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Improved End-Of-Life of Plastic Mulches

smallfruits.wsu.edu/plastic-mulches/

Deterioration, Degradation and Tillage of Soil-Biodegradable Mulch

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Synopsis:
BDMs deteriorate on the soil surface and degrade after soil incorporation. This outlines how to assess both.

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These notes provide information for presenters for this slide presentation on the end-of-life of soil-biodegradable mulches. Numbers in the text correspond to the slides in the presentation. Information in this document was summarized from publications listed in the Reference section.

1. This presentation provides information on the surface deterioration and degradation of BDMs in the field, the impact of environmental conditions, and disposal options.

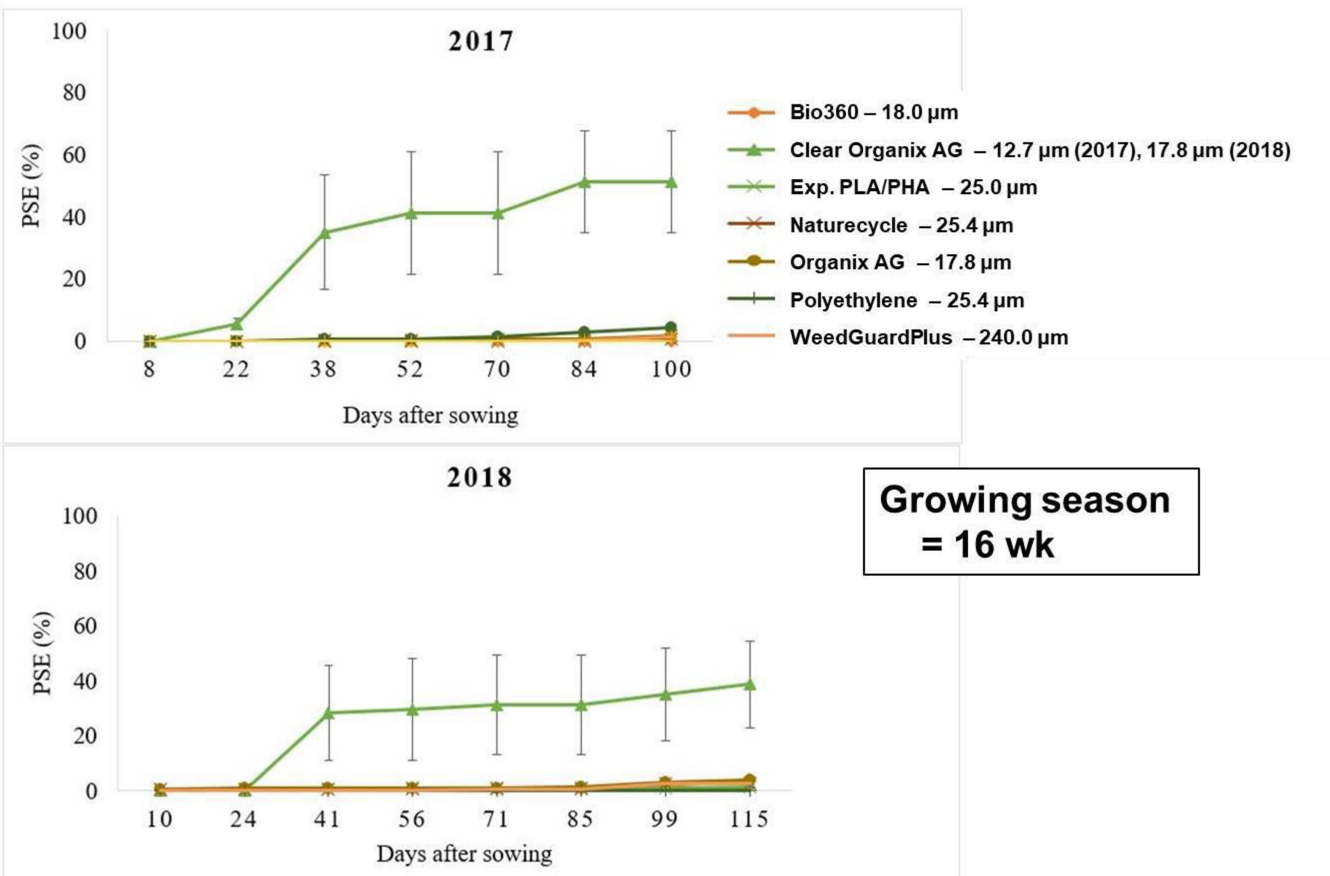
2. **Deterioration** is loss of physical or mechanical strength, observed through physical testing, microscopic imaging, or macroscopic observation (e.g., rips, tears, and holes).

