



<http://biodegradabledmulch.org>

# Biodegradable Plastic Mulches are Effective and Sustainable

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This material is based upon work that is supported by the National Institute of Food and Agriculture, under award number 2014-51181-22382. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.



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# PE mulch use in agriculture

- Weed management
  - Conserves moisture
  - Warms soil in spring
  - Hastens time to harvest
  - Increases yield
  - Reduces erosion
  - Increases crop quality
  - More efficient use of water and fertilizer
  - Reduces soil compaction
- Efficient double or triple cropping





# Biodegradable plastic mulch

Has the potential to be a sustainable technology if it:

- Provides benefits equal to PE mulch
- Reduces labor costs for removal and disposal
- Completely biodegrades
- Causes no harm to soil ecology or the environment





# Biodegradable mulch ingredients

Polymer trade name	Polymer(s) in biodegradable mulch <sup>1</sup>
Bio 360	Mater-Bi (TPS + PCL); PBAT
BioAgri	Mater-Bi (TPS + PCL); PBAT
Biocycle	Sucrose/PHA blend
Bio-Flex	PLA/co-polyester
Biomax TPS	Starch + TPS
Biomer L	PHA
Bionolle	PBS or PBSA; TPS + PLA + PBS/PBSA
Biopar	TPS + co-polyester
Biosafe	PBAT/TPS blend; PBS; PBSA
Eastar Bio	PBAT/TPS blend
EcoCover	Recycled paper
EcoFilm	Unspecified plastic
Eco-Flex	PBAT; TBS
Ecovio	PLA; PBAT/TPS
Eco-One	Unspecified plastic; oxo-degradable
EcoWorks	PBAT + PLA

Polymer trade name	Polymer(s) in biodegradable mulch
EnPol	PBS
Envio	PBAT; PLA; TPS
Garden Weed Barrier	Cellulose (paper)
GreenBio	PHA
Ingeo	TPS/PLA; PBS/PLA
Mater Bi	PCL/TPS; PBAT
Landmaster	Cellulose (paper)
Mirel	PLA + PHAs
Naturecycle	Starch
Paragon	TPS
Planters Paper	Cellulose (paper)
ReNew	PHAs
Skygreen	Terephthalic acid co-polyester
Weed Block	Cellulose (paper)
WeedGuard	Cellulose (paper)

<sup>1</sup> Abbreviations: PBAT polybutylene adipate terephthalate; PBS polybutylene succinate; PBSA PBS-co-adipic acid; PCL polycaprolactone; PHA polyhydroxyalkanoate; PLA polylactic acid; TPS thermoplastic starch

**Source:** Hayes et al. 2012. Biodegradable agricultural mulches derived from biopolymers. In Degradable Polymers and Materials, Principles and Practice, 2nd Edition. Am. Chem. Soc.



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# Biodegradable mulch ingredients

Ingredient <sup>1</sup>	Feedstock	Synthesis	ERBD in soil <sup>2</sup>
Cellulose	Biobased	Biological	High
PBAT	Hydrocarbon	Chemical	Low moderate
PBS	Hydrocarbon	Chemical	Low moderate
PBSA	Hydrocarbon	Chemical	Low moderate
PCL	Hydrocarbon	Chemical	Moderate
PHA	Biobased	Biological	Moderate high
PLA	Biobased	Biological & Chemical	Low
Sucrose	Biobased	Biological	High
TPS/Starch	Biobased	Biological	High

<sup>1</sup> Abbreviations: PBAT polybutylene adipate terephthalate; PBS polybutylene succinate; PBSA PBS-co-adipic acid; PCL polycaprolactone; PHA polyhydroxyalkanoate; PLA polylactic acid; TPS thermoplastic starch

<sup>2</sup> **Source:** Brodhagen et al. 2015. Biodegradable plastic agricultural mulches and key features of microbial degradation. Appl Microbiol Biotechnol (2015) 99:1039–1056.



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# Testing standards for biodegradable mulch

- Standard
- Performance
- Use
- New
- Amendment
- ASTM
- Composting



Figure 3. Laboratory apparatus employed to measure the biodegradability of plastic mulches under composting conditions via the ASTM D5338 standardized laboratory test.

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## Performance and Adoptability Biodegradable Mulch

biodegradablemulch.org

Report No. EXT-2019-01

January 2019

### Authors:

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Douglas Hayes

### Summary

Understanding standards is key to understanding how biodegradable plastic mulches are regulated and expected to perform. However the multitude of different standards for these products have produced some misunderstandings. After explaining what standards are and how society uses them, we clarify the content of various standards related to biodegradable plastic mulches and summarize their objectives and limitations.

