliferation." Potential pathogens may be E-coli, Salmonella and Listeria. It is the understanding of the LSC that about 5 years ago Tamarron was ordered by the CDPHE cease using untreated Glacier water for irrigation and only irrigate grass with potable water. CDPHE's reason was the potential for pathogen content in untreated water. The environmental regulatory agency was concerned that Tamarron residents, guests and their children frequent grassy areas where exposures to potential pathogens may occur, if such pathogens are contained in untreated irrigation water. Per UofA, the LSC believes that the same potential exists with Compost Tea. If Compost Tea is to be considered for use, TACO should require management from Happy Bee Lands obtain written approval from CDPHE that the product is safe vis-à-vis pathogen contamination.

4. Biochar

[3] Attachment C
[4] Attachment D

Biochar is essentially charcoal made from organic waste which is beneficial to soil. The addition of biochar will quickly raise the soil organic matter content, increase water holding capacity and improve soil structure.

The problem with Biochar is that its application does not appear to be practical for use in a high-density residential setting, Per the university of Arizona[5], "It takes a lot of Biochar." By calculation, perhaps 20 tons/acre to treat the top 6" of soil. Then to treat 6' of soil there would have to be way to work the Biochar into the soil at that depth. Something that would be costly and messy. On the surface 20 tons/ac of charcoal by itself would be messy.

5. <u>Nitrogen</u>

According to CSU[6], nitrogen is the most important nutrient for healthy turfgrass. Healthy, mowed, turfgrass is also very important to crowd out weeds. From one source or another, nitrogen fertilizer is a must if Tamarron lawns are going to be aesthetically pleasing.

6. <u>2,4-D</u>

2,4-D is the active ingredient in the Scotts treatment that has caused the most concern for the owners that have objected. It is one of the oldest broad leaf weed killers that is continually in use world-wide today. It is very short lived, degrading in soil in one to a few days. There is a plethora of opinions on the effects of 2,4-D. As such it has been listed for evaluation, evaluated, and then delisted by the US EPA, the WHO and the California Prop 65 process, all who have determined that there is inadequate evidence of long-term heath affects including that 2,4-D is carcinogenic[7].

There are reported short term effects of 2,4-D such a skin irritation from dermal exposure and gastro intestinal upsets from ingestion by which the exposure pathway would be limited to the liquid form. These concerns have been voiced by owners, especially those with pets that may walk on the grass before the spray is dry and has been absorbed by the weed. Appreciating this concern, a solution that the LSC recommends is that a commercial form of broadleaf weed control in dry granular form to be applied along with fertilizer by landscape staff. This would result in the weed control being introduced directly from the soil to the root of the weeds and eliminating the possibility of pets walking directly on newly sprayed wet grass. These products are readily available at Walmart, Home Depot, or any garden center. An additional benefit is the cost of dry bagged products is less than Scott's service.

7. <u>Conclusion</u>

The LSC recommends the following:

- Before further evaluation of the use of Compost Tea TACO requests that the product be certified by CDPHE for safe use in high density residential communities.
- Evaluate the *total* cost of Compost Tea/Biochar applications including the additional quantities of Compost Tea, Biochar, and any required fertilizer to meet the turf's nutritional needs (noted above and in supplemental documents), and soil preparation that may compound costs.
- Continue with the Landscape Committee Plan for 2023 Turf Treatment with two modifications. 1. Apply treatment in granular form to eliminate the potential for dermal contact or ingestion during the wet period. For spot treatment of aggressive weed growth substitute Alligare-Prescott with a more available (and far less expensive) product such a Weed-B-Gone.

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[5] Attachment E

[6] Attachment F

[7] Attachment G

Attachment A
La Plata Weed Control Plan

Weed Management Plan for Parcels in La Plata County

D.02

Name Tamarron Association of Condo Owners (TACO)
Date 6/8/2022 **Email** MSPELIZZA@msn.com
Site Address Tamarron Condos Common Areas

Notes:

- Any ground disturbance during drought makes weed control much more difficult in the long run
- Nearby weed infestations will continue to spread seeds to neighboring properties
- Focus on annual and biennials in spring before flowering/ seed occurs.
- Treat Canada thistle at bud stage or around September ONLY!!!
- Always use a surfactant such as MSO, @ .5oz/ gallon rate
- Reseeding grasses/ wildflowers in areas that have had weeds/ disturbance will help prevent future infestations
- Plant grass seed in October before significant snow falls-Consult Durango Nursery for recommendations

Product rates can always be found on the product label or La Plata County Weed Cards.
Some herbicides are not for use under or close to trees (Milestone). **Always read and follow the label.**
Don't waste your time & money, always calibrate your sprayer before making treatments!
Always add surfactant (Spreader 90 spring/fall, MSO summer 1oz/ 3 gallons).
Rates listed below are suggestions for spot spraying.

Weeds 1 Musk thistle, Houndstongue, salsify, oxeye daisy

Product Alligare- Prescott (available online)

Rate 2 oz/ gal @ **early spring growth stage before flowering** Mow/ pull/ spray before seeding occurs

Weeds 2 Cheatgrass AND ALL OTHER WEEDS under trees/ bare ground

Product Glyphosate 41%

Rate 3oz/ gal @ **early spring growth stage** Mow/ pull/ spray before seeding occurs/ After seeding occurs bag seed heads if possible

Weeds 4 Canada thistle **Product** Alligare- Prescott

Rate 2 oz/ gal **@bud or fall growth stage**

Site rehabilitation after weeds are controlled- Spraying/ digging, alone, is not effective unless future noxious weeds have competition to prevent further infestations.

If there are few or no competitive plants in the infested area, you may rehabilitate with:
☐ Dryland pasture mix ☒ Low grow mix in early to late November before significant snowfall
☐ Irrigated grass mix during the growing season when water is available ☒ Wildflower mix

La Plata County Use Below This Line

Plan Approved Yes ☒ No ☐ by Ben Bain, La Plata County Weed Control Manager 6/8/2022

Attachment B
Happy Bee Lands Proposal

Bee Happy Lands
A Project of Turtle Lake Refuge
848 East 3rd Ave Durango, CO 81301
970-317-0988

Organic Land Stewardship
2023 Proposal for Tamarron

May 22, 2023
Prepared for the Tamarron Association of Condominium Owners (TACO)

Purpose: Bee Happy Lands will perform organic land stewardship practices for TACO for the 2023 season. This includes the grassy areas around the Lodge, and the three condo clusters of Gamble Oak, Pinecone, and High Point. Bee Happy Lands' mission is to provide organic land stewardship practices that create a beautiful landscape and safe ecosystem for the wild pollinators, the collective watershed and local community. Our intention is to support the health and beauty of the pristine environment in and around Tamarron with least impact to the natural ecosystem.

Methods: Our methods work by increasing the fertility of the soil and creating the stability of the ecosystem, reducing weed presence while adding more desirable seeds into the landscape. We apply a variety of soil amendments to the land to enliven and regenerate the soil's microorganism's health. These supplements include compost tea, fungal soup, a biodynamic ash remedy, mycelium inoculants, biochar, and effective microorganisms. The microbial life force of the soil grows in momentum over time and diminishes the pioneer species (weeds) presence in the landscape.
In addition to applying the soil amendments, we harvest the requested species while applying seeds, compost and fine mulch in areas we work. By minimizing the impacts of our work methods (not using herbicides or ATV's or other forms of disturbance), we support the natural balance creating a healthy landscape. Our long-term goal is a beautiful and vibrant landscape for future seasons. We encourage optimal soil fertility and land stability while increasing overall health of the landscape. Ultimately the result is an overall increase of life force in the soil leading to minimized weed presence, increased overall ecosystem vitality and land regeneration that will continue to sustain ongoing in future seasons.

Cost Summary:

The cost for managing the land organically will include the manual labor, materials, and transportation costs. The staff will be paid hourly for their work manually harvesting the plants, applying seeds mulch and compost and the soil amendments. Materials include: grass seed mix, mulch, compost and organic soil amendments such as effective microorganisms, biochar, micronutrients, compost tea, fungal soup and the biodynamic ash remedy.

Total cost of organic land stewardship for TACO
Each Visit = $3,810

Recommend two site visits per season, spring and fall application = $7,620

Thank you!

For further information and questions,
please contact Katrina Blair at beehappylands@gmail.com
or call her at 970-317-0988.

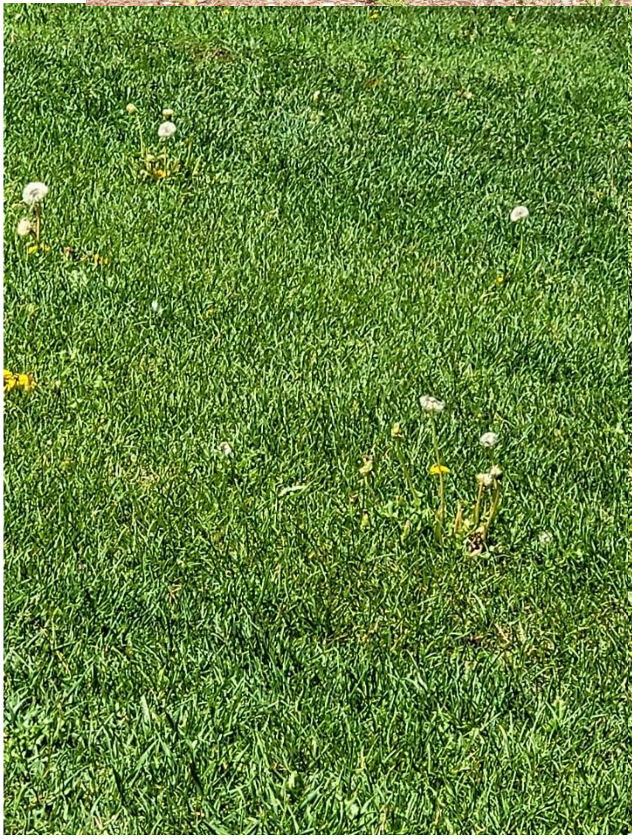
Thank you
Katrina Blair

References:

Weed Resources- Colorado State University Extension www.ext.colorstate.edu
Native Plant Revegetation Guide for Colorado, "Caring for the Land Series", Vol. III, 1998
Colorado Native Plant Society, May, 2002. "Plant species to Avoid in Landscaping, Revegetation, and Restoration" Horticulture and Restoration Committee http://www.conps.org
Natural Resource Conservation Service, 1999. PLANT database http://plants.usda.gov/plants/invasive USDA Agricultural Research Service, 2000. INVADERS DATABASE SYSTEM. http://invader.dbs.umt.edu/ Dremann, Craig, 1998. "Weeds & Persistent exotics on public lands". Craig's Juicy Native Grass Gossip No 6. http://www.ecoseeds.com/juicy.gossip.six.html
Noxious Weeds – Colorado.gov https://www.colorado.gov/pacific/agconservation/noxiousweeds

Attachment C
Photographs of Bee Happy Lands Clients Property

Photographs of Rotary Park Durango (June 2023)



Photographs of Brookside Park Durango (June 2023)

Photographs of Sunshine Gardens Condominiums Durango (June 2023)

Attachment D
University of Arizona Compost Tea

az1739 June 2017

Compost Tea 101: What Every Organic Gardener Should Know

Valerisa Joe, Channah Rock and Jean McLain

Figure 1 (left) No Compost Tea added to the plant. After two 2 weeks of water. (right) Compost Tea added to the plant. After 2 weeks of water + compost tea.

Introduction

Growers of organic produce in the Southwestern United States face many challenges, including variation in water and temperature, and exposure to insects and disease. As a result, smallholder organic farmers are increasingly relying on soil additives such as compost tea that improve product quality, use less water, deter pests, and reduce reliance on chemical additives (Diver, 2002). But what exactly is compost tea? Do the benefits of using compost tea outweigh any concerns? For example, can it contain pathogens, and if so, do applicators have to worry about coming into contact with pathogens? This publication provides facts about making compost tea, and reviews both the benefits and potential disadvantages to help smallholder farmers to make educated decisions regarding the use of compost tea.

What is Compost Tea and How is it Made?

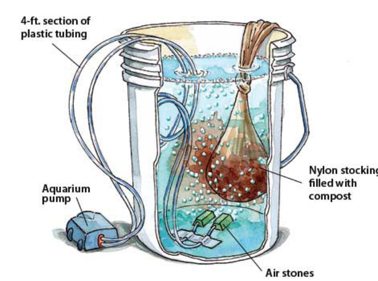
Compost is organic matter (animal product, plant product, or manure biosolids) that has been decomposed into a nutrient-rich humus-like material to be used as a fertilizer and soil amendment (Bezanson, 2014). Generally, compost tea is produced through steeping compost in water, just like a bag of tea in hot water, producing an organic-rich, high-nutrient liquid (Ingram and Millner, 2007). The smallholder farm may see commercially-available products with names such as "compost extract," "compost leachate," "organic tea," or "manure tea," but all of these refer to the watery end-product of circulating water through compost while maintaining conditions conducive to the microbial activity needed to break down the base organic material.

