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DELIVERABLE No. 23: Final Publishable Report

(Lead Participant – BIOCYCLE)

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PROJECT N°: **FP6-513116**

ACRONYM: **BIO-SHELTER**

TITLE: A novel, innovative and sustainable technique for the manufacture of biodegradable tree shelters with a known life

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SUMMARY

Tens of thousands of deaths are caused worldwide by natural disasters triggered by weather including hurricanes, flooding and cyclones. Human activities have polluted the atmosphere to such an extent that they may be contributing to climate change. In the last 40 years the atmospheric concentration of carbon dioxide (CO_2) has risen by 21% (currently 385 parts per million)[1].

One way to reduce the level of CO_2 emission into the atmosphere is through the cultivation of forests to create "carbon banks". Trees help to significantly reduce emissions by capturing CO_2 via photosynthesis and storing it as bio-mass in a process known as sequestration. Young trees and saplings grow more rapidly than mature specimens and consequently absorb more gas. Afforestation is a recognised method for CO_2 sequestration and can be used as mitigation under the Kyoto agreement. This has led to the planting of hundreds of millions of trees in Europe each year. Sweden alone plants in excess of one hundred million trees annually.

One of the biggest problems facing young trees and saplings in their early stages of growth is attack by insects or animals. This costs European forestry commissions millions of Euros each in creating and restocking new plantations. Therefore, a physical barrier such as a tree protector (shelter or spiral) is often used to protect the young tree during their early stages of development. This form of protection has proven very effective and can increase yields by up to 25%.

The objective of the **Bio Shelter** project is to develop a biodegradable tree protector using a combination of natural fibres and a tuneable polymer matrix. The solution will seek to reduce CO_2 emissions into the atmosphere and the product will utilise materials that are both sustainable and biodegradable.

Prototype tree protectors have been successfully manufactured (shown above) using a number of biodegradable material systems. Ongoing field trials indicate that several of the material systems may be suitable for use as tree spirals.

[1] http://en.wikipedia.org/wiki/Carbon_dioxide

OVERVIEW

The current generation of tree shelters are typically fabricated from thermoplastic materials including polyethylene (PE) and polyvinyl chlorine (PVC). Such materials are not biodegradable and consequently require removal from site after use and subsequent disposal.

The principle objective of Bio Shelter project was to develop a tree protector using natural biodegradable reinforcement, such as hemp or flax, in conjunction with a blended biodegradable polymer matrix having a tuneable life determined by the blended matrix. The material will breakdown and biodegrade naturally with no harmful by products and be the platform for a low-cost maintenance-free tree shelter.

Technical Objectives

- The development of a compatibiliser which can be blended with poly(lactic acid) and starch to control the rate of degradation
- The development of a range of several blends of biodegradable polymer, starch and natural fibres that produce a range of disintegration times up to 36 months when exposed to the normal range of European weather conditions.
- The development of an extrusion screw profile and processing window that will maintain sufficient fibre length and not degrade the polymers during processing
- The development of a range of material blends and processing technology to extrude biodegradable tree protectors with a cost of no more than €4 / metre

Economic Objectives

- Provide up to a **10%** increase in growth rate and up to **25%** increase in yield for timber producers
- Reduce imports to the EC of wood products by up to **€200 million p.a.** safeguarding hundreds of jobs
- Win at least **10%** of the European tree protector market estimated to be worth in excess of €**100 million p.a**.
- Create export opportunities for biodegradable tree protector into North America **-** a market worth more than **€200 million**.

Societal Objectives

- Improve the yield of new tree plantations to absorb up to 25% more CO_2 for the same plantation area through the use of tree protector
- Produce a tree protector which fully biodegrades by microbial action harmlessly into the soil after a designated life.
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APPROACH

The structure of the project was such that the work programme could be conveniently divided into two main areas of focus:

- Development of material systems
- Manufacturing process development

Materials

A number of biodegradable blends were investigated in this project including several containing poly(lactic acid), a renewable material derived from cereal crops such as corn. Extrusion grade PLA, PLA2002D (Natureworks) was used which has a specific density of 1.24 g cm^{-3} and a melt temperature of 210 ^{o}C. In addition, natural fibre reinforcement (chopped hemp fibres) with a specific density of 1.48 g cm^{-3} was also included in the product formulation for two main reasons; to provide additional stiffness, and to reduce the material cost per unit.

