Performance and Adoptability

Biodegradable Mulch

biodegradablemulch.org

Report No. EXT-2018-01 **June 2018**

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

Authors:

Douglas G. Hayes[1]

Markus Flury[2]

[1] University of Tennessee, dhayes1@utk.edu

[2] Washington State University, flury@wsu.edu

Summary

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.

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.

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

In January 2018, the European Standard EN 17033: *Plastics–Biodegradable mulch films for use in agriculture and horticulture–Requirements and test methods* was released [1]. The standard was developed by the European Committee for Standardization, Technical Committee CEN/TC 249 Plastics and applies to all European Union countries plus Macedonia, Norway, Sweden, Switzerland, Serbia, Turkey, and the United Kingdom. This standard regulates the requirements for biodegradable plastic mulch films (BDMs): their composition, biodegradability in soil, effect on the soil environment (ecotoxicity), mechanical and optical properties, and the test procedures for each of the listed categories. It does not apply to mulch films that are being removed from the fields after use.

Above: Used polyethylene mulch is sometimes stockpiled on farms when disposal is unavailable or too costly. Biodegradable plastic mulch is intended to provide the same productivity and water management benefits that PE mulch provides but is designed to degrade to CO_2 and water when tilled into the soil.

This standard is an important achievement that will hopefully facilitate increased replacement of conventional polyethylene mulches by BDMs in the production of fruits, vegetables and other specialty crops. The end-of-life options for polyethylene mulches are undesirable: landfilling or recycling, stock-piling or illegal burning [2]. Plastic fragments remaining in the field or formed from stockpiles are likely to be dispersed in the environment, where they are

MONTANA STATE UNIVERSITY

WASHINGTON STATE UNIVERSITY

UTIA INSTITUTE OF AGRICULTURE THE UNIVERSITY OF TENNESSEE a hazard to biota. Fragmentation is exacerbated by sunlight and other environmental factors, leading to embrittlement. The fragments can further degrade into micro- and nano-plastics, which can lead to further harm. In contrast, BDMs are designed to be plowed into the soil, where fragments will be biodegraded by microorganisms.

Until the release of EN 17033, no standard existed that was issued by an international organization such as ASTM International, International Organization for Standardization (ISO), or CEN that pertained directly to biodegradation of plastics (particularly BDMs) in soil. Standards have existed for the biodegradation of plastics under compost and marine environments (e.g. ASTM D6400 and D6691, respectively) since 1996 and 2001, respectively. These standards (and the standardized testing methods referred to therein) have been misrepresented to reflect biodegradation in soil. "TÜV Austria (formerly Vinçotte), a certification body authorized by European Bioplastics (an association representing the interest of the European bioplastics industry [3]), developed an "OK biodegradable SOIL" label for plastics, to certify full biodegradability and the absence of ecotoxicity in soil [4,5]. ASTM developed a working document for biodegradability of plastics in soil in 2012, WK29802, which ultimately was not adopted due to an absence of consensus among the committee members. Therefore, EN 17033 breaks new ground for international organizations and is unique from the previous efforts by its focus upon BDMs rather than plastics in general. However, French and Italian national standardization organizations, the Association Francaise de Normalisation (AFNOR) and Ente Nazionale Italiano di Unificazione (UNI), respectively, developed standards to define the biodegradability of BDMs in soil: AFNOR NFU 52-001 and UNI 11495, respectively, which influenced the preparation of EN 17033.

