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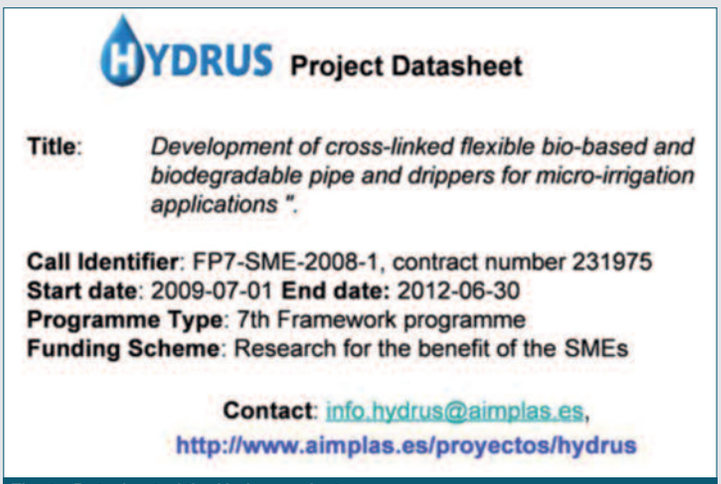
THE HYDRUS PROJECT: NEW-BIODEGRADABLE CHEMICAL FORMULATIONS FOR MICRO-IRRIGATION APPLICATIONS

The EC founded (FP7) Hydrus project is an ongoing project focused on the development of pipes and drips for micro-irrigation applications produced starting from bio-based and biodegradable polymer materials. The consortium is made of six small medium enterprises (SMEs), and four research and technological performers (RTDs). UniPi-IPCF-CNR (the unique Italian partner, which works as RTD) formulated the new biodegradable compound at the Lab level.

The Hydrus project, titled "Development of cross-linked flexible bio-based and biodegradable pipe and drippers for micro-irrigation applications" (see datasheet in Fig. 1) is an ongoing EC founded project, within the FP7 framework, section Capacities, research area: SME-1 research for small-medium enterprises (SMEs). The consortium (Fig. 2) is made of six small medium enterprises (SMEs) from Germany, Spain, Slovenia and the Netherlands, and four research and technological performers (RTDs) from Spain, Italy, the Netherlands and Belgium. AIMPLAS (Spain) coordinates the project, whose main objective is the development of pipes and drips for micro-irrigation starting from bio-based and biodegradable polymer materials.

Micro-irrigation, also known as drip irrigation or trickle irrigation, is an irrigation method that applies water slowly to the roots of plants, by depositing the water either on the soil surface or directly to the root zone, through a network of valves, pipes, tubing, drippers or emitters (Fig. 3). Of the various forms of micro-irrigation, drip irrigation is the one most widely used because it can save water, reduces the use of horticultural chemicals, it is relatively insensitive to environmental effects, and increases the rate of plant growth. Drip irrigation is an effective irrigation system in terms of water conservation. The use of micro-irrigation is rapidly increasing around the world, and it is expected to continue to remain a valuable irrigation method for agricultural production. According to the Food and Agriculture Organization of the United Nations, FAO, only 11% of the total world land area can be farmed without being irrigated, drained or otherwise improved [1]. Micro-irrigation can be used on most agricultural crops, although it is


HYDRUS Project Datasheet

Title: *Development of cross-linked flexible bio-based and biodegradable pipe and drippers for micro-irrigation applications ".*

Call Identifier: FP7-SME-2008-1, contract number 231975
Start date: 2009-07-01 **End date:** 2012-06-30
Programme Type: 7th Framework programme
Funding Scheme: Research for the benefit of the SMEs

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Fig. 1 - Datasheet of the Hydrus project

Due to the ongoing character of the project, and the potentially patentability of the project results, no significant technical data came be here given and discussed.

currently most often used for high value culture such as vegetables, ornamentals, vines, olives, fruit crops and greenhouse plants. In Europe, the percentage of irrigated crop area over the cropland is 7.9% [2]. This percentage means that in Europe there are more than 24 millions of hectares irrigated with different methods. From this, 2.25% of total irrigated crop area (540,000 ha) is irrigated using a micro-irrigation system [3]. In other words, around 11,000 millions of meters of polyethylene micro-irrigated pipes (20,000 m/ha) are currently needed in Europe, thus representing a very big market for pipe manufacturers. Moreover, the use of micro irrigation systems is expected to reduce the water consumption around 60%, i.e. 70,000 millions m^3/year.

