

# The Mater-Bi® biodegradable film for strawberry (*Fragaria x ananassa* Duch.) mulching: effects on fruit yield and quality

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## Abstract

Two trials in different agricultural farms were carried out from October 2014 to June 2015 with the aim to assess the advantages linked to the substitution of the low density polyethylene (LDPE) films for soil mulching with the Mater-Bi® biodegradable films in the strawberry cultivation under tunnel in Campania. Lifetime of biodegradable mulch and influence of type of mulch on the yield and the quality of cvs Sabrina and Fortuna were evaluated. Plants were cultivated on mulched, raised beds, high 40 cm from bottom soil. Mater-Bi® film was 20 µm thick while LDPE film was 50 µm thick. The physical-chemical parameters (firmness, pH, total soluble solid content, titratable acidity and skin colour) and some bioactive compounds (total polyphenols, flavonoids, anthocyanins, antioxidant activity) of fruits were determined by three samplings effected in consecutive months (from March to May 2015) of the harvest cycle. Biodegradable film guaranteed an effective mulch along the whole strawberry cycle (9-10 months including the time of drawing up of film). Yields of cv Sabrina on LDPE was 18% higher than those on Mater-Bi® while the opposite was detected in cv Fortuna (+10%). The physical-chemical parameters of fruits were not modified by the mulches. The content of the bioactive compounds, instead, resulted, in each time of sampling, significantly higher in fruits picked on Mater-Bi® based film.

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## Introduction

The use of plastic mulch in agriculture has increased dramatically in the last decades throughout the world. This increase is due to benefits of mulching such as increase in soil temperature, reduced weed pressure, moisture conservation, reduction of certain insect pests, higher crop yields, and more efficient use of soil nutrients (Kyrikou and Briassoulis, 2007; Kasirajan and Ngouajio, 2012). In 2013, the world demand for plastic films in agriculture reached 4 millions of tons: 17% of the whole amount was used in Asia while 16% was allocated in Europe (AMI, 2014). In Europe the use of plastics accounts for 510,000 tons, 40% of which is concentrated in Spain and Italy, mainly devoted to mulching and greenhouse cover (APE, 2013). Plastic mulches are, usually, manufactured in low-density polyethylene (LDPE) and their life cycle in the field depends on crop time span. At the end of the cultivation cycles, plastic films have to be removed from the field and disposed of according to the European Directives relevant to waste management, *i.e.*, 99/31/EC, 2000/76/EC, 2008/98/EC (European Commission, 1999, 2000, 2008). The most common illegal practices of plastics disposal in agriculture include: burning in the field, heaping on the field edge, illegal dumping or rototilling into the soil (Guerrini, 2015). In order to overcome these environmental impacts, the introduction of biodegradable mulches represents a really promising alternative to the polyethylene films, promoting a sustainable and environmentally friendly solution for the agricultural activities (Kasirajan and Ngouajio, 2012; Conti *et al.*, 2014). The biodegradable plastic mulch biodegrades in the soil, developing organic matter without releasing harmful substances.

The aim of this paper was to assess the performance of the biodegradable mulching film Mater-Bi® by Novamont S.p.A. (Novara, Italy) in strawberry crops, compared to the conventional LDPE on strawberry fruit production. The quantitative and qualitative effects on fruit production induced by the use of the two different types of mulch were evaluated in two trials carried out in different farms associated with the Cooperative Sole located in Parete (Caserta, Southern Italy). This study is part of the project: *Introduction of biodegradable mulching in Mater-Bi® for fruit and vegetable crops* (PA.BI.OR.FR.U), funded by the Campania Region under the PSR 2007-2013, measure 124.

