Sustainable Mulch MANAGEMENT

Plastic Mulches in Horticulture Production

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Improved End-Of-Life of Plastic Mulches

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California State University Chico
UF University of Florida
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PDO Technologies
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In This Issue...

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NEWSLETTER COMMITTEE

Lisa DeVetter, head editor
lisa.devetter@wsu.edu
360-848-6124

Carol Miles, co.editor
cmiles@wsu.edu
360-848-6150

Cover photo *ReGen Monterey*

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

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Project team and advisory board met at NWREC [Jennifer Buckles, WSU]

And We're Off! Advisory Board Kick-off Meeting

Lisa DeVetter, Washington State University

Researchers, extension specialists, growers, film manufacturers, and recyclers met in Mount Vernon, Washington this February. They were all united in finding a solution to one vast question—how to deal with the growing amount of agricultural plastic mulch waste coming off strawberry farms?

Plastic mulch plays an important role improving on-farm productivity and efficiencies through its ability to suppress weeds, optimize soil moisture and temperature, and overall improve crop growth and quality. The problem is plastic mulch is primarily made from non-biodegradable polyethylene (PE) that is mostly landfilled and seldom recycled due to issues related to contamination and costs. Also of concern is that some plastic mulch waste enters our soil and aquatic systems as a pollutant. With increasing global use of plastic mulch, the problem of how to sustainably deal with this waste product is growing.

Our new USDA NIFA grant (Award #2022-51181-38325) titled, *"Improving End-of-Life Management of Plastic Mulches in Strawberry Systems"* is designed to address this problem by advancing the science, knowledge, and practice of new soil-biodegradable mulch (BDM) and plastic recycling technologies.

The four-year-long project started recently with a kick-off project team and advisory board meeting in February 2023 at the Washington State University Northwestern Washington Research and Extension Center in Mount Vernon. In this newsletter, we introduce the objectives of the project, so readers are aware of the scope and direction we are going. This newsletter, our project website, and growing social media presence will be used as a platform where we will continue to share updates and progress [that] our project team and collaborators are making.

PROJECT OBJECTIVES

1. Compare benefits of commercially available and emerging BDMs to conventional PE mulch in diverse strawberry systems including California, Florida, Washington, and Nebraska. Evaluate and modify BDMs to improve fumigant retention properties.
2. Explore and optimize recycling technologies for improved end-of-life outcomes of conventional PE mulch for strawberry systems. Assess the effectiveness of different mulch removal and cleaning techniques, explore advanced chemical recycling of used PE mulch, assess the feasibility of recycling used PE mulch as an asphalt binder to make pavement, and test the feasibility of using PE mulch waste in the construction of composite products (e.g., decking boards).
3. Characterize and evaluate degradation, residence time of mulch fragments, and environmental fate of BDM degradation products in agricultural soils under various conditions within the strawberry cropping system.
4. Evaluate individual, sociocultural, and structural influences on decisions regarding plastic mulch end-of-life management.
5. Identify direct and indirect economic and environmental impacts, and optimal strategies for reducing plastic mulch pollution.
6. Deliver project information and outputs to stakeholders; evaluate success in technology transfer.

Used agricultural plastics ofen contain high levels of soil, field organics, and other contaminants. [ReGen Monterey]

Recycling Mulch: A Closer Look at Advanced Recycling

Kevin DeWhitt, PDO Technologies, Inc.; Robert Schucker, Circular Polymer Resources, Inc.; and Lisa DeVetter, Washington State University

Used polyethylene (PE) mulch is literally *dirty*. It has "contaminants" or "tramp" that includes water, soil, and organic matter that presently limit commercial recycling opportunities compared to other plastics. However, that is changing with renewed investment in advanced (chemical) recycling technologies and supporting research.

The recycling method that is most prevalent in North America is mechanical recycling. Recovery of plastic from waste via mechanical recycling occurs through a process of sorting, washing, grinding, pelletizing, and compounding. While it is often considered "the best" end-of-life outcome for used plastic, it is much more sensitive to contaminants. Used PE mulch may have a ~70-80% contaminant load (by weight), making mechanical recycling difficult, as those contaminants must be removed through washing, which adds significant cost to the recycling process.

Mulch film may also be unsuitable for mechanical recycling as exposure to solar radiation during the growing season can degrade its polymeric structure. Furthermore, mechanical recycling can only be performed 3-4 times on a plastic product, and then the molecular structure of the plastic is deteriorated by the repeated heating during extrusion. Recycled paper has the same limitation, and thus the ability to repeatedly mechanically recycle a product is not infinite.

