Sustainable Mulch MANAGEMENT

Plastic Mulches in Horticulture Production

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Improved End-Of-Life of Plastic Mulches

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In This Issue...

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Mulch Matters Podcast

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Mention of trade names does not indicate endorsement or promotion.

Cover photo *Nayab Gull*

National Institute of Food and Agriculture
U.S. DEPARTMENT OF AGRICULTURE

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Research Update in the Golden State—Mulch Trial in California Strawberry

Lisa DeVetter, Associate Professor, Washington State University

Winter is a good time to think about sunshine, warmth, and coastal breezes—especially if you reside in the overcast Pacific Northwest like I do. That's why for this newsletter article I thought I would highlight some of our collaborative field trials in California with Naturipe, PolyExpert, and CNG as well as the California Marine Sanctuary Foundation, University of California Extension, and Cal Poly.

Let's start at the beginning. We've been doing soil-biodegradable mulch (BDMs) trials in California strawberry systems since 2020. Driving down from Washington to central California for field trials during the height of the pandemic was sure memorable—but that's another story. Long story short—we trialed black BDMs and performance was comparable to the grower-standard totally impermeable film (TIF) control. However, we kept getting the question from growers and members of the strawberry industry—can we get green BDM? Strawberry growers in central California preferred green mulch primarily due to its ability to slightly elevate soil temperatures, but not as greatly as black plastic mulch. The green color was also mentioned by some to look more "environmentally friendly."

Growers asked and we listened. In October 2022 we applied green BDM made with Mater-Bi feedstock alongside several other mulch treatments (Table 1) in a randomized complete block design experiment with our grower collaborators at Naturipe in Prunedale, California. In total, we experimented with six mulch treatments applied to 80 ft long plots (108 plants/plot) replicated four times using 'Monterey' strawberry.

In addition to green BDM, we continued to evaluate black BDM made with different feedstocks and a new product called Solar Shrink. Solar Shrink is made from non-biodegradable polyethylene, but it's engineered to have improved recycling outcomes

Table 1. Mulch treatments used in a 'Monterey' strawberry field trial in Prunedale, CA. Mulch treatments were applied Oct. 27, 2022, and bare-root plants were planted Nov. 1, 2022.

Name	Color	Thickness (mil)	Feedstock	Abbr.
Ecovio® by BASF, *soil-biodegradable*	Black	1.1	PLA + PBAT	Eco_BDM
Mater-Bi by Novamont (Bio360), *soil-biodegradable*	Black	1.1	Starch based, PBAT copolyester	BioB_BDM
Mater-Bi by Novamont (Bio360), *soil-biodegradable*	Green	1.3	Starch based, PBAT copolyester	BioG_BDM
Solar Shrink, 66-inch, *recyclable*	Black	NA	Polyethylene	Solar1
Solar Shrink, 72-inch, *recyclable*	Black	NA	Polyethylene	Solar2
Standard TIF, *control*	Green	~1.3	Polyethylene	Control

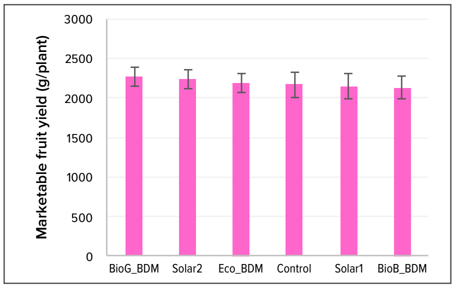

Figure 1. Cumulative marketable fruit yield of 'Monterey' strawberry grown with different mulch treatments (see Table 1) in Prunedale, CA, 2022-2023.

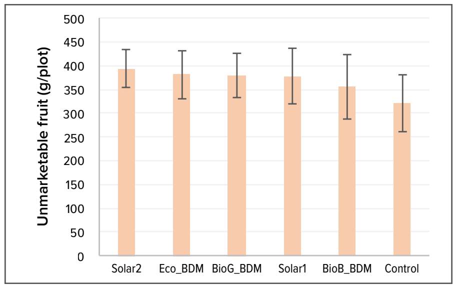

Figure 2. Cumulative unmarketable fruit yield of 'Monterey' strawberry grown with different mulch treatments (see Table 1) in Prunedale, CA, 2022-2023.

