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Review

Preformed and sprayable polymeric mulch film to improve agricultural water use efficiency

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ABSTRACT

Plastic mulch films are widely used in agriculture to enhance crop production by suppressing weeds, conserving soil water and increasing soil temperature. The majority of plastic mulch films are however not biodegradable and are typically removed after each growing season. Recovery of these plastics from the soil is difficult and can affect successive crop yields while causing substantive cost to the environment and farmers. Due to increasingly stringent regulations regarding use of non-degradable plastic in agriculture they are likely to be phased out in the near future. In the past 10 years several classes of 'biodegradable' materials have been studied but most of these films are reported to be relatively weak in mechanical properties, not efficiently degradable and cost prohibitive.

More recently, researchers have turned their attention to sprayable biodegradable polymer coatings for use on soils due to their easy application and versatility. The ability to mix natural additives, plasticizers and fillers to control and improve the mechanical and biodegradation properties of the core polymeric mulch film has been the driving force behind the development of these next generation sprayable polymeric mulch films.

There have been many excellent review articles and papers written about polymeric mulch film, but the developing sprayable polymer systems have not been reviewed to the same extent. This paper focusses on the research progress in the area of biodegradable and sprayable polymer mulch film with emphasis on polymer formulations, properties and application. It also discusses current research to highlight the importance, potential benefits and future challenges in developing a cost effective biodegradable sprayable film for use in production agriculture.

Contents

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1. Introduction

The history of plastic use in agriculture dates back to 1948 when polyethylene was first used as a greenhouse film to replace expensive glass (Anderson and Emmert, 1994). According to the American Society for Plasticulture, "the use of plastics in agriculture," is mostly as mulch films, drip irrigation tape, row covers, low tunnels, high tunnels, silage bags, hay bale wraps, plastic trays and pots used in transplant and bedding plant production (Lamont and Orzolek, 2004). An American Plastics Council (1994) study (Amidon Recycling, 1994) has reported sales of LDPE to agriculture market between 236–244 million pounds in 1992–1993. Hussain and Hamid (2003) has reported that approximately 2,250,000 tons/year of plastic being used globally for agriculture, horticulture and related application (Fig. 1).

Plastic mulch was first noted for its ability to reduce soil water loss and increase soil temperature (Emmert, 1954) and reported to directly affect the soil microclimate by modifying the surface radiation (Liakatas et al., 1986). Water savings achieved by using plastic mulch can be substantial and help in ensuring consistent nutrient supply (Lippert et al., 1964) promoting early yields and reducing nitrogen (N) leaching (Bhella, 1988). Hou et al. (2010) has studied the effects of plastic mulching on soil temperature and evapotranspiration on potato (*Solanum tuberosum*) growth and yields under drip irrigation in an arid zone in China in 2006 and 2007 and reported an increase of 2–9 °C soil temperature under plastic mulching condition. The effect of mulching on evapotranspiration, however reduced beyond 60 days. Scott (2007) published a literature review on the impact of mulches on the landscape plants and the environment. A comparison of different coverage materials such as clear film, black film, black paper, aluminized, green leaves, grass clipping and clear film over black film and their impact on soil temperature has been reported by Hill et al. (1982). All mulches altered soil temperature such that black and clear films warmed soil temperature up to 7 °C while aluminized, leaves and grass clipping slowed the rate at which soils warmed and cooled.

Fig. 1. LDPE films used as plastic mulch, source (taken from Subrahmaniyan and Mathieu, 2012).

The influence of the use of drip irrigation system and different mulching materials (PM_1 = black LDPE; PM_2 = LDPE white on black coextruded; BM_1 = black biodegradable spray with chitosan; BM_2 = black biodegradable spray with galactomannans and agarose) on soil thermal behaviour, Irrigation Water Productivity (IWP), yield and quality features of ornamental sunflower stems was also investigated (Anifantis et al., 2011). The study showed that the mulching plastic films increased the soil temperatures around 2 °C, compared with the un-mulching soil, at 20 cm depth in order of $PM_1 > PM_2 > BM_2 > BM_1 >$ UM for sunflower yield.

Browen et al., 1990 has reported that heating of the soil accelerates seed germination in melons and consequently allows early planting so that the cultural cycle is achieved successfully. They also found that vine crops were most responsive to microclimate modification with clear plastic more effective than black plastic mulch. Elmore (1990) has also reported the positive effect of solarisation on weed control with mulch.

It is estimated that 1 million tons of mulch plastic film is used worldwide every year in agriculture including fresh market vegetables (Halley et al., 2001) while Ngouajio et al. (2008) reported 1 million tons of plastic films for fresh market vegetables only.

Low density polyethylene film (LDPE) is the most commonly used plastic due to its ability to transmit long wave radiation, provide good mechanical properties and for ease of layout and removal (Ammala et al., 2011). The use of LDPE is on the increase due to new emerging markets in Asian countries dominated by China and India. In 2006, world consumption was ~700,000 tonnes/year representing ~10% of the total plastic consumption in Agriculture (Espi et al., 2006). Since 2007, market dynamics of plastic mulch have been changing with LDPE film being replaced by blended films HDPE film (40%), LL/LDPE (60%). Existing plastic based mulch films are non-degradable (Garthe and Kowal, 1994) and consequently pose a potentially huge long term environmental risk due to its accumulation and as pollutant and contaminant (Albertsson et al., 1987). Removal of these films is time-consuming (about 16 h/ha) and despite the use of machines, manual hand labour is still required. (McCraw and Motes, 1991).

In an attempt to overcome these limitations, degradable polyolefins have been designed to provide the required mechanical integrity which can later degrade to ostensibly non-toxic end