## Materials and methods

Concurrent field experiments were conducted in two farms (Cantone and Pezone) where two different strawberry cultivars, Fortuna and Sabrina, respectively, were grown. In each farm, two types of soil mulch materials were compared: black biodegradable film in Mater Bi® (20 µm thick) vs traditional black LDPE plastic film (50 µm thick). Each type of mulch was applied on 1000 m<sup>2</sup> surface area under

multiple tunnels with a cubature  $<3 \text{ m}^3 \text{ m}^{-2}$ , covered with 0.018 mm thick Multisolar film. Fortuna and Sabrina fresh nursery seedlings were transplanted, respectively, on October 10 and 20 2014 respectively, on raised beds, which were 0.80 m wide, 0.40 m high and separated from each other by 0.30 m aisles. On each bed the plantlets were arranged in double rows, with spacing of 0.35 m between the two single rows and of 0.20 m between the plants along the row; the average plant density was 8.6 plantlets per  $\text{m}^2$ . In each mulched area, 20 experimental plots per replicate were randomly selected and encompassed with coloured plastic strips; each plot contained 20 plants in the same raised bed. Crop fertilisation, irrigation and protection were managed according to the farm protocols. Fifteen harvests of cv Fortuna and nineteen harvests of cv Sabrina were performed in all the experimental plots, starting on February 9, 2015 and ending in the same year, on May 26 for cultivar Fortuna and on June 3 for Sabrina. At each harvesting time, the marketable strawberry fruits were divided in two commercial categories (extra+1<sup>st</sup> and 2<sup>nd</sup>) and weighed. In three harvests (mid-March, mid-April, mid-May), 5 ripe fruits per plot were random sampled and transferred to the laboratory for the determination of physical-chemical and bioactive compounds. The physical-chemical parameters (firmness, pH, total soluble solid content, titratable acidity and skin colour) were evaluated according to the International Union for the Protection of New Varieties of Plants descriptors (UPOV, 2012).

The extraction of bioactive compounds (total polyphenols, flavonoids and anthocyanins) was performed as described by Tomás-Barberán and Espín (2001) with some modifications.

The total polyphenol content in strawberry fruits was determined by the Folin-Ciocalteu method (Singleton and Rossi, 1965) and expressed as milligrams of gallic acid equivalents per 100 g of fresh weight. The total flavonoid content was determined by the aluminium chloride colorimetric method (Zhishen *et al.*, 1999) and the results were expressed as milligrams of catechin equivalent per 100 g of fresh weight. The total monomeric anthocyanins were estimated by a pH-differential method (Giusti and Wrolstad, 2001) and expressed as cyanidin-3-glucoside equivalent per 100 g of fresh weight. The antioxidant activity of strawberry extract was measured by 1,1-diphenyl-2-picryl-hydrazil according to the method of Brand-Williams *et al.* (1995), with some modifications and expressed as mmol Trolox equivalent per gram of fresh weight.

### Statistical analysis

Data related to the total crop production of the two mulching treatments were processed in order to evaluate the homoscedasticity of the two group variances, then analysed by the T-test with 20 replicates per each treatment. Qualitative and bioactive compounds values were expressed as means  $\pm$  standard deviation. A two-way analysis of vari-

ance was performed per each cultivar according to a model with mulching types and harvesting time as fixed factors and their interaction. The Tukey's test was performed for mean separation. Differences were considered significant at  $P \leq 0.05$  and they are indicated with different letters. All analyses were performed using JMP software (statistical discovery, v. 5.1, 2005; SAS, Cary, NC, USA).