There are various methods used to manufacture composts depending on the scale of the process. Generally, small scale production is preferred by home gardeners or smallholder farms, and uses "static aerated pile" or "in-vessel reactor" methods, whereby compost is placed in an enclosed space and maintained in an aerobic state to encourage microbial biodegradation of organic matter (EPA, 1993). Microbial metabolism releases heat into the surrounding matrix, which aids in degrading pathogenic organisms that may be present in the raw organic matter. Target temperatures of ≥131°F (55°C), easily attainable in desert climates of the Southwest, can effectively kill most pathogens (Chen et al., 2011; EPA, 1993).

Though compost tea formulations are commonly available in garden stores, farmers' markets, and through the internet, organic growers can produce their own compost tea by saturating available manure/compost mixtures with water and collecting the leachate.

The most common methods used in smallholder compost tea production are listed in Table 1. Commercial and home formulations of compost tea are often supplemented with nutrient additives, including molasses, yeast, humic acid, soluble kelp, and fish hydrolysates (Durham, 2006). Regardless of which method is used, the end result is the same: a nutrient-rich liquid that allows organic growers to effectively recycle animal and/or plant biomass. The nutrient-rich condition shared by all compost teas, while providing benefits to soils and plants, is also the primary reason why compost tea can be a potential problem, as the addition of nutrient additives and water can cause pathogen proliferation.

Table 1. Common Aeration Compost Tea Methods

Method of Compost Tea	Processing Details	Diagrams
1. Bucket-Bubbler	This is the most common technique used to make compost tea among home growers. Aeration is supplied to the compost bucket using 1 or 2 hoses; the nozzle size does not matter as long as air is able to disuse through the bucket. Diffusion mats and aquarium-style stones and/or an impeller can be used to produce compost tea very rapidly (Ingham, 2015; Martin, 2014). This method "brews" mixes the composts and water together, for 3 days to fully extract all the nutrients from the compost.	 (Garden Gate eNotes, 2010)
2.Trough	This method is used for commercial production of compost tea. Compost, in a container with holes in the bottom, is suspended in the air over a trough. Water is poured over the compost, letting the tea drip from the top container into the bottom trough. Aeration can be added to circulate the compost tea, similar to the bucket method. Brew time is longer than bucket bubbler, can be up to 3 weeks because of the large volume of compost tea being made (Ingham, 2000).	

What are the Benefits of Using Compost Tea?

There are a number of documented benefits to applying compost teas to soil and/or plants, including increased soil water retention, improved soil fertility, and reduced reliance on the need for chemical pesticides and fertilizers (Dearborn, 2011). Regular compost also produces benefits to both plants and soils, but unlike compost tea, has not been acknowledged to reduce plant pathogens (On et al, 2015). Compost tea applied directly to plant foliage has been shown to suppress phytopathogens on a variety of edible crops, including tomatoes (Scheuerell and Mahaffee, 2002).

The benefits of compost tea application are enhanced in arid environments where irrigation water may be limited. Organic farms are reported to use less water than conventional farms (Stolze, 2000), and studies in Australia suggest a correlation between decreased irrigation water use and the application of compost tea (Hansen et al, 2001). Evidence indicates that increased water holding capacity in organic fields reduces the overall need for water application (Bot and Benit, 2005), but enhanced awareness of water management by organic farmers, in tandem with a greater willingness to directly observe soil moisture (Madigan et al, 2009), all conceivably contribute to decreased water usage with the application of compost tea. In addition, compost adds labile nutrients to soil, which in turn induces microbial proliferation. Optimal water supplies enhance microbial activity in the rhizosphere (Brady and Weil, 2010), where the labile nutrients are metabolized and released for plant growth. Thus, the use of compost tea can reduce water needed for plant growth, while concomitantly providing multiple benefits to the soil and plant.

Are there Concerns Related to the Use of Compost Tea?

As stated above, compost teas are widely available, easy to use, and provide multiple benefits to organic gardeners; however, some caution should be exercised in using this product. Generally, commercial production of compost teas lacks regulation (Ingham, 2002). Though the composting process is adequate for destroying most pathogens, deviation from this process (such as addition of water and supplements during the brewing process, which could result in decreased temperatures in the compost), could result in the survival of pathogens commonly found in animal feces, including *Salmonella*, *Listeria*, and *Escherichia coli* (Table 2), all of which are able to proliferate in soil with viability of up to 20 years (van Elsas et al, 2010; Dhiaf et al, 2010). Thus, while animal feces are an excellent pre-cursor of compost tea due to high nutrient content, they also may carry foodborne pathogens that can potentially cause illness to consumers of raw produce.

Though the potential for foodborne pathogen presence in compost tea is real, it must be stressed that links between foodborne illness and compost tea have not been established in peer-reviewed medical literature. Microbial populations in compost tea vary due to geological region, sources of starting material, and incubation time, and the lack of regulation makes it difficult to monitor pathogen presence in compost tea. Smallholder farmers are advised to follow the guidelines in the next section to assure maximum likelihood of safe production and minimum pathogen exposure.

Consumers of commercially available compost teas should have an awareness that, in addition to pathogens, formulations may bear a microbial signature of soils local to where the compost tea was manufactured. Generally, this is not an issue, as proper treatment will kill all microbes (beneficial and otherwise), but mixing microbes from different soil regions could potentially introduce non-indigenous soil-borne plant pathogens and other non-beneficial microbes (Leaf Filter Gutter Protection, 2016). Microbes are known to influence soil pH, nutrient cycling, and water content; thus adding non-native soil microbes could have negative effects on soil composition (Brady and Weil, 2010).

Common Pathogenic Bacteria Species found in Compost Teas

In the United States, foodborne illness affects about 48 million people annually according to the Centers for Disease Control (CDC). There are many pathogenic bacteria that cause foodborne illness, including *Escherichia coli*, *Salmonella* and *Listeria*, each of which have been found in compost tea (Ingham, 2000).

Guidelines for Safe Use and Handling of Compost Tea

As stated above, foodborne illness has not been connected to the use of compost teas used on produce that is consumed raw, but the potential for pathogen exposure exists. To decrease the risk of foodborne illness, growers can implement these four easy-to-follow recommendations:

1. **Use compost tea only on non-edible plants or on non-edible portions of plants:** By far the best preventative measure for avoiding pathogen exposure is to use compost teas only on non-edible plants. By limiting the use of compost to non-edible plants, there is less chance of pathogen transfer into the human food chain. United States Department of Agriculture (USDA) guidelines state that compost teas

Table 2. Foodborne Pathogens Found in Animal Feces

Pathogenic Bacteria	Common Properties	Timeline of illness	Symptoms of Infection
Escherichia coli (*E. coli*)	• Most *E. coli* species do not cause illness • There are specific strains of *E. coli* that can cause illness. The most notorious is *E.coli* O157:H7, which is one of the most common causes of foodborne outbreaks in leafy greens and meats (Wang et al., 2016; Solomon et al, 2003)	Symptoms occur 6-48 h after ingestion Can last 1-7 days	Nausea Vomiting Diarrhea Fever
Salmonella	• One of the leading causes of foodborne illness in the U.S. and worldwide • Commonly found in the intestines of animals, including, chickens, turtles, and lizards (Crum, 2005)	Symptoms occur 6-72 h after ingestion Can last 4-7 days	Nausea Bloody vomiting Cramps Bloody diarrhea Fever Headache
Listeria	• Commonly found in soil and water • Not as common as *Salmonella* and *E. coli* outbreaks, but the mortality rate is very high, resulting in death in up to 30% of cases • *Listeria* has the ability to grow in colder conditions (Madigan et al, 2009; Farber et al, 1996)	Symptoms occur 3-70 days after ingestion	Fever Muscle Aches Nausea Diarrhea

should not be used on edible crops unless it is important for the production of crops.

When compost teas are used on edible crops, it is suggested that they be applied to the soil above plant roots, rather than directly to the foliage. Following application, growers should adhere to the 90-120 day rule set by the USDA. The 90-120 day rule states that compost applied to crop soil should not be harvested within 120 days when edible crop is in contact with the soil, and not harvested within 90 days of all other edible crops. This rule applies to all compost, even if no animal by-product has been used in the production of the compost, because there is the potential of pathogen growth (USDA, 2000).

2. **During compost production ensure bacterial killing temperatures:** Living in the arid Southwest, temperatures in spring and summer will usually heat compost to above a temperature of 131°F needed to kill pathogenic microorganisms. However, temperatures in fall and winter can create conditions for pathogenic bacterial growth. When making compost for compost teas, use in home gardens or smallholder organic farms, monitoring of interior temperature of the compost, along with constant turning to aerate the composting mixture, should result in minimal survival of pathogens.
3. **Wash hands and clothing immediately after gardening:** Proper hand washing is the most effective measure for preventing the contraction and spreading of foodborne illness. Since *E. coli, Salmonella* and *Listeria* are all commonly found in soil and water, and are not limited to compost and compost teas, thoroughly washing your hands and clothes will reduce the likelihood of spread of disease (CDC, 2015).
4. **Be aware of the lack of regulation in commercial compost tea production:** When buying commercially-produced compost teas, organic producers should keep in mind that regulations for this product are limited, and sometimes non-existent. As a result, labels will provide only the most limited product information. However, reputable sellers and compost tea producers, if asked, should be able to provide information regarding the initial contents of the compost and bacterial monitoring data, especially E coli. An inability or refusal to provide such data should make the consumer more cautious, making guidelines 1 to 3 (above) all the more important.

The benefits of compost tea, including delivery of a high-nutrient, natural plant fertilizer in a way that provides multiple benefits to the plants and soil, are well documented. Adherence to the four easy guidelines stated above will help in assuring the production of safe and sustainable fresh produce using compost teas.

References

1. Diver, S. (2002). Notes on Compost Teas: A Supplement to the ATTRA Publication Compost Teas for Plant Disease Control. Appropriate Technology Transfer for Rural Areas publication, Fayetteville, AK.
2. Bezanson, G.S., Ells, T.C., and Prange, R.K. (2014). Effect of Composting on Microbial Contamination and Quality of Fresh Fruits and Vegetables - a Mini-Review. Acta Horticulturae.1018:631-638.
3. Ingram, D.T., and Millner, P.D. (2007). Factors Affecting Compost Tea as a Potential Source of Escherichia coli and Salmonella on Fresh Produce. Journal of Food Protection. 70(4):828-834.
4. Environmental Protection Agency (EPA). (1993). 40 CFR Parts 257, 403 and 503 (FRO-4203 3): Standards for the use and disposal of sewage, Final Rule, Fed. Register, 58, 9248. US Government Printing Office, Washington DC.
5. Chen, L., de Haro Marti, M., Moore, A., and Falen, C. (2011). The Composting Process. Dairy Compost Production and Use in Idaho. The University of Idaho-CIS: 1179:1-5.
6. Scheuerell, S., and Mahaffee, W. (2002). Compost Tea: Principles and Prospects For Plant Disease Control. Compost Science & Utilization. 10(4):313-338.
7. Durham, H. (2006) Additives boost pathogens in compost tea. Agricultural Research. 54:22.
8. Garden Gates eNotes. (2010). [Online] Available from: http://www.gardengatenotes.com/images/2010/10/101019-large.jpg. [Accessed 2 October 2015]
9. Diver, S. (2002). Appropriate Technology Transfer for Rural Areas. [Online] Available from: https://www.slideshare.net/ElisaMendelsohn/notes-on-compost-teas-9584536 [Accessed 3 February 2017]
10. Ingham, E. (2015) Brewing Compost Tea. Kitchen Gardener. 29. [Online]. Available from: http://www.finegardening.com/brewing-compost-tea [Accessed 2 July 2015].
11. Martin, C.C.G. (2014). Potential of Compost Tea for Suppressing Plant Diseases. CAB Reviews. 9(32):1-38.
12. Ingham, E.R. (2000) The Compost Tea Brewing Manual. Soil Foodweb Incorporated. Corvallis, Oregon, USA.
13. Dearborn, Y. (2011). Compost Tea-Literature review on production, application and plant disease management. San Francisco Department of Environment Toxic Reduction Program: IPM Task Order # 3-18
14. On, A., Wong, F., Ko, Q., Tweddell, R.J., Antoun, H., and Avis, T. (2015). Antifungal Effects of Compost Tea Microorganisms on Tomato Pathogens. Biological Control. 80:63-69.
15. Stolze, M, Piorr, A., Haring, A., Dabbert, S. (2000). The Environmental Impacts of Organic Farming in Europe. University of Hohenheim Department of Farm Economics 410A.
16. Hansen, B; HF Alrøe; ES Kristensen (2001) Approaches to assess the environmental impact of organic farming with particular regard to Denmark. Agriculture, Ecosystems and Environment. 83:11-26.
17. Bot, A. and Benit J. (2005) The importance of soil organic matter key to drought-resistant soil and sustained food and production. Food and agriculture organization of the United Nations. Rome, Italy.
18. Madigan, M., Martinko, J., Dunlap, J.M., and Clark, D.P. (2009) Brock Biology of Microorganisms 12th Ed. (Pearson Education, San Francisco, CA).