Processing

Stage #1

The biodegradable polymer blend was dry-mixed to the desired ratio and then starve fed into a twin-screw extruder at position "**A**" as shown in ***Figure 1***. Natural fibre was fed part way along the length of the extruder at position "**B**" into the molten polymer blend. The screw profile was designed such that; (i) the biodegradable polymers did not degrade during processing due to excessive shear and, (ii) the natural fibres were well dispersed in the blend and maintained a sufficient proportion of their initial length to provide an improvement in mechanical performance.

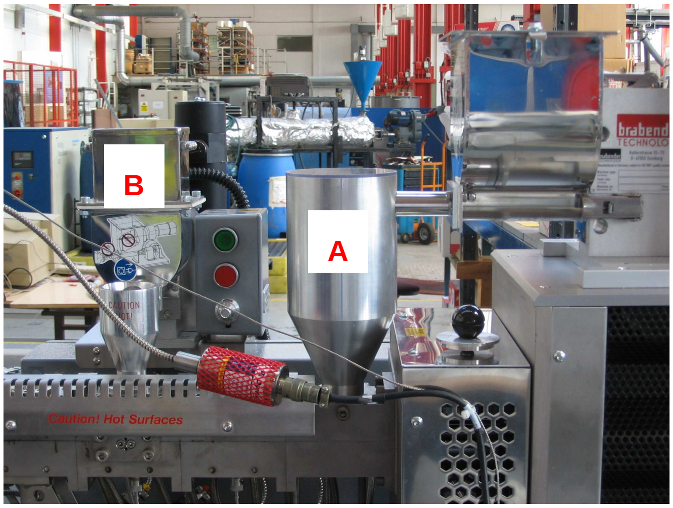
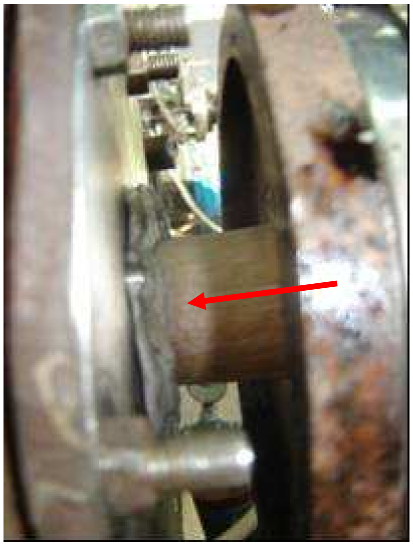


Figure 1 Photograph showing the twin-screw extruder feed zones for the polymer blend (**A**) and natural fibre (**B**)

Stage #2

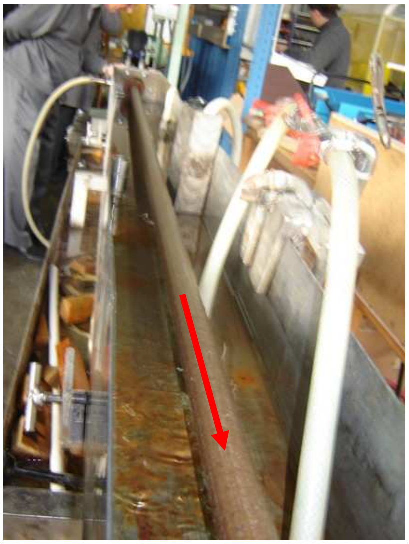
The compounded material produced in ***Stage #1*** were fed into single-screw extruder and extruded into a tube and spiral profile for evaluation. ***Figures 2a & b*** show the manufacturing of the tube at two stages of the process with the red arrow indicating the direction of flow. A rotating cutter located at the end of the water bath was used to produce tree spirals.

