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Improved End-Of-Life of Plastic Mulches

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Summary

Mulching is a widely accepted practice in specialty crop production. Specialty crops significantly contribute to daily diets, farm revenue, job creation, agricultural diversification, and food security. Mulching optimizes soil microclimate, regulates temperature, conserves moisture, suppresses weeds, and prevents soil erosion, fostering favorable conditions for crop growth and higher yields. Moreover, mulching reduces herbicide use, enhances food safety, and improves overall crop quality, offering both economic and environmental benefits.

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Impact of mulching on specialty crops performance

- This factsheet aims to provide information about mulching and how mulches impact specialty crop yield and quality.
- Specialty crops are defined as a broad range of agricultural products, including fruits, vegetables, tree nuts, herbs, and spices. Ornamental and nursery crops, including floriculture, are also examples of specialty crops.
- Mulching is defined as a horticultural practice that involves covering the soil surface around plants with a layer of organic or inorganic material that serves multiple purposes such as weed suppression, soil moisture retention, temperature regulation, and overall enhancement of crop production.

Specialty crops — Definition and significance in agriculture

According to the United States Congress, specialty crops are “a broad range of agricultural products, including fruits, vegetables, tree nuts, dried fruits and vegetables, as well as ornamental and nursery crops, including floriculture” (7 U.S.C. 1621 note). Specialty crops play a crucial role in daily diets, as they are regularly consumed: vegetables often feature in lunch or dinner, fruits serve as snacks, and herbs and spices are used in various seasonings. Landscapes are also impacted through the cultivation of these crops. Therefore, specialty crops have an important and economically impactful role in agriculture and human nutrition. Specialty crops also share a commonality in that they refer to all crops except those that receive direct income support under Title I of the Agricultural Improvement Act of 2018, also known as the “Farm Bill”.

The cultivation of specialty crops in the United States is on the rise and gaining increased attention within the agricultural community, especially with the inclusion of provisions addressing specialty crop-related issues in the Food Conservation and Energy Act of 2008 (Harris et al., 2008). The 2018 Farm Bill continues this trend by expanding provisions related to specialty crops, placing a strong emphasis on research in this sector and promoting American specialty crops on the foreign markets (H.R.2 - 115th Congress, 2018).

Specialty crops are important to human nutrition as they are rich in essential vitamins, minerals, antioxidants, and dietary fiber. They contribute to a well-rounded, nutritious diet and are associated with improved health outcomes. The significance of diet in promoting human health and well-being has gained global recognition. According to Dietary Guidelines for Americans, a diet balanced around vegetables and fruits can help regulate high blood pressure, decrease the risk of heart disease and stroke, support eye health and digestive functions, and positively affect blood sugar and mental health (U.S. Department of Health and Human Service [HHS], 2020-2025).

Crop quality is of paramount importance in agriculture for both domestic and export markets. The quality of these products has a direct impact on consumer satisfaction, as higher-quality fruits and vegetables are more appealing in taste, texture, and appearance. Consequently, this may lead to increased consumer demand and competitive markets for growers. Additionally, crop quality affects the shelf life of products, reducing post-harvest losses and enhancing marketability. Specialty crop growers use an array of tools and practices to optimize the economics of crop quality and yield, with mulch being an example of one important tool.

Current and traditional mulch technologies

Mulching has been an important practice in horticultural settings since ancient times (Rakow, 1998). Mulching is the process of covering bare soil for its enrichment and insulation (Iqbal et al., 2020). Mulch materials are vast and include bark chips, straw, compost, green and animal manures, and other organic materials, along with various films. Mulches may also be "living" or terminated at certain growth stages, so the residue provides mulch functionality. The use of lithic mulch such as stones, volcanic ash, pebbles, and other rock materials can be traced back to 200 B.C., potentially even earlier (Lightfoot, 1994). Wood products, such as bark chips, shredded wood, and sawdust are common mulches that provide moisture retention and weed suppression when applied as a thick layer (3-6 inches). Compost products used as mulch, such as green manure and leaf cuttings, act as both fertilizers and mulch. This provides added carbon and macro- and micronutrients to soil, which contributes to plant and soil health (Kader et al., 2017). Film- or woven-type mulches, such as weed mats/landscape fabrics and non-biodegradable polyethylene (PE) and soil-biodegradable films (often abbreviated "BDMs"), provide ease in application for large scale production of specialty crops as they can be applied mechanically with a tractor and mulch layer. Paper-based mulch rolls are also available (e.g., WeedGuard) and can be laid by machine.