19. Brady, N., and Weil, R.R. (2010). Elements of the Nature and Properties of Soils: 3rd Ed. Pearson Education, Inc., Upper Saddle River, NJ.

20. Dirk van Elsas, J., Semenov, A.V., Costa, R., and Trevors, J.T. (2010) Survival of Escherichia coli in the environment: fundamental and public health aspects. The ISME Journal: Multidisciplinary Journal of Microbial Ecology. 5:2:173-183.

21. Dhiaf, A., Abdallah, F.B., Bakhrouf, A. (2010) Resuscitation of the 20-year starved Salmonella in Seawater and Soil. Annals of Microbiology. 60:1:157-160.

22. Leaf Filter Gutter Protection. (2016) [Online] Available from: http://www.leaffilter.com/blog/home-exteriors/outdoor-landscaping/which-soil-is-best for-your area/ [Accessed 2 November 2016].

23. Centers for Disease Control (CDC). (2016). Burden of Foodborne Illness: Findings. [Online] Available from: https://www.cdc.gov/foodborneburden/2011-foodborne-estimates.html.

24. Solomon, E.B., Pang, H.J, Matthews, K.R. (2003) Persistence of Escherichia coli O157:H7 on Lettuce Plants following Spray Irrigation with Contaminated Water. Journal of Food Protection. 12: 2196-2405.

25. Wang, R., Luedtke, B.E., Bosilevac,J.M., Schmidt, J.W., Kalchayanand, N., Arthur, T.M. 2016) Escherichia coli O157:H7 Strains Isolated from High-Event Period Beef Contamination Have Strong Biofilm-Forming Ability and Low Sanitizer Susceptibility, Which Are Associated with High O157 Plasmid Copy Number. Journal of Food Protection. 9: 11: 1875-1883.

26. Crum, N.F. (2005). Non-typhi Salmonella empyema: Case Report and Review of the Literature. Scandinavian Journal Diseases. 37:852-857.

27. Farber, J. M., Ross, W. H., & Harwig, J. (1996). Health risk assessment of Listeria monocytogenes in Canada. International Journal of Food Microbiology, 30(1-2), 145 156.

28. United States Department of Agriculture- National Organic Program; Final Rule (2000). [Online] Available from: https://www.gpo.gov/fdsys/granule/CFR-2011-title7-vol3/CFR 2011-title7-vol3part205/content-detail.html [Accessed 2 November 2016].

29. Center for Disease Control (CDC) (2015) Show Me the Science - Why Wash Your Hands? [Online] Available from: https://www.cdc.gov/handwashing/why-handwashing.html [Accessed 3 February 2017]

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Attachment E
University of Arizona Biochar

AZ1752 November 2017

Guide to Making and Using Biochar for Gardens in Southern Arizona

Janick F. Artiola Ph.D. and Lois Wardell Ph.D.

What is Biochar?

Biochar is actually just **charcoal** or black carbon, made from the incomplete combustion of **wood** or other **biomass** products. With growing interests in "green" and "carbon-negative" materials, biochar commonly refers to charcoal made from organic wastes such as tree trimmings, scrap wood, and plant material left from agricultural harvests. Like a campfire, wood biomass will burn without any other external fuels or energy. Since burning wood does not add **fossil carbon** to the atmosphere, burning wood or making biochar is a carbon-negative process.

The chunks of charred wood left over from a campfire is a form of biochar. In handling those pieces of campfire biochar, it is easy to note that it is lighter than the wood it came from. In the fire, the most flammable parts of the wood burn away first leaving pores, or airspaces in the charred remains (Figure 1). This porous sponge-like property of biochar makes it useful for many things such as the production of activated carbon filters used to purify water. Industrial production of biochar employs **pyrolysis**; a means of combustion without much air or oxygen and is more efficient in that it produces little **ash**. However, for most uses, including gardening, biochar can be made at home in a purchased or homemade burner as explained further in this publication.

Figure 1.The black portion of the match is charcoal, a light, porous material, made mostly of carbon and other elements. Photo: J.Artiola

Traditional Biochar Uses

Prior to the discovery of oil, natural gas, and coal as energy sources, wood and charcoal were the only means to heat, cook, blacksmith, distill, and power early steam engines. Charcoal production became an important industry since it is lighter and easier to transport than wood. Converting wood to charcoal means it is ~50-75% lighter to carry and yet keeps ~50-60% of the energy as a fuel. Unfortunately, this has been and still is one of the causes of deforestation in many regions of the world that lack access to fossil fuels to meet basic household energy needs.

Biochar is actually an ancient technology for improving soil fertility for agriculture dating back as far as 8,000 years ago in South America. The ancient Amazonian civilizations used biochar to transform the poor quality red soil into a rich black fertile soil. According to John Roach in National Geographic News (NGN 2008), these dark soils "are hundreds to thousands of years old, yet to this day they retain their nutrients and carbons, which are held mainly by the charcoal." Similar uses of biochar by earlier civilizations are also found in Peru, Ecuador, West Africa, and Australia.

Traditional techniques for the addition of charcoal (and ash) to soils was probably done with controlled burning of crop residues and/or local vegetation. Additionally, production methods include pit or mounds that are set on fire and then covered with soil to allow for slow smoldering (Figure 2). Even wood ash is particularly useful in reducing soil acidity and adding depleted nutrients such as calcium, potassium, and magnesium to mineral-poor soils.

Figure 2 Traditional Biochar Production. Burning piles of biomass and covering it with soil will allow it to burn slowly with limited air. Source: https://www.biochar-journal.org/en/ct/59-Biochar-in-the-time-of-cholera

Biochar Rediscovered

Improving the condition of soils for agriculture has been the main use of biochar worldwide. New uses such as biofuels, carbon storage, and removing contaminants from water, soil and air are also well known. One author offers 55 uses for biochar (Schmit 2012). Four main factors have renewed interest in the production and use of biochar for agriculture.

First: Biochar is a great way to turn organic waste into something useful and long-lasting. Sources for biochar include any type of plant or animal waste including: trees, shrubs, and grasses; and agricultural residues such as corn stalks, rice hulls, manure, and sewage.

Second: Unlike fossil fuels, the production of biochar does not generate additional carbon dioxide (CO_2) gas emissions that are primarily responsible for global warming. Therefore, making biochar is carbon-negative process.

Third: Carbon sequestration is another application of biochar. As plants grow, they remove CO_2 from the atmosphere; convert the carbon (C) from the CO_2 into roots, stems and leaves while releasing oxygen (O_2) that we breathe. If plant and organic wastes are allowed to decompose, they return most of the CO_2 to the atmosphere (up to 90% within a few years). Biochar is a very stable form of organic carbon lasting hundreds to thousands of years in the soil (Figure 3). Therefore, biochar production helps lower the CO_2 concentration in the atmosphere by not decomposing and storing the carbon long-term. This is a form of carbon sequestration. Some estimates suggest that half of the carbon from the CO_2 that plants remove from the atmosphere can be stored as biochar in soils (Lehmann et al., 2006).

Fourth: Biochar has several agricultural benefits (IBI 2017). Biochar is a sought-after soil additive that increases macronutrients in depleted soils commonly found in hot and wet climates, reduces soil acidity, improves soil texture, and increases the water holding capacity. In addition, recent studies have shown that biochar can reduce nutrient losses and reduce migration of agricultural chemicals such as pesticides and herbicides.

Will Biochar Benefit Alkaline Soils? The use of biochar as a soil additive goes back thousands of years in tropical areas where soils are usually acidic with very low organic matter content and depleted of macronutrients such as calcium and potassium. In contrast, soils in arid and semiarid climates of the Southwest have large supplies of these nutrients and are alkaline (pH greater than 7.5), but are still lacking in organic matter (Artiola & Walworth 2009). Biochar can be beneficial to any type of soil. The addition of biochar to our desert soils will quickly raise the soil organic matter content, increase water holding capacity and improve soil structure. Desert soils do offer special challenges as some research has shown that biochar may also temporarily raise the soil pH and salinity.

IMPORTANT PROPERTIES OF BIOCHAR IN AGRICULTURE

* Creates a use for waste organic material
* Carbon-negative: it does not generate additional CO_2 emissions
* Carbon sequestration: provides long-term carbon storage
* Improves soil fertility in several ways

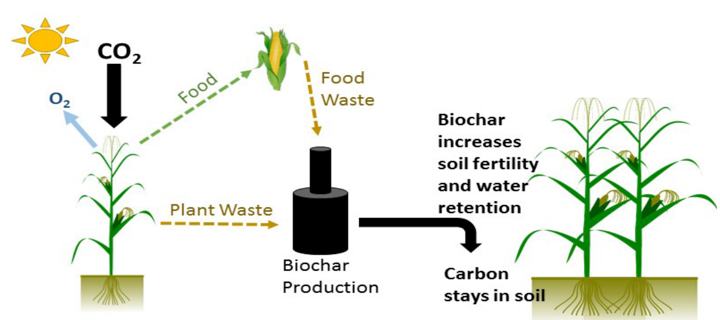

Figure 3. Biochar can help reduce the CO_2 levels in the atmosphere when applied to soil. Carbon from CO_2 is sequestered by plants and ends up as biochar. Image: L. Wardell

Figure 4. Compost piles and green waste (insert) in Tucson. Photos: J. Artiola

Figure 5. Native grasses growing in biochar amended soil after one month of drought. Source: J. Artiola

Compost vs Biochar for the Garden

Driving the effort to develop uses for green wastes, composting has become a common practice. According to the EPA, 34.5 million tons of yard waste was generated in 2014 in the US. Over 60% of yard waste went to composting, with 7.6% burned for energy and just under one-third (10,790,000 tons) ending up in a landfill. Both compost and biochar have their benefits and it is ideal to mix them for a home garden. Although compost is a form of carbon that decomposes much faster in soils than biochar carbon, compost is more readily available. Gardeners can mix biochar with compost to have quick and long-lasting benefits of raising soil organic matter content.

Presently, tens of thousands of tons of yard waste are landfilled in Arizona. However, programs from the City of Phoenix (CoP 2017) and the Tucson-based University of Arizona student organization Compost Cats (CC 2017) along with others are increasingly using urban green wastes (together with food scraps and manure) to produce and sell compost. Like biochar, compost produced from yard waste in Arizona (Figure 4) can have lots of salts, which can be removed by leaching before the compost can be safely used in nursery potting mixes. Arizona homeowners interested in producing compost in their backyards should refer to the UA Cooperative Extension Publication #AZ1632 for additional information.

Arizona Biochar: Pine Forest and Mesquite Yard Wastes

Arizona has an unending supply of pine forest and mesquite woody wastes. The cooler, higher altitudes produce pine trees where the forestry and wood industry generate a lot of pine waste biomass. In the lower altitudes where it is hot and dry, mesquite trees flourish. Mesquite is an invasive species in rangelands worldwide that is disliked for its ability to tap into precious groundwater resources and for the way it discourages the growth of native grasses. Ranchers and land managers in Arizona spend millions of dollars each year trying to control mesquite. Mesquite is a popular landscape tree in the desert

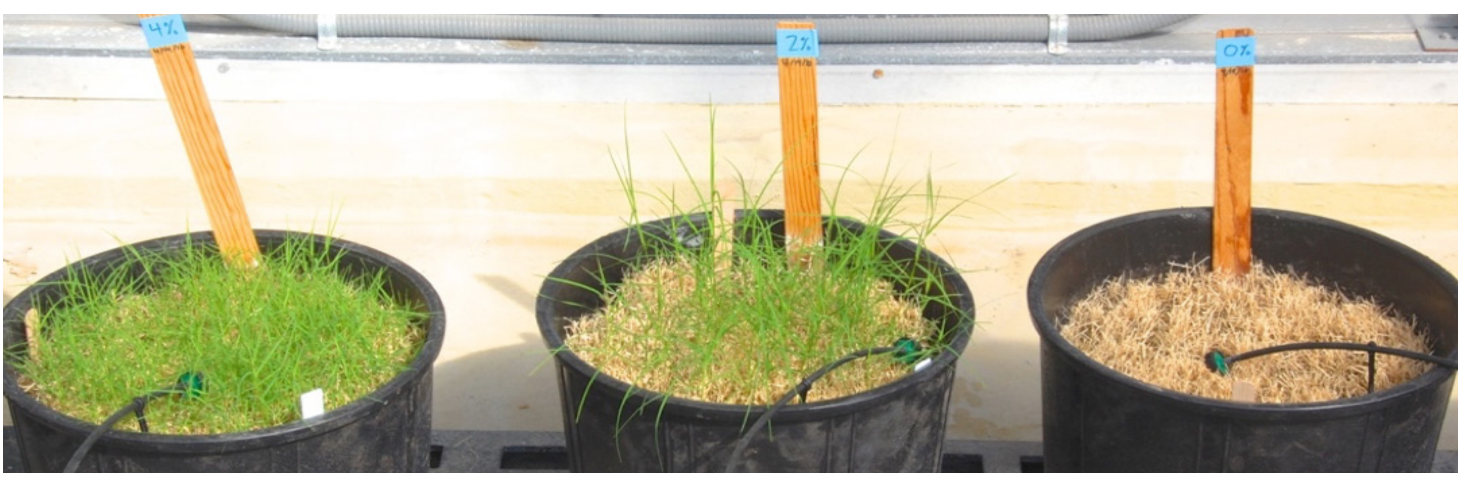

Figure 6. Bermuda grass growing in biochar amended soil after 28 days of drought. The left pot contains 4% biochar (by weight) in the soil and had nearly 100% recovery. The center pot contains 2% biochar and had a recovery of 40-60%. The right pot with 0% biochar had 0% recovery as evidenced by the brown color. Source: Artiola et al., (2012)

cities so ample yard waste is also generated there. This is why researchers at the University of Arizona have focused much of their biochar research on these two sources of wood biomass.