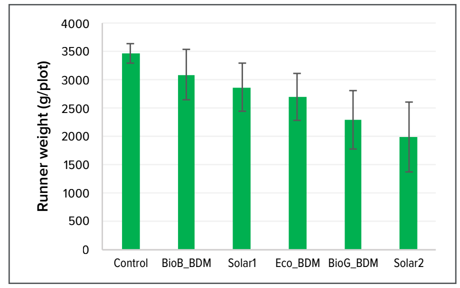

Figure 3. Cumulative runner weight of 'Monterey' strawberry grown with different mulch treatments (see Table 1) in Prunedale, CA, 2022-2023. Data are from two replicates.

due to less soil contamination. Furthermore, it's advertised as being thinner so less overall PE mulch would be used. It's an attractive option for farming operations that cannot use BDMs, such as certified organic growers, and increases the "tools in the toolbox" for farmers looking to reduce their plastic mulch waste.

What did we learn? When it came to yield, cumulative marketable and unmarketable fruit yields were statistically the same across all treatments (Figures 1 and 2, respectively). This means all mulch treatments maintained yield—quite a promising result and consistent with other trials. Furthermore, there were no differences in fruit size nor timing of fruit production (data not shown).

We did see differences in runner production, and it was greatest in the TIF control and lowest in the Solar Shrink (72-inch wide) treatment (Figure 3). If you are new to strawberry, runners are above-ground stems that contribute to the spreading of the plant. In commercial strawberry production in California and elsewhere, runners are not good as they compete with the fruit-producing mother plant for limited resources. Thus, growers remove runners and having fewer runners to remove is a positive when thinking about labor management and promoting fruit production. We suspect runner production was greatest in the TIF control due to soil temperature promoting more vigor, but this is an area of potential future study.

Soil temperature was also measured at a 2-inch depth (Figure 4). Unfortunately, we can't comment too much on the green BDM treatment as the logger malfunctioned. But overall, we observed soil temperatures were higher under the black BDM made with Mater-Bi feedstock through April 2023, then tended to be higher under the TIF control for the rest of the season. In contrast, soil temperature tended to be lower under the Solar Shrink treatments.

What does this tell us to date? For one, none of our mulch treatments had a statistically significant impact on yield or fruit size. Another way to look at this is that these new mulch treatments, regardless of color or feedstock, performed the same as the grower standard TIF control when it comes to yield. However, there are some more details to consider. We did observe the green BDM deteriorated faster than the other treatments. This may lead to greater weed pressure and weed management costs, so this will need to be considered closely in future studies.

The increased deterioration observed with the green BDM was expected, as well. The green BDM lacks the additive carbon black, which acts as a UV stabilizer. Without carbon black, the polymer that comprises a BDM starts to break down when exposed to UV radiation (i.e., sunlight).

More research is on the horizon. We plan to continue to trial green BDM along with other BDM treatments. One article in this newsletter authored by PhD student Nayab Gull will provide an update on trials in Washington. Yield, fruit quality, weed suppression, mulch intactness, and in-soil degradation will continue to be monitored in diverse locations including California, Washington, Florida, and Nebraska. Our team will also continue to investigate Solar Shrink given the promise it holds for operations that currently or will engage in recycling in the future. Either way, all of the mulches showed promise in commercial systems and contribute to building our confidence in them for commercial applications.