Figure 2 (a)



Bio Shelter material leaving extruder die and entering calibrator

Figure 2 (b)



Bio Shelter product running through the water bath having exited the calibrator

Environmental Testing

Two types of environmental tests were conducted on the biodegradable material blends; field trials and accelerated weathering. The field trials involved planting samples in pots which were exposed to normal European weather conditions including sunlight, precipitation and temperature variations. Accelerating weathering was performed using a Q.U.V accelerated weathering tester which cyclically subjected the test materials to 8 hours dry UV light at elevated temperature followed by 4 hours condensation at 50 ^{o}C.

PROJECT RESULTS

The main results are as follows:

- Several material blends successfully compounded into pellet form
- Pellets compression moulded into test pieces and environmentally tested
- Weight change monitored as a function of time both “in the field” (***Figures 3***) and in environmental chamber
- Several material systems exhibited encouraging results
- Prototype tree spirals manufactured for evaluation

Of the four materials shown in Figure only the “Material B” material began to disintegrate within the test period and, hence, there is no data shown after Day 92. All three remaining materials have maintained sufficient structural integrity up to 157 days of testing.

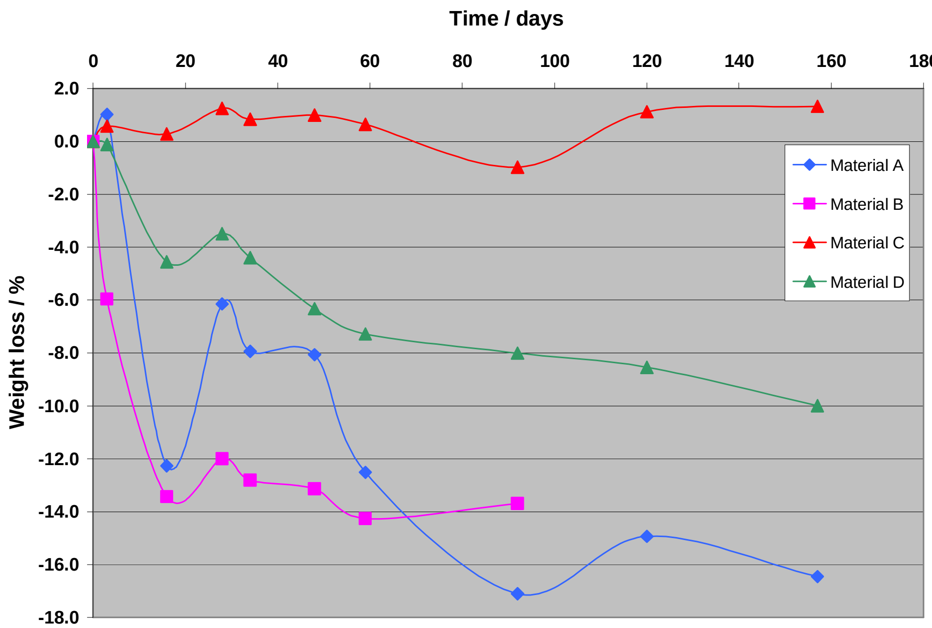


Figure 3 Graph showing the weight change as a function of time of several biodegradable material systems. Samples were located in plant pots with half below and above ground and exposed to European weather conditions.

Conclusions

Prototype tree protectors have successfully been produced using a number of candidate material systems and representative samples have undergone long-term environmental tests. Field trial results to date indicate that three materials (Materials A, C and D) may offer a biodegradable alternative to existing “non biodegradable” tree protectors. The next step will be to gain product certification which is the ultimate aim of the consortium.

The Bio Shelter production prototype is planned to be launched during 2008 upon completion of the environmental trials and once product certification has successfully be realised. The intention is to launch at one of the main European agricultural or horticultural shows such as Salon du Végéta 2008, one of the largest horticultural shows in France.

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GENERAL PROJECT INFORMATION

A Novel, Innovative and Sustainable Technique for the Manufacture of Biodegradable Tree Shelters with Known Life

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