Advanced recycling is an attractive alternative to mechanical recycling but currently is not widely used. Advanced recycling includes chemical and thermal recycling, which are not new recycling technologies, but are gaining more attention lately as they are much less sensitive to contaminant load. Through advanced recycling, recovered plastic is converted into its original polymeric building blocks, called monomers, in a two-step process—first by a thermochemical process called ***pyrolysis*** that produces pyrolysis oil, followed by a secondary process (***steam cracking*** or fluidized bed catalytic cracking) that converts the pyrolysis oil to ethylene and propylene. This is one particular method to recycle plastics through chemical and thermal techniques; there are many other methods that can yield a variety of final products.

A common concern with thermal techniques like pyrolysis is the generation of hazardous emissions. During pyrolysis, a small portion of the plastic materials end up as a non-condensable vapor, similar to propane. In the method developed/used by the company PDO Technology, this gas phase is recycled internally as a source of thermal energy (offsetting the need for imported propane). Combusting this gas mixture always results in a small emissions profile. This emissions profile is, in turn, always subject to air quality permitting requirements; in every state where the PDO equipment has been permitted, the air emissions are minor in species concentration(s), and well below the state and federal regulatory levels. Emissions are tracked by the permitting authorities at the local and state level and records are available to the public at any time.

Mechanical and advanced recycling are complementary. In essence, what cannot be recycled mechanically due to cost or technological constraints would ideally be recycled via advanced recycling using pyrolysis. PE mulch film is gathered at harvest and typically landfilled or stockpiled, or in some states, burned in the field. Open-field burning produces unwanted greenhouse gasses like CO_2 and has more negative environmental consequences than pyrolysis. Our project team will be exploring advanced recycling of used PE mulch and findings will be a key outcome for our collaborative research on improving end-of-life outcomes of agricultural plastic mulch. Constraints such as acquiring the needed volume of used mulch for commercial operations and implementation of low-cost pre-treatment options in the field during gathering are issues our project team will address through cooperative interactions with companies such as Circular Polymer Resources, Inc.

What is pyrolysis? Pyrolysis is a chemical transformation process involving carbon-based ("organic") material, including fossil fuel-based carbonaceous materials (e.g., plastics). When materials like plastics are heated in the absence of oxygen, they cannot burn or combust. The only chemical pathway left is breakage of the chemical bonds (called scissioning). The end result is a mixture of various sizes of hydrocarbons (including liquids called pyrolysis oil as well as gasses ranging from methane to butane). Any tramp material that is commingled with the plastic feed typically remains in the original reaction system and is known as char (not ash, since there is no combustion). This process is done at high temperatures (>500 °C) in the absence of oxygen.

What is steam cracking? Steam cracking is a process by which gaseous or liquid hydrocarbons are broken down into smaller hydrocarbons. These smaller hydrocarbons (e.g., ethylene) can be harvested and recycled. Steam cracking involves the use of a reactor, catalyst (e.g., metal oxides), and high temperatures.

Hydromulch applied to blueberry raised beds.

MulchH2O Update: A Berry Good, Certifiably Organic Biodegradable Mulch

Ben Weiss, Washington State University

Plastic mulches made from polyethylene (PE) are quintessential across a broad range of specialty crops. Benefits of plastic mulches include optimization of soil temperature and moisture, weed suppression, and lower labor costs due to not having to pay people to hand weed or apply herbicides. However, these benefits come at a cost.

By 2026, $15.7 billion dollars of agricultural film will be used globally (Markets & Markets, 2021). The lion's share of this plastic will be landfilled, buried, incinerated, or tilled into the soil. Film made from non-biodegradable PE also costs money for farmers to dispose of in the form of transportation and tipping fees. While soil-biodegradable mulches (BDM's) made from plastic feedstocks have made great strides for conventional cropping systems, no current BDM is allowed in Certified Organic production in the United States. This is largely due to a lack of 100% biobased BDM products, which is required to be Certified Organic. Enter hydromulch—a Certifiably Organic mulching system made from recycled cellulosic fibers (e.g., paper), tackifier (an adhesive), and water.