Biochar can help protect turf grass from drought conditions. Research at the University of Arizona has shown that biochar produced from pine forest waste, when applied to soil, increased plant growth and helped protect several native grass species from drought (Figure 5). In a drought experiment (Figure 6), biochar significantly increased the survival rate of Bermuda grass. After one month of drought (no water) the Bermuda grass without any biochar did not recover at all and remained brown. Adding 2% biochar by weight to the soil increased the survival to 40-60%. With 4% biochar, nearly 100% of the Bermuda grass recovered. This is due to biochar increasing the water holding capacity of soils.

In the same study, Romaine lettuce grew better with biochar in the soil. Adding up to 4% biochar (by weight) to a loamy sand soil from Red Rock, Arizona, doubled lettuce yields. The romaine lettuce plants grown without biochar weighed an average of 50 g (1.8 oz). Lettuce grown in soil with 4% by weight biochar were about twice the size, weighing on average 110 g (0.22 lbs) (Figure 7). In other experiments, biochar also helped reduce the fertilizer losses below the root zone and increased plant yields (Artiola et al., 2012).

Lessons Learned: In the very beginning of the above studies the biochar had adverse effects on Romaine lettuce and Bermudagrass. In a saline soil environment such as a desert, plants will generally contain higher levels of salt. These salts will concentrate further when these plants are converted to biochar. When added to the soil, the salts will then wash out of the biochar causing sudden changes in the salt levels of the soil. Our observations showed that these changes affected seed germination, and seedling and plant growth (data not shown). However, after watering the plants several times, the

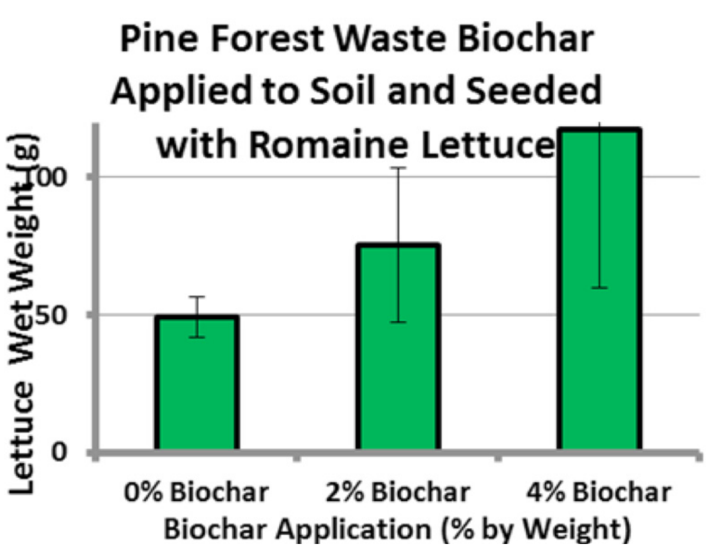

Figure 7. Adding biochar to soil increased the growth of lettuce. Source: Artiola et al., (2012)

soil pH and salinity conditions returned to normal levels. This suggests that biochar has only a temporary effect on the soil salinity of desert soils common in Arizona. See next sections for tips on how to avoid this.

Additional Research: Biochar has some similar properties to activated carbon, found in many pitcher, faucet, and refrigerator filters for drinking water. Activated carbon removes many organic and some metal contaminants from water; so, what about mesquite biochar? In a study at the University of Arizona, biochar made from mesquite yard waste was tested to see how well it would remove common organic contaminants including benzene (common in gasoline), trichloroethylene (TCE) (solvent degreaser), and atrazine (common herbicide). The biochar effectively removed the contaminants. For example, one kilogram (2.2 lbs) mesquite biochar retained more than 15 grams (1/2 oz) of benzene and the same amount of biochar retained about one gram of TCE after 3 days of contact time with water tainted with these solvents.

The weed killer Atrazine, one of the most widely used herbicides, was also removed from water by mesquite biochar—over half of the atrazine was removed from the water over a 24-hour period. Therefore, biochar has excellent potential for filtering contaminants from urban, agricultural, and even industrial wastewaters. However, more research and demonstration projects are needed to figure out safe and effective ways to trap these and other chemicals from wastewaters and protect our precious water resources.

How to Make Biochar for Home Use

1. Selecting a Burner/Stove to Make Biochar

Many websites advise digging a trench or a pit to burn your green wastes into biochar but this may be against some urban fire codes or pose a fire risk when the weather is dry. If shopping for a biochar stove, keep in mind that they may also be referred to as wood or biomass gasifiers. The term gasifier describes a stove that will regulate the air during wood burning. Without much air, the most flammable parts of the wood will vaporize as the wood heats up once the fire starts. It is this vapor, or gas, that burns the hottest and makes for a smokeless wood stove (that can make biochar too).

Home Fire Pit/Chiminea or BBQ/Smoker This is the least efficient method. But if you're curious, it is a simple way to start. The black charred wood remaining from a campfire or from cooking with wood in a BBQ grill is biochar. To maximize the amount of biochar and minimize the amount of ash, use a uniform size of wood chunks (wood from a chipper works well) and start a fire. Carefully watch your wood fire and when the yellow flames are about out, it is time to stop the fire by using a lid and suffocating the fire or by quenching it with water.

Cone Stove The simplest biochar stove is a cone or sometimes called a Japanese kiln (Figure 8). This allows air to reach only

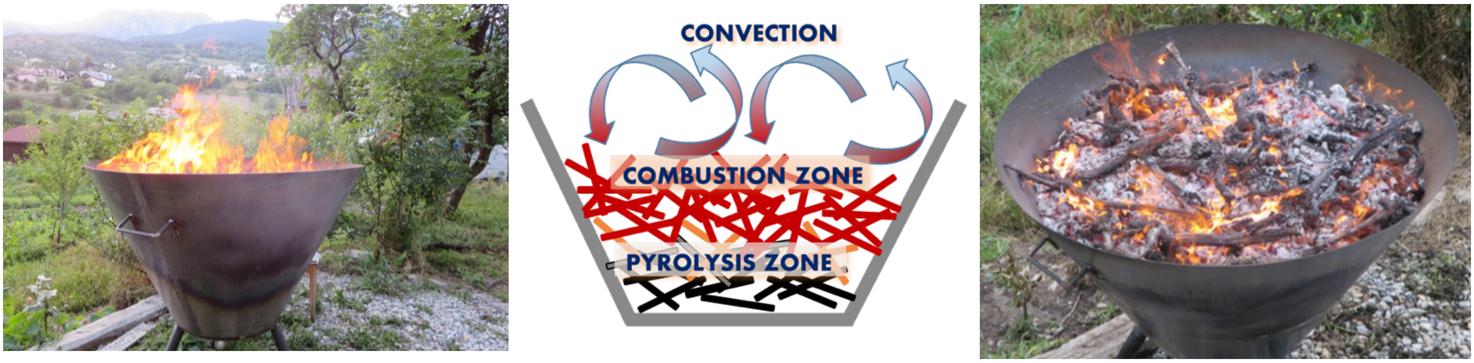

Figure 8. Japanese kiln (left). Source: www.ithaka-journal.net/86. Biochar is produced in the pyrolysis zone where less air is available (center). Source: Image by L. Wardell. Cone with coals -- wood layer is added when the top layer begins to coat with ash (right). Source: www.ithaka-journal.net/86

the top layer, forming biochar below in the bottom called the "pyrolysis zone". When the top layer begins to coat with ash it is time to add another layer of wood or stop the fire by suffocating it with a lid or dowsing it with water.

Gasifier Stove There are several stoves on the market that homeowners can buy (or build) to cook with and make biochar (Figure 9). These works because the low oxygen conditions needed to make biochar can be created inside an open container by controlling the air that enters from the bottom part where heat produces gases. More air can be forced near the top of the flames to increase combustion efficiency and eliminate smoke.

CAUTION: The top flames are much hotter than the coals and may reach temperatures well above 1,300°F (700°C). Note that there are many variations to the design shown in Figure 9 with either active or passive forced air entry.

The steps for the production of high quality biochar using yard waste (wood branches) includes a small wood chipper and a biochar stove (Figure 10). It is important to stir the woodchips inside the stove during the combustion process or carefully burn in layers. Using gasifier stoves with forced air reduces the amount of smoke and ash. As soon as the flames die out, move the smoldering coals into a metal can or old pot and seal tightly with a lid. This will prevent air entry and stop the wood from burning further. Then the biochar sits outdoors to cool for several hours. Water can also be used to quench the fire. A batch of mesquite biochar is in the far-right image (Figure 10), using a quarter coin for scale.

2. Choosing Which Yard Waste to Use

Almost any dry organic "green" waste is suitable for making biochar. Homeowners in Arizona with large backyards often have a readily available source of green waste from landscape trees such as Mesquite, Palo Verde, and Mulberry that would make good biochars.

Yard Waste Preparation If you want to produce biochar of consistent size, ready to use in your garden, then the size of the yard waste should also be consistent. Wood chippers produce consistent size wastes that can easily be packed into various types of stoves for the production of biochar. Not

Figure 9. Basics of a Top-Lit Updraft Gasifier stove good for cooking and/or making biochar (left). Source: www.biochar-international.org. One of many types and sizes of camp stoves (center, no endorsement implied). Photo: L. Wardell. Instructions to make one are easily found online. Sizes range from coffee cans (right) to 55-gallon drums. Source: https://energypedia.info/wiki/File:Micro_Gasification_2.0_Cooking_with_gas_from_ dry_biomass.pdf

Figure 10. Mesquite Yard Waste (left), Wood Chipper (center-left), Woodgas Gasifier Stove© (center-right, no endorsement implied), Biochar (right). Photos: J. Artiola

CAUTION:

Avoid making biochar from mixed wastes or wastes residues from plants used in hedges such as oleander because this and other plants contain chemicals that protect the plant. If these toxins are not completely burned off, they could adversely affect other plants (Figure 11)

Figure 11. Oleander Hedge. Photo: J. Artiola

all methods for the production of biochar require the use of wood chippers. However, if you end up with large chunks of biochar, they should be crushed before adding to soil. See the cautions in this publication for handling biochar.

3. Biochar Preparation and Soil Application

Does Size Matter? There are no clear recommendations for what biochar size is best to apply to soils. This is because biochar is usually an uneven mixture of carbon-rich particles/ chunks that can range in size from dust (< 1 millimeter or < 0.04 inches) to several centimeters. Studies have shown that small biochar particles fill with water faster, retain nutrients, and sorb pesticides better than larger size particles. Under normal field conditions, water, nutrients and other chemicals, will not penetrate deep into large biochar particles because small spaces locate deep in the biochar stay filled with air. If biochar is produced using large size wood logs or branches more than 5 cm in diameter (2 inches or more), then it may be desirable to break larger char pieces to an average size no more than a half centimeter (3/8 inch).

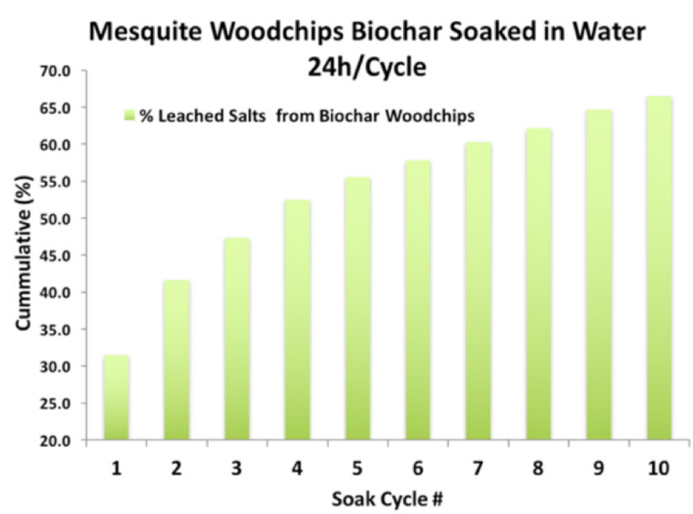

Figure12. Soaking biochar in water can remove much of the salt. Soaking the biochar once (for 24 hours) removed ~30% of the salt. Repeating the soaks 10 times removed up to 65% of the total amount of salt. Source: J. Artiola

CAUTION: As with most dry soil and dust size particles, breathing biochar dust can be hazardous. Research on soot exposure by chimney sweeps found a range of additional health concerns (Soot, 2017). Cutting or chipping the wood beforehand is preferable over crushing the biochar to avoid making extra biochar dust. But woodchip fires must be stirred often for even combustion. In dry climates, it is also important that biochar is mixed in with the soil or compost and not placed on the garden surface where it can be exposed to wind. Store biochar in sealed containers or bags. If crushing dry biochar, wear a dust mask. Wetting the biochar before using or crushing will help contain the dust. Always handle biochar outdoors.

