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RESEARCH ARTICLE

STUDIES ON COMPOSITE BIODEGRADABLE FILMS FOR SOIL MULCHING-A REVIEW

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ABSTRACT

Mulch is a product used to suppress weeds; raises soil temperature and conserve water in crop production and landscaping. Plastic mulch is often used in conjunction with drip irrigation. By using plastics film and sheet in agriculture, water can be conserved and production increased. One issue for the industry is recovery of plastic film from mulch applications when the material is often torn and dirty. Sustainability is a big issue and efforts are being made to improve recovery and recycling rates. The environmental impact of persistent plastic wastes is evoking more global concern as alternative disposal methods are limited. Incineration may generate toxic air pollution, and satisfactory landfill sites are limited. Recently, the continuously growing concern of the public for the problem has stimulated research interests in biodegradable polymers. In this study, the different biodegradable films that are exclusively used for mulching were discussed in detail.

INTRODUCTION

Mulch is a layer of dissimilar material placed between the soil surface and the atmosphere. In soil management relationships, mulching has been reported to influence organic matter content, activity of microorganisms, availability of soil nutrients, control of erosion and soil compaction (Stowell, 2000). Many different natural and synthetic types of mulch are available today, but all perform at least three basic functions: they reduce soil water losses, suppress weeds, and protect against temperature extremes. Different types of material such as residues from the previous crop, brought-in mulch including grass, perennial shrubs, farmyard manure, compost, byproducts of agro-based industries, or inorganic materials, synthetic products and different biodegradable films can be used for mulching. (Lal, 2000). Mulches break the impact of the droplets, reducing soil erosion and crusting and increasing the penetration of water into the soil. In addition, mulches improve soil structure in several ways. As organic mulches decompose, they provide organic matter that prompts soil particles to aggregate. Large aggregates increase aeration and improve moisture conditions in the soil. These conditions, in turn, encourage additional root development and biological activity, further enhancing soil structure. The ideal mulch is economical, readily available, and easily applied and removed; stays in place well; and supplies organic matter to the soil, yet is free of noxious weeds, insects, and diseases

Synthetic /plastic mulch

Benefits of plastic mulch include: increased and earlier harvests, higher quality produce, better weed control and insect management, and more efficient use of irrigation water and fertigation nutrients (Lamont, 1996). Emmert (1956) found black polyethylene mulch to be the cheapest and most efficient method used to mulch vegetables. The development of the polyethylene polymer in the 1930's, and its release onto the market in the early 1950's in the form of plastic films, allowed for profitable production of certain vegetables within plastic covered structures (Lamont, 1996). Plasticizers, such as polyols and fatty acids, are often added to modify the mechanical properties of biopolymeric films and these may cause significant changes in the barrier properties of the material. Poor moisture barrier properties in the plastic mulch can be improved by the addition of hydrophobic materials, by laminating a hydrophilic film with another layer or by forming a composite film in which both hydrophilic and hydrophobic components are dispersed in a cosolvent and then dried (Cheng *et al*., 2008).

Types of Synthetic / Plastic mulches/Black mulch

Black and clear mulches have shown the greatest soil warming potential among the various mulch colors (Ham *et al.,* 1993). However, black and clear mulches heat the soil in different ways, and how the mulch is applied to the soil is directly related to its effectiveness. Black mulch reflects less short-wave radiation (10 %) and absorbs more radiation (90 %) than any other colored mulch (Teasdale, 1995).Black mulch effectively stops weed growth by intercepting nearly all-incoming radiation and, in combination with its soil warming effects, promotes early season weed growth. Early season weed growth is confined and suppressed by clear plastic mulch as the season progresses, making removal of the plastic and cultivation unnecessary (Ricketson and Thorpe, 1983).

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Clear mulch

Clear mulch absorbs only 5 % of short-wave radiation, reflects 11 %, but transmits 84 % of it (Tarara, 2000). Clear mulch surface temperatures do not reach the levels found on black plastic due to their low absorption rates of short-wave radiation. Clear plastics actually heat the soil by transmitting light to the soil surface, rather than conducting heat like dark plastics (Ham and Kluitenberg, 1994). Consequently, laying clear mulch loosely across the soil creates an insulating air gap between the mulch and soil that results in higher daytime temperatures under clear plastic than black plastic mulch. If clear plastic is laid tightly across the bed its effects will be minimized, and in this situation black plastic laid tightly across the bed would be more effective at heating the soil (Liakatas *et al.,* 1986).

White mulch

White mulch absorbs 51 % of short-wave radiation, reflects 48% into the atmosphere, and transmits only 1 % of it to the soil (Tarara, 2000). This low rate of radiation absorption (clay loam soils have an absorption rate of 70-86% depending on moisture levels (Tarara, 2000)), and high rate of reflection leads to soil temperatures that are at or below temperatures found on bare ground (Ham et al., 1993, Decoteau et al., 1989). Although, increased foliage found over white plastic does not necessarily lead to higher photosynthate produced (Decoteau et al., 1989). Dark colored mulches (black or red) typically have higher surface temperatures than clear or white mulch (Decoteau et al., 1989). The heat absorbed by dark colored mulches is conducted to the soil surface, which raises the soil temperature (Tarara, 2000). Therefore, it is very important to apply dark plastics tightly over the bed to maintain good soil -to- mulch contact.