EN 17033 requires laboratory testing of BDMs for (1) chemical composition (in particular for regulated metals and hazardous substances [6]), (2) biodegradation in soil, (3) ecotoxicity (i.e., toxic effects on plants, invertebrates, microorganisms), and (4) selected physical characteristics (e.g., thickness, tensile stress, light transmission). Specific criteria associated with the tests are given in Table 1. The inclusion of criteria for composition (e.g., maximal concentrations of heavy metals), biodegradability, and ecotoxicity to plants are consistent with compostability, marine, and the Vinçotte 'OK Soil' standards, and ASTM WK29802. However, one major difference between EN 17033 and WK29802 is that the former specifically addresses plastics before their exposure to environmental factors (which can alter chemical bonding), while the latter includes separate categories for unweathered and environmentally weathered plastics to meet the criteria. A major criterion of EN 17033 is the requirement of ≥90% biodegradation under aerobic conditions for the plastic (i.e., conversion of organic carbon into CO2) in a natural topsoil from an agricultural field or forest at 20 to 28^{o}C conditions within 2 years using a standardized test to measure CO2 respiration. Specific criteria pertaining to the biodegradability requirement are given in Table 2. The table shows that the requirement can be met by either the BDM or its components. The ecotoxicity tests are more stringent than those of ASTM D6400, for instance, involving plants, invertebrates (earthworms), and microorganisms. The three levels of ecotoxicity tests pertain to different soil exposure pathways, i.e., soil solid material, pore water, and pore gases. Plants and microorganisms would experience toxicants mainly through contact and uptake of soil pore water, while earthworms would also be exposed to toxicants through ingestion of soil material and the soil's gas phase.

Table 1. Testing requirements and criteria for biodegradable plastic mulches, as outlined in EN 17033 (Sections 5 and 6).

Criterion	Test Method [1]
I. Constituents	
• Concentration limits for heavy metals [2]	EN 17294-2
• No hazardous substances of "very high concern" (<0.1%) [3]	
• Loss of ignition at 550°C (≥60%) [4]	
II. Biodegradation	
• ≥90% conversion of mulch's carbon into CO_2 within 2 years under ambient soil conditions [5]	ISO 17556 [6]
III. Ecotoxicity	
• No acute ecotoxicity to plants (≥90% of germination rate and plant growth achieved compared to mulch-free soil)	OECD 208 [7]
• No acute ecotoxicity to invertebrates (earthworms: *Eisenia fetida* or *E. andrei*; <10% difference in mortality rate and biomass amount compared to mulch-free soil [8])	ISO 11268-1,and -23 [7]
• No acute toxicity to microorganisms (nitrification inhibition of bacteria: nitrification should be ≥80% of that achieved for BDM-free soil)	ISO 15685 [7]
IV. Dimensional, mechanical, and optical properties [9]	
• Tensile stress at break ≥18 MPa (MD); ≥ 16 MPa (TD) [10]	ISO 727-1 and -3
• Light transmission of ≤3% (only for black and opaque films)	
V. Miscellaneous	
• Proper labeling; preparation of a test report by manufacturer	
• Surface area should not decrease <10% during deployment (if best practices are used).	Annexes G and H of EN 17033

[1] For many of the tests, other societies such as ASTM have nearly equivalent tests that are acceptable for use in the standard; [2] <150 mg/kg for Zn, <50 mg/kg for Cr, Cu, and Pb, <25 mg/kg for Ni, and <0.5 mg/kg for Cd and Hg; [3] see reference [6]; [4] indicator of the content of organic material; [5] See Table 2 for more details; [6] compared to other standardized tests such as ASTM D5988, ISO 17556 is unique in its use of a "standard soil" consisting of industrial quartz sand, Kaolinite clay, natural soil, and mature compost (serving as organic carbon source); [7] modified version of test required; [8] chronic toxicity earthworm tests with 28 and 56 d exposure can also be used to fulfill the standard, as specified in EN 17033; [9] several of the requirements differ between 3 ranges of nominal thickness, <10 μm, between 10 and 15 μm, and >15 μm; other criteria not listed in this table pertain to tolerance of thickness, roll length, tensile strain at break, and impact resistance; [10] MD and TD refer to machine direction and transverse direction, respectively. Films of <10 μm must possess tensile stress of ≥16 mPa.

Table 2. Specific criteria pertaining to 90% biodegradation under ambient soil conditions in 2 years.

