Functional polysaccharides and cellulose fibres: spray mulching for a sustainable agriculture

By

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Biopolymers in crop protection

Mulching allows:
- Reduction of spontaneous weeds
- Control of soil humidity and temperature
- Reduction of water evaporation
- Reduction in the use of pesticides
- Reduction of product dirtiness

in Italy
- Greenhouses and tunnel: 25,000 ha
- Low tunnel: 25,000 ha
- Mulching: 75,000 ha
### World plastic consumption (tons) in agriculture

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Greenhouses</strong></td>
<td>180.000</td>
<td>350.000</td>
<td>450.000</td>
<td>700.000</td>
</tr>
<tr>
<td><strong>Low tunnels</strong></td>
<td>88.000</td>
<td>122.000</td>
<td>168.000</td>
<td>301.600</td>
</tr>
<tr>
<td><strong>Direct covers</strong></td>
<td>22.500</td>
<td>27.000</td>
<td>40.000</td>
<td>80.000</td>
</tr>
<tr>
<td><strong>Mulching</strong></td>
<td>270.000</td>
<td>370.000</td>
<td>650.000</td>
<td>1.240.000</td>
</tr>
<tr>
<td><strong>Silages</strong></td>
<td>140.000</td>
<td>265.000</td>
<td>540.000</td>
<td>820.000</td>
</tr>
<tr>
<td><strong>PP twine</strong></td>
<td>100.000</td>
<td>140.000</td>
<td>204.000</td>
<td>300.800</td>
</tr>
<tr>
<td><strong>Hydroponic systems</strong></td>
<td>5.000</td>
<td>10.000</td>
<td>20.000</td>
<td>50.000</td>
</tr>
<tr>
<td><strong>Microirrigation</strong></td>
<td>260.000</td>
<td>325.000</td>
<td>625.000</td>
<td>950.000</td>
</tr>
<tr>
<td><strong>Others (bags, nets, ...)</strong></td>
<td>80.000</td>
<td>130.000</td>
<td>150.000</td>
<td>300.000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>1.145.500</td>
<td>1.739.000</td>
<td>2.847.000</td>
<td>4.742.400</td>
</tr>
</tbody>
</table>
Used plastic films management

Collection

accumulation

abandon

incineration
Available mulching films

Traditional:
LDPE - EVA

Biodegradable: Mater Bi

Principal characteristics of mulching films:
- Durability
- Environmental resistance
- Resistance to pesticides and chemicals
- Additional functions (like reflectivity)
## ECONOMIC EVALUATION

<table>
<thead>
<tr>
<th>Material</th>
<th>Price (€/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PE granules</td>
<td>0.9</td>
</tr>
<tr>
<td>PE Black mulching film</td>
<td>1.80</td>
</tr>
<tr>
<td>Starch</td>
<td>0.5</td>
</tr>
<tr>
<td>Mater Bi Black mulching film</td>
<td>4.00</td>
</tr>
</tbody>
</table>

*UNFAVOURABLE TO MATER BI INTRODUCTION*
Innovative approach: biopolymers and fillers from renewable resources in spray formulations

TARGET: To realise a composite material made of polysaccharides based polymers (such as those contained in large quantities in seaweeds, crustaceous or fruits) to be applied directly on soil from water dispersions. The solution contains also natural fibers which creates a sort of textile, and also pigments can be added. The thickness is regulated by the concentration and by the speed of application.
### Natural fibers as reinforcement. Properties in comparison with engineering fibers