Dr. Emery Emmert is commonly referred to as the "Father of Plasticulture" since he was the scientist credited with pioneering the use of PE mulch within agricultural settings (Grubinger, 2004). Plastic was first used to replace the glass covers of greenhouses, which then transitioned later to a mulch product covering the soil. The implementation of PE mulch has been traced back to the 1950s, ranging from low to high-density PE. Much of the research accomplished before the 1960s evaluated the impact of black and clear films on crop performance (Lamont, 2005). The high efficiency and efficacy of PE mulch supported the exponential increase in PE mulch adoption and production over the century, including the use of green colored PE mulch in certain systems (Kasirajan and Ngouajio, 2012). Additionally, there are PE films with an incorporated aluminum layer designed to enhance reflectivity, serving as a deterrent to specific arthropod pests. This reduction in pest pressure may result in lower transmittance of insect-vectored viruses and other diseases. The use of PE mulch is allowed in organic agriculture in the United States, though their contribution to plastic waste generation and pollution makes their use controversial.

Soil-biodegradable mulch was developed as an environmentally friendly alternative to PE mulch and is designed to biodegrade in soil through the metabolism of native soil microorganisms (Corbin et al., 2013). BDM was introduced in the 1990s shortly after the German government advocated for the development of biodegradable thermoplastics with Novamont and Bayer BK being leaders in the production of compostable and biodegradable feedstocks. Feedstocks used to make BDM are typically a blend of biobased and synthetic plastics. Caution is advocated when using BDM, as many oxo-degradable mulches are falsely labeled as being biodegradable. Oxo-degradables form persistent, non-biodegradable microplastics. Furthermore, no commercially available BDM is allowed in organic agriculture in the United States (see "Ongoing research" on page 4).

Importance of mulching and its effect on yield and crop quality

Mulching is widely used for its horticultural and weed suppressive benefits that enhance crop yield and quality. The main horticultural benefit of mulching is optimization of the soil microclimate for the specific crop and/or climatic conditions under which the crop is grown. Mulch color is the primary variable that can be modified and influences how mulches augment the soil microclimate, particularly soil temperature. Color can be adjusted during the manufacturing process through the addition of colorants (e.g., pigments or dyes) that in turn influence how light is absorbed or reflected when it interacts with the mulch surface. Greater light absorption from black or dark-colored mulches leads to soil warming, while light-colored mulches reflect more light and have an overall cooling effect (Table 1).

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Mulches can also influence soil moisture by reducing evaporation from the soil surface, although in some cases overall crop water demand may be greater due to increased crop growth and transpiration (the natural process of water vapor exiting plant leaves). Mulches also function as a physical barrier that can reduce or eliminate weed seed germination, thus reducing or eliminating the need for herbicides and/or mechanical weeding. However, some weed species may still be able to puncture and penetrate through mulches [e.g., nutsedge (*Cyperus* spp.) and horsetail (*Equisetum* spp.)]. Weeds can also grow through planting holes. Therefore, pre-emergent herbicides and/or mechanical weeding may be beneficial depending on weed pressure and/or the species being managed. Mulches can eliminate edible crop tissue contact on the soil surface which reduces rot, enhances the cleanliness of the harvested tissue, and can promote food safety and overall crop quality.

Guide to mulch selection

Selecting the right mulch and installing it properly is essential for maximizing its benefits. As mentioned above, the color of plastic mulch affects soil temperature and weed suppression. Plastics are available in several colors, but black is most widely used, especially in temperate climates (Table 1). Additionally, red, blue, green and yellow mulches produce distinct radiation that reflects into the crop canopy. Research into colored mulches has shown inconsistent results, and they are not widely used in commercial production except for green mulches in strawberry production in California and white or white-on-black mulches in climates with high summer temperatures.

BDM, unlike PE mulch, is designed to be tilled after use and biodegrade in the soil. BDM can perform similar to PE mulch in warming the soil and managing weeds, but initially costs up to 2 times more while reducing or eliminating the cost of mulch removal and disposal at the end of the season. Economic considerations should therefore factor in initial costs as well as the potential cost savings which will vary regionally based on labor and disposal costs (see “Economic and environmental benefits of mulching” on page 4). Before purchasing, users should verify that the BDM being considered meets standards of biodegradation. Some relevant standards include EN 17033, ASTM D6400, ASTM D5338, and TUV-Austria OK Biodegradable Soil.

Table 1. Plastic mulch film characteristics, including color, soil temperature regulation (warming or cooling effect), weed suppression, price, and properties (modified from Lamont, 2017). Information applies to both conventional and soil-biodegradable plastic mulches.