Last year, Washington State University and North Dakota State University (WSU and NDSU, respectively) began strawberry trials with hydromulch. The goals of this research includes designing and developing hydromulch formulations, testing application technologies, observing effects on crop yield and quality, and evaluating soil health and economic impacts. This year WSU is looking into hydromulch's use in blueberry in Eastern Washington, where the national organic blueberry industry is concentrated. NDSU will be evaluating hydromulches on vegetable crops.

One of the main aspects of hydromulch we are looking into is ideal formulations *(see page 4)*. Last year we experimented with multiple tackifiers. We found guar gum superior to psyllium husk, as it did a better job suppressing weeds. It will be interesting to see if this finding holds up in Eastern Washington because a researcher by the name of John A. Cline and his colleagues found that a tackifier was not needed in drier climates (Cline et al., 2011).

Another change in formulation is our testing of a new paper stock this year. We are comparing bogus paper—a paper product purchased through Uline—to a slurry obtained from a local apple tray manufacturing company in Washington State. While we do not yet have any data to report, it is exciting because the slurry is theoretically more scalable.

An experimental portable pump system is used to apply small volumes of hydromulch on top of raised beds in a blueberry field.

continued on page 4

WSU graduate student Ben Weiss discussing hydromulch application with technician Brian Maupin and advisor Dr. Lisa DeVetter.

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During last year's research with day-neutral strawberries in Washington and North Dakota, hydromulch was found to be comparable to PE mulch at weed suppression. The exception to this was pigweed and thistle, which hydromulch did not suppress. However, despite this lack of weed suppression the hydromulch outperformed PE in terms of yield. This means that the effect of these weeds on crop performance was negligible.

Another important aspect of mulch performance is soil temperature modification. Soil temperature under PE-treated plants was higher than under hydromulch. Cooler soils could be beneficial in warmer climates concerned with heat stress. Despite soil temperature effects, total yield was not affected in western Washington and plots treated with hydromulches containing 6% tackifier produced greater yields than plots treated with PE mulch. In the future, we plan to adjust hydromulch color and observe effects on soil temperatures and crop growth.

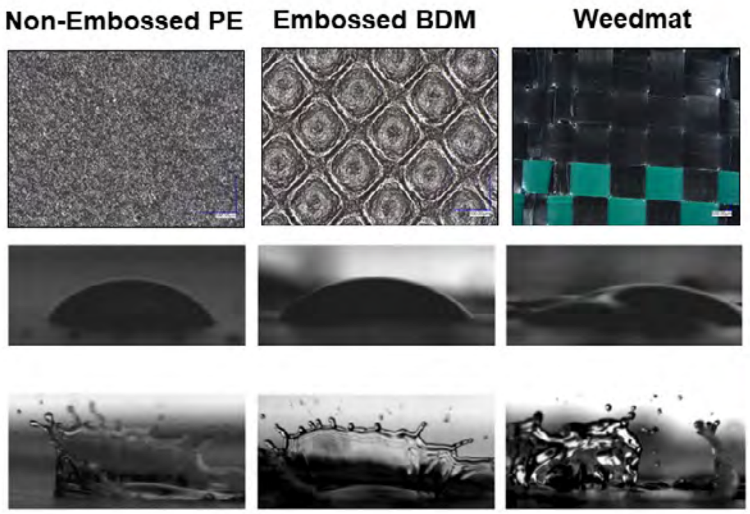
One of the most exciting things about hydromulch is its potential to be multifunctional where other mulches are not. For example, farmers at Cloud Mountain Farm Center are already contemplating the addition of beneficial nematodes to hydromulch to manage larval populations of codling moth. Similarly, adding conventional pesticides to hydromulch may one day reduce the need to spray pesticides, which could protect pollinators and the broader ecology. Furthermore, hydromulch contributes to closed-loop agriculture because it is made of recycled paper. We dream of a day when the cardboard used to carry food from manufacturers to retail outlets has its inks washed out and is utilized as mulch to protect the crops it once transported. This could save retailers and farmers money and create secondary revenue streams for enterprising grocers and distributors.

