Guidelines for biodegradable mulching

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SECTION 2 – Guidelines for Biodegradable Mulching

Introduction

Mulching plastic systems can really help in the intensification of agriculture preserving soil condition while saving inputs, but the end-of-life management of traditional mulch films can be very difficult, they cannot be recycled and may leave plastic residues in soil if not properly removed. Furthermore the plastic mulch films removal at the end of the crop cycle is time consuming.

Plastic pollution (the so called “white pollution”) has a negative impact on soil. According to a recent report[1] every year 15,000 tons of microplastics are released in European soils, with an impact on crops growth with a progressive yield reduction up to 15%.

Within the FoodLAND project, to boost a sustainable intensification of agriculture through the introduction of combined agro-ecological practices, Novamont is developing biodegradable in soil mulch films according to EN17033 standard, so that they can be left in the soil without negative effects for the soil and environment while avoiding the production of agricultural plastic waste.

The main objective of this deliverable is to supply a customized guidelines for food hub operators reporting the best practices for a correct use of the biodegradable in soil mulch film under the specific crop and Food Hub requirements.

Novamont biodegradable and compostable bioplastics

Novamont designed a range of completely biodegradable and compostable thermoplastic materials to provide a low impact environmental solution and solve specific problems in different sectors, such as the separate collection of organic waste, packaging, catering, hygiene, agriculture and many other areas.

Novamont’s bioplastics are produced using renewable resources made from plant material such as starches from different crops (e.g. corn, other cereals and potatoes) and vegetable oils. Specifically biopolymers are obtained by a polymerization process consisting in two steps of reaction involving diacids and diols (monomers) and giving finally biopolyesters. Bio-polyesters are then worked throughout reactive extrusion involving biomasses, existing biopolymers and additives for producing bioplastics with the finalized functionalities for the application. Specific biopolymer grades have been developed for a range of agricultural applications including mulch film.

[1] Conventional and Biodegradable Plastics in Agriculture For the European Commission DG Environment. Project conducted under Framework Contract No ENV.B1/FRA/2018/0002 Lot 1 (https://ec.europa.eu/environment/system/files/2021-09/Agricultural%20Plastics%20Final%20Report.pdf)

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Novamont's bioplastics for mulch film are designed in compliance to the OK Biodegradable Soil and the European standard EN17033; these are standards that guarantees the complete biodegradability of biomaterial in soil at room temperature and with the absence of toxic effects in the soil and in the environment. In addition to this, EN17033 defines the specific mechanical and optical characteristics that a mulch films must have in order to be laid in a fully mechanized way and to efficiently control weeds. In addition, mulching film complies with the principles on biodegradation and environmental impact of International standards (European standard UNI EN 13432:2002, UNI EN 14995: 2007; American standard ASTM 6400:04).

Mulch film made of biodegradable and compostable biopolymers

By minimising the impact on the environment and saving time and resources in managing the end of life of mulched crops, mulch film made of biodegradable biopolymers provides an agronomically and environmentally efficient alternative to traditional mulch film. Such film has similar mechanical properties and usage characteristics to traditional plastic films. Properly the biodegradable film is laid and perforated with the same machinery used for traditional plastic film and as it can be laid very thin it provides excellent yields per kg of product. Thanks to the biopolymer capacity to biodegrade when incorporated into the soil, mulching film is converted into organic matter, water and carbon dioxide eliminating the production of plastic waste. So at the end of the crop, the film does not be removed or disposed, allowing significant reductions in labour costs, saving the time required for removal and disposal. Furthermore if traditional non-biodegradable plastic is not correctly removed and disposed, may leave plastic residues in the soil that can accumulate and generate soil pollution. The use of biodegradable mulch has been estimated to reduce overall greenhouse gas emissions: estimated savings are over 500 kg of CO_2 equivalent per hectare of mulch (considering coverage of the land with 6,000 m^2/ha of mulch)[2]. Moreover, biodegradable mulching practices reduce consumption of non-renewable energy resources by around 80% compared with traditional plastic film. This data was obtained considering the typical end-of-life scenario for plastic materials in Italy where 10% is recycled, 14% is incinerated and 78% is sent to landfill after use.

