Soil-Biodegradable Mulches: *Workshop*

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Synopsis:
Soil-biodegradable mulches (BDMs) are increasingly used in agriculture to replace conventional plastic mulch. This is an introduction to what BDMs are made from.

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USDA United States Department of Agriculture National Institute of Food and Agriculture

What is soil-biodegradable mulch?

This workshop series provides slide presentations on soil-biodegradable mulches (BDMs). These notes provide additional information for presenters. Numbers in the text correspond to the slides in each presentation. Information in this document was summarized from publications listed in the Reference section.

1. This presentation provides information on the standards, materials, and feedstocks that define soil-biodegradable mulch, and descriptions of composition and use.
2. BDM is an alternative to PE (polyethylene) mulch as it provides comparable crop production benefits: weed control, moisture retention, soil temperature modification,

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early harvest, increased yield and quality. BDMs are designed to be tilled into the soil after use, eliminating waste and disposal challenges. Note that BDMs should NOT go into recycling facilities as they will contaminate other recycled material.

3. Introduction of BDMs began in 1990 when the German government published a call for research and development of biodegradable thermoplastics. In 1991 Novamont introduced the Mater-Bi line, and in 1996 Bayer BAK introduced line extrusion and injection molding grades. In 2009 United States Department of Agriculture (USDA) Specialty Crop Block Grant (SCBG) program started to investigate BDMs. By 2014 BASF had produced BASF/Organix Solution BDM.
4. BDMs are made from feedstocks that are: (i) biobased, (ii) derived from fossil fuels, or (iii) a blend of the two. Biobased polymers are divided into 3 categories (Table 1): **a)** extracted directly from natural materials such as starch, thermoplastic starch (TPS), and cellulose; **b)** produced by chemical synthesis from biologically derived monomers, such as synthetic polymerization of lactic acid into polylactic acid (PLA); and **c)** produced by microorganisms, such as polyhydroxyalkanoates (PHA). High-amylose starch is processed into TPS by extrusion with water and alcohols at relatively high temperatures. TPS costs less than other starch feedstocks and now is the most common biobased feedstock used in plastic BDMs. PLA can be produced relatively inexpensively in large quantities compared to other biobased biopolymers. Poly(hydroxybutyrate) (PHB) and poly(hydroxyvalerate) (PHV) are the two most important commercial PHAs. Polymers such as PLA or PHA have low mechanical properties compared to PE. Plasticizers are additives which improve the mechanical properties of the plastic during processing, and can affect post-extrusion characteristics of the plastic. The primary plasticizers that are added to TPS are alcohol (principally glycerol), polyoxyalkenes, and surfactants. Most common biobased BDM feedstocks are TPS, PLA, and PHA.
5. It is important to know that percent biobased content is not an indicator of biodegradation. For example, PLA requires high temperature for biodegradation. Manufac-

Table 1. Categories of biobased polymer feedstocks.

Extracted from natural materials	Produced by chemical synthesis	Produced by microorganisms
starch, thermoplastic starch (TPS), and cellulose	synthetic polymerization of lactic acid into polylactic acid (PLA)	polyhydroxyalkanoates (PHA)
TPS processed from high-amylose starch, cheaper than other starch feedstocks	PLA produced relatively inexpensively compared to other biobased biopolymers	Poly(hydroxybutyrate) (PHB) and poly(hydroxyvalerate) (PHV) most important commercial PHAs

turing plastic mulch (including BDMs) involves the addition of plasticizers, fillers (e.g., $CaCO_3$), lubricants, nucleating agents, stabilizers and colorants/dyes. The additives used in commercial plastic BDMs may or may not be produced from GMOs. Most commercially available PLA and PHA are produced through fermentation using GM yeast and bacteria for increased productivity. Biobased mulches are not tested for the presence of GMOs since DNA may be degraded following fermentation and processing to the point where GMO status is not discernable using available broad-spectrum quantitative polymerase chain reaction (PCR) tests.