Degradation is the conversion or mineralization of carbon (C) to carbon dioxide (CO_2) resulting in changes in the chemical structure, physical properties or appearance. ASTM defines biodegradable plastics as plastics that degrade from the action of naturally resulting organisms such as bacteria, fungi and algae. Polyethylene mulch (PE) is not biodegradable as polymers have chemical bonds that microbes do not have the metabolic pathways to break apart. Biodegradable plastics use natural or synthetic polymers that have similar bonds, but can be broken apart by microbes.

3. The degradation of BDMs is largely affected by both mulch material properties and the degradation environment. The physical and chemical properties of mulch material and its degradation mechanism are important considerations for soil degradation. For example, materials that absorb moisture and have a glass transition temperature (Tg) at or lower than ambient temperature can degrade faster, andresults in cross-linking due to environmentalweathering. Glass transition temperature is the point when materials transition from a glassy state (rigid) to a rubbery state (flexible). Above the glass transition temperature, materials are more flexible for moisture and microorganisms to access. Soil conditions, including soil temperature, moisture, and microorganisms present in soil, are environmental factors that influence the degradation rate.
4. Polylactic acid (PLA) and polyhydroxyalkanoate (PHA) are the two most commonly used biopolymers to produce BDM. PLA is a synthetic polymer produced from lactic acid that is fermented by microorganisms and made from biobased materials, such as corn and sugar beet pulp. PLA has a relatively high glass transition temperature of approximately 60°C (140°F). The high glass transition temperature of PLA along with its hydrophobic nature account for its slow degradation rate under ambient conditions. Industrial compost temperature is set at around 60°C (140°F) for expedited degradation. PHA is extracted and purified from a natural polyester fermented by microorganisms from renewable resources, such as sugar and vegetable oil. The glass transition temperature of PHA is approximately 5°C (41 °F) and PHA readily degrades under ambient conditions. The cost of PHA is, however, higher than PLA.
5. Monitor the deterioration and degradation throughout the life cycle of the material by measuring BDM properties (physical and chemical). Monitoring is done in storage to ensure structural integrity, in the field to assess functionality, and after use to assess the degradation in soil or composting. Physicochemical analyses can be physical/ mechanical (tensile strength, elongation at break, weight loss, thickness) or chemical. Chemical analysis methods include Fourier transform infrared (FTIR) spectrometry, molecular weight analysis, thermal properties, nuclear magneticresonance (NMR), ash content (determined by elemental or thermogravimetric analysis), gel content, and radiocarbon analysis.
6. Visual assessment of deterioration is measured as a decrease in mulch area—percent soil exposure (PSE), photography, colorimetry, macroscopic observation and microscopic examination, including scanning electron and laser confocal microscopy (Fig. 1).

The graph (Fig. 2) shows the PSE during the sweet corn growing season ofabout 16 weeks in Mount Vernon, WA in 2017 and 2018. Zero PSE denotes completely intact mulch while 100% PSE denotes completely deteriorated mulch. Ratings were in 1% increments up to 20% PSE, and in 5% increments thereafter. PSE was highest for Clear Organix AG mulch and reached 51% and 39% by the end of the season in 2017 and 2018. Other black plastic BDMs and PE mulch had minimal (<5%) deterioration throughout the growing season in both years.