Removing Salts Leaching salts from biochar (or even compost) is more complicated than simply rinsing it off. Laboratory experiments were conducted and found that rinsing the biochar removed very little of the salt. Soaking the biochar repeatedly using fresh water each time is the best way to wash the salt out. Soaking the biochar once for 24 hours removed about 30% of the salt (Figure 12). Repeating the soakings ten times removed over 65% of the salt. Removing salt will be less effective with larger particles. The exact amount of water and soaking times were tightly controlled in the laboratory; so, doing this ten times is not necessary. At home, letting the biochar sit (submerged) in water overnight or longer should remove a lot of the salt in two or three soaks. Soaking and drying the biochar several times also helps lower the pH of the biochar, which is usually very alkaline (pH above 9). However, salt content of your yard waste will vary with factors such as soil salinity and plant species.

Mixing Biochar with Compost Biochar lacks nutrients like nitrogen and phosphorous so mixing it with compost or manure is a helpful option. Biochar has the ability to sorb these nutrients and keep them in the soil longer and is better than using compost alone. Mixing up to 1 part compost with 1 part biochar is effective at increasing the time nutrients stay in the soil, but most gardeners start with ratios closer to 10 parts of compost to 1 part biochar to be sure that plants tolerate it well. Before adding this mixture to soils, or using it in a potting mix, it should be aged for several weeks under moist conditions to allow for the exchange of nutrients between the two materials. This will also help microorganisms, worms, etc. found in compost to adjust to the biochar. This step also helps beneficial fungi that grow on plant roots to develop quickly once the biochar-compost mix is applied to soil (Charging a, b 2017). Increasing the nutrients in biochar in this way is called "charging".

4. How much Biochar?

Published studies do not agree on a specific amount of biochar that must be added to soil for optimum benefits. Application rates vary from 1 metric tonnes/hectare (Mt/ha) (~ ½ tons/acre) to well over 100 Mt/ha (446 tons/acre). There are several reasons for this, here are just a few of them:

The quality of biochar will depend on things like the source of wood used, the temperature it was burned, the size of biochar pieces, and if it was soaked in water or had any other special treatment.

Biochar research projects around the world used very different soils, from nutrient poor tropical soils to sandy desert soils with high salt content.

The crops or plants used will need different soil conditions and endure different types of environmental and climate stresses.

It takes a lot of biochar You will need about 2 kg (4.4 lbs) of dry green yard waste to produce 0.5 kg (1.1 lbs) of biochar, depending on the type of waste used. If your garden is a about 5x5 meters (17x10 feet), then to add 1% biochar into the top 15 cm (6 inches) of soil, you will need about 55 kg (120 lbs) of biochar or about 50 kg (110 lbs) of biochar or about 200 kg (440 lbs) of dry green waste. This is the same as mixing approximately one part biochar to 100 parts soil by weight (1:100).

Recommendation 1: If the biochar is applied by itself, try using it in small plot areas at increasing amounts (1, 2, 4%...). More biochar may be applied to garden soils over time or when mixed with compost. Also, use biochar as backfill for outdoor plants mixing up to 5% (~1:20 parts of biochar to soil).

Recommendation 2: Higher biochar soil applications are possible using compost-biochar mixes. Follow normal compost application guidelines for Arizona.

Recommendation 3: Avoid applying biochar to garden soils that will be turned over regularly or stay dry for long periods. Plowing or rototilling dry soils amended with biochar may release biochar dust into the air. Caution! Do not use biochar or biochar-compost mixes as top mulches because small biochar particles (which are about 10 times lighter than soil particles) may become airborne in windy-dry weather.

5. Where Can I Get Biochar?

To date there are no large commercial facilities that produce biochar in the Southwest US. The US Biochar Initiative (USBI 2017) is an excellent source of information and also maintains a list of where to purchase biochar and biochar equipment. Additionally, biochar soil additives and soil blends are beginning to find their way into retail stores and online markets but are expensive. As with any commercial product to be added to the garden, be sure it is specifically sold for garden use. Biochar made for other purposes (such as biofuel) may contain unwanted contaminants. Also, follow the safety cautions mentioned in this document as even "low-dust" commercial biochars will still have some dust that is hazardous to inhale.

Summary

- The use of biochar as an amendment to improve soil goes back to thousands of years, as does its production for basic heating and cooking needs. Until recently the modern use of charcoal did not extend beyond barbeque cooking.
- Homeowners can now produce biochar with yard wastes using a variety of stoves and kilns either purchased or home-made following basic fire safety rules. Biochar is great for outdoor cooking and can improve the quality of garden soils.
- Biochar is a great way of using green waste that is good for the climate and environment.
- Adding biochar to soil will store carbon for many generations and help lower CO_2 gas emissions, a major cause of global warming.
- Semi-arid soils common in the Southwest are not ideally suited to benefit fully from biochar amendments since they have an alkaline pH and plenty of salts. Biochar commonly add salts and raises the pH of these soils short time.
- Adding biochar to semi-desert soils will make plant more drought resistant, reduce plant nutrient losses, and when mixed with compost will also improve soil structure.

Biochar materials should be handled and applied to soils prudently, (Table 1).

Table 1. Recommendations and Cautions for using biochar in home gardens.

Recommendations	CAUTIONS
Avoid mixing yard wastes when making biochar.	Biochar materials must be handled outdoors and stored in sealed bags to avoid dust exposure.
Use biochar with average sizes ¼ inch or less.	Wear a dust mask or wet biochar before handling to reduce dust.
Soak biochar overnight (then drain) several times before use to remove the concentrated salts.	Avoid disturbing garden soils when dry to limit dust exposure.
Ratio of biochar to soils can range from 1:100 to 1:10 (if pre-mixed with compost) in the garden.	Do not add biochar to top mulches.
Use biochar in soil backfills, in potting mixes or better yet, with compost mixes.	
Keep the biochar in the ground where it is not easily airborne.	

Glossary

Ash: The product of a wood fire after complete combustion. Ash may contain many trace minerals and elements including: carbonates, oxides, and hydroxides of calcium, potassium, magnesium, sodium, iron, copper, manganese, zinc, and phosphates and sulfates, and other trace elements.

Bulk Density: Average weight of a material divided by its volume. A typical agricultural soil is assumed to have a bulk density of 1.3 grams/cubic centimeter (g/cm^3) (11 lbs/gallon), but this may vary by more than 30% depending on the soil composition and compaction.

Charcoal: Black material (also called black carbon) produced by the partial combustion of wood. It is composed mostly of carbon and smaller amounts of oxygen and hydrogen in addition to the trace elements and minerals also found in ash.

Fossil Carbon: Buried ancient plant and animal carbon deposited hundreds of millions of years ago now extracted and used as coal, petroleum and gas fuels.

Organic: Scientific term (used in this publication) – any carbon-based material or biomass from plant and animal tissue and wastes, and many types of synthetic chemicals such as plastics.

Pyrolysis: The chemical decomposition of organic material at elevated temperatures in the absence of oxygen. It should not be confused with Torrefaction.

Torrefaction: A mild form of pyrolysis at temperatures typically between 200 and 320 °C (~390-600 °F). Any organic material (such as green coffee beans for example) is placed in closed oven and roasted, not burned, using an external source of heat.

Wood: Plant-derived, organic material made mostly of carbon, oxygen and hydrogen, compose of sugar polymers (cellulose and hemicellulose), complex aromatic polymers (lignin), and smaller amounts of nitrogen, phosphorous, calcium and potassium and other trace elements also found in the ash.

References and Websites of Interest

-Artiola, J. F. and J. L. Walworth. 2009. Irrigation Water Quality Effects on Dissolution and Leaching of Organic Carbon from a Semi-arid, Calcareous Soil. Soil Science.174:7, 365-371.

-Artiola, J.F., C. Rasmussen and R. Freitas. 2012. Effects of a Biochar-Amended Alkaline Soil on the Growth of Romaine Lettuce and Bermudagrass. Soil Science. 177:9 561-570.

-Charging a. 2017. How to charge biochar. https://www.permaculture.co.uk/articles/how-charge-biochar

-Charging b. 2017. Charging and Inoculating Biochar. http://livingwebfarms.org/wp-content/uploads/2016/03/Inoculating-Biochar1.pdf

-CC. 2017. Compost Cats. http://www.compostcats.com

-CoP. 2017. City of Phoenix. https://www.phoenix.gov/publicworkssite/Pages/Commercial-Green-Organics.aspx

-Gasifier. 2017. How to make a biochar Gasifier. https://www.engineeringforchange.org/how-to-make-a-biochar-gasifier/

-Draper K, Biochar in the time of cholera, the Biochar Journal 2015, Arbaz, Switzerland. ISSN 2297-1114. www.biochar-journal.org/en/ct/59. Version of 23 th May 2015. Accessed: 30.11.2017.

-IBI. International Biochar Initiative. 2017. http://www.biochar-international.org/biochar.

-NGN. 2008. http://news.nationalgeographic.com/news/2008/11/081119-lost-cities-amazon.html

-Lehmann, J., and S. Stephen. 2009. Biochar for Environmental Management. Earthscan publisher.

-Lehmann, J. J. Gaunt, and M. Rondon. 2006. Bio-char sequestration in terrestrial ecosystems – a review. Mitigation & Adaptation Strategies for Global Change. 11:403-427.

-Permaculturenews. 2017. https://permaculturenews.org/2016/11/18/biochar-brief-history/

-Soot. 2017. Soot, as found in Occupational Exposure of Chimney Sweeps. https://www.ncbi.nlm.nih.gov/books/NBK304418/

-Young, K.M. 2014. Small scale composting in the low desert of Arizona. University of Arizona Cooperative Extension Publication #AZ1632.

-Master Gardeners. University of Arizona Cooperative Extension website. https://extension.arizona.edu/master-gardeners

-Schmidt, H-P. 2012. 55 uses of biochar. Ithaka Journal 1/2012: 286–289 (2012) www.ithaka-journal.net

-Schmidt HP, Taylor P (2014): Kon-Tiki flame cap pyrolysis for the democratization of biochar production, Ithaka-Journal for biochar materials, ecosystems and agriculture (IJ-bea), Arbaz, Switzerland, ISSN 1663-0521, pp. 338 -348, www.ithaka-journal.net/86

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This information has been reviewed by University faculty.
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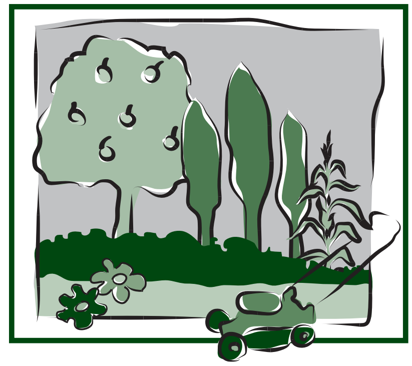
Attachment F
Colorado State University Turf Maintenance

Colorado State University
Extension

Lawn Care

Fact Sheet No. **7.202** Gardening Series | **Yard**



by T. Koski and V. Skinner*

Quick Facts

- Proper watering can promote a deeply rooted, healthier turf.
- Let grass species and health, soil conditions, and weather conditions dictate irrigation practices, not the number of days between waterings.
- Mow bluegrass, ryegrass, fescue and wheatgrass to a height of 2 to 3 inches. Buffalo-grass and blue grama lawns can be mowed to this height, but also do well unmowed.
- Core cultivation is essential for all lawn areas, especially those that are thatchy or subject to high traffic.

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Before planting a lawn, decide on the desired quality, how the lawn will be used, and how much time and money you are willing to invest. Have your soil tested. Contact your Colorado State University Extension county office for information on soil testing. Soil amendments can easily be added before planting. High quality sod or seed also helps ensure a satisfactory lawn.