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### The Role of Standards for Use of Biodegradable Plastic Mulches: Truths and Myths

Biodegradable plastic mulches (BDMs; Fig. 1) are important materials employed in the sustainable production of vegetables and other specialty crops. They provide many benefits to farmers including reduced weeds, water conservation, and improved crop quality and yield. Unlike conventional polyethylene mulches, which after their laborious retrieval cannot be sustainably disposed of, BDMs are designed to be inexpensively plowed into the soil, where they will fully biodegrade into carbon dioxide, water and cell biomass. Standards play a key role in certifying how BDMs will perform when employed in the field; however, standards relating to BDMs are frequently misunderstood and interpretations may differ between the target audiences being addressed. In order to help clarify the role that standards play in relation to BDMs, we first review what standards are and the role they play in society. We then take a look at standards that currently are used for BDMs, followed by a discussion of their objectives and limitations.

### Overview of Standards

Standards are commonly encountered in everyday life, but their exact purpose is often misunderstood or unknown. It is important to clarify their purpose, as standards determine the kinds of choices and opportunities that are possible in our social world. In short, standards are the written and enforced rules of society (Busch 2011). More specifically, standards set thresholds that must be met by a product or practice in order to be



Figure 1. Biodegradable plastic mulches employed in the production of specialty crops.



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# Testing standards for biodegradable mulch

Standardization Organization	Standard Name	Comments
European Committee for Standardization (CEN)	<b>EN 17033</b> (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
Association Francaise de Normalisation (AFNOR)	<b>NFU 52-001</b> (2005): Biodegradable Mulches for Use in Agriculture and Horticulture - Mulching Products - Requirements and Test Methods	French standard pertaining to biodegradable mulches
Ente Nazionale Italiano di Unificazione (UNI)	<b>UNI 11495</b> (2013): Biodegradable Thermoplastic Materials for Use in Agriculture and Horticulture - Mulching Films - Requirements and Test Methods	Italian standard pertaining to biodegradable mulches
ASTM, International	<b>ASTM D6400</b> (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 <sup>1</sup>
TUV Austria (formerly Vincotte) <sup>2</sup>	<b>OK Biodegradable SOIL</b> (label)	Certifies that plastic materials will biodegrade fully and will not promote ecotoxicity in the soil
<sup>1</sup> ISO (International Organization for Standardization) has equivalent standards; <sup>2</sup> 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.		

Source: Dentzman and Hayes, 2019



# Mulch biodegradability

- Biobased ≠ biodegradable
- Companies may misrepresent their products as biodegradable
  - Look for the standard tests on the label
  - Oxo- and photo-degradable ≠ biodegradable
- Just because 'organic' is in the product name, doesn't mean the product is allowable for use in certified organic agriculture
  - Organix AG
  - FilmOrganic
- Always check with your certifier before using a product in certified organic agriculture



# Oxo-degradable plastic

- **Made with conventional plastic:** high density polyethylene (HDPE), low density PE (LDPE), polypropylene (PP), polystyrene (PS), polyethyleneterephthalate (PET), polyvinylchloride (PVC)
- Includes additives that promote oxidation of the material, triggered by UV light, heat, and oxygen
- Product becomes brittle and fragments
- Independent third party standard  
ASTM & ISO test data show small percent or no film fragments utilized by soil microorganisms



*3 years after mulch application, Everett, WA  
Photo by Andy Bary*



# Oxo-degradable plastic

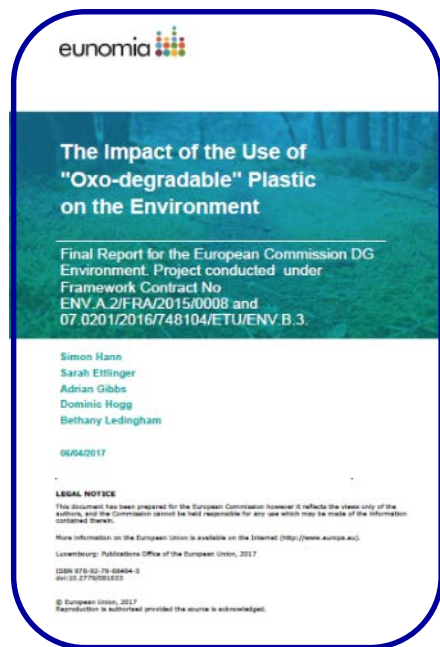
100707015 - FTC Concludes ECM BioFilms Made False, Misleading, and Unsubstantiated Claims About the Biodegradability of Plastic Products Treated as



FEDERAL TRADE COMMISSION  
PROTECTING AMERICA'S CONSUMERS

FTC Concludes ECM BioFilms Made False, Misleading, and Unsubstantiated Claims About the Biodegradability of Plastic Products Treated with Its Additive