Types of biodegradable mulch film

Thanks to the versatile characteristics of Novamont biopolymer designed for agricultural applications, the related biodegradable mulch film can be used in different environmental conditions, for the cultivation of different species of plants and at different times of the

[2] Razza F., Farachi F., Degli Innocenti F., 2010, Assessing the environmental performance and eco-toxicity effects of biodegradable mulch film, pubblicato sui Proceeding della conferenza: LCA FOOD 2010 VII international Conference on life cycle assessment in the agri-food sector, Bari (Italy) September 22- 24 2010 – ProceedingsVolume 2 (378-383)

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year. Materials are primarily chosen to suit climate, length of production cycle and growing conditions (in the open field or as a protected crop). Properly three biomaterials have been developed for different needs:

- Standard material for horticultural spring summer cycles
- Materials for long life crops (exceeding 6 months)
- organic farming material

Starting from these biomaterials related mulch film has been optimised for the specific required characteristics: shelf life in the field, colour, mechanisation, thickness and agronomic performance. The tuning of life in field is primarily related to film thickness; it is also possible to make films starting from 10 microns, according to the specific needs of the crop cycle: an average life from 2 to 6 months could be reached using 10 to 15 microns films; 20 microns-thick films can be used for crops with a cycle up to10 months and beyond 10 months a thickness up to 30- 40 microns is suggested. The typical range of properties relating to biodegradable mulching film with thickness from 12 to 18 μm is reported in the table below.

Table 2: Characteristics of mulching materials

Typical characteristics of mulching materials	Value	Method
Tensile strength (MPa)	20÷40	ISO 527-3
Elongation at break (%)	250÷500	ISO 527-3
Young modulus (MPa)	100÷300	ISO 527-3
Density (g/cm³)	from 1,23 to 1,29	ASTM D792
MFR (g/10')	from 3 to 7	ASTM D1238

Biodegradable in soil mulch films can be produced in different colour according expected soil conditions and agronomic effect on the crops. Most used mulch film colours are: black (weed control), white / black (double face, soil cooling film), green (soil heating film and PAR cut off).

At the moment the most versatile and used biodegradable mulch film is the black one at 15 microns. The data collected in the field during tests over the course of many years of experimentation showed for the black biodegradable mulch film:

- excellent performance in the field in controlling weeds and in terms of agronomic yield and product quality, comparable with traditional plastic films.
- excellent versatility for use and mechanisation: can be used with the same laying and laying-perforating machinery used for traditional plastics and at the same speed.
- excellent agronomic versatility and compatibility: biodegradable mulching film can be used in a wide range of crops in varying environmental and climatic conditions.

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Biodegradable black films have been tested on a wide range of crops, in different climatic areas over at least 20 years, both in experimental and in commercial fields.

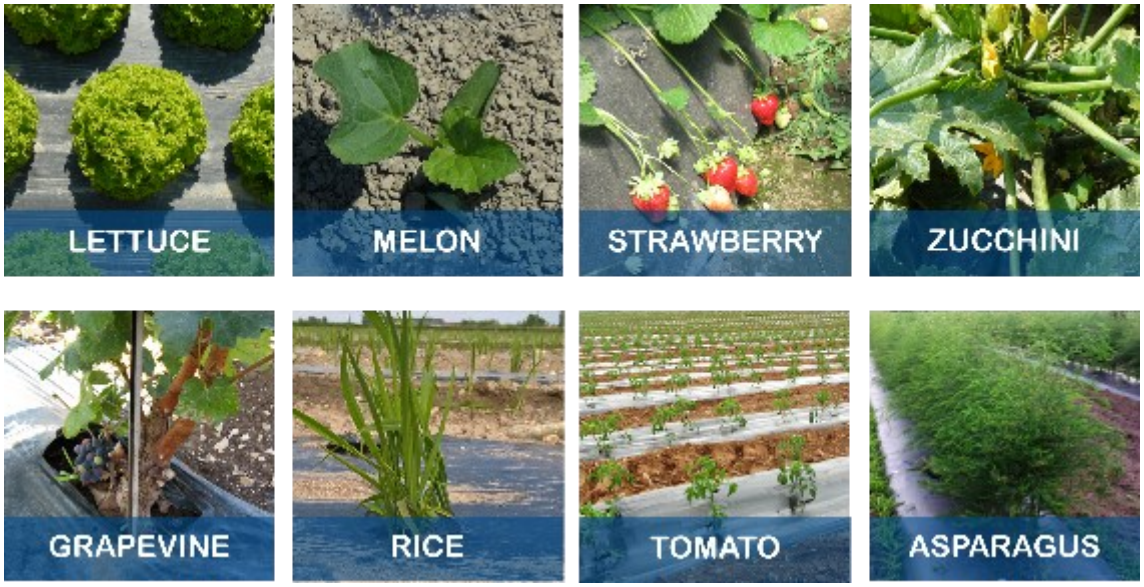

Figure 17: Main crops on which the biodegradable film has been tested

In the following table information about the wide applicability are reported.