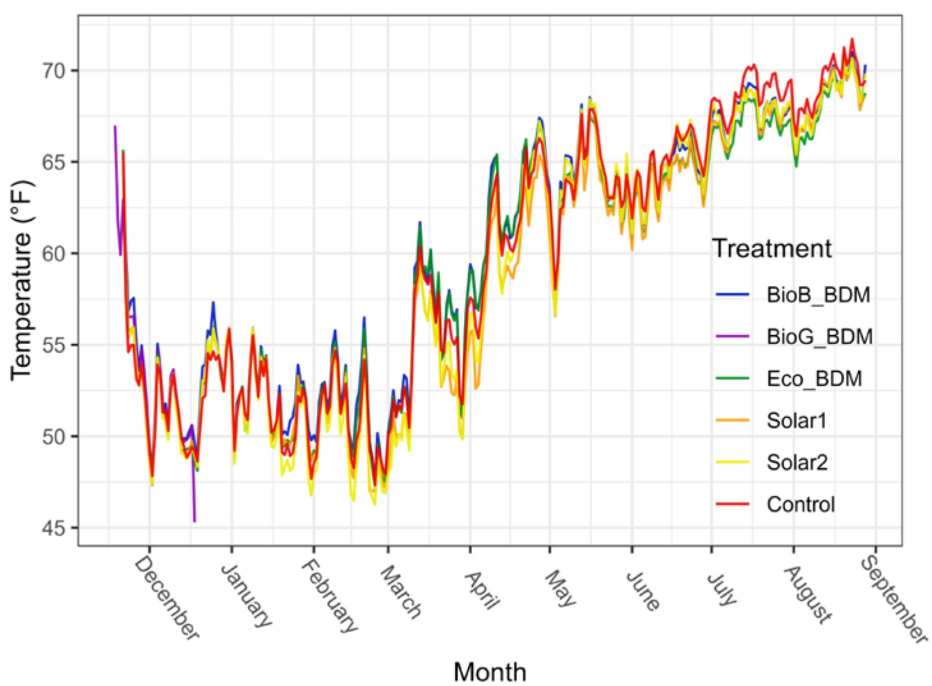

Figure 4. Daily average soil temperature at a 2-inch depth in 'Monterey' strawberry plots grown with different mulch treatments (see Table 1) in Prunedale, CA, 2022-2023. Data are from one replicate.

Notes from the Field

First Look at Biodegradable Mulch Trial in Washington

Nayab Gull, PhD Student, Washington State University (co-advised by Deirdre Griffin LaHue and Lisa Wasko DeVetter)

In agriculture, traditional plastic mulch film made from non-biodegradable polyethylene (i.e., "PE mulch") has long been favored for its role in increasing yields and profitability, achieved through weed control, temperature regulation, and moisture retention. However, the continuous use of PE mulch results in the accumulation of residual plastic films and their fragmentation into microplastics, causing irreversible soil pollution and global environmental concerns. To address these challenges, soil-biodegradable mulches (BDMs) have emerged as an eco-friendly alternative.

BDMs can offer the same advantages for specialty crop production as PE mulches with an added environmental benefit: natural biodegradation when incorporated or tilled into the soil. This not only preserves the horticultural benefits of PE mulch but also alleviates plastic waste accumulation and mitigates the environmental impact of agriculture. Encouraging the broader adoption of BDMs requires targeted research that addresses growers' concerns and utilizes economically significant crops, such as strawberry. The $2.5 billion strawberry industry in the United States provides a great example as the cultivation of this crop depends on PE mulch. However, strawberry growers are concerned about the resilience, durability, and economic viability of BDMs. On the bright side, growers are eager to learn more about BDMs and their potential for widespread commercial integration.

In 2023, Washington State University (WSU) initiated a two-year field trial using commercially available BDMs and is comparing them to conventional PE mulch. I know this because I am the graduate student overseeing this project with my supervisors. Specifically, we are evaluating mulch technologies in day-neutral strawberry production systems in northwest Washington. Our mulch treatments include black and green BDMs made with two different biodegradable feedstocks, a non-biodegradable reflective metalized mulch, and our traditional black PE mulch serving as an experimental control. The goal of this research is to evaluate mulch performance, weed suppression, crop productivity and quality, soil health, and economic impacts. Similar experiments are underway with research collaborators in California, Florida, and Nebraska so we can understand the performance of BDMs across these diverse production systems.

Our first-year preliminary results brought forth some intriguing results. The black BDM made with the Mater-Bi feedstock (starch-based, PBAT co-polyester) performed as effectively as the PE mulch control, delivering comparable yield, and showing impressive durability until the season's end. What's more, the black BDMs were a weed-free wonder, providing weed suppression equivalent to our PE mulch control.

It was also interesting to see the green BDMs had a higher rate of deterioration compared to PE mulch and our black BDMs. This was especially the case for the green BDM made with ecovio® biodegradable feedstock, which along with the no-mulch control generated the lowest yields. The higher rate of deterioration in green BDM treatments was due to the lack of carbon black, which acts as a UV stabilizer and prevents polymer breakdown when exposed to UV light.

