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The use of biodegradable mulch films on strawberry crop in Portugal

Raquel Costa*, Artur Saraiva, Lopo Carvalho, Elizabeth Duarte

Instituto Superior de Agronomia, Universidade de Lisboa, Tapada da Ajuda, 1349-017 Lisboa, Portugal

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ABSTRACT

The use of plastic mulch films in agriculture had its beginning in the middle of last century and since then its use has been intensified, with all the environmental problems related to their disposal. The biodegradable mulch films, which can be incorporated in the soil at the end of the crop cycle, appear as a possible solution for this problem. The goal of this work was to assess the performance of five biodegradable mulch films when comparing to conventional polyethylene (PE), in strawberry production (Fragaria × ananassa Duch.). The field tests were performed for two years in the region of Ribatejo—Portugal. Taking into account that there are few studies regarding the biodegradation rate of these new materials under Mediterranean soil and weather conditions, it was important to assess the effectiveness of their biodegradability. In laboratory, the biodegradation was assessed by respirometric test, and in the field, by measuring the percentage of area lost on buried mulch films, along time.

The biodegradable mulch films had similarly good results when comparing to the PE, with no significant differences in productivity or quality. Overall, the new biodegradable mulch films appear to be a viable substitute to the PE.

1. Introduction

More than 6 million tons of plastic materials are consumed in agriculture every year (Scarascia-Mugnozza et al., 2011), over 10% of which are plastic films for soil mulching (Joue't, 2001). As a consequence of their excellent properties, these films have spread throughout the world in a variety of crop species, improving yields, allowing earlier harvests, better preservation of soil temperature and more efficient conservation of water and fertilization (Kyrikou and Briassoulis, 2007). The worst consequence of using plastics in agriculture is related to the handling of their waste (Moreno and Moreno, 2008), because the conventional plastic films are made from polyethylene (PE) (Janssen and Moscicki, 2009) which cannot be biodegraded naturally in the field. Part of the plastic residues are commonly left on the field or burned uncontrollably by farmers, producing harmful substances with associated negative consequences to the environment (Briassoulis, 2006; Scarascia-Mugnozza et al., 2006). In order to reduce the impact caused by these residues, several practices are used, including recycling, incineration (Hemphill, 1993) and landfill deposition (Clarke, 1996). However, these practices have some disadvantages, mainly related to disposal costs (Clarke, 1996). At all, the continuous increase of plastic film consumption led to the serious waste problems and soil pollution that we are facing nowadays. To overcome these environmental impacts, the introduction of biodegradable mulches represents a really promising alternative to the PE films promoting a sustainable and environmentally friendly solution for the agricultural activity. At the end of their lifetime, these new materials have the advantage of being incorporated directly into the soil or into a composting system and undergo biodegradation by soil microorganisms (Moreno and Moreno, 2008).

The gradual biodegradation of these materials is not easy to control (Kyrikou and Briassoulis, 2007) and have economic and environmental implications, making the laboratory monitoring very important for the prediction of the field performance. Due to their chemical structure biodegradable polymers allow direct enzymatic degradation and are intrinsically biodegradable (like starch or cellulose) or photo or thermo oxidized when exposed to UV radiation or temperature, respectively (Sivan, 2011). Mater-Bi™, which is the raw material for the biomulchfilms used in this study, is a successful result of blending a synthetic component with starch (Bastoli, 1998).

The aim of this work was to assess the performance of five mulches made from biodegradable polymers when compared to

Abbreviations: GH, green house; OF, open field; PE, polyethylene; WVC, water volume content.

* Corresponding author. Tel.: +351 213 653 425.
E-mail address: raquelcosta@isa.utl.pt (R. Costa).

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Table 1
Characteristics of mulch films used in this study.

Modality	Trial	Mulch code	Thickness (μm)	Colour	Characteristics
Agrobiofilm® 1	Field and lab. Trials	CF 18B lot1	18	Black	Raw material Mater-Bi® 100% virgin
Agrobiofilm® 2	Field—2nd cycle- and lab. trials	CF 18B lot2	18	Black	Raw material Mater-Bi® with recycled material
Agrobiofilm® 3	Field—2nd cycle- and lab. trials	CF 20SB lot1	20	Silver on black	Raw material Mater-Bi® 100% virgin
Agrobiofilm® 4	Field—2nd cycle- and lab. trials	CF 20WB lot1	20	White on black	Raw material Mater-Bi® 100% virgin
NF	Field—2nd cycle- and lab. trials	NF 18B lot1	18	Black	Raw material Mater-Bi® grade NF
PE	Field and lab. trials	PE 35B	35	Black	Conventional mulch

conventional PE on strawberry crop production, since this culture has a long record in plastic use, and to assess the biodegradability of the mulches in real and lab conditions.

2. Materials and methods

The field trials took place in the region of Ribatejo, Portugal, being performed by a local farmer and supervisioned during two crop cycles (2010/2011 and 2011/2012).