Table 3: Mulch film applicability and characteristics

Cycle	Duration (months)	Crops	Thickness
SHORT CYCLE	1-3	lettuce	15µm (possible also 12 µm)
MEDIUM CYCLE	4-6	Zucchini, Pumpkin, Solanaceae (tomato, bell pepper, eggplant), Melon, Watermelon, Aromatics (Basil, Parsley,...), Potato, Cabbage, Corn, Industrial tomato, Green bean, Rice, Asparagus, propagating material	15µm
MEDIUM-LONG CYCLE	6-12	Strawberry, Onion, Garlic, Gherkin	from 15 to 18µm
LONG CYCLE	>12	Vine, Small fruit (blueberry, raspberry)	30-40 µm

Economic Implications

The market for biodegradable and compostable products in developing countries is being explored only recently, while the economic implications of the technology will be measured during the tests currently carried out at small-scale level in the target local

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Food Hubs (Subtask 4.1.2) and through the validation process to be carried out at larger scale in the next period (ST 5.1.2).

What is the cost for the mulch?

Actually the cost for the production of the biodegradable and compostable material is approx. 2-3 times higher than the traditional plastic film in terms of kg of material.

However biodegradable mulch films, since do not need to be removed from the soil (and therefore they do not need to retrain good mechanical properties at the end of the crop cycle) are generally thinner than traditional non-biodegradable (LDPE) plastic films.

Together with this the difference in the price of raw materials in EU countries can be mitigated by other factors:

- Cost reduction in collection and disposal of non-biodegradable plastic mulch in terms of labour costs,
- Elimination of negative externalities related to plastic and microplastic pollution which could be formed if non-biodegradable plastic mulch are not properly removed at the end of the crop cycle,
- Elimination of externalities linked to soil erosion derived by top soil fraction that remains trapped in the removed non-biodegradable mulches and cannot be recuperated, as pointed out in the a recent EU Study (https://www.eunomia.co.uk/reports-tools/conventional-and-biodegradable-plastics-in-agriculture/).

Considering the early stage of the project we are not able to perform a precise calculation of the price of the product for the final user, given the different market conditions in the project countries.

In order to make the transition toward a biodegradable mulch film possible, the target in the project will be to promote these innovation primarily in crops where non-biodegradable plastic mulches are already used in the traditional agricultural method.

Will the mulch be produced locally or will it have to be imported?

As is the case in all countries where Novamont sell its agricultural products, the filming process can be performed locally, while biomaterials (the granules) are produced in Novamont plants in Italy. This will reduce the cost of the final product and promote the local industries to differentiate their production with innovative materials. Novamont grades of biomaterial can be filmed with traditional plastic film industrial machineries (blown film extrusion) just modifying and optimizing the production settings to the biodegradable materials characteristics, like speed and temperatures so the filming process can be easily transferred in different countries.

How practical will be its use for small scale farmers?

Mulch film is a product used in agriculture since a long time, both in family gardens and on large field extension.

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The film can be laid on the ground manually, with small scale instruments such as manual mulching machine and finally with layers devices attached to agricultural machines of different sizes and powers. The use of biodegradable mulch films, eliminating the end of life operations (removal and disposal) helps the growers in the overall management of the crop, while reducing the labour time and costs.

Guidelines on implementation and management of biodegradable mulching in field.

In the Food Hubs selected for field tests biodegradable mulching practices are currently not in use.

This paragraph is intended to provide guidance to field operators and explain how to implement this technological innovation on the different cropping systems of interest. Here below a customized guidelines for the specific Food hub is provided, to describe a correct use and management of the biodegradable mulching in field operations.

Preparation of the soil

The methods used for working and preparing the soil (ploughing, milling, etc.) are largely the same as those used with traditional plastics for vegetable crops. However, in order to obtain the best results, both for controlling weeds and for the mechanical performance of the product, it is essential to prepare the soil correctly before laying out the biodegradable mulch film. The soil should be refined and prepared to ensure that stones and any crop residues, particularly harder items (e.g. corn or sorghum stalks, etc.), do not damage the film whilst it is being laid. Special care must be taken when laying mulch film over soil with a high percentage of rock fragments or stones, and if possible the surface must be prepared using a bed former machineries capable of burying the crop residues and rock fragments in the soil.

Figure 18: prepared soil for mulching operations

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Laying correctly the film will guarantees its durability in the field. Biodegradable mulch film should not be laid immediately after surface application of manure (even if it is mature), in order to prevent the organic fertiliser from causing early biodegradation owing to its high micro-organism content. However, if fertilisation is conducted one or two months in advance, as usually occurs in normal farming practices, then the film will not be affected in any way.

