NEW ERA AGRICULTURE MAGAZINE

Alternative and Emerging Mulch Technologies for Organic and Sustainable Agriculture

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Introduction:

Mulches are integral components of sustainable horticultural crop production because of their ability to suppress weeds, conserve soil moisture, modify soil temperature, and enhance crop productivity and quality. Mulches are particularly important in organic production systems because weed management options are limited. However, improper implementation or the use of unsuitable mulch materials for a particular application or climatic region can result in negative production and environmental outcomes. Most mulches used in commercial systems (Fig. 1) are extruded as films and consist of synthetic feedstocks, such as nonbiodegradable polyethylene (PE). Soil-biodegradable plastic mulch (BDM) films are also available as an alternative to PE mulch and are typically made with a blend of fossil fuel-based and biobased feedstocks. Mulches can also be made with natural materials, including crop residues, wood chips, gravel, and cover crops that may be allowed to grow (i.e., living mulches) or ended with a roller-crimper or other implement.

Moreover, end-of-life management of PE mulch entails stockpiling, burning, and landfilling, which can also contribute to soil and environmental pollution.BDMs are designed to function similarly to PE mulch but presumably eliminate plastic mulch pollution by biodegrading completely when incorporated into agricultural soils. The US National Organic Program mandates that, for use in organic agriculture, BDMs must be 100% biobased [determined by the American Society for Testing and Materials (ASTM) D6866]; however, no commercially available BDM films meet this criterion (7 CFR 205.2; US Department of Agriculture 2014a). In Oct

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2021, a rule change was proposed to alter the minimum allowable biobased content for BDM to 80%, but this change was not approved at the time of this publication.

factors also influence biodegradation rates. Commercially available BDMs are produced using a blend of biobased and fossil fuel-derived materials. Currently, the amount of

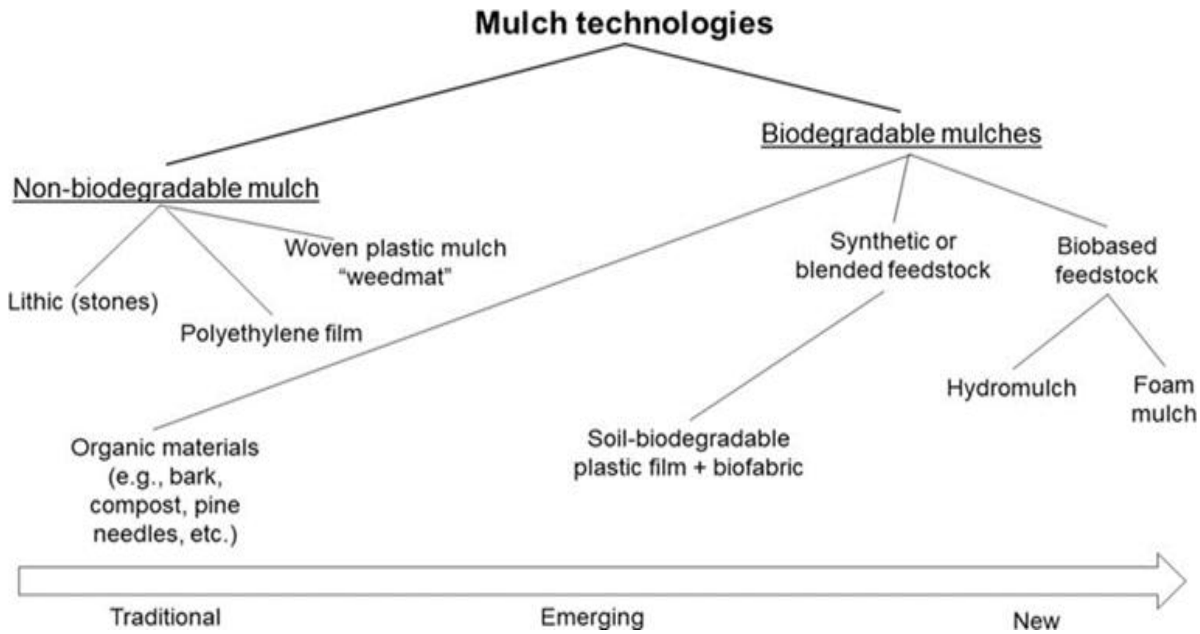

Fig 1. Mulch includes nonsoil biodegradable and biodegradable mulches, which may be derived from synthetic or natural materials

Soil-Biodegradable Plastic Mulches

All BDM films are designed to biodegrade in the soil after tillage via metabolism by native soil microorganisms and have been developed as a potential alternative to nondegradable plastic film mulches like PE mulch. Meta-analyses indicated that despite lower weed suppression, crop yields are not different across a diversity of specialty crops when BDMs are compared with PE mulch. Biodegradation of BDMs may take several years, depending on soil and climactic conditions unique to a site or region, and seasonal and specific polymer chemistry

biobased material in these mulches is less than the minimum required for use in certified organic agriculture in the US (7 CFR 205.601, 7 CFR 205.2; However, BDMs are allowed in organic production in some countries in Europe. For instance, BDMs were allowed in France under NFU 52-001 and in Italy under UNI 11495 for an extended period without specific requirements regarding biobased material content. In Jan 2018, the European Committee for Standardization (CEN) introduced the first international standard concerning

BDM use, which is known as European Standard EN 17033. Current BDM regulations in Europe do not mandate specific biobased content (Hayes and Flury 2018). In Canada, BDMs were initially approved for organic agriculture without specific biobased criteria; however, in 2016, the approval was adjusted by the Canadian Organic Program and required products to be 100% biobased (Organic Federation of Canada 2018).