Mulch Color	Soil Temp.	Weed Suppression	Price	Properties
Black	+3 - 5 °F	Good	$	• Most widely used • Absorbs incoming solar radiation, raising soil temperatures for improved crop growth • Effective at suppressing weed growth due to the absence of light penetration • Ideal for use in early crop stages when soil warmth is needed • Helps conserve soil moisture by reducing evaporation • May overheat plant roots if used in hot conditions and/or if the crop is heat sensitive
Clear	+8 - 14 °F	Poor	$	• Acts as a mini greenhouse, promoting plant growth • Reduces evaporation, conserving water • Allows light penetration, necessitating weed control • Exposure to sunlight can cause tearing
White-on-Black	-2 °F	Good	$+	• Reflects sunlight, therefore keeps soil cooler than black plastic mulch • Ideal for late summer or fall crops in climates where cooling is important • Prevents root overheating and reduces the risk of plants overheating due to excess heat absorption
Silver/ Metallic	-2 °F	Good	$$	• Disorients and discourages certain pests like aphids and thrips • Particularly useful for crops susceptible to aphids and thrips like onion and pepper • Reflects light onto the canopy, aiding in early fruit development • Soil remains several degrees cooler than under black plastic
Infrared-Transmitting	+4 - 6 °F	Good	$$	• Absorbs specific-colored wavelengths while efficiently transmitting heat (infrared) to the soil, heating it like clear mulches but with fewer weed germination problems

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Laying plastic mulch

Mechanical plastic mulch layers can apply mulch on raised or flat beds. For raised beds, machine layers often can simultaneously form raised beds that are up to 10 inches high and lay drip tape and plastic mulch in one pass. Regardless of whether a raised- or flat-bed mulch layer is used, the mulch must be fed through the roller bars and pulled out so that it passes under the guide wheels. BDM is more delicate than PE mulch, so it must be handled a little more gently. If it is damaged while laying, deterioration may be accelerated. It should not be applied as tightly as PE mulch because it continues to tighten as the weather warms. If it is installed too tightly at first, BDM will split as it tightens, and this will allow weeds to grow. Once machine settings have been adjusted, the speed of laying BDM is equivalent to PE mulch. More information, videos, and additional instructions visit the **WSU Mulch Technologies** webpage (https://smallfruits.wsu.edu/plastic-mulches/application-management/).

Economic and environmental benefits of mulching

The use of PE mulch has been perpetuated throughout the decades due to its low cost and efficacy. Standard PE mulch costs between $25 and $65 per 1,000 ft, making it attractive to growers. BDM, in contrast, ranges from $55 - $190 per 1,000 ft of film, and paper-based mulch costs around $160 - $390 per 1,000 ft, though paper films are available in smaller rolls, comparatively. Shorter roll length increases the overall cost of application in machine laying scenarios, as more stops are needed to replace the roll as it's laid out in the field (Ghimire and Miles, 2016). Using mulch reduces labor costs for pest and weed management, along with saving up to 25% more water, contributing to economic incentives (Marí et al., 2019). Cost can be reduced greatly when using biodegradable options such as BDM and paper mulch, as the expense of removal labor and machinery are eliminated. Because these products allow for more controlled crop growth, it can also influence harvest time. It has been shown that using mulch can lead to earlier harvest time due to plant growth and resource efficiency (Steinmetz et al., 2016).

There are many variables to consider when searching for an optimal mulch for a particular specialty crop system, including environmental benefits. Given mulches are used to influence the microclimate of land dedicated to specialty crop production, there is the potential for larger impacts on the surrounding landscape. Throughout the United States, the loss of important topsoil in agricultural land from wind and water erosion is a concern. Mulching helps to alleviate erosion challenges by covering the soil and acting as a barrier to wind and moving water that can remove particles of soil on the surface of the Earth. For example, living mulches supply roots and their exudates that hold onto surface soil, facilitate soil aggregation, and can enrich soil while functioning as a surface barrier. Laying out straw, wood chips, compost, and manure are common tactics to reduce the impact of wind and water erosion through its barrier properties and aids in soil moisture retention. Plastic mulch films also protect bare ground, acting as a barrier to wind and water erosion as well as evaporation from the soil surface, keeping moisture trapped and reducing runoff. Reducing erosion helps to preserve soil health by maintaining or improving fertility, as well as promoting aggregate stability and microbial activity. Supporting soil health greatly benefits specialty crop production along with the surrounding environment. Good soil health assists in sustaining important ecosystem services, like the ability of soil to filter water and air, and sequester carbon; therefore, nurturing the health of the larger ecosystem.

Keeping soil covered also assists in reducing compaction. Compaction is the hardening of the soil from foot traffic, machinery, and rain drops that can in turn create physical barriers stopping plants from growing robust root systems and accessing nutrients locked beneath the soil. Utilizing mulches also reduces pesticide and herbicide applications because mulching reduces weed growth by blocking sunlight, resulting in the need to apply less or no herbicides throughout the season. Mulches are included in Integrated Pest Management (IPM) plans as an important variable to reduce the impact of certain plant pathogens, as they support the growth of healthy and vigorous crops with greater defense capabilities (Romeh, 2018). Therefore, fewer pesticides may be required due to the cultural benefits of mulches. Overall, mulches may have a positive impact on the surrounding ecosystem if they lead to reduced pesticide usage and runoff, which may otherwise cause indirect harm to nontarget organisms. Mulching can therefore have a role in supporting healthy and productive soil and agro-ecosystems.