FOR RELEASE  
October 19, 2015



- FTC concluded company making false and unsubstantiated claims about oxo-products
- Designed to degrade very slowly: < 2% in 2 years
- Does not undergo biodegradation
- Not suitable for composting or anaerobic digestion
- Recommend prohibition of sales into markets where plastics are recycled:
  - Reduces quality of plastics recyclate
  - Cannot be identified and separated



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# USDA National Organic Program Rule

**Biodegradable biobased mulch film** was added to list of allowed substances on October 2014, but it **MUST**:

1. Be biobased (*ASTM D6866*)
2. Be produced without the use of non-biobased synthetic polymers; minor additives (colorants, processing aids) not required to be biobased
3. Be produced without organisms or feedstock derived from excluded methods (i.e., synthetic, GMO)
4. Meet compostability specifications (*ASTM D6400*, *ASTM D6868*, *EN 13432*, *EN 14995*, or *ISO 17088*)
5. Reach  $\geq 90\%$  degradation in soil within 2 years (*ISO 17556* or *ASTM D5988*)



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# Use of GMO in biodegradable mulch

- Genetically modified organisms (GMOs) are commonly used in the manufacture of biodegradable mulch:
  - Feedstocks, such as starch: corn, sugar beet
  - Fermentation of feedstocks: bacteria, yeast
  - Minor additives
- Difficult to determine GMO status of end product:
  - Source of feedstocks not disclosed
  - DNA may be degraded after fermentation and processing, thus not measurable



# Biodegradable mulch research 2015-2019



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# Mulch treatments 2015-2018

Treatment	Manufacturer	Thickness (mil)	Bio-based %
Bare ground			
BioAgri	BioBag Americas, Inc., Dunedin, FL	0.7	20-25%
Exp. PLA/PHA	Experimental Film	1.0	86%
Naturecycle	Custom Bioplastics, Burlington, WA	1.0	≤ 20%
OrganixAG (black)	Organix Solutions, Maple Grove, MN	0.7	10%
OrganixAG-Clr (clear)	Organix Solutions, Maple Grove, MN	0.5/0.6	10%
Polyethylene	Filmtech, Allentown, PA	1.0	< 1%
WeedGuardPlus	Sunshine Paper Co., Aurora, CO	10	100%