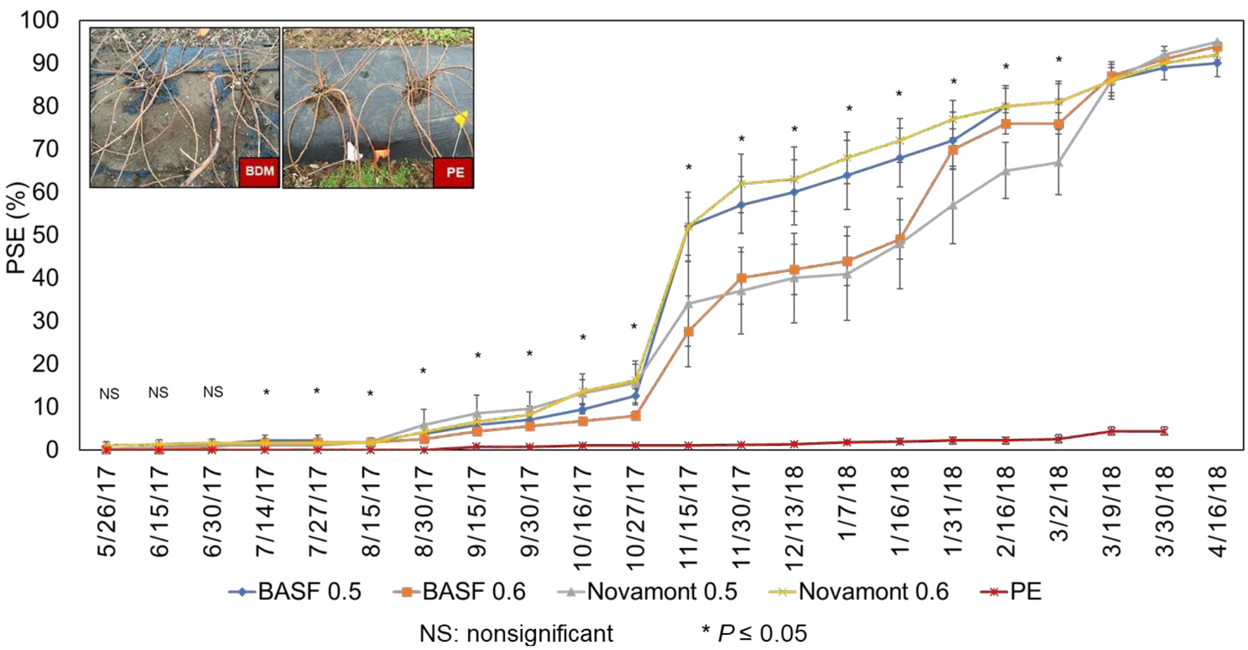
Figure 1. Visually assess deterioration by estimating percent soil exposure (PSE) due to rips, tears, or holes (left andcenter); scanning electron microscope (SEM) image to assess deterioration on a microscopic level.



Ghimire et al., 2020a

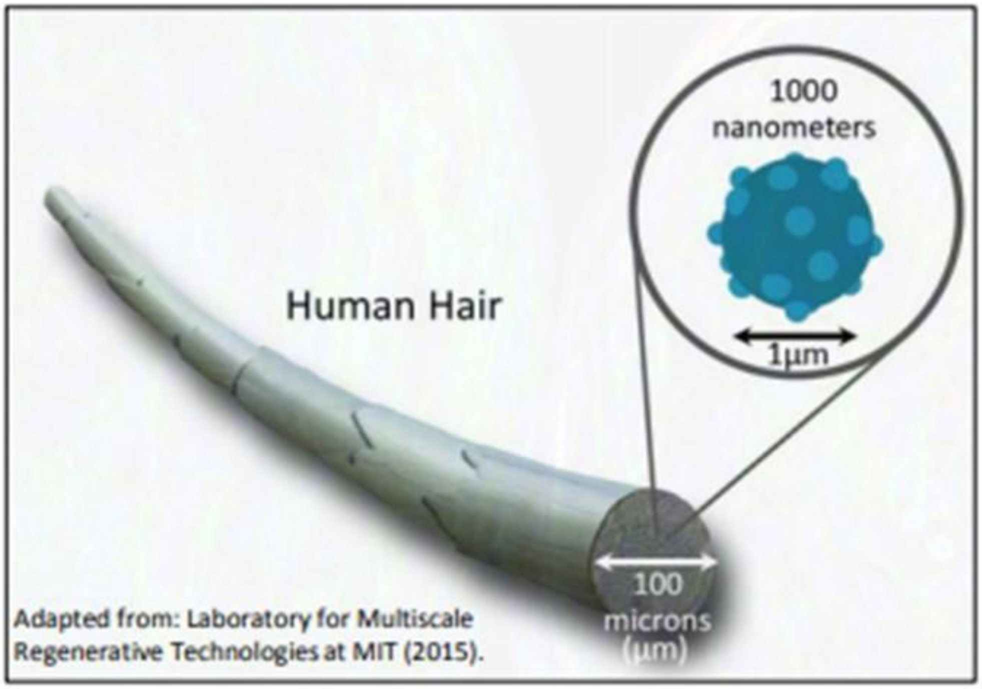
Figure 2. PSE during sweet corn growing season in Mount Vernon, WA; 0 = completely intact, 100 = fully deteriorated, ratings in 1% increments upto 20%, and 5% increments thereafter; error bar is ± one standard error of the mean.