Laying out the film

The laying out of biodegradable mulch film and the preparation of the soil are the most important operations to guarantee successful results in the field. The film can be laid manually (especially in case of small areas) or mechanically using the same machinery as for traditional plastic film and at similar speed and gear. In the case of mechanically laying it is essential to ensure the correct calibration of the mulch laying machine to ensure the biodegradable film is laid properly: the film tension must be reduced to a minimum to prevent it from being weakened during application, which could make it less effective. It is therefore advisable to adjust the brakes and clutch of the mulch laying machine so as to avoid applying excessive stress to the film during this operation.

Figure 19: Layed mulch film

In the case of **manually laying**, is more simple to avoid applying excessive stress to the film, but it is advisable don't step on layed mulch film and avoiding mechanical damages (breaks, punctures...) during the hilling the land around the film. It is also advisable to avoid using any rollers which pass over the film once it has been laid out in order to improve its adherence to the soil. Since it is very thin, biodegradable mulch film will stick to the ground perfectly after a few days.

Finally, care should be taken when using rollers for micro-perforations in the field (or to create perforations that allow irrigation waters to penetrate the soil more easily). If not adequately performed, these perforations may allow too much light to penetrate the film,

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stimulating weed growth which could prematurely damage the film. In order to avoid the problems associated with the improper application of micro-perforations, perforated films are also available. However, if carried out carefully, the micro-perforation of laid film is well tolerated, especially for shorter crop cycles (e.g. spring-summer lettuce).

In particularly windy areas, it is advisable to anchor the mulch film to the ground with small quantities of soil (a shovelful is sufficient) every 2-3 metres on exposed areas. It is advisable to lay the film and transplant cuttings at the same time (normally mulch machine provides laying and transplanting), or to minimise the time between these operations. This will make it possible to take full advantage of biodegradable mulch film.

Crops setup: film perforation, crops transplant, irrigation and agricultural inputs

Perforation is generally carried out when the film is laid and is therefore completely mechanised. It is conducted using the same machines and procedures used for traditional plastics, bearing in mind that biodegradable film is more elastic. Ideally the systems used should perforate the film when it is already positioned on the ground. For manual perforation, equipment should not be used that could produce holes with irregular edges (e.g. cut tin cans) because these cuts can damage the film prematurely. One of the best ways to make perforations is to use a knife to make a cut in a cross shape or in a T or Y shape. This technique reduces the amount of uncovered land around the transplanted cutting. Holes made using cylindrical implements (including hot cylinders) make it possible to create holes with “clean” edges suitable for biodegradable mulch film.

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Figure 20: Mulch film perforation

The use of biodegradable mulch film does not require any change in normal cultivation techniques. The biodegradable mulch film is compatible with the same irrigation systems used with traditional plastic mulch materials: drip irrigation, spray irrigation and surface irrigation (less commonly used with vegetable crops). The use of biodegradable mulch film does not lead to changes in the quantity of water used, capacity or irrigation intervals compared with traditional materials.

No research agencies, universities or end users have reported any damage or negative interactions between biodegradable mulch film and the use of fertilisers and agricultural inputs, at the same doses and periods used normally during cultivation with traditional plastic film.

Controlling weeds and duration of the film

Test results and data from the widespread use of black biodegradable mulch film in the field have shown it is as effective at controlling weeds as traditional materials of the same colour. However, particular attention should be paid to certain species of weeds: field tests have shown that major infestations of horsetail (Equisetum sp.) and sedge (Cyperus sp.) can damage biodegradable mulch film, which in any case also occurs with thinner varieties of traditional plastic materials. The duration of biodegradable mulch film in the field depends greatly on environmental factors (rain, thermal regimes, solar irradiation, etc.) and therefore it does not depend solely on the action of micro-organisms in the soil. Biodegradable mulch film with a thickness of 15 µm is used to grow a wide range of vegetable species with crop cycles of between 2 and 6 months: from lettuce or leaf crops transplanted in the spring or summer to solanaceae grown in the open field. For crops with a longer crop cycle e.g. the cultivation of strawberries with an annual cycle (or which remain in the field for between 9 and 12 months and which are transplanted in summer/autumn), biodegradable mulch film has shown good performance in typical conditions in Mediterranean areas (Spain and Italy), with thickness of 18- 20 µm. Biodegradable film maintains its mulching capacity for longer in autumnal crop cycles than in the spring or summer, owing to the reduced impact of temperature and solar irradiation, and due to the reduced activity of micro-organism populations in the soil. Finally, for crops for which the soil must be covered for periods of over a year, biodegradable film with a thickness of 40 µm and above is recommended. Applications include small fruits (raspberries) and new vine plantations.

End of the crop cycle

Biodegradable mulch film should not be removed or disposed of at the end of the crop cycle (an obligatory process for traditional plastic film); instead, it is worked into the soil. This operation provides biodegradable mulch film with the ideal environment to end its life cycle through the mineralising action of soil microorganisms, transforming it into water, carbon dioxide and biomass.