Organix-Clr 2017 & 2018 only



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# Pumpkin 2015 & 2016



## Sites:

1. Mount Vernon, WA
2. Knoxville, TN

- 5 rows per plot, 30 ft long row
- 'Cinnamon Girl' pie pumpkin



**Source:** Ghimire et al. 2018. HortScience 53:288-294.



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# Sweet corn & bell pepper

## 2017 & 2018

Mount Vernon, WA

- 'Xtra-Tender 2171'  
sweet corn



Knoxville, TN

- 'Aristotle'  
green bell pepper





# Percent soil exposure (PSE)



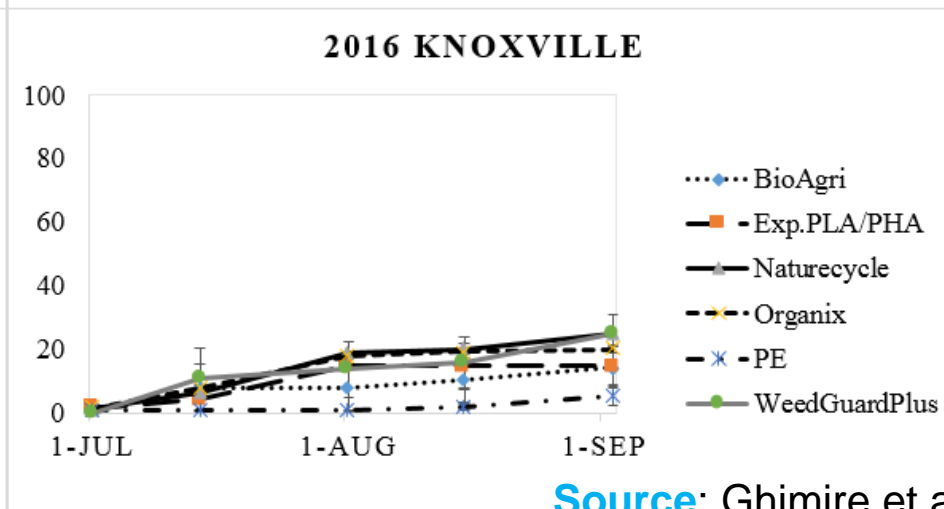
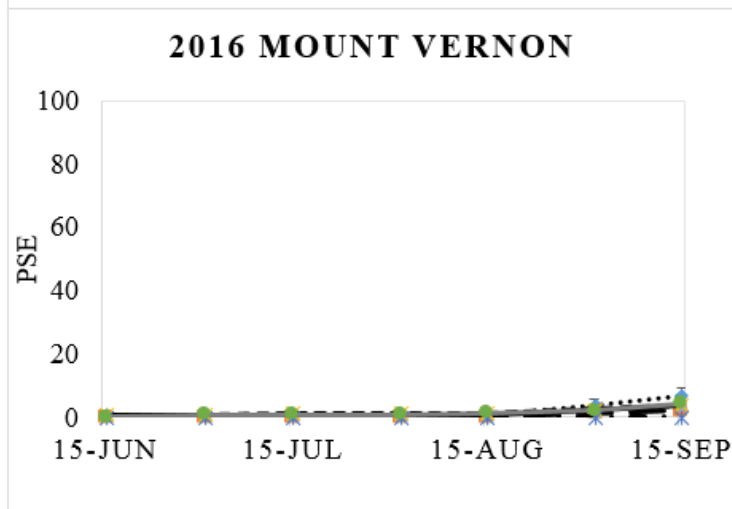
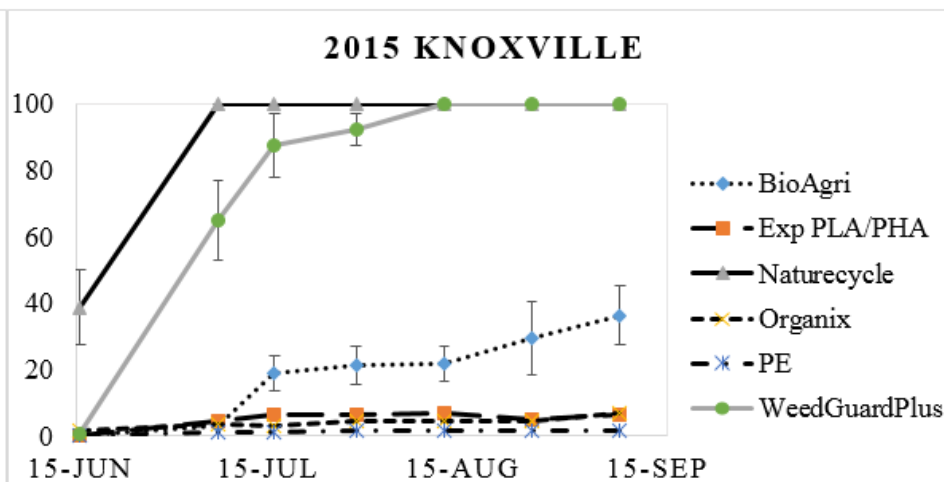
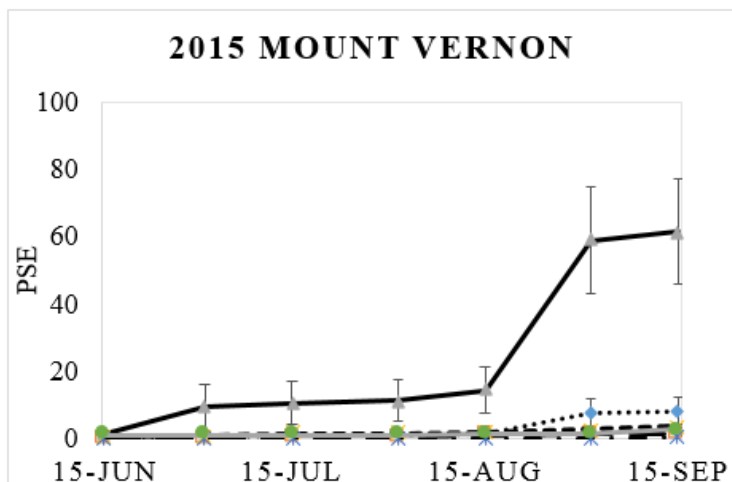
5%