This project is funded by the Organic Research and Extension Initiative grant, part of the USDA National Institute of Food and Agriculture. Grant number 2021-51300-34909. Learn more about hydromulches at **eorganic.info/node/35091**

Hydromulch Testing

Andrew Durado and Dilpreet Bajwa, Montana State University

Montana State University aimed to determine the best performing hydromulch out of 55 different formulations through mechanical and physical property testing. Hydromulch mulch sheets were prepared in the laboratory measuring 28 by 30 cm that contained a mixture of paper pulp (inset a), wood fiber (inset b), or hemp hurds (inset c) combined with a tackifier. The tackifiers evaluated were guar gum, psyllium husk, and camelina meal, at various concentrations. The hydromulch sheets were tested for tensile strength, puncture resistance, rain fastness, density, soil adhesion, porosity, and C:N ratio. The results showed that paper was the best fibrous material and guar gum was the top performing tackifier. Also, the addition of tackifier increased the properties in most experiments.



Physical Characteristics of Soil-Biodegradable and Nonbiodegradable Plastic Mulches Impact Splash Dispersal of *Botrytis cinerea*

Aidan Williams, Washington State University

An experiment conducted by Washington State University and Cornell investigated how the physical characteristics of different plastic mulches influence splash dispersal patterns of *Botrytis cinerea*, the fungal pathogen that causes gray mold in strawberries and several other crops. Gray mold is the primary disease responsible for yield losses in strawberry production worldwide and is spread by spores (conidia). Three different types of mulches used in commercial strawberry production were evaluated in the study: non-biodegradable polyethylene (PE) mulch, soil-biodegradable plastic mulch (BDM), and weedmat made from woven polyethylene.

Rain splash can spread conidia of *B. cinerea* over short distances (several inches), while wind can carry conidia several miles. To determine the impact that plastic mulch surfaces have on the dispersal of *B. cinerea* conidia, mulch topographic and liquid water infiltration characteristics were first evaluated. The PE mulch used in the study had a flat, smooth surface texture and was impermeable, BDM had an embossed surface and was also impermeable, but weedmat had large ridges and was semi-permeable. The semi-permeable nature of weedmat suggests that pools of water containing *B. cinerea* conidia may infiltrate through weedmat and reduce conidial availability for rain splash dispersal.

Splash dynamics were then evaluated in a fully enclosed screenhouse using a rain simulator system. The majority of *B. cinerea* conidia were dispersed 10 to 15 cm from the inoculum source with a maximum dispersal distance of 33 cm for all three mulches. Embossed BDM resulted in higher number of splashed conidia compared to PE and weedmat mulches. It is important to note that both PE mulch and BDMs can be embossed, so physical characteristics of specific mulches must be considered when assessing the risk for disease spread. Furthermore, the low conidial concentrations found in the splashed droplets in this study may not be enough to cause disease. Future investigations plan to study conidial splash dispersal in the field and better understand its pathological relevance.

FULL PAPER CITATION:

Wang, X., C. Mattupalli, G. Chastagner, L. Tymon, Z. Wu, S. Jung, H. Liu, and L.W. DeVetter. 2023. Physical characteristics of soil-biodegradable and nonbiodegradable plastic mulches impact conidial splash dispersal of *Botrytis cinerea*. PLoS ONE 18(5): e0285094. **https://doi.org/10.1371/journal.pone.0285094**.

Building a Better Industry: Q&A with Former Student, Brenda Madrid

We sat down with former Washington State University (WSU) graduate student, Brenda Madrid, to discuss her experiences and opinions on soil-biodegradable mulches (BDMs) and what the future of mulching in agriculture may look like.

Can you tell us a little about yourself and your educational background?

Brenda Madrid (BM): *I completed my Bachelor's, degree in Organic and Sustainable Agriculture at Washington State University. For my Master degree, I worked in Dr. Lisa DeVetter's Small Fruit Horticulture program. I gained exposure to different aspects of blueberry, raspberry, and strawberry production systems during my graduate program. Currently, I work for Driscoll's and lead agronomy trials in the Pacific Northwest.*

Explain your experiences with mulches in specialty crop production systems.

BM: *The main focus of my research was to evaluate how BDMs performed under the climatic and environmental conditions of western Washington. From previous studies we understood that some BDMs had the potential to deteriorate at slower rates in our region. We wanted to explore if the application of potentially degrading products (recommended by mulch manufacturers) would accelerate surface deterioration and visible in-soil degradation. I was also able to collaborate with Dr. Jessica Goldberger on a sociology study to assess the risks and uncertainties of incorporating [non-biodegradable polyethylene] PE mulch and BDMs into raspberry production systems.*

You have done several research studies on BDMs. What are your personal opinions on their adoption and acceptance in farming? Do you have any suggestions to offer the BDM production industry to make BDMs more appealing to farmers?