However, the real twist was that the green BDM made with Mater-Bi feedstock overall resulted in nearly identical yield and weed count as the PE mulch control. This challenges the traditional belief that mulch durability is the sole indicator of success. It's a compelling case for considering alternative mulches that can deliver comparable results in crop yield and weed suppression with minimal environmental impact. Furthermore, this increased deterioration may increase the rate of in-soil biodegradation—an added bonus for growers that want to see rapid breakdown of BDMs in fields they own or lease.

Surprisingly, metalized mulch consisting of PE with a thin coating of aluminum presented a good fit for weed suppression while maintaining fruit yield. There is also potential for reduced pest pressure from the metalized mulch, and our team is exploring how pest dynamics were impacted by our mulch treatments. Farmers and researchers need to explore regionally and environmentally influenced factors like planting density, crop choice, and climate for comprehensive assessment of mulch behavior. This requires a nuanced evaluation of mulch suitability with regards to specific situations and for certain crop species.

The initial research conducted at WSU is a significant step towards understanding the potential of BDMs, particularly in the context of high-value crops like strawberries. These findings can open up new avenues for climate responsible farming practices, offering a ray of hope for farmers seeking to embrace greener alternatives. As we move forward, it's important to continue exploring these eco-friendly alternatives, consider alternative end-of-life disposal methods for non-biodegradable mulch, conduct further research that addresses industry's questions, and share knowledge within the agricultural community to foster balanced cropping systems.

ACKNOWLEDGEMENT

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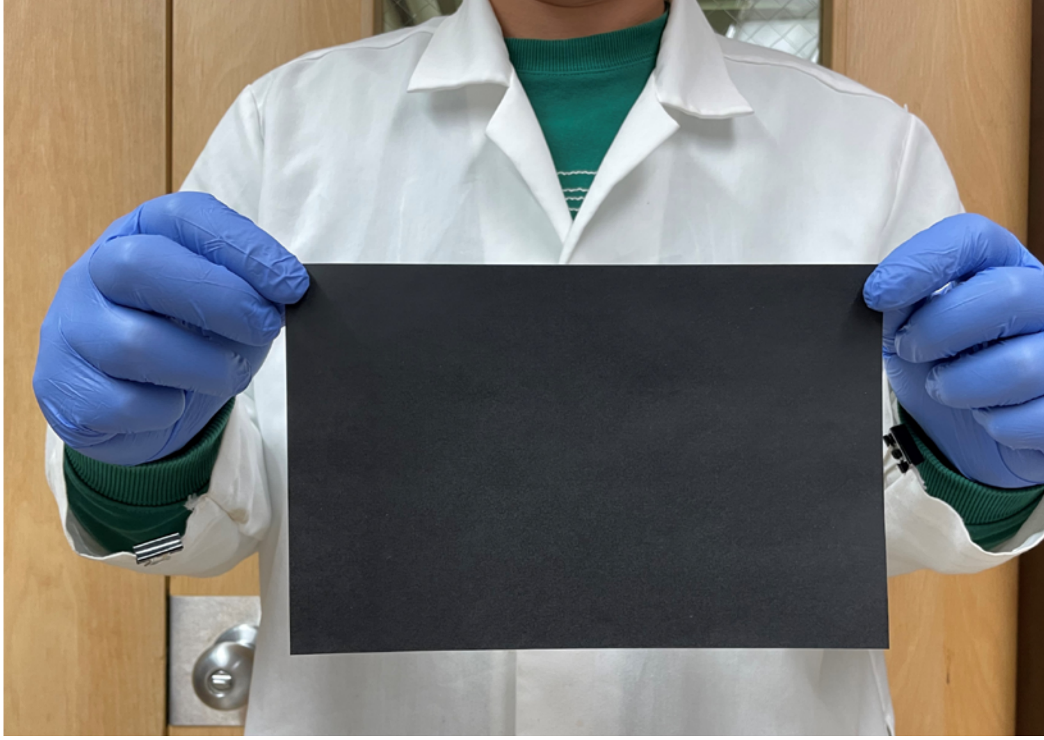

A researcher holds a sheet of lignocellulosic film. Image provided by Haishun Du, PhD Research Associate at University of Wisconsin-Madison.

What is Lignocellulosic Film?