40%



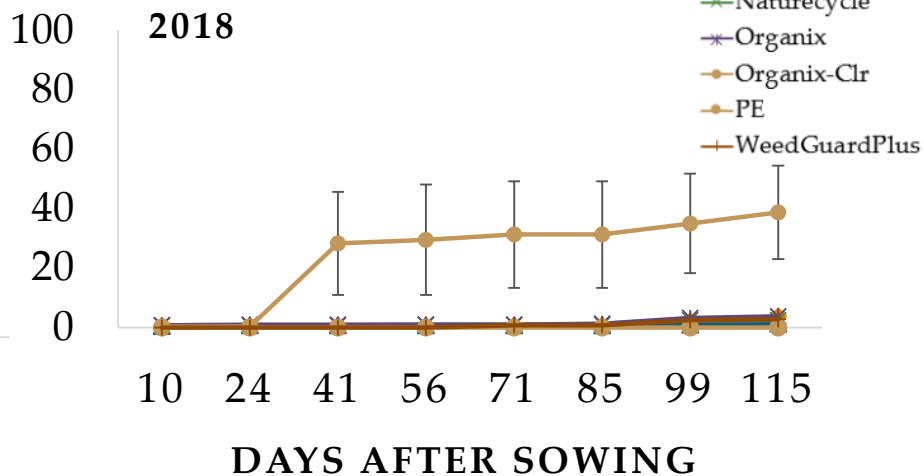
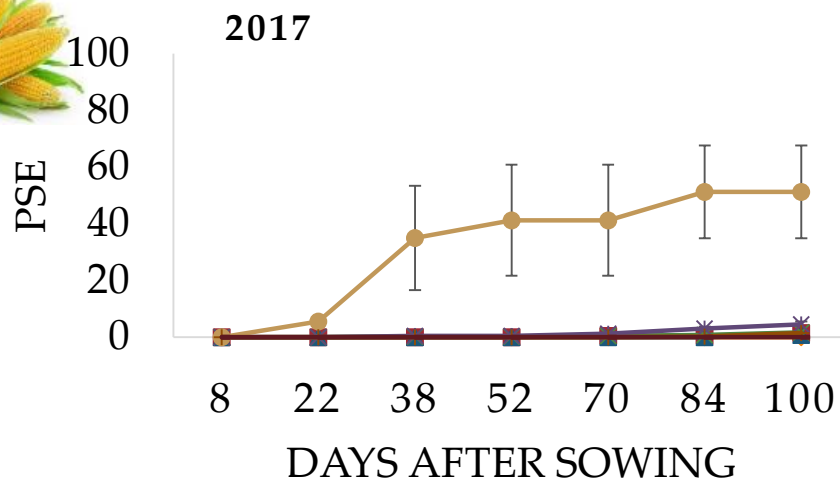
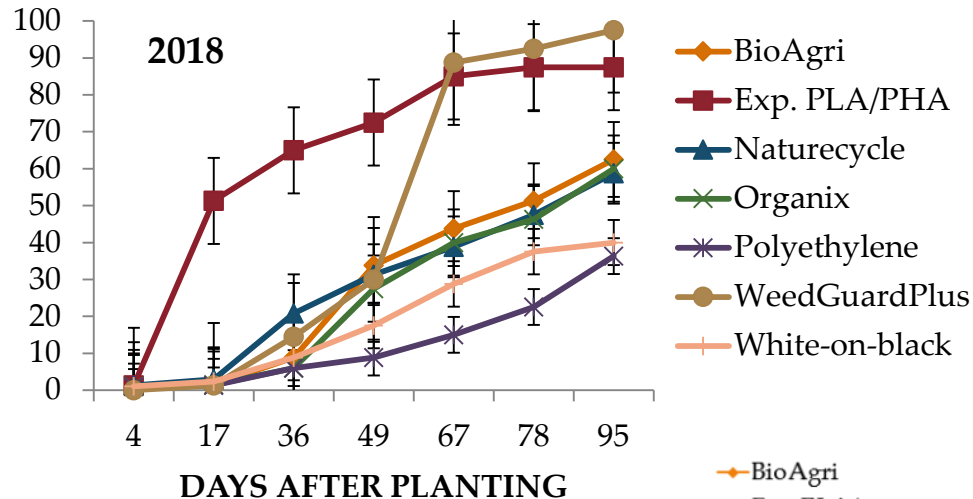
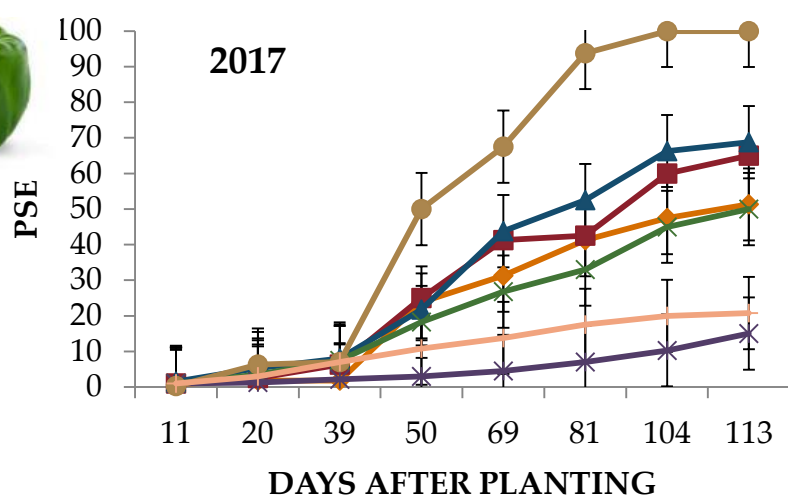
# Percent soil exposure (PSE)



Source: Ghimire et al. 2018.