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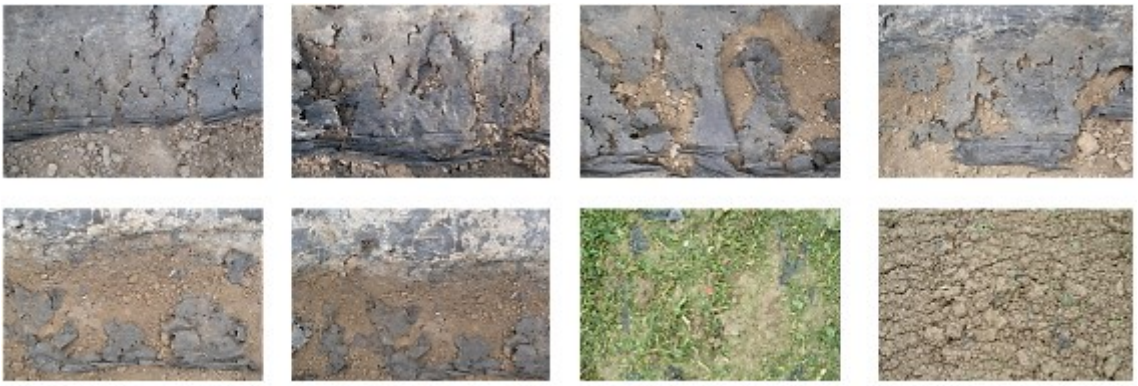

Figure 21: stages of mulch film biodegradation

Mulch film made of Novamont bioplastics which is left on the surface rather than being worked into the soil will take longer to biodegrade. A range of different operations can be used to work biodegradable mulch film into the soil depending on the type of soil and its state at the time of the operation. Soil conditions and environmental factors are therefore the fundamental elements in determining the biodegradation of the material. For example during the winter, with low soil temperatures, or in lands that remain saturated with water for long periods of time, the biodegradation processes will naturally take longer.

Biodegradable film storage

The processes used for storing biodegradable mulch film are different from those used for the storage of traditional plastics film. When not being used, rolls of biodegradable mulch film must always be stored inside the farm store in their original packaging, protected from water, light and sources of direct heat. If the rolls is not replaced in its original packaging after use, it is advisable to keep it upright to avoid flattening, deformation or breakage. Various tests have shown that when biodegradable mulch film is properly stored it can be used in subsequent seasons, with satisfactory performance and agronomic behaviour. Accidental breakages caused by improper storage of materials or damage during transport may have a negative impact on the life of the film in the field. If possible, any damaged parts of the film should be removed before use.

Performance evaluation and management of biodegradable mulching in field.

After following the best practices of biodegradable mulching film laying out, also the collection of field data is strongly suggested to carry out a comprehensive assessment of the mulching film performances and it allows to adapt the Novamont biomaterials to the specific regions and cropping system.

To facilitate monitoring and field assessment, a score evaluation has been defined for the different points of observation such as: Laying, film degradation in the exposed side, film degradation in the underground side, damages and tear resistance.

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In order to have a properly evaluation during field surveys on the mulch film, a simple numerical score system with values from 1 to 9 was chosen, according the following observations:

- Damages at laying: 1 = very high number of damages & hard to lay - 9 = no damages & easy laying
- Film degradation of the exposed side: 1 = 0% uncovered soil - 9 = 100% covered soil
- Film degradation of the underground side: 1 = film totally disappeared - 9 = film as new
- Damages (referring only to the exposed part of the sheet): any break, tear, hole, tear that appears on the sheet, reducing its functionality: 1 = very high number of damages - 9 = no damages
- Tear resistance of film exposed side: 1 = extremely fragile - 9 = very strong, elastic like new one

The collection of field digital photo is suggested to better prove the evaluation criteria used by Food Hub operators. Finally, during the trials would be useful also monitoring weather conditions whenever possible: temperature (minimum, average, maximum ° C), relative humidity (%), rainfall (mm), wind (m/s), soil temperature at 10 cm deep. Basically the designed plan for the mulch film assessment during the test could be summarized in the table below.

Table 4: Designed plan for the mulch film assessment during the test

Description	Survey modality	Timing for check
Degradation exposed side of film	SCORING (1-9)	Every 15 days
Degradation of the underground side of film	SCORING (1-9)	Every 15 days
Damages	SCORING (1-9)	Every 15 days
Tear resistance	SCORING (1-9)	Every 15 days
Laying damages	SCORING (1-9)	At beginning of test
Easy to lay	SCORING (1-9)	During laying
Weather conditions	Climatic station	Season of trials
Photographic survey		Every 15 days
Soil temperature	Temperature probe	daily

In order to help Food Hubs operators with the scoring assignment during the mulching test, an actual example of biodegradable mulch film assessment in field is reported following.

