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

Authors:

Katherine Dentzman

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

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.

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

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

approved by a given organization. Whether or not the thresholds for a standard are met is determined by standardized tests, which provide measures of precision, accuracy, time, cost, differentiation, reliability, and destructiveness (Busch 2011). Different organizations may then determine whether these measurements are sufficient to pass their threshold and meet their standard. If the standard is met, the product or practice may be adopted by the organization and/or given a certification authenticating that it has met a particular standard. In this way, standards have become a proxy for interpersonal relations, trust, and reputation (Busch 2011; Mutersbaugh 2005). That is, standards are meant to guarantee a certain level of quality and integrity, protecting consumers from unscrupulous practices and products, and arming them with information to make healthy and sustainable choices (Mutersbaugh 2005).

The approval of a particular product or practice may be granted by a national or international standards setting committee (Loconto and Busch 2012; Mutersbaugh 2005). Additionally, national or sub-national non-governmental organizations may set their own standards that improve upon, run parallel to, or diverge from national or international standards (Table 1). For example, the national non-governmental Certified Naturally Grown (CNG) program has standards that farmers and their products must meet in order to become certified and use the CNG label (CNG 2018). These standards have similarities, but also some key differences, to those of the national U.S. Organic Certification program, which sets standards that must be met for a farmer or a product to use the USDA Organic label (CNG 2018; USDA 2018). The International Federation of Organic Agriculture Movement (IFOAM) sets standards that individual national programs must meet in order to be approved by IFOAM and considered equivalent to other approved national programs (IFOAM 2018).

At all levels, standards represent the exercise of power; whoever has the authority and influence to set standards can create the rules that others must follow to receive certification. This action gives standards and the people that set them a great deal of power over what hurdles a product or practice must pass to be considered ‘acceptable’—and therefore useable and marketable. This circumstance can result in harmful standards when actors in power refuse to compromise, take minimal precautions, eschew local and public knowledge, and limit the review and rewriting of standards (Busch 2011). For instance, standards often focus on economic considerations, undermining ecological and social justice goals (Guthman 2004). The creation of standards is ultimately a matter of whose opinion is heard, whose opinion matters, and who has the power to bring their views to the table (Bacon 2010; Loconto and Busch 2012; Ponte and Cheyns 2013). When used appropriately and fairly, standards make manifest the ideals of society and ensure that products and practices are environmentally, socially, and economically sustainable (Bray, Sanchez and Murphy 2002; Busch 2011; Friedmann 2007).

What Standards Are Currently in Use for Biodegradable Mulch Films?

In January 2018, the European Committee for Standardization (CEN) released European Standard EN 17033. It is the first standard put forth by a major standard organization for certification of plastic mulch films as being “biodegradable” (in soil). It is based on previously released national-level and industrial organization standards (Table 2). As noted in a review

Table 1. Organizations that Prepare Standards and Certifications

International Organizations	
Organization Name	**Description**
ASTM, International	International organization providing technical standards for a wide range of products and processes. Over 140 member countries.
European Committee for Standardization (CEN)	International organization representing the interests of the European Union. Develops, maintains, and distributes standards. 34 member countries.
International Federation for Organic Agriculture Movements (IFOAM)	International umbrella organization providing standards for organic agriculture. 800 affiliates in 117 countries.
International Organization for Standardization (ISO)	International organization of representatives from national standards organizations. Provides industrial and commercial standards. 162 member countries.
Organization for Economic Cooperation and Development (OECD)	Intergovernmental organization providing standards for responsible business conduct. 36 member countries.
National Organizations	
Organization Name	**Description**
American National Standards Institute (ANSI; U.S.)	Private non-profit standards organization accrediting standards developed by government agencies, consumer groups, and others. Works closely with the U.S. government and represents the U.S. in the ISO.
Association Francaise de Normalisation (AFNOR; France)	French federal organization for standardization of a wide range of products and practices. Works in conjunction with ISO.
Canada Organic Regime (COR; Canada)	Federal regulatory and certification organization for organic agriculture in Canada. Regulates the use of the term 'organic' for farms and products.
Ente Nazionale Italiano di Unificazione (UNI; Italy)	Private non-profit standards organization for industrial, commercial, and service sectors in Italy. Recognized by the Italian government and represents Italy in the ISO.
National Organic Program (NOP; U.S)	Federal regulatory and certification organization for organic agriculture in the United States. Regulates the use of the term 'organic' for farms and products.
Non-Governmental Organizations	
Organization Name	**Description**
Certified Naturally Grown (U.S.)	Private non-profit U.S. standards organization certifying farms and farm products. Standards are similar to NOP standards; however some differ and regulation is more flexible.
Food Alliance (U.S.)	Private non-profit U.S. standards organization certifying farms and farm products. Focus on labor, animal welfare, and environmental sustainability. Requires continual improvement of practices.
Non-GMO Project (North America)	Private non-profit standards organization for all of North America. Provides 'best practice' standards for avoiding genetically modified organisms in ingredients, products, and manufacturing facilities.