# Percent Soil Exposure





# Mulch deterioration



14 July 2017



BioAgri



PLA/PHA



Naturecycle



PE



Organix-Blk



Organix-Clr



WGP



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# Weed Control



- WeedGuardPlus excellent for controlling weeds, especially nutsedge, during critical period





# Crop yield t/ha



	Pumpkin <sup>1</sup>	
	Mount Vernon	Knoxville
PE	<b>22.8 a</b>	<b>20.4</b>
Exp.PLA/PHA	21.0 ab	16.3
BioAgri	20.9 ab	18.8
Naturecycle	19.9 ab	17.3
Organix-Blk	18.4 bc	19.9
Organix-Wht/Blk	-3	-
Organix-Clr	-	-
WeedGuardPlus	15.3 c	16.2
Bare ground	8.7 d	15.3
<i>P-value</i>	<i>&lt; 0.0001</i>	<i>0.27</i>



<sup>1</sup> Data combined for 2015 and 2016

<sup>2</sup> 2017 only

<sup>3</sup> Mulch product not included



# Mulch performance

	Yield		Weed Control
Crop	vs. Bareground	vs. PE	vs. PE
Broccoli	+ <sup>1</sup>		
Cucumber	+	=	=
Eggplant	+	=	-
Pepper	=	=	-
Lettuce		-= <sup>2</sup>	
Melon	+	+=	
Strawberry		-+=	-
Sweet Corn	+	-=	-
Sweet Potato	+	+=	+
Tomato	+	=	
Zucchini		=	

<sup>1</sup> + BDM performed better, = BDM performed equivalent to, - BDM did not perform as well, and empty cell not measured.

<sup>2</sup> Reports provide variable results.

**Source:** Cowan and Miles. 2018.



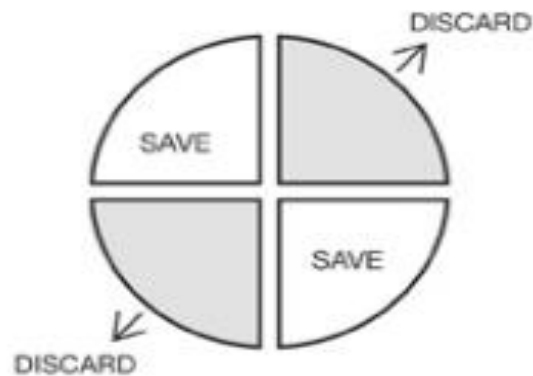
# Mulch incorporation





# Collecting mulch from soil

- Collect soil sample 3 ft<sup>2</sup> and 6 inch depth
- Quartering method, repeated 3 times per sample, ~5 gal. per sample
- Extract mulch fragments by wet sieving soil sample (2.4 mm screen)