- Can be applied to the mulch film, or its plastic basematerial in its primary form (e.g., in form of pellets or powder) without additives, and/or the masterbatches [1,2]
- Alternatively, can be applied to each organic constituent at concentrations present at >1%, as long as the minor organic components do not add up to ≥5%. [3]
- Can be achieved in absolute terms or relative to a positive control (reference material), such as microcrystalline cellulose.
- The test period can be <2 years; the measurements can be stopped if a plateau in CO_2 production is achieved.
- Operated at 20-28°C (25°C preferred); variance of temperature is limited to ±2°C.
- Uses a standardized soil, as specified in the ISO 17556 test method. [4]

[1] Also applies to compositional and ecotoxicity requirements given in Table 1; [2] masterbatch refers to a mixture of polymer and a relatively large concentration of additive (e.g., colorant) that is blended with the base polymer during preparation; [3] carbon black is not considered as an organic constituent, nor are carbonaceous fillers such as $CaCO_3$, and these constituents do not need to be tested; [4] details on the standardized soil are given in Table 1.

A unique aspect of EN 17033 is its focus upon BDMs rather than conventional plastics. Therefore, specific requirements pertaining to the films' properties are included, such as minimum tensile stress and other mechanical properties and a maximum light transmission (Table 1). The standard also contains specific requirements pertaining to labeling, including the declaration of a product class and preparation of a test report by the manufacturers.

Annexes (appendices) A-G of EN 17033 pertain to the testing methods, which give specifics on the different test conditions (Table 3). Annex G describes the benefits and the expected service life of BDMs, including the desired functions (e.g., to prevent weeds, limit water evaporation, protect from pests and diseases, isolate agricultural products from soil contamination, prevent soil slaking [the breakdown of soil aggregates when wetted], and warm the soil). Annex G also includes a classification of BDMs (Table 4) and a list of factors that degrade BDMs during service life (Table 5). Annex G further includes information concerning life time and deterioration during the use of BDMs in the field. For instance, excessive deterioration is defined as a loss of >10% of mulch surface area during a single growing season. For such a situation, if a farmer has employed best practices for BDM use (Annex H), and extreme events (e.g., extreme weather events such as floods or high winds, or damage by stray animals) are not involved, unused BDM samples from the same roll would be subjected to two separate laboratory treatments: subjection to ultraviolet radiation and soil burial for a minimum duration defined by the manufacturer. The loss of tensile stress at break for the two environmental factors should be within 50% and 20% for the two treatments, respectively; otherwise, the BDM film would be considered as defective. Annex H provides 'good practices' for use of BDMs, including soil preparation, deployment, preparing perforations in the films for plants, irrigation, soil incorporation, and storage.

Table 3. Annexes (appendices) detailing test conditions in the EN 17033.

Annex	Contents
A	Preparation of soils for ecotoxicity tests
B	Acute toxicity test for plant growth
C	Acute toxicity test with earthworms
D	Toxicity effect on earthworm reproduction
E	Determination of nitrification activity
F	Determination of light transmission
G	Artificial weathering and soil weathering

Table 4. Classification of BDM films based on expected service life (from Annex G).

Class	Typical crops and crop cycles	
	Black and opaque films	***Clear films*** [1]
A	Lettuce (1-2 mo)	Maize
B	Cucurbitacaea (4-6 mo)	Melon
C	Strawberry (6-12 mo)	
D	Vineyards and orchards (>12 mo)	

[1] The duration of the crop cycles for clear films varies widely with climate

Table 5. Factors affecting degradation of BDM films during their service life (from Annex G).

- Sunlight (which can promote photodegradation)
- Heat
- Soil moisture and precipitation
  - Wind (its direction and strength) or any other mechanical stresses, such as flapping, and hail impact
- Fumigants (e.g. chloropicrine) or herbicides (e.g., hydrocarbanilate-methylcarbanilate), but not fertilizer [1]
- Micro or macro flora and fauna present in soil (e.g., horsetail: *Equisetum* sp. or sedge: *Cyperus* sp)
- Soil type and preparation prior to BDM deployment
- Storage practices [2]
- Mulch deployment and perforation practices [3]

[1] "It has been reported that the use of .. soil fumigants .. or herbicides .. can lead to premature breakings of biodegradable mulch films. For this reason it is recommended to check the type of molecules present in the products to be applied and the dosage to be used. At present there is not enough scientific evidence supporting the use of biodegradable mulch film for soil disinfection using fumigation; if a film is applied on a soil which has been disinfected by fumigation or solarization, a slower disintegration and biodegradation speed may be expected." We note that BDMs do not meet EPA regulations for fumigation.