In the first period of observation (15 days from the laying) the biodegradable mulching film could appear as in the pictures below: film perfectly covers the soil (9), no lesions (9), film with a good tear resistance (9).

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DEGRADATION: 9

LESIONS: 9

STRENGTH: 9

In a second check (30-45 days from the laying) the mulching film status could appear as in the following picture: due first lesions (7) the mulching film doesn't totally cover the soil (degradation 8) but the film tear resistance is not yet decresead.

DEGRADATION: 8

LESIONS: 7

STRENGTH: 9

Moving on with the crop cycle as well as the mulching aging (after 60-90 days), the lesions could affect more widely the film and the progressive loss of the film tear resistance could lead to a fully disintegration. In the pictures below are reported different stages of film degradation in order to help the scoring assignment and demonstrating the typical damages kind and loss of mulching functionalities on the weeds control.

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DEGRADATION: 7
LESIONS: 6
STRENGTH: 5

DEGRADATION: 8
LESIONS: 6
STRENGTH: 8

DEGRADATION: 6
LESIONS: 4
STRENGTH: 3

DEGRADATION: 6
LESIONS: 4
STRENGTH: 3

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DEGRADATION: 7
LESIONS: 5
STRENGTH: 8

DEGRADATION: 6
LESIONS: 4
STRENGTH: 4

DEGRADATION: 5
LESIONS: 4
STRENGTH: 5

DEGRADATION: 4
LESIONS: 3
STRENGTH: 3

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DEGRADATION: 3
LESIONS: 2
STRENGTH: 1

DEGRADATION: 1
LESIONS: 1
STRENGTH: 1

Customized guidelines for biodegradable mulching trial on tomatoes crops.

In the framework of FoodLAND project several mulching trials in the Tunisian Food Hub will be carried out under the leading of ISACM. Properly, the partner ISACM will implement a mulching trial on tomatoes, a crop on which Novamont has collected in the years a significant experience and a lot of agronomical data related to the best agricultural practices to use biodegradable mulch film.

Cultivation of processing tomato

Italy has a great technical and agronomical experience in the cultivation of processing tomatoes, representing one of the main world producers. Novamont has acquired a good experience in mulching processing tomatoes in over 20 years of trials and commercial fields in Spain and Italy. The region of Navarra (Spain), in a good example of implementing biodegradable mulch films: today 80% of mulch film used is in fact biodegradable,

Biodegradable mulch films can be used with success especially where the harvest is mechanical; conventional mulch films can hamper mechanical harvesting operations. On the opposite, biodegradable mulch films can solve this problem, since they do not interfere with this operation.

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There are several varieties, with either round or elongated fruit, intended for different uses: sauce, concentrates, canned diced and whole tomatoes. The method of harvesting also varies according to the intended use: for example, manual harvesting is preferred for whole canned tomatoes, while mechanised harvesting is preferred for sauces and concentrates. Transplanting is carried out from April in single or double rows with variable spacing, also depending on the type of fruit. While the varieties harvested manually in some areas are traditionally mulched with black film.

Characteristics and agronomical results from the use of biodegradable mulch film in processing tomatoes

For the cultivation of processing tomatoes intended for both manual and mechanical harvesting, it is recommended to use 15-micron thick black biodegradable film. This has proven to be effective in various field tests both for controlling weeds and for optimizing the agronomical result.

Field trials

Depending on the area of cultivation, processing tomatoes may or may not require mulching. Generally, however, mechanical harvesting cannot be done when non-biodegradable film is used. The use of biodegradable mulch film for tomato cultivation has shown several advantages from the agronomical point of view starting with an enhanced plant growth, especially evident in the first phenological stages (the so called “starter effect”). Mulched plants have a more rapid and uniform growth of the plant in the initial stages, due to an increase in temperature and soil humidity. Biodegradable mulch film has been used for over 15 years in the main tomato production areas in Europe: Italy, Spain and France. Around 2000 hectares of industrial tomatoes are cultivated in the Spanish region of Navarra, which are almost entirely mulched. Biodegradable film is used on about 80% of this surface area, in order to reduce the possibility to leave plastic residues in the soil. In Italy, biodegradable mulch film is used in the main areas where processing tomato is cultivated, predominantly in Southern Italy. (Apulia, Campania and Emilia Romagna regions). Field data have shown that the use of biodegradable mulch film provide the following benefits when compared to not mulched crops:

- Effective weed control during the crop cycle, without the need for extra weeding on the bed, which in the early growth stages can compromise the growth of young seedlings;
- Rapid growth of plants in the early cultivation stages;
- Improved plant root development;
- problem-free mechanical harvesting of the fruit and without the presence of mulch film fragments in the harvested product;