Watering

Many factors influence lawn water requirements, and no two lawns are exactly alike. A healthy, high-quality bluegrass or ryegrass lawn may need up to 2.25 inches of water per week under hot, dry, windy summer conditions. It may require much less when the weather is cool or cloudy. Turf-type tall fescue may perform well with less water than a bluegrass lawn, if it can grow a deep root system. In many cases, however, tall fescue requires as much water as bluegrass to look good. Buffalograss and blue grama lawns can remain green for weeks without watering, even during the hottest summer weather.

Shady lawns and areas protected from the wind require less water over the growing season than more exposed turf. However, the roots of mature trees and shrubs also need water. You may have to water more in mature landscapes where the roots of many plants compete for water. Healthy turf, encouraged by proper mowing, fertilizing and cultivation, uses water more efficiently.

Application

Each time you water the lawn, apply enough water to moisten as much of the root zone as possible. Use a soil probe or shovel to determine what the average rooting depth is in your lawn. If the roots grow down 6 inches deep, water so the soil is moistened to that depth.

If the soil is mainly clay, apply 1 to 1 1/2 inches of water to moisten the root zone to a 6-inch depth. A sandy soil can be moistened to 6 inches by as little as 1/2 inch. It is important to know not only how deep the turf roots grow, but also how deep your irrigation water penetrates. Watering too deeply, especially on sandy soils, wastes water and allows it to percolate past the root zone.

Frequency

Based on the above, grass that grows on sandy soil must be watered more often than the same grass growing on clay or loam soils. Even after a thorough watering, sandy soils hold little plant-available moisture. They require more frequent irrigation with smaller amounts of water. Conversely, turf growing on a loamy-clay soil can be irrigated less frequently, with larger quantities of water. Watering less often means more efficient water use because of less loss to evaporation. It can also reduce the number of weeds that appear in the lawn.

With most soils, do not apply all the water in a short period of time. If applied too quickly, water often runs off of thatchy turf, from sloped areas, or from turf growing on heavy clay or compacted soils. In these cases, it is more effective to apply only a portion of the water and move the sprinkler or switch to another station to water another section of the lawn. This allows water to soak into the soil rather than run off. An hour or so later, apply the rest of the water. Core cultivation (aeration) can resolve some infiltration problems by reducing thatch and compaction. Wetting agents may enhance water movement into the soil, but they should not be considered a cure-all, especially when compaction or thatch are problems.

A sure sign that turf requires irrigation is a wilted appearance. One symptom is "footprinting," footprints on the lawn that do not disappear within an hour. This symptom

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Check with your local water department before you water at night. Some city ordinances prohibit irrigation during these hours to avoid the waste that occurs when sprinklers are left running in the same place all night.

During the season, regularly check mowing equipment for sharpness and adjustment.

Sharpen rotary mower blades every fourth mowing, especially when mowing fescue or ryegrass lawns. A dull mower blade will shred and fray leaf blades instead of cutting them cleanly. The result is a brown, unattractive lawn.

Check reel-type mowers for proper blade-to-bedknife adjustment before each mowing to avoid shredding and tearing of the grass leaves.

is soon followed by actual wilting, where the turf takes on a grayish or purple-to-blue cast. If only a few such spots regularly appear in the same general location, spot water them to delay watering the entire lawn for another day or so. These indicator spots help predict when the entire lawn needs watering.

A hardened or toughened lawn, attained through less frequent, deep irrigation, often withstands minor drought and generally has fewer disease problems. It is important, however, that the turf not be allowed to become overly drought-stressed between waterings. This weakens the turf and makes it more susceptible to insect and disease damage and to weed invasion.

During extended dry periods from late fall to spring, it may be necessary to water every four to six weeks if the ground is thawed and will accept water. Pay particular attention to exposed slopes, sites with shallow soil, and south- or west-facing exposures.

Time of Day

The most efficient time of day to water is late evening and early morning (between 10 p.m. and midnight or 8 and 9 a.m.). It generally is less windy, cooler and more humid at this time, resulting in less evaporation and more efficient use of water. Water pressure is generally better and this results in optimal distribution patterns. Contrary to popular belief, watering at night does not encourage disease development.

Mowing

The two most important facets of mowing are mowing height and frequency. The minimum height for any lawn is 2 inches. The preferred mowing height for all Colorado species is 2.5 to 3 inches. Mowing to less than 2 inches can result in decreased drought and heat tolerance and higher incidence of insects, diseases and weeds. Mow the lawn at the same height all year. There is no reason to mow the turf shorter in late fall.

Mow the turf often enough so no more than 1/3 of the grass height is removed at any single mowing. If your mowing height is 2 inches, mow the grass when it is 3 inches tall. You may have to mow a bluegrass or fescue lawn every three to four days during the spring when it is actively growing but only once every seven to 10 days when growth is slowed by heat, drought or cold. Buffalograss lawns may require mowing once every 10 to 20 days, depending on how much they are watered.

If weather or another factor prevents mowing at the proper time, raise the height of the mower temporarily to avoid cutting too much at one time. Cut the grass again a few days later at the normal mowing height.

Let grass clippings fall back onto the lawn, unless they are used for composting or mulching elsewhere in the landscape. Grass clippings decompose quickly and provide a source of recycled nutrients and organic matter for the lawn. Mulching mowers can do this easily. Side-discharge rotary mowers also distribute clippings effectively if the lawn is mowed at the proper frequency.

Grass clippings do not contribute to thatch accumulation. If herbicides are applied to the lawn, do not use clippings in the vegetable or flower gardens. Keep them on the lawn.

Thatch

Thatch is a tight, brown, spongy, organic layer of both living and dead grass roots and stems that accumulates above the soil surface. The interactions among environmental conditions, soil conditions and management practices (irrigation, mowing, fertilization) influence the rate and extent of thatch accumulation. Thatch tends to be a problem on Kentucky bluegrass, bentgrass and fine fescue lawns. It is rarely a problem with tall fescue, wheatgrass, bromegrass or buffalograss. Grass clippings do not contribute to thatch accumulation and should be returned to the lawn during mowing to recycle the nutrients they contain.

Measure thatch buildup by removing a small piece of turf, including the underlying soil. Try to slow buildup when the thatch layer exceeds 1/2 inch in thickness. The thickness can increase quickly beyond this point, making it difficult to control later. As the thatch layer thickens, it becomes the main rooting medium for the grass. This predisposes the turf to drought stress or winter kill and increases the possibility for insect, disease and weed problems. Also, fertilizers and pesticides applied to a thatchy lawn work less effectively.

Power Raking

This method of thatch removal has been used for years. Light (shallow) power raking may be beneficial if done often. Deep power raking of a thatchy lawn can be damaging, and often removes a substantial portion of the living turf.

Used properly, power raking of wet, matted turf can speed spring green-up by letting air move into the root zone and warm the turf.

Compost the thatch and organic material to kill any living grass before it's used as a mulch or soil amendment.

Core Cultivation or Aerating

This is more beneficial than power raking. It helps improve the root zone by relieving soil compaction while controlling thatch accumulation. Soil compaction, in fact, is one factor that contributes to thatch buildup.

Aeration removes plugs of thatch and soil 2 to 3 inches long (the longer, the better) and deposits them on the lawn. A single aeration using a machine with 1/2-inch diameter tines removes about 10 percent of the thatch if enough passes are made to achieve an average 2-inch spacing between holes.

Disposing of the cores is a matter of personal choice. From a cultural perspective, there may be an advantage

Table 1: Fertilizer application schedule for established Colorado lawns.

Turfgrass Species	Mid-March to April[1]	May to mid-June	July to early August	Mid-August to mid-September	Early October to early November[2]
	(nitrogen application rates are in pounds of nitrogen per 1,000 square feet of lawn area)				
High Maintenance					
Bluegrass/Ryegrass	1/2-1	1	not required	1	1-(2)
Low-Maintenance					
Bluegrass	1/2	1/2-1	not required	1	(1)
Turf-Type Tall Fescue	1/2	1/2-1	not required	1	(1)
Fine Fescue	1/2	1/2-1	not required	1/2-1	not required
Buffalograss/Blue					
Grama/Bermudagrass	Apply no N	1/2-1	1/2-1	Apply no N	Apply no N

[1] The March-April nitrogen application may not be needed if you fertilized late (September to November) the previous year. If spring green-up and growth is satisfactory, delay fertilizing until May or June.

[2] When grass is still green

- Optional N applications shown in (). Use extra nitrogen applications where a higher quality turf is desired or on heavily used turf.
- Make the final fall nitrogen application (October-November) while the grass is still green and at least two to three weeks before the ground begins to freeze in your area.
- On very sandy soils, do not fertilize turf after late September. Nitrogen can leach into groundwater during the winter months. Use slow-release nitrogen fertilizers (sulfur-coated urea, IBDU and natural organic-based fertilizers) on sandy soils throughout the year to reduce the potential for leaching losses.
- Nitrogen application can often be reduced by 1/4 to 1/3 when grass clippings are returned to the lawn during mowing. Nitrogen and other nutrients contained in the clippings are recycled into the lawn as they decompose. **Grass clippings do not contribute to thatch accumulation in lawns.**

to allowing the cores to disintegrate and filter back down into the lawn. Mingling soil and thatch may hasten the natural decomposition of the thatch. The little fluffs of thatch and turf that remain can be collected and composted.

Depending on soil type, core disintegration may take a few days to several weeks. Irrigation helps wash the soil from the cores. Dragging a piece of cyclone fence or an old metal door mat can speed the process. Running over the cores with a rotary mower can be effective but can dull the blade. Many commercial companies that perform core cultivation break up the cores with a power rake. If the cores are removed from the lawn, compost them before using them as a mulch or soil amendment.

Fertilization

Nitrogen is the most important nutrient for promoting good turf color and growth. Do not overstimulate the turf with excess N, especially during the spring and summer. Table 1 suggests nitrogen application programs for various lawn species. To obtain a high-quality, water-resistant turf with greater pest resistance, follow the suggestions in the table.

Overfertilization can contribute to thatch buildup and increased mowing requirements. Avoid underfertilization of bluegrass and ryegrass. These species can become unhealthy if not fertilized properly. Turf that does not respond to nitrogen fertilizer may be lacking in other nutrients, such as phosphorus or iron. Get the soil tested to determine which nutrient(s) are deficient.

Balanced or complete fertilizers contain various amounts of phosphorus, potassium, iron and sulfur. They are a good safeguard against a potential nutrient deficiency. If you leave clippings on the lawn, these nutrients are recycled from the clippings. If you remove clippings, this type of fertilizer is appropriate.

HOMEOWNER'S GUIDE TO:

Fertilizing Your Lawn and Garden

XCM-222

We all want a home landscape that is attractive – but did you know that some of our common landscape management practices can cause pollution? The improper use of lawn fertilizers has the potential to harm our water supplies and our environment.

Have you ever noticed a pond that was overgrown with weeds or algae? Chances are it received an excess of nutrients – perhaps from urban runoff from lawns or gardens. Drinking supplies may become contaminated the same way when nitrogen in fertilizer becomes nitrate. In severe cases, this contamination can even cause health problems.

Your yard can have a positive effect on water quality by slowing down and filtering runoff water, or it can contribute to water quality problems. It all depends on how you manage water, chemicals, and the landscape around your home. Fertilizer carelessly applied on one lawn may seem insignificant. On hundreds or even thousands of lawns, it can add up to polluted streams, lakes, and even groundwater.

WHAT YOU CAN DO TO PROTECT WATER QUALITY

- Fertilize your lawn and garden properly.
- Water only when needed.
- Use low-maintenance landscaping.
- Maintain a healthy lawn.

FERTILIZING YOUR LAWN FOR HEALTHY PLANTS AND CLEAN WATER

An effective lawn fertilization program actually starts in early fall, not in the spring. Spring applications alone may promote excessive top growth, leaving shallow root systems that poorly sustain lawns during hot dry spells or harsh winters. Fall fertilizer applications on established grass promote healthy root systems and hardy lawns.

One way to know how much fertilizer to apply is to take a soil test. If an analysis is not feasible, Table 1 shows the proper timing and amounts for various lawn types common in Colorado. The table assumes that all lawn clippings are left on the lawn to be recycled naturally. Keep in mind that over-fertilizing and other poor cultural practices are the primary reasons for thatch buildup, not grass clippings.

SELECTING A FERTILIZER

The label on all fertilizer bags contains three numbers that describe the amount of nitrogen (N), phosphorus (P), and postassium (K). For example a 40-pound bag of 20-10-5 fertilizer contains 20 percent (8 pounds) nitrogen, 10 percent (4 pounds) phosphorus as P_2O_5, and 5 percent (2 pounds) potassium as K_2O.

The remainder of the ingredients are fertilizer carriers such as sand or ground limestone, and sometimes micro-nutrients or an herbicide for weed control.

Plants do not distinguish between nutrients supplied by granular, liquid, or organic fertilizers. Select a lawn fertilizer based on nutrient analysis, convenience, and price. Slow-release fertilizers contain nutrients in a form that become available to plants throughout the growing season.

COLORADO STATE UNIVERSITY EXTENSION

This is advantageous because fewer applications are required and leaching losses are less likely. Avoid fertilizers that contain post-emergence herbicides for broadleaf weed control. Instead, spot spray or pull weeds in trouble spots.