7. This graph (Fig. 3) represents the PSE for a period of 1 year during raspberry production in Lynden, WA. All the black plastic BDMs reached about 90% PSE in one year while PE mulch remained almost completely intact. At 16 weeks after mulch application, all the BDMs had less than 10% PSE which is similar to the sweet corn experiment (<5%). The black BDMs used in sweet corn production were thicker than the BDMs used in raspberry production.
8. The degradation process takes place sequentially from film to fragment to micro-particles to nano-particles to the final stage of CO_2 + biomass in the soil. A human hair demonstrates the relative size of microns and nanometers (Fig. 4). On average, thickness of PE mulch and BDMs range between 12 to 37 microns which is approximately equal to 0.5 to 1 mil.
9. The graph (Fig. 5) shows the percent mulch recovery in Mount Vernon, WA using the soil quartering method after incorporation in the field. Mulch was applied once a year for 4 years (2015 - 2018). Plots were rototilled in spring after collecting samples and in fall before collecting samples. Paper BDM (WeedGuardPlus) shows complete biodegradation each year while other plastic BDMs have different rates of biodegradation. One year after the last soil-incorporation of BDM, recovery ranges from 10% to 30%, indicating that all of these BDMs are degrading at this field site.
10. Here is the link for the video of laying and tilling BDMs into the field, https://www.youtube.com/watch?v=aMjD4vbr9eA&feature=youtu.be