Aidan Williams, MS Student, Washington State University (advised by Lisa Wasko DeVetter)

Lignocellulosic film (LCF) is a biobased, biodegradable mulch created as an environmentally friendly alternative to non-biodegradable polyethylene (PE) mulch for use in horticultural systems. Modern horticultural systems are reliant on PE mulch in both conventional and organic production, as its efficacy at weed suppression and promoting crop growth combined with its relatively low cost is attractive to growers and has been incorporated into U.S. farming systems since the 1950s. Unfortunately, PE mulch contributes to the 1 billion pounds of agricultural plastic used each year in the U.S. (DeVetter et al., 2020). Removal and disposal of PE mulch is costly, and recycling is currently very limited in availability, leaving landfills as the only option for many growers. Unfortunately, these expenses have led to stockpiling, burning, and in-field burial of PE films at the end of the growing season, contributing to the potential for drastic environmental harm. Even when done correctly, it is difficult to remove all of the pieces of PE mulch from the field, as rips and tears lead to fragments being left behind and eventually getting tilled into the soil. These remnants can pollute terrestrial and aquatic ecosystems and contribute to microplastic pollution.

An alternative to PE mulch is soil-biodegradable mulch (BDM), which is typically made from a blend of biobased and synthetic feedstocks. Most BDMs are not allowed in organic systems, as organic certification currently requires 100% biobased content determined using ASTM D6866, meaning organic growers lack access to BDMs. PE mulch is allowed in organic systems as long as it's completely removed (National Organics Program sec. 205.601 and 205.206, 2023) but its contribution to plastic pollution and microplastic persistence in our ecosystems make it controversial to sustainability goals. Because LCF is made using only biobased ingredients, it has the potential to supply a sustainable alternative for organic growers.

LCF is developed using low-cost, abundant, and renewable woody biomass, such as poplar wood, sawdust, or forest residues at the University of Wisconsin-Madison. It is created using an environmentally friendly molten salt hydrate (MSH) solution, which is a concentrated aqueous salt solvent that is used to dissolve and disperse the woody biomass through a facile dissolution and regeneration process, so that it can be cast into a lignocellulosic film. MSH is made of inorganic salt, such as LiBr or $CaBr_2$, that can be easily recycled and reused.

By itself, lignocellulose is plant biomass, consisting of lignin, cellulose, and hemicellulose, which are naturally found in the cell walls of plants. Lignin is a natural aromatic polymer that slows down degradation by using UV blocking traits, along with hydrophobic and antimicrobial properties to help it maintain its structure. Cellulose is a polysaccharide created by a linear chain of thousands of beta linked glucose units. Cellulose is considered the most abundant natural polymer available, contributing to its renewability. Hemicellulose is also a polysaccharide; it is made up of different sugars, such as xylose and mannose.

LCF is currently not commercially available to growers but is under development and investigation. The performance and functionality of LCF will be tested through greenhouse and in-field trials starting in 2024. It is hypothesized that its properties should make it comparable to soil-biodegradable and PE mulches, thus providing an organic mulch alternative. Collaboration with Washington State University, the University of Wisconsin-Madison, University of Maryland, and Yale will help to further these studies.

The ingredients of LCF should be able to meet the criteria for organic production, including the requirement of 90% degradation within two years. LCF, like other BDMs, is made to be tilled into the soil at the end of the growing season, where it is left to decompose through the action of native soil microorganisms. This eliminates the cost of end-of-season labor for removal as well as transportation and tipping fees that growers using PE mulch incur. LCF also cuts the environmental impact of agricultural plastic pollution. The overall goal of LCF is to provide a biobased, fully biodegradable replacement to PE and petroleum-derived mulches, and to fill the need for functional, soil-biodegradable mulches in organic horticultural systems.

ACKNOWLEDGEMENT

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The process of making lignocellulosic film from raw wood chips. Images provided by Haishun Du, PhD Research Associate at University of Wisconsin-Madison.

Industry Perspective

The Ag Plastic Dilemma

By Michael W. Vincent, OPT USA, Inc.

Micro-plastics have been found in every corner of the environment. Volcanic activity off the coast of South America has revealed a new "epoch" as molten lava containing plastics is spewed from the earth. In defiance, the ocean mist has been found to contain micro-plastics. In Missouri a cave system closed for more than 30 years contains micro-plastics and scientists have found micro-plastics in the clouds surrounding the peak of Mount Fuji.