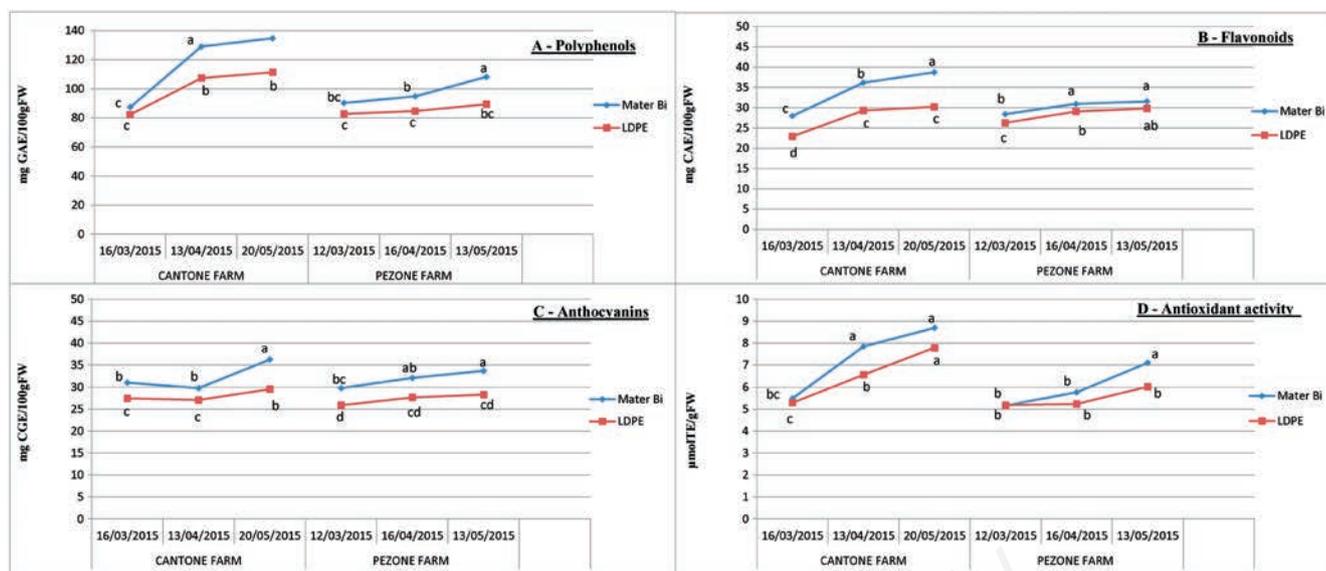
## Results and discussion

The Mater-Bi® biodegradable mulch covered soil effectively until the crops reached its maximum vegetative development; the lateral sides of the raised beds did not show a loss of anchorage to the soil due to a spread biodegradation until the end of the strawberry crop cycle. In Table 1, the yields of both the cultivars are shown. Total marketable yield of Sabrina was 15% higher with LDPE mulch than with Mater-Bi® one. The significant difference between the two mulches was due to the significantly higher production of the II category fruits on LDPE. Mean fruit weight of the Extra/I category fruits was higher on Mater-Bi® mulch while no difference was detected in the II category. Marketable yield per plant was significantly higher using LDPE film (533 g *vs* 461 g, respectively), whereas a significant higher amount of non marketable fruits was recorded with the Mater-Bi® biodegradable mulch. Differently from Sabrina, Fortuna cultivar showed higher total marketable yield when grown on Mater-Bi® biodegradable mulch (Table 1); in particular, the amount of the Extra/I category fruits was 18% higher than that produced with LDPE. Mean fruit weight was higher in Fortuna than in Sabrina for both the commercial categories, but the latter difference was smaller than that detected between the mulch types. Marketable yield per plant was significantly higher with Mater-Bi® film (651 g *vs* 584 g, respectively). The productive results obtained in our research are partly discordant with previous investigations (Cozzolino *et al.*, 2011; Cozzolino and Lombardi, 2013; Cozzolino *et al.*, 2013), mostly reporting higher yield of cultivars Candonga and Sabrina grown on Mater-Bi® biodegradable film compared to LDPE mulch. Other confirmations on the reliability of biodegradable mulches in Mater-Bi® were found in the *Agrobiofilm* Project, funded in the 7<sup>th</sup> Research Programme of the European Union. Trials carried out in Spain and Portugal either in open field or under tunnel, pointed out that mulches of 15 micron (in Portugal) or 20 micron thickness (in Spain) showed a mechanical resistance along the whole strawberry cycle, yielding as much as polyethylene mulch or even more, without worsening of fruit quality (Consorcio de Agrobiofilm, 2013; Costa *et al.*, 2014).