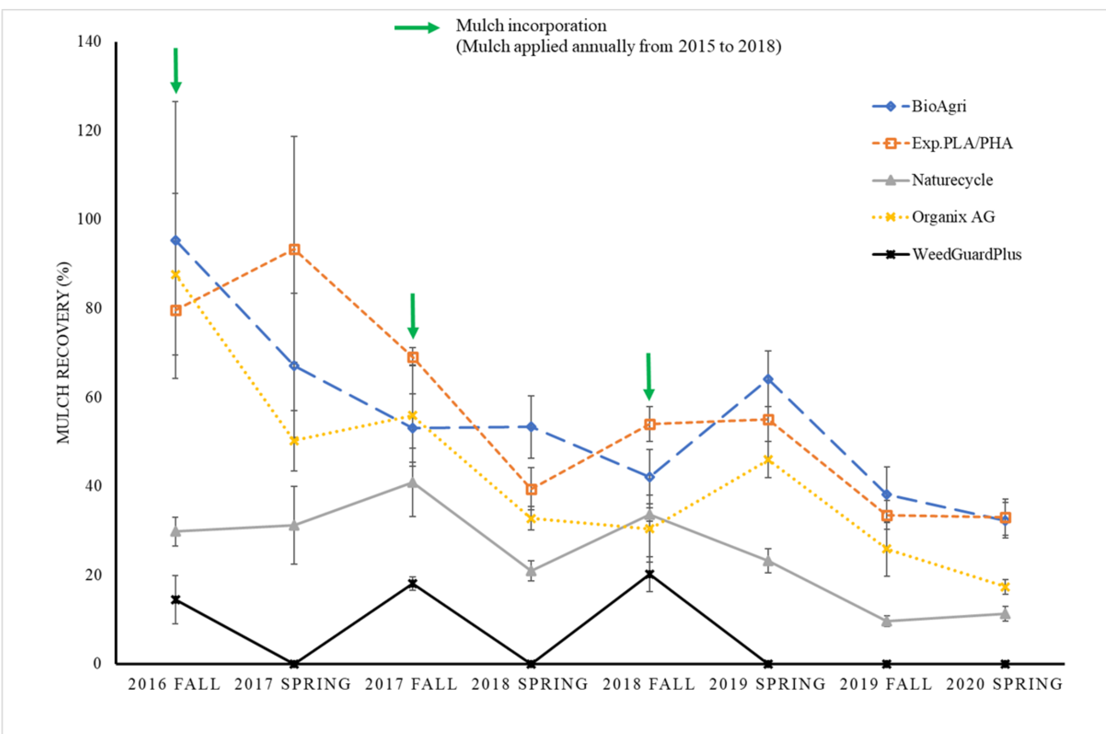
Zhang et al., 2020

Figure 3. PSE of mulch (0.5 = 12.7 µm thickness, 0.6 = 15.2 µm thickness) in raspberry production in Lynden, WA; 0 = completely intact, 100 = fully deteriorated, ratings in 1% increments up to 20%, and 5% increments thereafter; error bar is ± one standard error of the mean.



Hayes, 2019

Figure 4. A human hair demonstrates the relative size ofmicrons andnanometers.



Ghimire et al., 2020b

Figure 5. Percent recovery of BDM fragments in Mount Vernon, WA using the soil quartering method; mulch was applied once a year for 4 years (2015-2018), plots were rototilled in spring after collecting samples and in fall before collecting samples; error bar is ± one standard error of the mean.

Video 3:30 min https://www.youtube.com/watch?v=aMjD4vbr9eA&feature=youtu.be

Resources

These information resources provide background information and additional information to help you have a more thorough understanding of this topic. We encourage presenters to view each one so as to be better prepared for your presentation.

Biodegradation – Putting Biology to Work

https://ag.tennessee.edu/biodegradablemulch/Documents/biodegradation_factsheet.pdf

Finding Out How Biodegradable Plastic Mulches Change Over Time

https://ag.tennessee.edu/biodegradablemulch/Documents/Finding_out_how_biodegradable_plastic_mulches_change_over_time_FACTSHEET.pdf

Ghimire, S., E. Scheenstra, and C. A. Miles. 2020a. Soil-biodegradable mulches for growth, yield, and quality of sweet corn in a Mediterranean-type climate. HortScience 55:317-325.

Ghimire, S., M. Flury, E. Scheenstra, and C. Miles. 2020b. Sampling and degradation of biodegradable plastic and paper mulches in fieldafter tillage incorporation. Science ofthe Total Environment 703:1-7.

Micro- and Nanoplastic in Soil: Should We Be Concerned

https://ag.tennessee.edu/biodegradablemulch/Documents/Microplastics-soil-Factsheet-formatted.pdf

Summary and Assessment of EN 17033:2018, a New Standard for Biodegradable Plastic Mulch Films

https://ag.tennessee.edu/biodegradablemulch/Documents/EU%20regs%20factsheet.pdf

Video - Biodegradable Mulch Breakdown in Soil: Role of Microbiology

https://www.youtube.com/embed/-EqrF2y9lh0

Video - Biodegradable Mulch Installation and Till Down
https://www.youtube.com/watch?v=aMjD4vbr9eA&feature=youtu.be

Zhang, H., C. Miles, S. Ghimire, C. Benedict, I. Zasada, H. Liu, and L. DeVetter. 2020. Plastic mulches improved plant growth and suppressed weeds in late summer-planted floricane-fruiting raspberry. HortScience 55(4): 565-572.