Hydromulches

Hydromulch (also known as "hydramulch") consists of a water-applied slurry (Fig. 2) made from polysaccharide feedstocks and sometimes a tackifier (i.e., glue) that is sprayed onto the soil surface before transplanting. Hydromulches can be applied around existing trees or shrubs to prevent erosion, suppress weed emergence, and foster revegetation.

documented research of their use in horticultural production systems is limited and likely varies given nonuniformity in hydromulch.

Foam Mulches

Foam mulches are an emerging concept because they have dual purposes as mulch when applied directly to the ground and as a protectant when applied to plant surfaces. Foam mulches can be applied as aqueous foam, maintaining their structural integrity throughout a growing season and potentially providing weed suppression similar to PE mulch. One of the first documented foam mulch formulations was using sucrose as a bulking agent and gelatin as a polymeric material. The foam mulch was tested using lettuce (Lactuca sativa). Interestingly, daytime soil temperatures under the thinner foam mulch were consistently warmer than those

Fig 2& 3. Hydromulch application in field conditions & Biobased agrotextiles made from polylactic acid (PLA)

Despite the widespread use of hydromulches for restoration and erosioncontrol projects such as hydroseeding,

under the thicker foam mulch. This difference was attributed to shortwave solar radiation penetrating the thin foam layer and being absorbed by the soil surface. Blue foam mulch made with a mixture of cotton and cellulose fibers, gums, starches, surfactants, and saponins increased the yield of basil (Ocimum basilicum) and tomato compared with those under red and black foam mulch and an unmulched control. Similarly, all colors of foam mulch provided weed suppression comparable to that of PE mulch.These findings demonstrate the importance of mulch color on crop productivity. Overall, foam mulch holds promise as an organic alternative mulching material as long as all constituents are organic-approved. Foam mulch could be enhanced by incorporating biological control agents, pesticides, and/or foliar fertilizer, thus providing other plant growth benefits, however, more testing is required. Concerns associated with foam mulch include cost, development, application equipment needs, potential negative impacts on crops, availability, and durability under diverse field growing conditions.

Biobased Agrotextiles

Agrotextiles are classified as geotextiles that have been manufactured for specific use in agriculture, horticulture, fishing, forestry, animal husbandry, landscaping, gardening, aquaculture, or agro-engineering purposes. Some of the agricultural and horticultural applications of agrotextiles include shade cloths, greenhouse covers, and mulch mats (e.g., “weed mat”). Agrotextiles used for mulching are typically made from synthetic polymers, including polypropylene and polyethylene, and are either woven or nonwoven. Natural fibers such as jute (Corchorus olitorius or C. olitorius) and coco coir (derived from Cocos nucifera) may also as shade cloth, but they are usually not suitable for weed control because of their loose mesh and light porosity. Agrotextiles made with biobased ingredients are often referred to as “biofabrics” and include spunbond, nonwoven fabrics composed of polylactic acid (PLA) or PLA in combination with polyhydroxyalkanoate or aliphatic-aromatic copolymers (Fig. 3).

Challenges and Future Directions

The Food and Agriculture Organization outlined the “6R” approach to enhance sustainable outcomes of agricultural plastics; this approach includes refuse, reduce, reuse, recycle, recover, and redesign (Food and Agriculture Organization 2021). The 6Rs are based on definitions made by the European Union (European Parliament and the Council 2008; Zero Waste Europe 2019). Biodegradable mulches fall within the redesign approach but still need continued development and exploration to broaden the range of affordable mulch options available for conventional, organic, and sustainable farming operations. Cost-effectiveness is of paramount importance for on-farm adoption, and biodegradable mulches could be more economical in the long term if mulch removal and disposal costs can be eliminated. Therefore, biodegradable mulches can offer significant economic benefits by reducing longterm costs associated with mulch removal and disposal in addition to environmental benefits.

The potential impact that different mulching materials might have on soil health, crop productivity, and crop quality should be considered when investigating and ultimately selecting or promoting a mulch type in agricultural operations. Novel, organic-based mulches such as hydromulches derived from polysaccharides might offer some benefits through their degradation and breakdown, such as increased soil carbon and replenishment of minerals taken up by the crop. However, breakdown of organic mulches in soils can also lead to nutrient imbalances in some cases, which can be associated with yield loss. Unfortunately, the high carbon:nitrogen ratio of hydromulches can potentially limit yields because of soil nitrogen immobilization. Emerging mulch technologies should use materials with carbon:nitrogen ratios that do not lead to nitrogen immobilization. Alternatively, deployment could be aligned with farming practices that minimize the negative impact of immobilization on the crop via increased nitrogen supply. Adding nutrients, biostimulants, and pesticides may also be useful when designing multifunctional mulches with added value beyond modifying soil temperature and moisture and suppressing weeds. New soil-biodegradable and biobased mulch technologies should be explored in parallel with other technologies that improve the endof-life outcomes of nonbiodegradable plastic mulches including improved PE mulch retrieval and recycling strategies.

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