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Table 5: Field trial result about the use of biodegradable mulch films

Test	Total production (tonne/Ha)	Average weight of fruit (g)	Caliber (mm)
Test location: PUGLIA			
Black 15 µm	129,6	72	46
Bare soil	106,2	68	42
Test	**Total production (tonne/Ha)**	**Soluble solid content (°Brix)**	**Waste (%)**
Test location: EMILIA ROMAGNA			
Black 15 µm	101	5,10	1,7
Bare soil	95	4,95	2,9
Test	**Total production (tonne/Ha)**	**Average weight of fruit (g)**	**Waste (tonne/Ha)**
Test location: CAMPANIA			
Black 15 µm	138,5	68	10,2
Bare soil	130,7	71	12,5
Test	**Total production (tonne/Ha)**	**Average weight of fruit (g)**	
Test location: SPAIN (Navarra)			
Black 15 µm	169,03	59,33	
PE 15 µm	151,70	51,17	

Tunisian Food Hub mulching trials on tomatoes.

In the framework of FoodLAND project several mulching trials in the Tunisian Food Hub will be carried out under the leading of ISACM. In detail, the partner ISACM will implement a mulching trial on tomato, for this purpose a customized template for data collection has been produced and sent to the project partner (Field Evaluation Diary).

The trials in Tunisia are characterized by similar spring/summer temperature compared to Southern Italy. Considering the need of a biodegradable mulch film with an affordable cost and considering the similar characteristics compared to Southern Italy a fully black biodegradable in soil mulch film was chose as mulching material.

Finally considering that the mulch film will be laid manually, the selected width was 1000 mm to allow manual handling. For the tomatoes crop a need of 90 days in soil resistance was required therefore the selected thickness is 15 micron.

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Characteristics and agronomical results from the use of biodegradable mulch film in the horticultural crops

For the cultivation of the horticultural crops intended for both manual and mechanical harvesting, it is recommended to use 15-micron thick black biodegradable film. This has proven to be effective in various field tests both for controlling weeds and for optimizing the agronomical result.

Field trials

Depending on the area of cultivation, the horticultural crops may or may not require mulching. Generally, however, mechanical harvesting cannot be done when non-biodegradable film is used. The use of biodegradable mulch film for the horticultural cultivation has shown several advantages from the agronomical point of view starting with an enhanced plant growth, especially evident in the first phenological stages (the so called “starter effect”). Mulched plants have a more rapid and uniform growth of the plant in the initial stages, due to an increase in temperature and soil humidity. Field data have shown that the use of biodegradable mulch film provide the following benefits when compared to not mulched crops:

- Effective weed control during the crop cycle, without the need for extra weeding on the bed, which in the early growth stages can compromise the growth of young seedlings;
- Rapid growth of plants in the early cultivation stages;
- Improved plant root development;
- problem-free mechanical harvesting of the fruit and without the presence of mulch film fragments in the harvested product;

Tanzanian Food Hub mulching trials on beans.

In the framework of FoodLAND project several mulching trials in the Tanzanian Food Hub will be carried out under the leading of SUA. In detail, the partner SUA will implement a mulching trial on beans, for this purpose a customized template for data collection has been produced and sent to the project partner (Field Evaluation Diary).

The trials in Tanzania are characterized by similar summer temperature compared to Southern Italy. Considering the need of a biodegradable mulch film with an affordable cost and considering the similar characteristics compared to Southern Italy a fully black biodegradable in soil mulch film was chose as mulching material.

Finally considering that the mulch film will be laid manually, the selected width was 1000 mm to allow manual handling. For the beans crop a need of 110 - 150 days in soil resistance was required therefore the selected thickness is 15 micron.
Properly, the partner SUA will implement a mulching trial on beans. This crop usually may not require mulching, Novamont has collected interesting agronomical data related

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to the best agricultural practices on mulching of the green beans. Basically the use of mulching on beans crops could refer to the practices employed on the horticultural crops. Perforation is generally carried out when the film is laid. For manual perforation is suggest to make a small cut (1-2 cm) only on the seeding point. In case of climbing beans the use of supporting poles could be adopted, making a manual perforation of mulch film directly by the pole or making a small cut on film similar to the pole's diameter.

How the biodegradable in soil mulch film will enhance production and nutritional performances in the countries of interest for the project.

Considering the early stage of the project at the moment Novamont did not had the opportunity to collect production data related to the use of biodegradable in soil mulches in African countries, therefore project like FoodLAND help Novamont to expand the agronomical experience in different regions and on crops grown in different conditions.

Annexed to this Deliverable, a method and a data collection scheme, was provided to the project partner to collect productive and mulch performance information compared to cultivation on bare soils.