Table 2. Standards pertaining directly or indirectly to biodegradable plastic mulches

Standardization 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
Association Francaise de Normalisation (AFNOR)	NFU 52-001 (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)	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.

by Hayes and Flury (2018), Standard EN 17033 consists of requirements pertaining to inherent biodegradability and ecotoxicity in soil, composition (e.g., no heavy metals or hazardous substances), and dimensional, mechanical, and optical. The requirements are evaluated using standardized laboratory tests specified by standardization organizations.

ASTM (Fig. 2) and ISO have produced standards pertaining to biodegradable plastics in general (i.e. not specific to mulches) (Table 2). ASTM D6400 is one of the most commonly cited standards in reference to BDMs. The topics addressed by ASTM D6400 are similar to EN 17033, such as inherent biodegradability and ecotoxicity. However, biodegradation under ASTM D6400 is tested under composting conditions, while under EN17033 it is tested in ambient soil. Therefore ASTM D6400 and EN 17033 are not specific to BDMs in their intended use environment—actively farmed soil. For EN 17033, a standardized laboratory test that mimics soil conditions (including ambient temperature) is to be used. ASTM D5988 is one standardized biodegradability test that can be employed, as could other standardized tests equivalent to ASTM 5988 but prepared by other organizations. ASTM D6400, on the other hand, employs a standardized test method, ASTM D5338 (Fig. 3), which utilizes a laboratory test that simulates industrial composting conditions: the use of a compost-based medium, 58°C, etc. Both ASTM D5988 and D5338 tests involve comparable laboratory setups and both measure the production of carbon dioxide gas produced from aerobic mineralization by microorganisms (ASTM International 2012). The

Figure 2. Logo of ASTM International, a member organization that has established more than 12,500 standards focused on public health and safety.

requirements for inherent biodegradability in EN 17033 and ASTM D6400 also differ. The former standard requires 90% conversion of the mulch's carbon atoms to CO_2 (considered as being fully biodegraded) in 2 years using the ASTM D5988 test, while the latter requires 90% conversion of C into CO_2 within 180 days by the ASTM D5338 test. (There are related biodegradation requirements for special cases, as described in Hayes and Flury, 2018.) The soil and industrial composting environments differ greatly, not only in temperature, but also microbial communities.

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

The U.S. National Organic Program (NOP) maintains standards for the use of BDMs in certified organic agriculture. The Biodegradable Plastics Institute first petitioned for the use of BDMs to the National Organic Standards Board (NOSB) in 2012. In 2014, the petition was approved and BDMs were added to the National List (Organic Materials Review Institute [OMRI] 2015). This approval was based on four primary requirements.

1) BDMs must be completely biodegradable, which the NOP defines as showing at least 90 percent biodegradation in soil absolute or relative to microcrystalline cellulose in less than two years, as tested using ASTM D5988 (similar to the criterion used in EN 17033).
2) BDMs must be biobased with content determined using the ASTM D6866 standardized test (ASTM International 2018), which evaluates biobased content on the stable carbon isotope profile of the plastic material. Although biobased content was not a part of the petition submitted in 2012, it was decided by the NOSB that some specification of biobased content should be included. In the end, the percentage of biobased content was not specified; rather, the biobased content was simply to be measured and reported.
3) BDMs must be produced without organisms or feedstocks derived from excluded methods (e.g., no genetically modified organisms).
4) Farmers are required to take appropriate measures to ensure complete biodegradation (Malinconico 2017; OMRI 2015).

The second of these requirements created some confusion for certifiers and material evaluation programs (OMRI 2015). These entities wrote to the NOP, requesting a specific percentage of biobased content criterion for BDMs be specified. On January 22, 2015, Miles McEvoy, Deputy

Administrator of the NOP, addressed these questions by issuing Policy Memorandum 15-1, stating that all polymer feedstock for BDMs must be fully biobased (McEvoy 2015). This effectively meant that 100 percent of the feedstocks for BDMs must come from biobased sources, creating a blanket standard that eliminated potential confusion at the regulatory level. Currently, no commercially available BDM meets this requirement; OMRI reports that the highest biobased percentage form BDMs on the market is around 20 percent (OMRI 2015).