Although EN 17033 presents a more standardized framework for the use of BDMs, some unresolved issues still remain:

1. Does achievement of 90% biodegradability in 2 years under standardized lab testing conditions as specified in EN 17033 (Table 2) directly relate to in situ biodegradation under field conditions? Field conditions are inherently variable, and degradation of BDMs will therefore differ among locations, mainly controlled by soil type, climate, and weather. A standard cannot, and is not designed, to reproduce actual field conditions. Nonetheless, degradation tests with the standard should be compared to degradation under actual field conditions to be able to "calibrate" the standard. A similar dilemma exists for other standards involving laboratory tests that simulate environmental conditions, such as the marine environment.

2. The standard allows, and actually encourages, the testing of the BDMs in powder form. While this may be desirable and reasonable for a standard test (better uniformity and contact), this also increases surface area of the material to be biodegraded, and thus will likely lead to a higher biodegradation rate than if an intact mulch film was tested. While the test will indicate whether a plastic will degrade, its results will not necessarily translate to the time required for complete degradation of films in a field. Increasing time for biodegradation in soil will also increase the possibility of plastic fragments leaching through the soil into deeper layers with less microbial activity or leaching even into groundwater.

3. Soils are variable. No two soils are exactly the same; but, soil scientists classify soils into soils that are similar to each other. Different classification schemes are available. However, the standard does not make use of such soil classification, but rather non-generically just specifies to use a topsoil from an agricultural field or a forest. This brings up two issues: (1), agricultural soils and forest soils are very different from each other, particularly in Europe, where agricultural lands and forests are separated often by topography and suitability of soils. (2), Biodegradation is expected to differ between these two types of soils, and among different agricultural soils. This leads to the question whether it would not be advisable to use a more standardized natural agricultural soil for the standard, or make at least more specific recommendations of a soil type to be used based on soil taxonomy. To reduce the issue of soil variability, there is an option in EN 17033 for a standard soil consisting of industrial quartz, kaolinite, natural soil, and compost; but, such a mixture can hardly be called a soil.

These issues are yet to be resolved, and research (see Acknowledgments) is ongoing to resolve many of these questions.

Acknowledgments:

Funding was provided by the by the USDA Specialty Crops Research Initiative, Coordinated Agricultural Project (Award 2014-51181-22382). We thank Jennifer M. DeBruyn and Margarita Velandia (University of Tennessee), Shuresh Ghimire and Carol Miles (Washington State University), and Dan Martens, Sara Guerrini, and Francesco Degli Innocenti (Novamont, Novara, Italy) for their reviews.

References and Resources

[1] **EN 17033: 2018**, *Plastics-Biodegradable mulch films for use in agriculture and horticulture-Requirements and test methods. European Standard, European Committee for Standardization, Brussels, Belgium, 2018.*

[2] Moore, J., Wszelaki, A.L., “Plastic Mulch in Fruit and Vegetable Production: Challenges for Disposal” (Report No. FA-2016-02 December 2016), https://ag.tennessee.edu/biodegradablemulch/Documents/Plastic_Mulch_in_Fruit_and_Vegetable_Production_12_20factsheet.pdf (accessed 19 March 2017)

[3] European Bioplastics, http://www.european-bioplastics.org (accessed 19 March 2018)

[4] TÜV Austria, Compostability? Biodegradability? Biobased?, http://www.okcompost.be/en/home/ (accessed 3 March 2018)

[5] Giulia Bettas Ardisson, Maurizio Tosin, Marco Barbale, and Francesco Degli-Innocenti, Biodegradation of plastics in soil and effects on nitrification activity. A laboratory approach, Front Microbiol. 5: doi: 10.3389/fmicb.2014.00710 (2014).

[6] European Chemical Agency (ECHA) Candidate list of substances of very high concern, https://echa.europa.eu/candidate-list-table (accessed 20 March 2018).