From ingestion of a credit-card-sized volume of plastic per week to inhaling microfibers from our clothes, clearly the negatives outweigh the positives when we are talking about plastics.

Not so fast! Plastics are not evil! It is our irresponsible use and disposal that is the problem.

Aside from the obvious conveniences that plastics afford us on a daily basis, take a look around you and remove everything that contains plastics for a feel of the impact. There are enormous benefits that the average person does not think about when they demand the elimination of plastics.

The HealthCare Industry would be completely reformed without plastics. I am not speaking in a good way. Imagine the inability to provide even flexible tubing for an IV drip. Now take that to the invasive procedures that require flexibility to repair veins and other vital organs.

Imagine the weight of your groceries as you lug them from the car to the kitchen. Now, take that thought and apply it to global transport of food and medicine. We aren't even talking about packaging production yet and the CO_2 emissions are skyrocketing.

How do I figure? The weight difference alone caused by moving from plastic packaging to other materials reduces the quantity that can be shipped via air freight or over the road by trailer or ocean container. This results in more shipments and drastically increases the energy consumed. The efficiencies of those supply chains would also be negatively impacted, creating shortages and delays in deliverables.

An additional bit of data that needs to be considered when evaluating the evils of plastics would be the impact of the alternative. From the University of Michigan to Anthropocene Magazine you will find that a reusable is not always better. Often the energy and resources consumed to create the alternative has a far worse environmental impact. A reusable bag has been found to only become net positive after approximately 100 uses. Reusable water bottles are a bit better hitting net positive after about 20 uses.

Agriculture is no different. Let's take polymulch or plastic mulch for an example. The benefits are great when considering the use of plastic films in farming. Growers can expect 30% better yields with plastic mulch than without and that alone is an impressive figure. If you add in the reduction of erosion, water conservation, and reduced pesticides you start to have a rather compelling argument to continue and increase the use of plastics in food production.

With all the obvious and not so obvious benefits we already enjoy from the use of plastics and, given the negative impacts of digressing to the world prior to the polymer age, should we not be looking for solutions that create circularity? It seems that solving the gap between end-of-life and new life is where our efforts would be focused.

At OPT USA, Inc. we are working on Micro Recycling Pods (MRPs) that are mobile units able to process plastics on site or at source. Our technology allows plastics to go from scrap or waste directly back to manufacturing. Clean ready for production PCR or PIR direct from source.

These machines are capable of cleaning and fully processing agricultural plastics into production-ready pellets. Improved volume to weight metrics, reduced shipping distances, improved recycling efficiencies, and elimination of disposal costs for farming.

Ocean Plastic Technologies

OPT USA, Inc.
It's what we do.

Questions or comments?
https://optusa.earth/contact or **michael@opt.earth**

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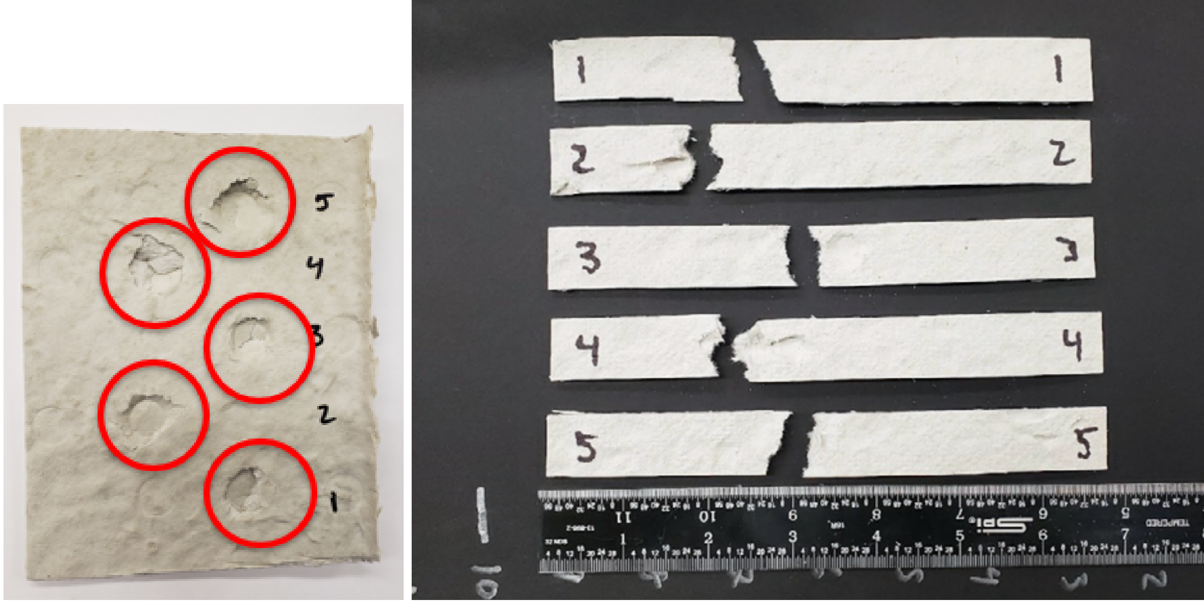