<table>
<thead>
<tr>
<th>Fiber</th>
<th>Specific gravity [g/cm³]</th>
<th>Tensile strength [GPa]</th>
<th>Tensile modulus [GPa]</th>
<th>Specific strength [GPa/g.cm⁻³]</th>
<th>Specific modulus [GPa/g.cm⁻³]</th>
<th>Cost ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sisal</td>
<td>1.20</td>
<td>0.08-0.5</td>
<td>3.98</td>
<td>0.07-0.42</td>
<td>3.82</td>
<td>1</td>
</tr>
<tr>
<td>Flax</td>
<td>1.20</td>
<td>2.00</td>
<td>85</td>
<td>1.60</td>
<td>71</td>
<td>1.5</td>
</tr>
<tr>
<td>E-Glass</td>
<td>2.60</td>
<td>3.50</td>
<td>72</td>
<td>1.35</td>
<td>28</td>
<td>3</td>
</tr>
<tr>
<td>Kevlar</td>
<td>1.44</td>
<td>3.90</td>
<td>131</td>
<td>2.71</td>
<td>91</td>
<td>18</td>
</tr>
<tr>
<td>Carbon (standard)</td>
<td>1.75</td>
<td>3.00</td>
<td>235</td>
<td>1.71</td>
<td>134</td>
<td>30</td>
</tr>
</tbody>
</table>
Waste fibers available from industrial activities

- Exhaust
- Cellulose
- Tomatoes peels
- Chestnuts skin
SPRAY FILMS FOR FLOWERS

Polysaccharide mixture plus paper pulp fiber (1 l/m²) distributed by a high pressure spray machine at 150 bars
FLOWERS
EXPERIMENTAL
CULTIVATION
February - June 2005
EMERGENCE OF BUDS WITHOUT HUMAN HELP FOR SPRAY

Spray A

Spray B

Spray C

21 March 2005
4 DAI
Stem height

---Spray compositions---

---PE films---

Mater Bi
Pot plants with black spray film

Sprayed pot

14 dic. 2004
Large fields application
Test for tomatoes cultivation in Puglia
Harvesting time

Black spray film

7 July 2004 - 4 months after mulching
Strawberry cultivation

February 2005 - 1 months after mulching
STRAWBERRY CULTIVATION

4 months after coating installation

23 May 2005
Agronomical results on strawberry production
Roto-tillage of spray mulching
Residual mulching film in the soil

% on initial weight

months from the tillage

0 1 3 8 12
Biodegradation curves for Cellulose and different Spray films

- Cell
- Spray 1
- Spray 2
- Spray 2 + Ca
SEM Analysis
Spray 1 films

downside $t=t_0$

downside after 60 days
Economical evaluation

In table we report the actual costs of some of the materials tested during the experimental cultivations (PE, Mater Bi of two different thicknesses, and Polysaccharides with fibers) and the cost of a paper mulching proposed on the market.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>PE</th>
<th>Paper</th>
<th>Mater-bi</th>
<th>Mater-bi</th>
<th>Water-based Polysaccharides +waste fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (mm)</td>
<td>0.045</td>
<td>-</td>
<td>0.015</td>
<td>0.012</td>
<td>0.050</td>
</tr>
<tr>
<td>Film weight (g/m²)</td>
<td>45</td>
<td>110</td>
<td>18</td>
<td>14</td>
<td>60</td>
</tr>
<tr>
<td>Area covered per kg of film (m²/kg)</td>
<td>22</td>
<td>9</td>
<td>55</td>
<td>70</td>
<td>20</td>
</tr>
<tr>
<td>Cost per kg of film (euro/kg)</td>
<td>1.39</td>
<td>1.55</td>
<td>5.50</td>
<td>5.50</td>
<td>1.0</td>
</tr>
<tr>
<td>Mulched area (kg/ha)</td>
<td>0.063</td>
<td>0.172</td>
<td>0.100</td>
<td>0.079</td>
<td>0.060</td>
</tr>
<tr>
<td>Removal costs (euro/ha)</td>
<td>73</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Disposal costs (euro/ha)</td>
<td>36</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total costs (euro/ha)</td>
<td>484</td>
<td>1032</td>
<td>600</td>
<td>474</td>
<td>350</td>
</tr>
</tbody>
</table>
Tests on vineyards in Puglia
Tests on vineyards in Campania (2009)
Tests on peppers in Spain (2009)
Tests on ornamental plants in Netherlands (2010)
Tests on garlic and eggplants in Xuzhou (China) (2011)
Biodegradable pots (to be used instead of polyethylene pots or polystyrene nursery pots)

Bio-hydroplastics

- starch
- alginate
- chitosan

Bio-wastes employed

- olive
- coconuts
- tomatoes
- Artemisia
Cultivation tests in Bari (Italy) 2011
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