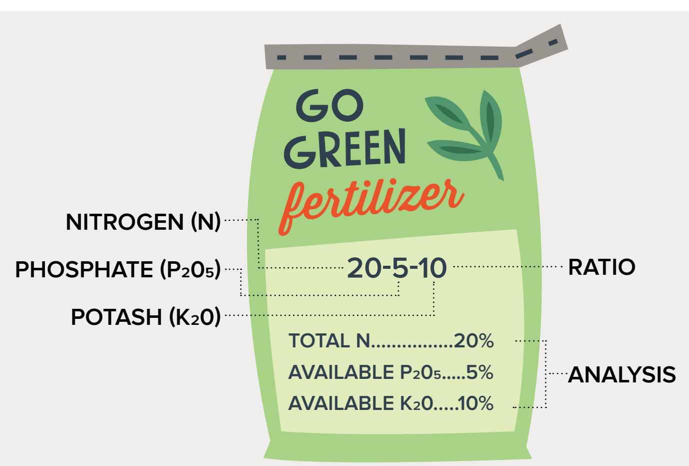
Most established Colorado lawns have adequate phosphorus (P) and potassium (K) in the soil without applying additional fertilizer. Applying a typical blended N-P-K fertilizer product based on your lawn's nitrogen (N) needs will usually result in application of more P and K than most Colorado lawns require.

DETERMINING HOW MUCH TO BUY

Determine how much fertilizer you need before you make a purchase to avoid storing leftover materials. Measure the area of your lawn to get an idea how many square feet you have to fertilize. Read the fertilizer bag to determine how much nitrogen is in the bag. For example, if you want one pound of N per 1,000 square feet from a 46-0-0 product, you need to apply nine pounds of fertilizer on a 4,000 square foot lawn (see Table 1.) Fertilizer applied above the recommended rate is wasted money and potentially harmful to water resources and aquatic life. Excess fertilizer also overstimulates lawn top growth, requiring more frequent mowing.

Table 1. Pounds of fertilizer required for various lawn sizes using a one pound N/ 1,000 sq. ft. application rate.

SQUARE FEET OF LAWN	% NITROGEN (N) ON LABEL — FERTILIZER REQUIRED FOR 1 LB. N/1,000 SQ. FT. RATE						
	5	10	15	20	25	34	46
500	10	5	3	2.5	2	1.5	1
1000	20	10	6	5	4	3	2
2000	40	20	13	10	8	6	4
4000	80	40	26	20	16	12	8
6000	120	60	39	30	24	18	12
	POUNDS						



APPLYING LAWN FERTILIZER

Most garden stores have spreaders that are calibrated for their products. The directions on the fertilizer bag usually tell where to set the applicator as well.

If you are not sure where to set the spreader, put it on a "low" setting to avoid over-fertilizing. Go back over the lawn at a right angle to the first application if you did not get enough on the first pass. This will insure a more uniform application. Always sweep up fertilizer that landed on sidewalks and driveways onto the lawn afterwards.

COMMERCIAL TREE AND LAWN CARE COMPANIES

If all of this sounds too complicated, you may want to consider using the service of a professional company to maintain your landscape. A reputable service offers licensed applicators who are trained to handle and apply chemicals properly.

Some areas of consumer caution should be noted.

- **Do you really need the "perfect lawn"** provided in a "full-service" lawn care package? A low-maintenance program might be more suitable.
- **Are routine insecticide applications desirable?** The vast majority of the insects found in Colorado lawns are neutral or beneficial – lawn insecticides are only occasionally needed under our conditions.
- **Are routine herbicide applications needed?** Weeds are not the cause of an unhealthy lawn – they are the result. In many cases, an attractive lawn can be maintained with sound watering, fertilizing, mowing, and aeration.
- **Are all of those fertilizer nutrients necessary?** Most commercial fertilizers contain phosphorus (a potential water pollutant) even though in many cases it is already adequately supplied in your soil. Consider a soil test before applying fertilizer nutrients besides nitrogen.

In short, a "one-size-fits-all" lawn program may not be best for you or the environment. Question the blanket use of chemicals in favor of a more tailored program.

FERTILIZING LANDSCAPE AND GARDEN PLANTS

Nutrient requirements for garden plants can vary considerably. In general, nitrogen promotes leafy top growth. Phosphorus is needed for good root development. Potassium is necessary for winter hardiness, disease resistance, and general plant health.

Always improve the soil prior to planting by incorporating a good organic soil amendment such as aged manure or compost to develop a rich, well-drained soil. If plants show yellowing leaves, consult your county Extension office or Master Gardener for nutrient recommendations. Iron deficiency may cause yellow landscape plants in Colorado.

Most established trees and shrubs planted in well- drained, fertile soils do not need annual fertilizer applications.

Table 2. Recommended nitrogen fertilizer schedule where clippings are not collected.

FERTILIZER APPLICATION SCHEDULE FOR ESTABLISHED COLORADO LAWNS					
GRASS TYPE	MID-MARCH TO APRIL[1]	MAY TO MID-JUNE	JULY TO EARLY AUG.	MID-AUGUST TO MID-SEPTEMBER	EARLY OCT. TO EARLY NOVEMBER (WHEN GRASS IS STILL GREEN)[2]
(pounds of nitrogen per 1000 square feet of lawn)					
LOW-MAINTENANCE BLUE GRASS/ RYEGRASS[3]	1/2	1/2	**NOT** REQUIRED	1	1 (OPTIONAL)
TURF-TYPE TALL FESCUE	1/2	1/2-1	**NOT** REQUIRED	1	1 (OPTIONAL)
FINE FESCUE	1/2	1/2-1	**NOT** REQUIRED	1/2-1	NOT REQUIRED
BUFFALOGRASS/ BLUE GRAMA/ BERMUDAGRASS	APPLY **NO** N	1/2-1	1/2-1	APPLY **NO** N	APPLY **NO** N

[1]The March-April nitrogen application may not be necessary if you fertilized late the previous fall (Sept. to Nov.). If spring green-up and growth is satisfactory, delay fertilizing until May or June.

[2]On sandy soils, do not fertilize after late September. Winter precipitation can cause nitrogen to leach into groundwater. Slow-release fertilizers, such as sulfur-coated, and natural, organic-based fertilizers are recommended on sandy soils to prevent leaching losses.

[3]High maintenance bluegrass lawns with heavy use may benefit from an additional ½ pound for each spring application.

Adapted from Colorado State University Extension Fact Sheet 7.202, Lawn Care.

However, if plants are growing poorly and you cannot identify a specific pest or weather-related reason, a nutrient deficiency may be the problem.

The easiest and most economical method of fertilizing is to sprinkle a balanced liquid or granular fertilizer material under the plant and water it in. Mulching will help conserve moisture, protect roots, and prevent the loss of soil and nutrients.

Vegetable gardens are a great place to incorporate composted waste materials from your kitchen and garden. Aged or composted animal manures are also a good way to improve garden soils.

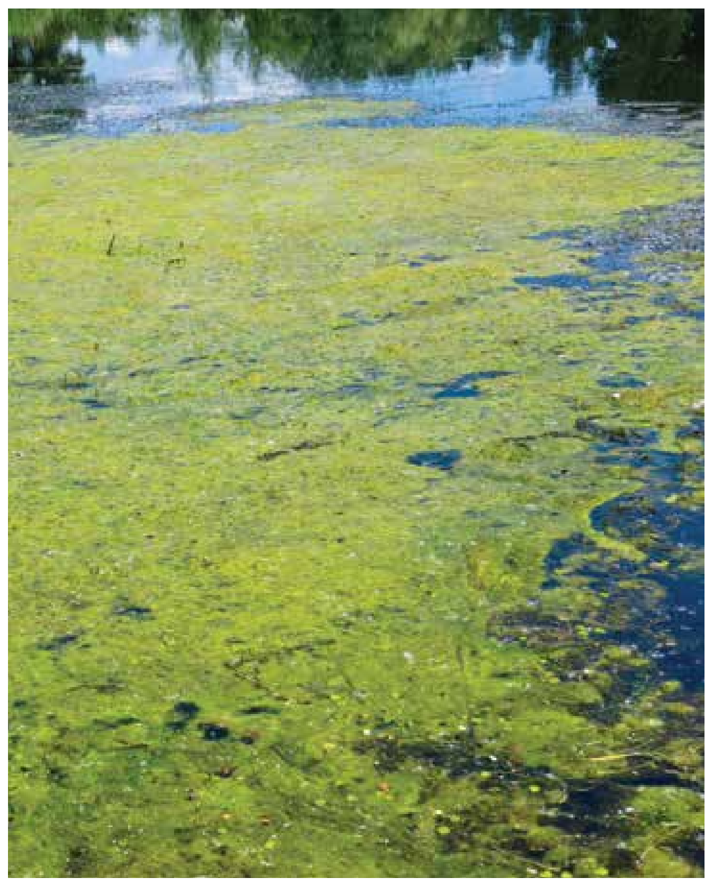
Some vegetables, such as corn or tomatoes, may benefit from the addition of a low analysis, complete mineral fertilizer (such as 5-10-5) added at the rate of approximately 10 to 20 pounds of material per 1,000 square feet of garden. Corn requires more N than tomatoes. Fruit production can be delayed if too much N is applied to tomatoes. (See Fact Sheet 7.611, Fertilizing the Vegetable Garden.)

MAINTAINING A HEALTHY LAWN

When grass is dense and vigorous, it competes effectively against most pests. A sound watering and fertilization program is basic for a healthy lawn.

Other things you can do include:

- When installing new or replacement sod, prepare your soil well with deep tillage and compost amendments.
- Maintain a mowing height at 2½ to 3 inches. This encourages deeper rooting and heat resistance.



Excess fertilizer nutrients from lawn and garden runoff can cause overgrowth of aquatic weeds and algae, degrading fish and wildlife habitat and recreational opportunities.

A yard under xeriscape can be maintained with less water and fertilizer in many situations.

- Mow often enough so that you can mulch grass clippings on the lawn to recycle the nutrients. Leaving grass clippings does not cause thatch.
- Core aerate your lawn at least once a year to encourage good rooting and water penetration.
- Keep your mower blade sharpened to avoid ragged cutting that increases moisture loss and stress.

WATERING YOUR YARD

Poor watering practices are probably responsible for more landscape problems in Colorado than any other single factor, except maybe our weather. Over- watering causes the loss of nutrients to the environment and is not particularly good for most landscape plants. However, making precise watering recommendations is difficult due to a combination of factors that includes different plant moisture needs, different soil types, and varying weather conditions.

In general, a sandy soil should receive ½ to 1 inch of water per application, while a clay soil should receive less frequent and gradual applications of 1 to 1 ½ inches of water. A dense stand of Kentucky blue grass may need up to 2 inches of water per week during the hottest part of the summer, but other grasses such as tall fescue may thrive on less if they have well- developed roots.

Over-watering is wasteful and can transport contaminants via runoff from the soil surface or percolation below the root zone. Homeowners with automatic sprinkler systems need to pay attention to weather patterns and their landscape's water needs. Turn off or reset sprinklers after rain or during periods of cool weather (See Fact sheet 7.239, Operating and Maintaining a Home Irrigation System).

LOW-MAINTENANCE LANDSCAPES

You can make a positive impact by designing your landscape with plants that require less water and fertilizer, and have fewer pest problems.

Alternatives to Kentucky blue grass, such as buffalograss, blue grama grass, and turf-type fescue can provide a beautiful lawn that requires fewer resources. However, be aware that each alternative grass has its own advantages, disadvantages, and maintenance needs. Often, homeowners plant grass in areas that are too shady, or that have steep slopes or poor soils where lawn grass just doesn't grow well.

More fertilizer and water are not the answers in these cases. It's usually best to replace this grass with hardy ground covers, ornamental bunch grasses, or mulch. Xeriscape or low-maintenance landscape plants are less dependent on fertilizer and water inputs.

Additionally, they help attract songbirds, butterflies, and beneficial insects. Check with your local nursery for recommendations specific to your area. Also, visit **extension.colostate.edu** to find the following fact sheets: Creative Landscaping (7.228), Xeriscaping: Ground Cover Plants (7.230), Sustainable Landscaping (7.243), and Watering Established Lawns (7.199).

Finally, landscapes designed to hold rain and snow melt are environmentally friendly because they result in less water runoff. Keeping any part of your property that borders surface water in a dense natural vegetation can help filter out chemicals that might be carried in runoff water.

SIMPLE THINGS YOU CAN DO TO PROTECT WATER QUALITY

- Redirect downspouts to vegetated areas.
- Select landscape plants that are well adapted to your site and have low water requirements.
- Mow your grass high and often so that clippings and their nutrients can be recycled.
- Water your lawn on an "as-needed" basis, rather than on a pre-set schedule.
- Adjust sprinklers to avoid watering paved areas.
- Treat specific weedy areas rather than resorting to general "weed and feed" mixtures.
- Use only the amount of fertilizer or compost that is recommended. More is NOT better.
- Keep fertilizers and pesticides off sidewalks and driveways.
- Wash off fertilizer application equipment on the lawn, not on the sidewalk or driveway.
- Maintain natural buffer areas where no chemicals are applied between your property and any stream, lake, or drainage way.