In this framework, the main objective of the Hydrus project is the development of pipes and drips for micro-irrigation starting from bio-based and biodegradable polymer materials. The pipe and drips will maintain their functional properties during lifespan and biodegrade after use. Therefore, removal and disposal after use will be no longer required, as it is currently, thus solving the most important problem related to the use of micro-irrigation pipes. The main innovations claimed in Hydrus are:

1) use of bio-based materials. A minimum 75% final product composition will be obtained from renewable resources;
2) biodegradability in soil. The main innovation of the project is the biodegradability of the final product in soil (aerobic conditions in top layer) or in composting processes, which will result in the significant reduction of the cost for removal of the product after the end of its life of use;
3) development of micro-irrigation pipe and drip using biodegradable materials and standard extrusion pipe extrusion and injection moulding equipment. There is no technical information available for pipe and drips production using a biopolymer as a base material. The melt flow index and the melt strength of the blend have to be adjusted to obtain similar output than when standard polyethylene is used;
4) development of controlled reactive extrusion for biopolymers at pilot plant and industrial level. Controlled reactive extrusion of biodegradable materials has been studied at laboratory level but still does not have any significant industrial application. Reactive extrusion is a process that seems very promising for the blending of biodegradable materials in order to produce a final material with tuned properties. The major challenge is to control both processes in a "selective manner", in order to avoid secondary reactions. This will be done controlling the amounts of reactive agents, initiators, coupling agents, as well as choosing the location of the feed point along the extruder in order to achieve the desired results and the machine parameters (temperature profile, residence time, and need of auxiliary equipment such as IR oven);
5) improvement of the thermal and chemical resistance of biodegradable materials. By means of cross-linking or other structural changes, molecular weight of polymers can be increased leading to a better thermal and chemical resistance. This is a key issue in order to meet the requirements of the target application;
6) fine tuning of mechanical properties. Reactive extrusion with flexible materials or plasticizers will enhance tailor-made properties.

Fig. 2 - The Hydrus consortium


Fig. 3 - Examples of the micro-irrigation technique

The biodegradable materials currently available on the market, potentially suitable as starting materials to obtain the final compounds to make pipes and drippers, show a low content of bio-based components (between 30-45%) and cannot fulfil all the requirements for the Hydrus application, mainly related to the thermal and the chemical resistance.

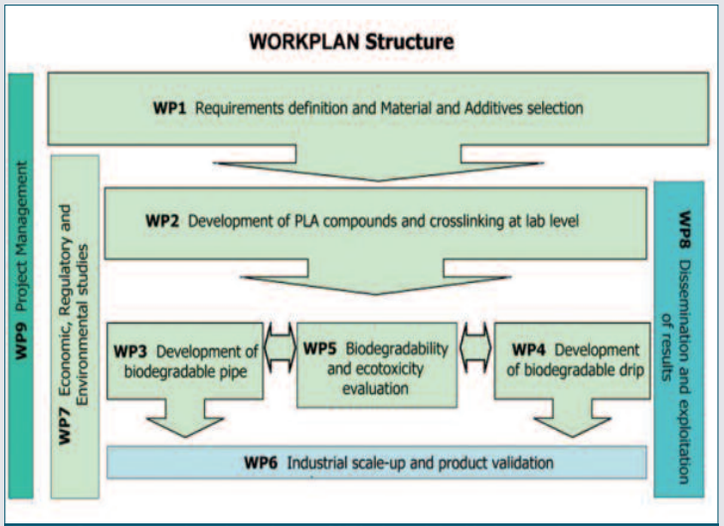

Fig. 4 - Structure and work packages (WP) plan of the Hydrus project

To overcome these limitations, the strategy developed within the Hydrus project (Fig. 4) starts from the design of chemical modification of commodity biodegradable plastics (mainly PLA-based), by means of a cross-linking process, promoted by a radical peroxide. Since cross-linking usually triggers rigidity, a plasticizer (biodegradable and from renewable resources) was added during the reactive extrusion step. The RTDs (Fig. 5) developed the final compound formulations and follow their scale up at pilot plant level. In particular, the new compounds were formulated at lab level by UNIPI-IPCF, leaders of WP2. The formulations they proposed were tested and optimized to be suitable for the extrusion and injection moulding processes, to produce pipes (AIMPLAS) and drippers (TNO) respectively. All the formulations were tested for biodegradability, following European standards in soil and in composting conditions (EN13432). Industrial scale up of compound production is currently carried out by FKUR, one of the SMEs involved in the project. Noteworthy, UNIPI-IPCF also performed the characterization at the molecular level of all the compounds produced in any step of the project, to check whether and how different processing conditions could tune thermo-mechanical properties and structural features (such as cross-linking percentages and molecular weight) of the final materials. As a general result**,** Fig. 6 shows a pipe prototype obtained starting from the biodegradable compound developed within the Hydrus project.

Indeed, the new biodegradable compound developed within the Hydrus project turned out to be suitable for the final application, and showed:

1) good processability in a conventional pipe extrusion line;
2) good mechanical properties and elastic recovery;
3) good chemical resistance.