Samples of hydromulches that have been tested for puncture resistence (left) and tensile strength (right).

Some fundamental properties to consider for organic hydromulch development

Dilpreet S. Bajwa, Professor, Montana State University
Co-Authors: Andrew Durado, Greta Gramig, Sharon Weyers, Lisa Wasko DeVetter, Alice K. Formiga, and Suzette Galinato

Mulch has emerged as an effective alternative to applying herbicides in organic farming. As this readership likely knows, mulch helps to suppress weeds, reduce soil-water evaporation rate, and control soil temperature. In fact, mulch can increase yields by up to 100-200% by regulating soil temperature and suppressing the growth of weeds. The widely used low-density polyethylene (LDPE) is not commonly recycled at the end of the crop season because it is dirty, weak, and tears. Therefore, LDPE is often landfilled, burned, or buried, both harmful to the surrounding ecosystem. Studies have also shown that even after removal traces of LDPE fragments remain in the soil, move to nearby water sources, and may even be ingested by humans.

To overcome this issue, many studies have been done to create a cellulose-based product that is biodegradable but still performs similarly to LDPE. One possible solution is a biodegradable cellulosic-based liquid slurry known as "hydromulch". Biodegradable hydromulch is typically composed of fibrous cellulosic materials such as recycled paper pulp, cotton, or straw, mixed with a small amount of tackifier to help the fibers adhere to one another and soil. Tackifiers in essence act as the "glue" that bind fibers together and those evaluated to date include xanthan, low and high amylose compounds, psyllium, lignin, camelina seed meal, lesquerella seed meal, guar, pectin, methyl cellulose, and waxy starch. Typically, dry ingredients are mixed with water, allowing the hydromulch to be sprayed onto the soil and once dry, leaving a hardened mulch layer. Ideally, the hydromulch will break down and decompose into the soil at the end of the growing season through the action of native soil microorganisms. Note for use in certified organic agriculture, all ingredients must be approved for organic use and practitioners should always check with their certifiers.

Understanding material properties and characteristics is fundamental to designing and developing high-performance, safe, cost-effective biodegradable hydromulch formulations. The physical properties include density, porosity, soil adhesion, rain fastness, carbon to nitrogen ratio (C:N ratio), and biodegradability. The density helps to regulate the hydromulch film thickness, ground cover, and application rate. Porosity controls the water evaporation rate from the soil and helps to buffer the soil temperature from large fluctuations and adhesion ensures the bonding to soil particles and their longevity. Low porosity and high soil adhesion are favored.

Rain-fastness measures the amount of material washed off or lost during a rain event; a low mass loss is desirable. As the mulch materials degrade, they may improve soil fertility, measured by the C:N ratio. Highly biodegradable materials are preferred that add to the soil fertility. The two mechanical properties that dictate the performance of hydromulch are tensile strength and puncture resistance. Both are co-related as they measure the overall material strength. High tensile and puncture resistance are associated with improved tear strength and ability to suppress weed growth. Testing these properties in a controlled laboratory environment before any field trials is beneficial and this work is ongoing as hydromulch research advances.

Learn more about our project at: **https://eorganic.info/hydromulch**

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Recent Publications

RESEARCH

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Upcoming Events

THE 7TH AGRICULTURAL PLASTICS RECYCLING CONFERENCE & TRADE SHOW

Dates: August 14-16, 2024

Location: The Dana on Mission Bay
San Diego, California

More Information:
https://agplasticconference.com/

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