**QUARTERING A SAMPLE**  
(TOP VIEW)

**Source:** Ghimire and Miles. 2018.



# Measuring mulch fragments

- Graph paper  
conversion factor:  $\times 1.189$

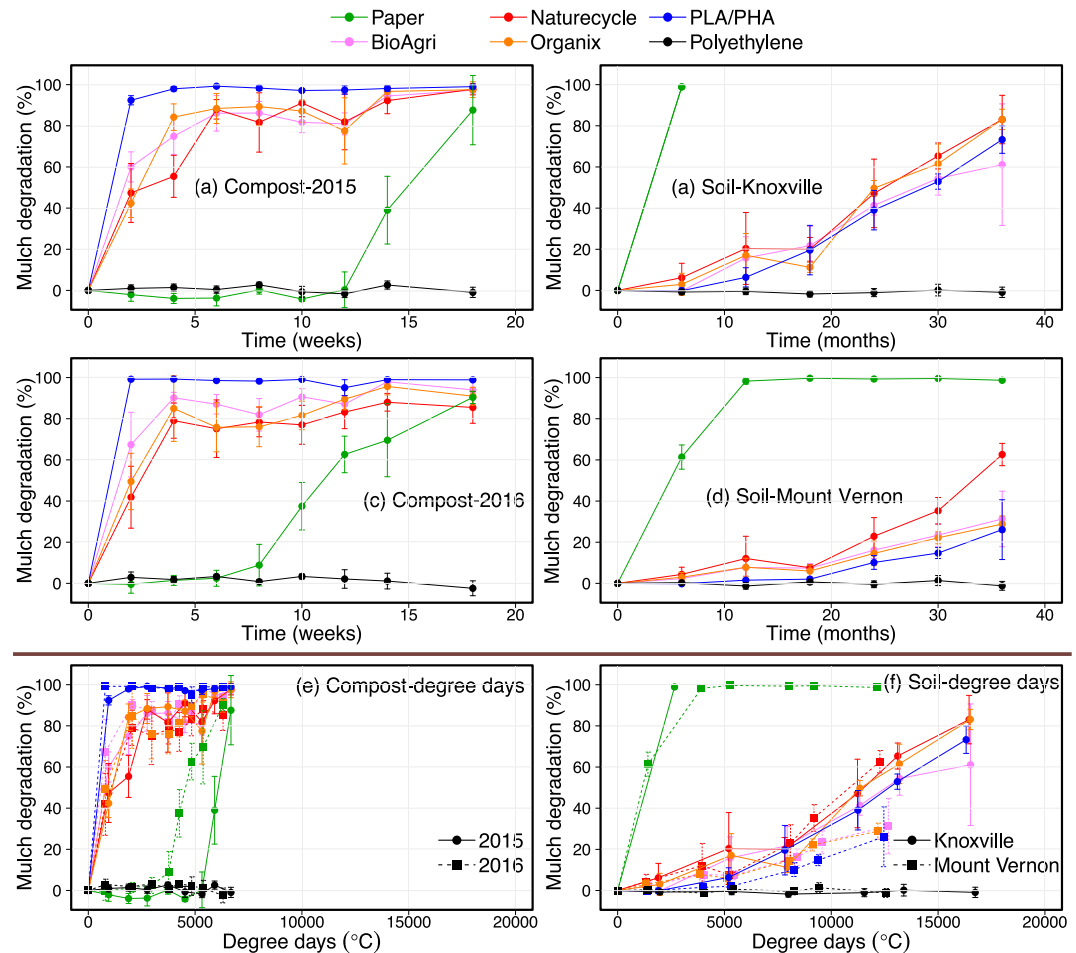


- Image J software  
conversion factor:  $\times 0.868$





# Biodegradation in soil and compost



- ASTM soil test in lab shows degradation in 2 years



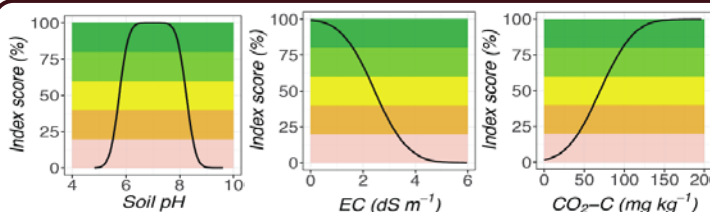
# Impacts on Soil Health

- USDA Kit
- Curves used to transform data into a score for each parameter
- Add all scores into 1 soil indicator value in order to compare treatments and locations



Biodegradable  
mulch

## Soil Health Assessment



## Soil Health Indicators

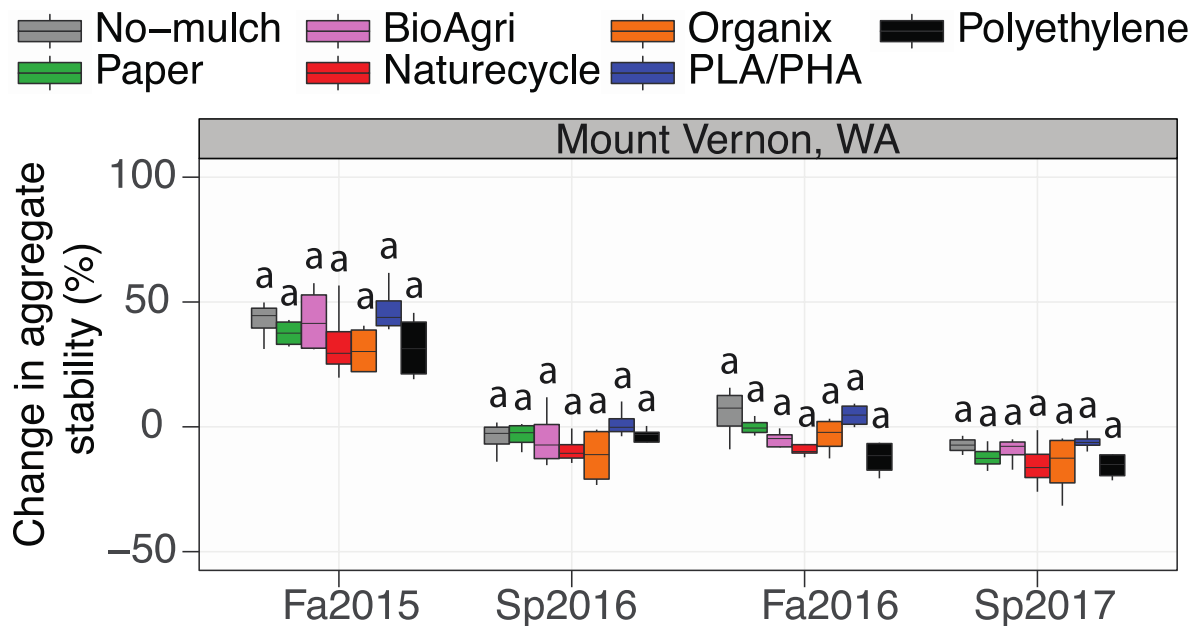
- **Structure Indicators**
- **Hydraulic Indicators**

- **Biological Indicators**
- **Chemical Indicators**

- **Fertility Indicators**
- **Salinity & Sodicity**



# Impacts on Soil Health



- Effect of time and location greater than treatment effect
- Sintim et al., 2019, Agriculture, Ecosystems and Environment, 273:36-49.