**Table 1. Yield of strawberry cultivars Sabrina and Fortuna grown on low density polyethylene or Mater-Bi® mulching films in two farms.**

	Yield ( $\text{t ha}^{-1}$ )				Fruit mean weight (g)		
	Category Extra and I	Category II	Total marketable	No marketable yield	Marketable yield	Category Extra and I	Category II
Pezone farm; cv Sabrina mulching film							
Mater-Bi®	29.4	7.5	36.9	4.1	461	26.4	17.4
Poliethylene	32.1	10.5	42.6	3.4	533	24.7	17.6
Significance (P value)	<i>n.s.</i>	<i>&lt;0.001</i>	<i>&lt;0.01</i>	<i>&lt;0.05</i>	<i>&lt;0.01</i>	<i>&lt;0.001</i>	<i>n.s.</i>
Cantone farm; cv Fortuna mulching film							
Mater-Bi®	42.9	14.4	57.3	1.1	651	33.4	18.7
Poliethylene	36.3	15.5	51.8	1.8	584	32.5	18.7
Significance (P value)	<i>&lt;0.01</i>	<i>n.s.</i>	<i>&lt;0.01</i>	<i>n.s.</i>	<i>&lt;0.01</i>	<i>&lt;0.01</i>	<i>n.s.</i>

The probability levels of the differences between the means, according to the Student's t test, are reported in italics. *n.s.*, not significant.



**Figure 1.** Contents of polyphenols (A), flavonoids (B), anthocyanins (C), and antioxidant activity (D) in fruits of strawberries cvs Sabrina and Fortuna cropped in Pezone farm and Cantone farm, respectively. Each picture shows trend of a nutraceutical compound in relation to time of sampling, type of mulch and farm/cv. Different letters separate the means of each significant comparison of the interaction time of sampling  $\times$  type of mulch in agree to Tukey's test ( $P < 0.05$ ).

The mulching type did not significantly influence the fruit physical-chemical parameters in both the cultivars tested (data not shown). On the opposite, as shown in Figure 1, total polyphenols, flavonoids, anthocyanins content and the antioxidant activity, either in Sabrina or in Fortuna fruits, were significantly influenced by the biodegradable mulching in all the three sampling times. All the antioxidant compounds always attained higher concentrations in the fruits grown on Mater-Bi<sup>®</sup> mulch compared to the LDPE one; besides, they were enhanced with the photoperiod elongation. To our knowledge, it is difficult to state if these plant responses are correlated or not to abiotic stresses (nutrient deficiency, water or thermic stress, *etc.*). Indeed, red and green lettuce showed an increase in flavonoid glycosides and caffeic acid derivatives under a scheduled fertilisation with nitrogen deficiency. On the other hand, other studies showed that some cultivation managements, such as mulching systems could enhance the phytochemical compounds content in strawberry fruits (Anttonen *et al.*, 2006; Fan *et al.*, 2012). The identification of abiotic factors, which are modified by Mater-Bi<sup>®</sup> mulch, and their interactions with strawberry physiology will be the objectives of our future research.

Different bioactive compounds have been identified and characterised in strawberry fruits and epidemiological studies have widely shown their nutraceutical effects and health benefits (Giampieri *et al.*, 2012; Van De Velde *et al.*, 2013).

## Conclusions

This study demonstrated that the use of mulching biodegradable materials in strawberry could be an alternative to the polyethylene film and, in this respect, Mater-Bi<sup>®</sup> did not decrease marketable yield. The noticeable difference is that the removal of polyethylene film requires laborious and expensive work, whereas biodegradable mulch can be directly rototilled into soil, where it will be degraded in 6-12 months, saving time and resources to the farmers. This study also revealed the influence of the biodegradable mulch on the antioxidant compounds

accumulation in fruits, compared to LDPE mulch. These results, together with the other emerging positive aspects, may represent a further valid motivation to recommend replacing LDPE film with biodegradable mulch in strawberry cultivation.

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