Ongoing research

Research into new and existing mulch technologies is ongoing at universities and private entities worldwide. Many multidisciplinary, multi-institution projects have explored various commercially available BDMs in multiple specialty crop systems and their impact on crop production, produce quality, soil health, and economics. Resultant findings enables specialty crop advisors, farmers, and policy makers make informed decisions regarding BDM use.

Recycling of PE mulch is also being explored given some farmers may be unable to switch to BDM. One of the biggest barriers to mulch recycling is contamination by soil and plant debris, which adds weight and transportation costs when transporting used mulch and requires de-contamination. Soil particles on uncleaned mulch could damage recycling equipment and contribute to inefficiencies, which can make mulch film recycling financially unviable. Improving mulch removal from the

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field so that it is efficient and minimizes soil contamination is essential to improving both mechanical and chemical recycling outcomes. Novel PE mulch technologies may also enhance recycling outcomes, particularly if less PE material is used, it's stronger and leads to less fragmentation during removal, and/or it has reduced soil contaminant load. New products on the market claim to meet this aim and may be a good option. Other mulch technologies that claim biodegradability are on the market, but standards or certifications of compostability and in-soil biodegradability should be assessed as many products are erroneously sold as biodegradable (Ghimire et al., 2018). Products advertised as biodegradable or compostable but not meeting standards or certifications are not recommended.

In addition to promising new mulch films for conventional farmers, research is being done to create more biodegradable options for certified organic farmers. Currently, there is no commercially available plastic BDM for organic production in the United States. There are several other requirements an organically allowable BDM film would have to pass through. For example, NOP rule § 205.3 states that an organic BDM must be biobased and must adhere to one of many compostability metrics (i.e., ASTM D6400, ASTM D6868, EN 13432, EN 14995, or ISO 17088; NOP, 2022). BDM must also degrade at least 90% based on ISO 17556 or ASTM D5988 specifications (NOP, 2022).

Currently, there are two nationally recognized research initiatives dedicated to the development of an organically certified mulching system tailored for use by organic farmers. One of them is evaluating the use of lignocellulosic film. Lignocellulose is the world's most common waste feedstock for biopolymer production and is 100% biobased, making it an appealing feedstock for certifiably organic mulch films (Chandra and Madakka, 2019). Lignocellulosic films can take the form of traditional plastic mulches that can be laid onto beds, meaning farmers could easily transition to this material without buying new equipment. While promising, lignocellulosic films are untested in specialty crop agriculture, so their efficacy at weed suppression and other crop horticultural properties are unknown.

Another potential option for organically certifiable BDM is hydromulch. Hydromulch ingredients include cellulosic fibers, water, and a tackifier (i.e., "glue"). This work is being conducted by another project at the national level with hydromulch formulations being paper based and under testing. Paper was selected as a feedstock because of its abundance in recycling streams, low cost, and due to its biobased nature. Current hydromulch research is focused on the efficacy of hydromulch formulations at suppressing weeds and optimizing growth conditions across various specialty crops and field conditions. These crops include strawberry, blueberry, broccoli, carrot, and onion. Hydromulches have shown promising results, however, its use also presents significant logistical hurdles to adoption. There will be a need for farmers to purchase or build specialized equipment to blend and apply hydromulch. Another point to consider is an affordable supply chain of recycled paper devoid of plastics and other contaminants (e.g., PFAS) common to paper production, a criteria for large scale production. Learn more about the **MulcH20 research initiative** (https://eorganic.info/hydromulch).

Conclusions

Mulching in specialty crop production is essential. Specialty crops are integral to agriculture, human nutrition, and the global economy. They contribute significantly to farm revenue, create jobs, and play a pivotal role in human nutrition. Furthermore, specialty crops enhance agricultural diversification, improve food security, and contribute to international trade. To meet the demand for high-quality specialty crops, mulching has emerged as a valuable horticultural practice. Mulching impacts crop yield and quality in several ways: optimization of soil and sometimes canopy microclimate, regulation of soil temperature, conservation of soil moisture, reduction of weed competition, and mitigation of soil erosion. These factors collectively create a more favorable environment for crop growth, leading to higher yields and economic benefits. The physical barriers provided by mulch can also decrease the use of herbicides and promote food safety and overall crop quality. Mulching not only benefits crop yield and quality but also has economic and environmental advantages.

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Additional Information

Visit the **WSU Mulch Technologies project** website (smallfruits.wsu.edu/plastic-mulches) for more information about BDMs in fruit and vegetable crop production systems. You can also find us on social media!

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