Plastics for tree shelters: characterization of polypropylene tube residues after up to 20 years in the reforestation area

J. Martínez Urreaga[1,2], F.R. Beltrán[1,2], G. Gaspar[1], J. A. Oliet Palá[3], M.U. de la Orden[2,4]

[1]Dpto. Ingeniería Química Industrial y del Medio Ambiente, E.T.S.I. Industriales, Universidad Politécnica de Madrid, José Gutiérrez Abascal, 2, 28006-Madrid, Spain.
[2]Grupo de Investigación: Polímeros, Caracterización y Aplicaciones (POLCA).
[3]E.T.S. de Ingeniería de Montes, Forestal y del Medio Natural, Universidad Politécnica de Madrid
[4]Dpto. de Química Orgánica I, Universidad Complutense de Madrid, Facultad de Óptica y Optometría, Madrid,
Keywords: tree shelters, residues, degradation, EoL scenarios.
Presenting author e-mail: mariula@ucm.es

Tree shelters (Fig. 1) are plastic tubes used to improve the development and survival rates of young seedlings. In addition to protecting young plants from predators and wind, tree shelters allow some control of the light that reaches the plant and the microclimate (temperature and relative humidity) inside (Oliet et al., 2007; Puértolas et al., 2010). These characteristics make tree shelters a very effective tool, especially in some environments, for example, under water stress or excessive light radiation, so they are now widely used, not only in forest restoration but also in other applications in agriculture, such as fruit tree plantations and vineyards.

The most commonly used plastics are polyolefins, especially polypropylene (PP). In smaller quantities, plastics containing biopolymers, such as mixtures of PP with thermoplastic starch, are also used (Arnold & Alston, 2012). In this case, the biopolymer's function is to accelerate the in situ degradation of the tube shelter.

Fig. 1. PP tree shelters not used (left) and recovered from different reforestation processes carried out in Spain, 10 and 20 (right) years ago.

Due to the greater social concern for issues such as environmental pollution or littering, the question of the fate of tree shelters residues, after use, is currently of high interest. It must be taken into account that the tubes must keep up and maintain its shape for a few years while the tree protrudes from the tube and still protects the plant from browsing (Jacobs, 2011). After that period, there are two main alternatives for the residues of the tree shelters:

- Leave them in the area of use (unmanaged dumping). This alternative can cause significant problems of micro and nano-plastics formation and release of plastic additives in the environment.
- Collect the residues, which avoids the above problems but implies an economic and environmental cost. The collected waste can be sent to energy recovery, or recycled if its state allows it. In this case, it is necessary to consider that recycling can be difficult due to the high proportion of dirt in the residues and the significant photochemical and thermooxidative degradation of the polymer.

Regarding the viability of waste removing, it is necessary to differentiate between the current applications of tree shelters. In applications such as fruit tree plantations, waste access is expected to be relatively simple and, therefore, the cost of collection could be moderate. However, access to certain reforestation areas can be complicated and the cost of collection could be high in those cases. Arnold & Alston conducted a life cycle assessment of the production and use of polypropylene tree shelters and reported that the collection of the residues could be, in certain circumstances, a slightly worse alternative than abandoning it in the environment. In these circumstances, the use of tubes made of biopolymers, with a faster degradation, could have a slight environmental advantage (Arnold & Alston, 2012). However, the situation is changing in recent years, due to new regulations for the development of a circular economy, which promote the recycling of plastics (European Commission, 2018).

To select the most appropriate alternative for the residues in each case, it is necessary to know its degradation and contamination depending on the time of use. In this work, PP tubes recovered from different reforestation processes in Spain have been analyzed. In some cases, tree shelters were installed 20 years ago. The structure and composition of the aged tubes have been studied by infrared (IR) and visible spectroscopy, differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), microscopy and microhardness measurements.

Results and discussion

Fig. 1 shows PP tree shelters recovered from different reforestation processes carried out in Spain. Even after 10 years in the area of reforestation, the tube maintains its shape. After 20 years, the tubes have suffered a great degradation and only fragments can be collected.

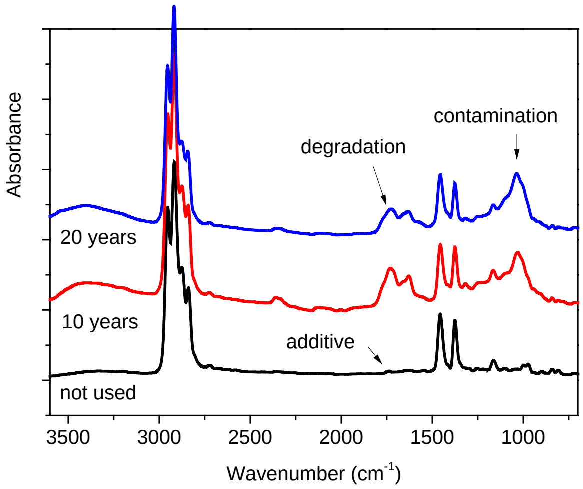

Fig. 2. IR spectra of the different tree shelters.

Fig.2 shows the IR spectra corresponding to the different tree shelters. The spectrum of the unused tube confirms that the polymer is PP and shows the presence of and ester-type additive. The spectra of the used tubes reveal intense degradation and contamination of the plastic. While the band centered at 1036 cm^{-1} can be assigned to silica and silicates coming from the soil, the bands appearing between 1600 and 1800 cm^{-1} correspond to C=C and C=O bonds present in compounds formed during the thermooxidative and photochemical degradation of PP.

In summary, the results of this work indicate that PP tree shelters suffer intense degradation and contamination during use. However, even after more than 10 years, recovery is possible, thus avoiding problems of contamination by microplastics and release of additives.

Acknowledgements

This project received funding from European Union's Horizon 2020 research and innovation program under grant agreement No. 860407 BIO-PLASTICS EUROPE. The authors would like to acknowledge the financial support of MINECO-Spain (project CTM2017-88989-P) and Universidad Politécnica de Madrid (project UPM RP 160543006).

References

Arnold, J.C., Alston, S.M., 2012. Life cycle assessment of the production and use of polypropylene tree shelters. J. Environ. Manage. 94, 1-12

European Commission, 2018. A European strategy for plastics in a Circular Economy. http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1516265440535&uri=COM:2018:28:FIN (accessed December 2019).

Jacobs, D.F., 2011. Reforestation of a salvage-logged high-elevation clearcut: Engelmann spruce seedling response to tree shelters after 11 growing seasons. West. J. Appl. For. 26, 53-56

Oliet, J.; Jacobs, D. 2007. Microclimatic conditions and plant morpho-physiological development within a tree shelter environment during establishment of Quercus ilex seedlings. Agricultural and Forest Meteorology 144: 58-72

Puértolas, J., Oliet, J.A., Jacobs, D.F., Benito, L.F., Peñuelas, J.L., 2010. Is light the key factor for success of tube shelters in forest restoration plantings under Mediterranean climates? Forest Ecol. Manag. 260, 610-617