The Purpose of Standards Is Misunderstood: Limitations of Standards

The intent of standards for BDMs is to ensure their quality and integrity in agriculture. In particular, these standards are meant to exclude materials that claim to be biodegradable—but in fact are not fully metabolized by microbes—from using the term. For example, oxodegradable agricultural mulch films have historically used the term 'biodegradable' as a marketing tool (Federal Trade Commission 2015; Miles 2017). However, these mulches do not fully biodegrade in the scientific sense of the term, i.e., fully breakdown into water, CO_2, and microbial biomass (Malinconico 2017). Although oxodegradables undergo macroscopic disintegration, they leave soil-borne microscopic particulate behind that can potentially pollute the soil. By enforcing a standard for biodegradable mulch films, consumers can have confidence that the products will fully biodegrade and not harm the soil. Additionally, consumers would be assured that all certified BDMs have passed tests and met standards of quality and performance.

While standards for BDMs guarantee that the products have passed given lab-scale tests for composition, inherent biodegradability, and ecotoxicity, they do not necessarily guarantee a particular degree of performance in fields. Standardized tests are conducted under controlled environments that do not necessarily mimic the environment encountered on farms that involve variable environmental, soil, crop, and management conditions. All of these factors play a role in determining the speed and extent of biodegradation, and it is difficult to simulate all of these conditions in a single laboratory test (Malinconico 2017). In addition, the standardized laboratory tests such as ASTM D5338 and D5988 employ plastics that have been size-reduced into a fine powder. In contrast, mulch fragments tilled into the soil will be much larger, which will lead to longer duration for biodegradation to occur, since less surface area of the mulches will be exposed to the microorganisms (Chinaglia, Tosin and Degli-Innocenti 2018). Moreover, the standardized tests measure inherent biodegradability, referring to a standard potential for biodegradation.

An important point of confusion is why 90% biodegradation (i.e., conversion of the plastic's carbon atoms into CO2), and not 100%, is used as a criterion in standards such as ASTM D6400, EN 17033, and the USDA NOP standards. One reason is that a significant portion of the plastic is incorporated into microbial biomass, as demonstrated by a recently published study investigating the biodegradation of ^{13}C-labeled BDM feedstock (Zumstein et al. 2018). Another involves the precision of the biodegradability lab tests (Zumstein et al. 2018). Internal studies conducted by ASTM, for instance, have shown that 90% conversion of the carbon atoms of readily biodegradable reference materials, such as cellulose, into CO2 is typically achieved when using the standardized tests and the 3-5 recommended replicate experiments (R. Narayan,

personal communication). Therefore, ASTM and other standards organizations consider 90% conversion to be equivalent to full biodegradation.

Standards are often taken out of context by manufacturers and consumers. A common example is that compliance of a biodegradable plastic to ASTM D6400 allows the plastic to be considered as "biodegradable". However, as discussed above, ASTM D6400 refers to biodegradability and non-toxicity under industrial composting conditions, not the conditions usually encountered by mulches after being tilled into the soil. Moreover, biodegradability criteria in standards must be directly associated with the specific environment that is relevant to the plastic material's typical end-of-life.

Conclusions

Standards pertaining to biodegradable plastic mulches are intended to ensure consistency and quality while also excluding unscrupulous manufacturers from marketing misrepresented products. They are not, as sometimes may be assumed, a guarantee of complete biodegradation on-farm within a certain timeframe. Rather, requirements for biodegradation are among many criteria listed in standards that are designed to ensure reliable performance above and below the soil by biodegradable plastic mulches. This is a common misunderstanding that has hopefully been clarified here.

A number of similar yet different standards are associated by stakeholder groups with biodegradable plastic mulches, as represented in Table 2. These employ different standardized tests and include different requirements, such as biodegradation testing environment. This makes the standardization of biodegradable plastic mulches all the more confusing and difficult for farmers to interpret. The new international standard, EN 17033, may increase the consistency of biodegradable plastic mulch regulation across countries and their standard-setting organizations. In the meantime, in this factsheet we have provided information on each standard relating to biodegradable plastic mulches so that the differences and intentions may be better understood.

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