A well-managed landscape can be part of the solution instead of contributing to water quality problems.

SMALL CHANGES

ADD UP

COLORADO STATE UNIVERSITY
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More information on protecting water quality can be found
in the other Homeowner's Guides at **extension.colostate.edu.**
XCM-119, Household Water Conservation
XCM-220, Pesticide Use Around the Home and Garden
XCM-221, Alternative Pest Management for the Lawn and Garden
XCM-223, Protecting Water Quality and the Environment

Fertilizing Your Lawn and Garden - This publication was written by
R. Waskom, T. Bauder, and E. Wardle

Attachment G
2,4-D Environmental Regulatory Findings

2,4-D

GENERAL FACT SHEET

What is 2,4-D?

2,4-D is an herbicide that kills plants by changing the way certain cells grow. 2,4-D comes in several chemical forms, including salts, esters, and an acid form. The toxicity of 2,4-D depends on its form. The form also affects what will happen to 2,4-D in the environment and what impacts it may have, especially on fish. 2,4-D is used in many products to control weeds, and it is often mixed with other herbicides in these products.

2,4-D was first used in the United States in the 1940s. Agent Orange, an herbicide used during the Vietnam War, contained both 2,4-D and 2,4,5-T. Dioxin, a by-product of 2,4,5-T, led to the ban of Agent Orange.

What are some products that contain 2,4-D?

Products containing 2,4-D may be liquids, dusts, or granules. The liquid forms may be concentrated or ready-to-use. There are over a thousand products with 2,4-D in them that are sold in the United States.

Always follow label instructions and take steps to avoid exposure. If any exposures occur, be sure to follow the First Aid instructions on the product label carefully. For additional treatment advice, contact the Poison Control Center at 1-800-222-1222. If you wish to discuss a pesticide problem, please call 1-800-858-7378.

How does 2,4-D work?

2,4-D kills broadleaf weeds but not most grasses. 2,4-D kills plants by causing the cells in the tissues that carry water and nutrients to divide and grow without stopping. Herbicides that act this way are called auxin-type herbicides.

How might I be exposed to 2,4-D?

Products with 2,4-D may be used on farms, home lawns, roadsides, industrial areas, and pastures. You may be exposed if you are applying 2,4-D and you get it on your skin, breathe it in, or eat or smoke afterwards without washing your hands. You also may be exposed if you touch plants that are still wet with spray. You can limit exposure by following the label carefully if you are using products that contain 2,4-D. You can also stay away from grass or plants that have been treated until the leaves are dry.

NPIC General Fact Sheets are designed to provide scientific information to the general public. This document is intended to promote informed decision-making. Please refer to the Technical Fact Sheet for more information.

What are some signs and symptoms from a brief exposure to 2,4-D?

Pure 2,4-D is low in toxicity if eaten, inhaled, or if it contacts the skin, and some forms are low in toxicity to the eyes. However, the acid and salt forms of 2,4-D can cause severe eye irritation. People who drank products containing 2,4-D vomited, had diarrhea, headaches, and were confused or aggressive. Some people also had kidney failure and skeletal muscle damage. People who spilled 2,4-D on their skin developed skin irritation. Breathing 2,4-D vapors can cause coughing, a burning feeling in the airway, and dizziness.

Pets may be exposed to 2,4-D if they touch grass or other plants still wet from spraying and then groom their feet or fur, if they drink the pesticide, or possibly if they eat grass that has been treated with 2,4-D. Dogs may be more sensitive to 2,4-D than other animals. Dogs and cats that ate or drank products with 2,4-D in them developed vomiting, diarrhea, loss of appetite, lethargy, drooling, staggering, or convulsions. See the fact sheet on Pets and Pesticide Use for more information.

What happens to 2,4-D when it enters the body?

In humans, 2,4-D is not absorbed well through the skin or lungs, but it is absorbed into the body if swallowed. Sunscreen, insect repellents, and drinking alcohol may increase how much 2,4-D is absorbed through the skin. Once inside, 2,4-D moves throughout the body but does not build up in any tissues. The human body gets rid of most of the 2,4-D in the urine without changing it into anything else. More than 75% of the absorbed 2,4-D leaves the body in the first 4 days after exposure.

Is 2,4-D likely to contribute to the development of cancer?

Scientists have not found a clear link between 2,4-D and cancer in people. Because 2,4-D is often mixed with other herbicides, it is difficult to tell if 2,4-D or one of the other herbicides might be linked to cancer. Some studies have suggested that there may be links between non-Hodgkin's lymphoma and exposure to 2,4-D by itself, but other studies have not found any evidence of this.

In 2004, the EPA decided that 2,4-D could not be classified with regard to its ability to cause cancer because there was not enough data.

Has anyone studied non-cancer effects from long-term exposure to 2,4-D?

Animals fed high doses of 2,4-D for several weeks sometimes had fewer young or the young did not have normal skeletons. This only happened if the amount of 2,4-D fed to the mothers was enough to affect the mothers. 2,4-D has not been linked to health problems in human mothers or infants.

Are children more sensitive to 2,4-D than adults?

While children may be especially sensitive to pesticides compared to adults, there are currently no data to conclude that children have increased sensitivity specifically to 2,4-D.

What happens to 2,4-D in the environment?

2,4-D goes through different changes in the environment depending on its form. Most of the time, 2,4-D breaks down in soil so that half of the original amount is gone in 1-14 days. This breakdown time is called the "half-life" of the pesticide. One form of 2,4-D, the butoxyethyl ester, had a much longer half-life in aquatic sediment of 186 days.

2,4-D is broken down by bacteria in water and in soil. Water alone can also break down 2,4-D. 2,4-D has been found at low levels in shallow groundwater and streams in both rural and urban areas.

Can 2,4-D affect birds, fish, or other wildlife?

How 2,4-D affects animals and plants depends on the form of 2,4-D. Some of the ester forms of 2,4-D can be very toxic to fish and other aquatic life. The salt forms may be only slightly toxic to aquatic animals. Aquatic animals are more sensitive to 2,4-D as water temperature rises. 2,4-D may be moderately toxic to practically non-toxic to birds if they eat it. Eggs sprayed with 2,4-D still hatched and the chicks were normal. 2,4-D is practically non-toxic to honeybees. It is not expected to be a hazard to other beneficial insects.

Where can I get more information?

For more detailed information call the National Pesticide Information Center, Monday - Friday, between 8:00 AM and 12:00 PM Pacific Time (11:00 AM to 3:00 PM Eastern Time) at 1-800-858-7378 or visit us on the web at http://npic.orst.edu. NPIC provides objective, science-based answers to questions about pesticides.

Date Reviewed: March 2009

NPIC is a cooperative agreement between Oregon State University and the U.S. Environmental Protection Agency (U.S. EPA, cooperative agreement # X8-83458501). The information in this publication does not in any way replace or supercede the restrictions, precautions, directions, or other information on the pesticide label or any other regulatory requirements, nor does it necessarily reflect the position of the U.S. EPA.

Candidates Found Not to Meet the Criteria: 2,4-dichlorphenoxy acetic acid (2,4-D); 2,4-D n-butyl ester; 2,4-D isopropyl ester; 2,4-D isooctyl ester; propylene gylcol butyl ether ester (of 2,4-D); 2,4-D butoxyethanol ester; and 2,4-D dimethylamine salt

Jul 26, 2013

Candidates for Listing Via the Authoritative Bodies Mechanism Found Not to Meet the Formal Identification Criteria: 2,4-dichlorphenoxy acetic acid (2,4-D); 2,4-D n-butyl ester; 2,4-D isopropyl ester; 2,4-D isooctyl ester; propylene gylcol butyl ether ester (of 2,4-D); 2,4-D butoxyethanol ester; and 2,4-D dimethylamine salt

On November 18, 2005, the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA) issued a Notice of Intent to List *2,4-dichlorphenoxy acetic acid (2,4-D); 2,4-D n-butyl ester; 2,4-D isopropyl ester; 2,4-D isooctyl ester; propylene gylcol butyl ether ester (of 2,4-D); 2,4-D butoxyethanol ester; and 2,4-D dimethylamine salt* as known to the state to cause reproductive toxicity under the Safe Drinking Water and Toxic Enforcement Act of 1986[1] (Register 2005, No. 46-Z). This action was proposed under the authoritative bodies listing mechanism,[2] based on documents published by the U.S. Environmental Protection Agency (U.S. EPA) on *2,4-dichlorphenoxy acetic acid.* The documents are titled, "Drinking Water Criteria Document for 2,4-D" (U.S. EPA, 1988) and "Reregistration Eligibility Decision for 2,4-D" (U.S. EPA, 2005).

OEHHA has determined that there is insufficient evidence that the criteria in Title 27, California Code of Regulations section 25306(d) have been met. Therefore, OEHHA will not proceed at this time with the Proposition 65 listing process for *2,4-D salts and esters* as known to cause reproductive toxicity.

Chemical Reference

- 2,4-Dichlorophenoxyacetic Acid
- 2,4-D n-Butyl Ester
- 2,4-D Isopropyl Ester
- 2,4-D Isooctyl Ester
- Propylene Glycol Butyl Ether Ester (of 2,4-D)

- 2,4-D Butoxyethanol Ester
- 2,4-D Dimethylamine Salt

Related Notices

- Notice of Intent to List Chemicals: (2,4-dichlorphenoxy) acetic acid, 2,4-D n-butyl ester, 2,4-D isopropyl ester, 2,4-D isooctyl ester, Propylene gylcol butyl ether ester (of 2,4-D), 2,4-D butoxyethanol ester, 2,4-D dimethylamine salt *Nov 18, 2005*

Footnotes and References

References

US Environmental Protection Agency (US EPA, 1988). Drinking Water Criteria Document for 2,4-D. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment.
U.S. Environmental Protection Agency (U.S. EPA, 2005). Reregistration Eligibility Decision for 2,4-D. Office of Prevention, Pesticides and Toxic Substances, U.S. Environmental Protection Agency.

[1] Commonly known as Proposition 65, the Safe Drinking Water and Toxic Enforcement Act of 1986 is codified in Health and Safety Code section 25249.5 *et seq*.

[2] See Health and Safety Code section 25249.8(b) and Title 27, Cal. Code of Regs., section 25306.

2,4-D

The term 2,4-D is used here to refer to the free acid, 2,4-dichlorophenoxyacetic acid (CAS No. 94-75-7). Commercial 2,4-D products are marketed as the free acid, alkali and amine salts and ester formulations. 2,4-D itself is chemically stable, but its esters are rapidly hydrolysed to the free acid. 2,4-D is a systemic herbicide used for control of broad-leaved weeds, including aquatic weeds. 2,4-D is rapidly biodegraded in the environment. Residues of 2,4-D in food rarely exceed a few tens of micrograms per kilogram.

Guideline value	0.03 mg/l (30 μg/l)
Occurrence	Levels in water usually below 0.5 μg/l, although concentrations as high as 30 μg/l have been measured
ADI	0–0.01 mg/kg body weight for the sum of 2,4-D and its salts and esters, expressed as 2,4-D, on the basis of a NOAEL of 1 mg/kg body weight per day in a 1-year study of toxicity in dogs (for a variety of effects, including histopathological lesions in kidneys and liver) and a 2-year study of toxicity and carcinogenicity in rats (for renal lesions)
Limit of detection	0.1 μg/l by gas–liquid chromatography with electrolytic conductivity detection
Treatment performance	1 μg/l should be achievable using GAC
Guideline value derivation	
• allocation to water	10% of upper limit of ADI
• weight	60 kg adult
• consumption	2 litres/day
Additional comments	The guideline value applies to 2,4-D, as salts and esters of 2,4-D are rapidly hydrolysed to the free acid in water.
Assessment date	1998
Principal references	FAO/WHO (1997) *Pesticide residues in food—1996 evaluations* WHO (2003) *2,4-D in drinking-water*

Epidemiological studies have suggested an association between exposure to chlorophenoxy herbicides, including 2,4-D, and two forms of cancer in humans: soft tissue sarcomas and non-Hodgkin lymphoma. The results of these studies, however, are inconsistent; the associations found are weak, and conflicting conclusions have been reached by the investigators. Most of the studies did not provide information on exposure specifically to 2,4-D, and the risk was related to the general category of chlorophenoxy herbicides, a group that includes 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), which was potentially contaminated with dioxins. JMPR concluded that it was not possible to evaluate the carcinogenic potential of 2,4-D on the basis of the available epidemiological studies. JMPR also concluded that 2,4-D and its salts and esters are not genotoxic. The toxicity of the salts and esters of 2,4-D is comparable to that of the acid.