Biodegradable mulches

Polyethylene films are used extensively in agriculture as greenhouse covers, forage covers, and agricultural mulch. Worldwide yearly consumption for polyethylene mulch film alone is currently over 1 billion pounds (Jensen, 1998). Plastic mulches and row covers help retain soil moisture, increase soil temperature, inhibit weed growth, and reduce insect damage, and thereby increase yields (Anderson, 1995). Most mulch is used for vegetable and fruit production due to their relatively high value. Disposal or recycling of polyethylene films, however, has become a daunting problem. Agricultural mulch, in particular, is very difficult to recycle due to contamination with dirt and debris as well as loss in mechanical properties from ultraviolet (UV)-catalyzed oxidation. Many landfills reject mulch film because of pesticide residues and, thus, it must be treated as hazardous waste. (Hofstetter, 1991). Polymer Degradation and Stability deals with the degradation reactions and their control which are a major preoccupation of practitioners of the many and diverse aspects of modern polymer technology. Deteriorative reactions occur during processing, when polymers are subjected to heat, oxygen and mechanical stress, and during the useful life of the materials when oxygen and sunlight are the most important degradative agencies. In more specialised applications, degradation may be induced by high energy radiation, ozone, atmospheric pollutants, mechanical stress, biological action, hydrolysis and many other influences. (Giacomo Scarascia *et al*., 2006)

Characterization of Biodegradable Film

There are several methods for characterize the biodegradable films which are using Atomic Force Microscopy (AFM), Fourier Transform Infrared (FTIR), Differential Scanning Calorimeter (DSC), Thermo Gravitation Analyzer (TGA) and last but not least Scanning electron microscope (SEM). Atomic Force Microscopy (AFM) is rather new method to characterize the surface of biodegradable film. (Matthias, 1997) Fourier Transform Infrared Spectroscopy (FTIR) is most useful for identifying chemicals that are either organic or inorganic. It can be utilized to quantitate some components of an unknown mixture. The wavelength of light absorbed is characteristic of the chemical bond as can be seen in this annotated spectrum. (*Garthe,* 2002). Scanning electron microscope (SEM) envisages the micro structure of bonds and hence most commonly used for characterization of biodegradable film.

Naturally- occurring Biodegradable mulch

The biodegradables mulch films are made from naturally occurring polymers include: polysaccharides e.g., starch from potatoes and corn, their derivatives, cellulose from marine crustaceans; proteins such as gelatin (collagen), casein (from milk),keratin (from silk and wool) and zein (from corn); polyesters such as poly hydroxyl alkanoates formed by bacteria as food storage; lignin; shellac and natural rubber poly lactic acid, jute, flux, silk, cotton can fall into the category of natural polymers where the monomer is produced by fermentation.(Garthe, 2002). Soil microbes break down the starch into CO_2 and water. Warm, moist conditions that favor the microbes speed up biodegradation. Sticky starches help them adhere to soil, keeping them from blowing away/ littering. Biodegradable mulch would have the dual advantages of avoiding costs of removal and disposal as well as contributing humus to the soil. Several different types of degradable mulch have been considered, including polyethylene film containing prooxidants (Maddever *et al.,* 1989) starch–polyvinyl (PVOH) resistant (Otey, 1974) biodegradable polyesters films, (Mayer,1994) and coated paper or fiber mats (Vandenberg *et al.,* 1972, Bastiaansen *et al*.,1996).

Other types in Biodegradable mulch

Rice starch and its major components, amylose and amylopectin, are biopolymers, which are attractive raw materials for use as barriers in packaging materials. They have been used to produce biodegradable films to partially or entirely replace plastic polymers because of its low cost and renewability, as well as possessing good mechanical properties. However, wide application of starch film is limited by its mechanical properties and efficient barrier against low polarity compounds. This constraint has led to the development of the improved properties of rice-based films by modifying its starch properties and/or incorporating other materials. A variety of starch-based polymers are blended with high performance biodegradable polyester polymers in order to determine the applicability of films to be processed on a film blowing line and to perform well in mulch film field trials (Pete Halley, 2001). Films based on biopolymers are generally sensitive to the relative humidity of the air since they are normally hygroscopic and have limited mechanical resistance compared with synthetic films (Weber *et al.,* 2002).

Nevertheless protein-based films display high deformability. A possible solution to improve the mechanical characteristics of protein-based films could be the mixing of these biopolymers with synthetic polymers (Tharanathan, 2003), such as poly (vinyl alcohol) (PVA), which is also hydrophilic and biodegradable. Some studies on the development and characterization of films based on PVA and protein blends have been published, such as PVA/wheat, PVA/collagen hydrolysate and PVA/gelatin have demonstrated the presumed biodegradability of these blended films. Numerous investigations have been reported on the studies of films made from chitosan (Ana *et al.,* 2010) and chitosan blends with natural polymers Chitosan provides unique functional, nutritional, and biomedical properties, and its present and potential uses range from dietary fiber to a functional ingredient and processing aid. Some of the well known applications of chitosan include its use for prevention of water pollution, medicine against hypertension, antimicrobial and hypocholesterolemic activity, flavor encapsulation, seed coating, film-forming, and controlled release of food ingredients and drugs (Hochmuth, 2001).

CONCLUSION

Biodegradable polymers have wide application in agriculture and they may be made from renewable resources such as starch, cellulose or degradable polymers. Biodegradable polymer films are degraded by the processes involving sunlight, heat and mechanical stress, eliminating the need for pick-up and disposal at the end of the season. The polymers eventually are converted through microbial activity in the soil to carbon dioxide, water and natural substances. The goal to replace only a part of the higher-cost plastics with lower-cost polysaccharides is not the best strategy (Rowell *et al.*, 2007). They have been used to produce biodegradable films to partially or entirely replace plastic polymers because of its low cost and renewability, as well as possessing good mechanical properties (Xu *et al*., 2005). Hence we can conclude that biodegradable polymers can replace the existing polymers used in mulching.

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