The soil is characterized as an old fluvisols (SRA, 1977) with a loamy sand texture, considered a very poor soil, due to the very low amount of organic matter (1%) and slightly acid (pH (H_2O) 5.5–6.5).

The climate is classified as temperate with dry and hot summer and wet winter, according to Köppen's climate classification (Instituto de Meteorologia, 2011).

All biodegradable mulches used in the trials were produced with raw material Mater-Bi™ and their characteristics are present in Table 1.

2.1. Performance in field

During the field trials the meteorological conditions, fruit productivity and quality, soil temperature and water volume content (WVC) and the biodegradation of the mulches were assessed. To monitoring the meteorological conditions, in addition to the data of the national hydro resources information (SNIRH, 2012), a meteorological station measuring air temperature, relative humidity, solar radiation and rainfall was placed next to the field trial. For data gathering and storage a Campbell Scientific data logger was used (model CR1000).

In order to monitor the soil temperature and WVC under the mulches, in 1st cycle, three "Decagon 5TM" probes were placed on each modality, at three different depths, 10, 20 and 30 cm. In the 2nd cycle, the soil monitoring followed the same procedure for all mulches but only two depths were monitored, 10 and 20 cm, since it is the area on which 50 to 90% of the roots are located (Palha et al., 2005).

The 1st crop cycle started in October 2010, ended in May 2011 and the strawberry cultivar used was "Honor". For the productivity and quality assessment, three rows were stretched for Agrobiofilm® 1 and PE in open field (OF) conditions. Three monitoring plots, containing 25 plants each, were randomly chosen for each modality. Although it was not one of the objectives of this work, but since the farmer also performed an area with production under greenhouse (GH) using the same mulches, it seemed interesting to follow the fruit productivity and quality, according to the experimental design of the open field (OF) trials. Unfortunately it was not possible to monitor air or soil conditions under the GH trial. The 2nd cycle started in October 2011 and ended in June 2012. The strawberry cultivar used was "Camarosa" and the mulches tested were Agrobiofilm® 1, 2, 3 and 4, NF and PE. For productivity and quality, a row was stretched in OF conditions and three plots of 10 plants were randomly chosen in each modality.

In both cycles, the stretching of the mulches and the opening of the holes for plants were performed mechanically, and the planting was done manually. Fruit harvesting was done three times per week and the total productivity per hectare was assessed. Aiming the fruit quality, total soluble solids (°Brix) were measured by refractometry with an Atago Digital Pocket refractometer. To perform the analysis, 200 g of strawberries were sampled, per modality every harvesting day.

2.2. Biodegradation assessment

Under field conditions, new mulch samples were placed in plastic net frames (20 × 20 cm) and buried next to the field trials at a depth of 20 cm and an angle of 20° to avoid water accumulation, from April to September 2012.

The modalities used were (i) reference material for checking soil activity (ashless cellulose filters); (ii) non-biodegradable material (PE) (iii) all Agrobiofilms® (1, 2, 3 and 4) and (iv) NF.

Fifteen frames were used per modality on a total of 105 frames. Three replicates were taken for each modality per month, during 5 months. Using the image analysis software Image J, after taking the mulch samples from the net frames and washing them from soil and roots removal, the amount of lost area was measured.

Image J is a public domain Java image-processing program developed at the National Institute of Health, USA, which presents several image processing and analysis capacities (National Institute of Health, 2012).

Under controlled conditions, in order to determine the ultimate aerobic biodegradation of Agrobiofilm® 1, respirometric tests were performed according to DIN EN ISO 17556 (ISO, 2003). Agrobiofilm® 1 was selected to perform these tests since it was the common mulch used in the two crop cycles of the field trials and it showed the best performance. The soil used as inoculum was sampled from the field trials according to the internal method of the National Institute of Agricultural Research (INIA, 2012).

The respirometric tests were performed in discontinuous and continuous systems. In discontinuous, 300 g of soil (at about 50% of the water retention capacity), 200 mg of mulch or cellulose cut into small pieces (<2 mm) and a container with a $Ba(OH)_2$ solution for the retention of the CO_2 released were introduced in each glass flask. The flasks were opened regularly to allow aeration and replacement of the $Ba(OH)_2$ solution. The flasks were maintained at 20 °C ± 1 °C for 120 days.

The continuous test took place on the UmicLab equipment that aerates and measures continuously, through the use of a carbon dioxide analyser, the amount of CO_2 present in the air flow output. In each flask 800 g of soil (at 50% of water retention capacity) and 800 mg of mulch or cellulose cut into pieces (<2 mm) were introduced. The flasks were maintained at 25 ± 1 °C for 88 days.

The percentage of biodegradation was calculated according to the standard and the results are shown in Fig. 4.

2.3. Statistical analysis

Data were subjected to analysis of variance ($P < 0.05$) and the difference between means was determined by Tukey test.