6. Standards for biodegradation are intended to ensure their quality and integrity in agriculture. Standards are meant to exclude materials that claim to be biodegradable but are not fully metabolized by microbes, which results in plastic fragments in soils, causing pollution. Ability of a BDM to meet the composting standard is considered the first critical test of biodegradability; if a mulch is not compostable, it will likely not biodegrade under field conditions. Standards for BDMs do not guarantee a particular degree of performance in fields. Performance depends on the production system (crop, climate, soils, etc.) and mulch formulation and thickness.
7. There are several BDM standards written by different countries as shown in Table 2. For example, TUV Austria certifies that plastic materials will biodegrade fully and will not promote ecotoxicity in the soil.
8. ASTM and ISO standards pertaining to biodegradable plastics are not specific to mulch. ASTM D6400 is one of the most commonly cited standards in reference to BDMs. Biodegradation under ASTM D6400 is tested under industrial composting conditions. This standard employs a standardized test method, ASTM D5338, which utilizes a laboratory test that simu-

Table 2. BDM Standards (Dentzman and Hayes, 2019).

Standard Organization	Standard Name	Comments
European Committee for Standardization (CEN)	**EN 17033** (2018) Plastics– Biodegradable Mulch Films for Use in Agriculture and Horticulture– Requirements and Test Methods	First international standard directly pertaining to biodegradable mulches by an international organization. Includes specifications for both biodegradable material/ feedstock and biodegradable mulch product such as dimensional, mechanical and optical properties, ecotoxicity, and biodegradation.
Ente Nazionale Italiano di Unificazione (UNI)	**UNI 11495** (2013) Biodegradable Thermoplastic Materials for Use in Agriculture and Horticulture - Mulching Films - Requirements and Test Methods	Italian standard pertaining to biodegradable mulches
ASTM, International	**ASTM D6400** (2012) Standard Specification for Labeling of Plastics Designed to be Aerobically Composted in Municipal or Industrial Facilities	Pertains directly to biodegradation under industrial composting conditions, and is often misrepresented[1]
TUV Austria (formerly Vincotte)[2]	**OK Biodegradable SOIL** (label)	Certifies that plastic materials will biodegrade fully and will not promote ecotoxicity in the soil

[1] ISO (International Organization for Standardization) has equivalent standards

[2] TUV Austria is not a standards organization but is a certification body authorized by European Bioplastics, an association representing the interest of the European bioplastics industry.

lates industrial composting conditions: the use of a compost-based medium, 58°C, etc. European Standard EN 17033 released by the European Committee for Standardization (CEN) in January 2018 was the first standard put forth for certification of biodegradable plastic mulch films. Its requirements regulate composition, biodegradability in soil, and ecotoxicity, as well as dimensional, mechanical and optical properties; and test procedures are included for each. A major criterion of EN 17033 is the requirement of ≥90% biodegradation under aerobic conditions in a natural topsoil from an agricultural field or forest at 20 to 28°C conditions within 2 years, using a standardized test to measure CO_2 evolution. The reasons that 90% biodegradation and not 100% is used as a criterion in standards is that a) a significant portion of the plastic incorporated into microbial biomass is difficult to measure, and b) the limited precision of biodegradability lab tests.

9. Oxo- and photo-degradable plastics are made with conventional plastic: HDPE, LDPE, PP, PS, PET or PVC. Also included are additives that cause the material to become brittle and break apart into fragments when exposed to UV light, heat and/or oxygen (Figure 1). Oxo- and photo-degradable mulches are not biodegradable, compostable, or recyclable, and cannot be placed in anaerobic digesters. There is a resurgence in their use, due to the interest in BDMs and large price difference between BDMs and oxo- and photo-degradable mulches. The European Union (EU) will prohibit single-use plastic products and products made from oxo-degradable plastic, European Parliament Directive 2019/904 Article 5, 5 June 2019, to be applied by 3 July, 2021.

Fig. 1. Oxo- and photo-degradable plastic includes additives that cause the material to turn brittle and break into fragments when exposed to UV light, heat, and/or oxygen.

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.

Biodegradable Plastic Mulch and Suitability for Sustainable and Organic Agriculture
http://pubs.cahnrs.wsu.edu/publications/pubs/fs103e/

Oxo-degradable Plastics Risk Environmental Pollution
https://ag.tennessee.edu/biodegradablemulch/Documents/oxo%20plastics.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

The Role of Standards for Use of Biodegradable Plastic Mulches: Truths and Myths
https://ag.tennessee.edu/biodegradablemulch/Documents/Standards%20Factsheet%20Formatted%20revised%2015Jan2019.pdf

Video: Biodegradable Mulch Breakdown in Soil: Role of Microbiology: https://www.youtube.com/embed/-EqrF2y9lh0