BM: *I believe some BDMs have the potential to be sustainable alternatives to PE mulch. I don't believe there is a one size fits all BDM and that is where it can get complicated. In-soil degradation is influenced by multiple biotic and abiotic factors that usually vary among field sites. A BDM may perform well in one field, but not degrade rapidly or completely in another. The BDM may have to be "tailored" to the farm/region, the grower's production system and goals. Therefore, BDMs need to be tested under variable field conditions to assess performance and determine if and where they are most successful. I think the biggest factor will be time. If long-term studies determine true, complete in-soil degradation is occurring then more growers may be open to using BDMs. However, continuous education of the product and dissemination of on-farm trial results will be key for researchers, growers, and mulch distributors.*

What does the future of mulching in specialty cropping systems look like to you?

BM: *I see a push in the industry to move away from traditional PE mulch, especially in organic systems. The need is there and that will likely create more opportunities and willingness among growers to try new mulching alternatives. More options will be better so growers can decide which mulching option is suitable for their operation and goals (weed management, yield improvement, etc.), but overall, I think the future is promising for creating more sustainable systems.*

Recent Publications

ACADEMIC

Abbate, C., A. Scavo, G.R. Pesce, S. Fontanazza, A. Restuccia, and G. Mauromicale. 2023. Soil bioplastic mulches for agroecosystem sustainability: A comprehensive review. Agriculture 13(1):197. **https://doi.org/10.3390/agriculture13010197**

Adhikari, K., A.F. Astner, J.M. DeBruyn, Y. Yu, D.G. Hayes, B.T. O'Callahan, and M. Flury. 2023. Earthworms exposed to polyethylene and biodegradable microplastics in soil: Microplastic characterization and microbial community analysis. ACS Agricultural Science & Technology, 3, 340-349. **https://doi.org/10.1021/acsagscitech.2c00333**.

Yu, Y., A.F. Astner, T.M. Zahid, I. Chowdhury, D.G. Hayes, and M. Flury. 2023. UV-weathering and proteins affect aggregation kinetics and stability of biodegradable nanoplastics in aquatic environments. Water Research, 120018. **https://doi.org/10.1016/j.watres.2023.120018**.

Wang, X., C. Mattupalli, G. Chastagner, L. Tymon, Z. Wu, S. Jung, H. Liu, and L.W. DeVetter. 2023. Physical characteristics of soil-biodegradable and nonbiodegradable plastic mulches impact conidial splash dispersal of *Botrytis cinerea*. PLoS ONE 18(5): e0285094. **https://doi.org/10.1371/journal.pone.0285094**.

EXTENSION

Miles, C., B. Madrid, L.W. DeVetter, and B. Weiss. 2023. Soil-biodegradable plastic mulch for organic production systems. Washington State University Whitepaper. Available: **https://smallfruits.wsu.edu/documents/2023/05/soil-biodegradable-plastic-mulch-for-organic-production-systems.pdf**.

Upcoming Events

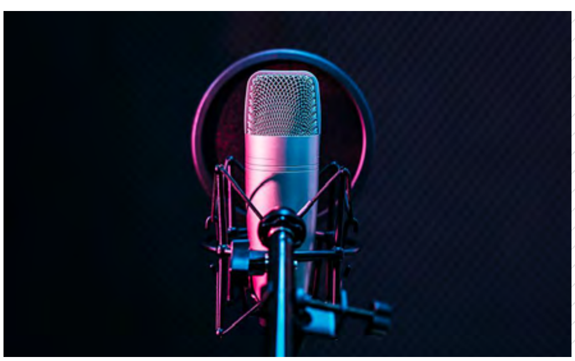
TRANSITIONING TO A SUSTAINABLE, CIRCULAR ECONOMY FOR PLASTICS

Dates: June 8-9, 2023

Location: Seattle, WA

The U.S. Department of Energy's (DOE) Bioenergy Technologies Office (BETO) and Advanced Materials & Manufacturing Technologies Office (AMMTO) will host *Transitioning to a Sustainable, Circular Economy for Plastics,* a workshop to convene stakeholders for a discussion of the current challenges and opportunities in transitioning to a sustainable domestic economy for plastics.

More information:
https://www.energy.gov/eere/bioenergy/events/workshop-transitioning-sustainable-circular-economy-plastics



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Also, we're pleased to announce that we are currently working on development of a new podcast. Stay tuned so you can listen in!