Here below is reported an estimation related to the potential increase in production for tomatoes and other horticultural crops such as beans (against bare soil condition):

Tomato under biodegradable mulch films vs bare soil:

- approx. 15-20% reduction in water consumption;
- improved production both in terms of quantity (increase in Gross Saleable Product from 10 to 30 %) and quality (fruits with more uniform colouring at harvest, with a greater number of red fruits and an increase in Brix of the juice (even if not statistically confirmed), fewer rotten and green fruits compared to non-mulched plants).

Beans under biodegradable mulch films vs bare soil::

Regarding beans we do not have precise data collected in our database. It will be therefore very important to see the agronomical results in terms of quantity and quality of the crop and water consumption. These two aspects are generally expected to be favourably impacted by the use of a biodegradable mulch film.

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Conclusions

The Food and Agricultural Organization of the United Nations (FAO) forecasts that global food production will need to increase by 70% if the population reaches 9.1 billion by 2050.

The implementation of Sustainable Development Goal n°2 entails a shift to a more sustainable agriculture and food systems. In the near future it would be increasingly necessary to strengthen resilience to the effects of climate change while ensuring food security.

Mulching is a consolidated agronomic technique used to prevent weed growth, improving soil heal and fertility, while preserving soil moisture granting enhanced crop yields as well as precocity. Mulching has also some other positive environmental effects such as temperature regulation of soil and plant roots, minimum nutrient losses, cut down soil erosion and compactness, improving physical conditions of soil.

The application of traditionally, non-biodegradable plastic mulch film provides these benefits but entails also two main critical issues: (1) A proper disposal of the mulch films in waste management plants at the end of its life, resulting in higher cost for farmers and for the municipalities; (2) Environmental pollution due to accidental dispersion of non-biodegradable plastic fragments in the arable fields (white pollution).

Certified biodegradable in soil mulch films (according to EN 17033) offers an agronomically and environmentally efficient alternative to traditional plastic films, minimizing environmental impact and saving time and resources in managing the end-of-life of mulched crops.

Data collection regarding mulch film application performed in FoodLAND Food Hubs in African Countries and other areas that will be selected to evaluate climatic conditions not yet tested, will enable further developments of biodegradable materials for agricultural applications suitable also for North African countries.

This research activity will support the development of products that’s do not accumulate in soil that will allow their application in areas and regions where these solutions are not available or effective, potentially providing a small contribution to the achievement of the UN 2nd Sustainable Development Goal (End hunger, achieve food security and improved nutrition and promote sustainable agriculture).

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Annex 1

Data Collection regarding biodegradable in soil mulch film performance and resistance								
Description	**Survey modality**	**20 days**	**45 days**	**60 days**	**85 days**	**100 days**	**150 days**	**End cycle crop**
Degradation exposed side of film	SCORING (1-9)	9	9	8	7	7	6	4
Degradation of the underground side of film	SCORING (1-9)	9	9	8	7	7	6	1
Damages	SCORING (1-9)	9	9	8	7	7	6	2
Tear resistance	SCORING (1-9)	9	9	8	7	7	6	1
Weather conditions & Notes (storms, rains..)	Climatic station & notes	dry, Tmax - Tmin	some days of rains Tmax - Tmin	short rains Tmax - Tmin	dry Tmax - Tmin	windy Tmax - Tmin	dry Tmax - Tmin	dry Tmax - Tmin
Photographic survey		✓ (global view, focus on plant, focus damages exposed side, focus damages underground side..)	✓ (global view, focus on plant, focus damages exposed side, focus damages underground side..)	✓ (global view, focus on plant, focus damages exposed side, focus damages underground side..)	✓ (global view, focus on plant, focus damages exposed side, focus damages underground side..)	✓ (global view, focus on plant, focus damages exposed side, focus damages underground side..)	✓ (global view, focus on plant, focus damages exposed side, focus damages underground side..)	✓ (global view, focus on plant, focus damages exposed side, focus damages underground side..)

Field map

mulched	bare soil	mulched
bare soil	mulched	bare soil
mulched	bare soil	mulched
mulched	mulched	mulched
bare soil	bare soil	bare soil
bare soil	bare soil	bare soil
mulched	mulched	mulched
mulched	mulched	mulched

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Data Collection regarding inputs and agricultural production								
Description	Survey modality	date	date	date	date	date	date	End cycle crop
Use of Fertilizers	Quantity and type							
Use of plant protection products	Quantity and type							
Soil management and tillage	description of management							
Irrigation	Quantity of water provided							
Rain	mm of rain in the period of cultivation							
soil characteristics	soil type and depth							
mulch film application	date							
Product Yield	t/ha							

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