At the moment (3rd and last year of the project), the validation of the pipes and drippers produced using the new biodegradable compounds developed within the Hydrus project is under investigation in crop fields, in real final application environments.

Besides its technical objectives, Hydrus project aims at improving the EU Plastic Industry competitiveness, in particular, but not limited to, companies focusing on the micro-irrigation market. Plastic industry in Europe is dominated by SMEs (99%) [4]. Although often highly ambitious, the vast majority of the SMEs lack the resources to develop innovative materials and methods of work. By outsourcing the research and development activities foreseen in this project to the four RTD performers, the SMEs involved in the Hydrus project (Fig. 2) will be able to confront a technical challenge: the development of a new biodegradable/bio-based micro-irrigation system, eventually cheaper than the ones currently on the market, which will provide them a competitive position in the current agricultural market. The RTD performers (Fig. 2 and 5) will provide the research results to the SMEs that mainly contribute carrying out activities to validate and to exploit them, according to the concept of '*Research for SME*'.

The achievement of the above mentioned objectives will result for the participating SMEs, representing the different types of SMEs involved in the micro-irrigation chain and marketing, in:

- FKUR (*Compounders)* will increase their knowledge by the use of processes that until now have not been widely developed at industrial scale, such as the reactive process and the reactive extrusion among different biodegradable materials and other additives to obtain the final formulation to be processed into pipes;
- EXTRULINE and TOTRA *(Pipe manufacturers* and *Manufacturers of accessories)* will diversify their offer, giving their activity a more flexible profile as they will offer new products inexistent nowadays for micro-irrigation: a biodegradable pipe and accessories (such as drippers, emitters, etc.), respectively;
- BAIX, FORMFLEX and METAZET *(*as *micro-irrigation systems' producers and installers) will* produce pipe and/or offer their customers the new product with the advantage of its biodegradability, maintain-

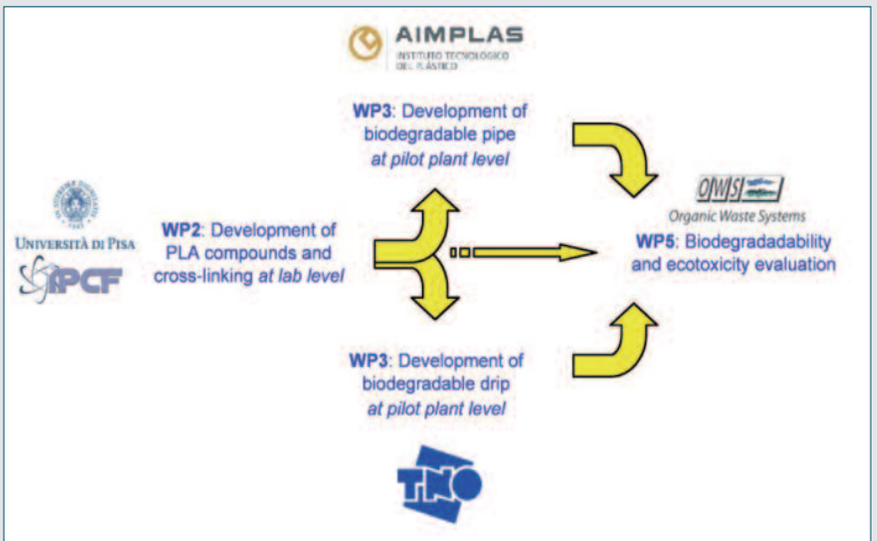

Fig. 5 - RTD's role in Hydrus project

Fig. 6 - The pipes produced using the new biodegradable compound developed within the Hydrus project (white one), and those produced with polyethylene (PE), the currently used resin for pipe (black one)

ing all the properties of currently available polyethylene pipes;

- BAIX, FORMFLEX and METAZET *(as end users)* will benefit from the biodegradability of the new pipe which will eliminate cost of collection and removal that traditional pipes cause.

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RIASSUNTO

Progetto Hydrus: nuove formulazioni chimiche biodegradabili per l'utilizzo in micro-irrigazione

Il progetto Hydrus, finanziato nell'ambito del 7° programma quadro dalla Commissione Europea, ha come scopo la realizzazione di sistemi per la micro-irrigazione (tubi e gocciolatori) in materiale plastico completamente biodegradabile. Partecipano al progetto 6 piccole-medie aziende europee, e 4 istituti di ricerca europei. L'unico partner italiano, UniPi-IPCF-CNR, ha messo a punto a livello di laboratorio la formulazione del nuovo termoplastico biodegradabile, formulazione poi ottimizzata dagli altri partner europei per consentirne l'estrusione e lo stampaggio ad iniezione.

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