# For more information

## [www.biodegradablemulch.org](http://www.biodegradablemulch.org)

### **NEW** [The Role of Standards for Use of Biodegradable Plastic Mulches: Truth and Myths](#)

Understanding standards is key to understanding how biodegradable plastic mulches are regulated and expected to perform. However, the multitude of different standards for these products have produced some misunderstandings. After explaining what standards are and how society uses them, we clarify the content of various standards related to biodegradable plastic mulches and summarize their objectives and limitations.

[pdf file]



### **NEW** [On-Farm Biodegradable Mulch Case Study: Cloudview Farm - Washington State](#)

Following a trial of four types of mulches, the farm operators of Cloudview Farm concluded that biodegradable plastic mulches were a useful alternative to polyethylene (conventional plastic) mulch, but they had concerns about aesthetics and soil health over time.

[pdf file]



### **NEW** [On-Farm Biodegradable Mulch Case Study: Omache Farm - Washington State](#)

This is the inaugural report of a series of case studies of farms that have field-tested biodegradable mulches. The Omache Farm operators preferred polyethylene (conventional plastic) mulch over paper, and biodegradable plastic mulch over polyethylene plastic mulch. Reasons included weed control, labor, and plant growth.

[pdf file]



### **NEW** [Soil Sampling Method to Assess the Amount of Mulch Fragments in the Field after Tillage](#)

A method to estimate the amount of visible mulch fragments in the soil is presented. This method does not measure the rate or extent of biodegradation, but it does assess the initial stage of mulch degradation after soil incorporation.

[pdf file]



### **NEW** [Impact of Biodegradable Plastic Mulch on Specialty Crop Production](#)

Research on the efficacy of biodegradable plastic mulches (BDMs) has focused on its effects in vegetable and fruit crop production systems. This summary of research results provides a quick reference to the scientific literature on the use of BDM for vegetable and fruit crops. For some crops, several studies have been carried out in production systems around the world, and findings may vary.

[pdf file]



### **NEW** [Important Considerations for the Use of Biodegradable Mulch in Crop Production](#)

This Washington State University factsheet reviews factors to consider when considering use of biodegradable plastic mulch, such as the amount needed, installation procedures, and labor savings at end-of-season relative to use of conventional polyethylene mulch.

[pdf file]



### [A Summary and Assessment of EN-17033:2018, A New Standard for Biodegradable Plastic Mulch Films](#)

A European Union standard for biodegradable plastic mulch was enacted in January 2018. The standard imposes biodegradation requirements for biodegradable plastic mulch or its constituents and establishes the standardized laboratory testing processes to determine if the product meets the requirements. Issues that remain, but which can be addressed by additional research, are identified.

[pdf file]



### [Mulch Calculator](#)

An interactive "mulch calculator" assists farmers in determining the quantity of mulch needed and provides cost comparison to polyethylene plastic mulch.

[pdf file] [Excel worksheet]



### [The Economics of Adopting Biodegradable Plastic Mulch Films](#)

The questions farmers should ask and have answered when considering adoption of biodegradable plastic mulch are the focus of this University of Tennessee fact sheet. Product cost, disposal cost, end-of-season labor implications, and other economic factors are addressed.

[pdf file]



### [Biodegradable Plastic Mulch and Suitability for Sustainable and Organic Agriculture](#)

Biodegradable plastic mulch (BDM) offers crop production benefits similar to polyethylene (PE) mulch but is designed to be tilled into the soil after use, thereby eliminating waste and disposal challenges associated with PE mulch use. This Washington State University fact sheet explains the use of plastic mulch in agriculture, what plastic BDMs are made from, and what constitutes biodegradability. It also provides information about the suitability of plastic BDM for organic agriculture.

[pdf file]



### [Oxo-degradable Plastics Risk Environmental Pollution](#)

Oxo-degradable plastic mulch is a re-emerging alternative to biodegradable plastic mulch and conventional plastic mulch. However, oxo-degradable plastic is not biodegradable in field conditions; fragments will remain in the soil or surrounding environment for decades, where they become micro or nano particles that are pollutants in soil and water systems. There is a call to ban oxo-degradable plastic packaging in the U.S. and EU because it poses risk to our environment.

[pdf file]



### [Soil Fumigation and Biodegradable Plastic Mulch](#)

Biodegradable mulches are not EPA-approved tarps for soil fumigation. This fact sheet explains the limitations of biodegradable mulch use in soil fumigation systems.

[pdf file]





# Acknowledgements

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