Super durable plastic film tested for greenhouses

ETFE is a plastic film, which until now is mainly used in design architecture like the Olympic swimming stadium in Beijing. But the material can also be used as a greenhouse cover. A main advantage is the durability and therefore the reduction of waste, as research shows. This advantage is becoming more important these days as sustainability has become a hot topic.

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In Ontario a greenhouse with ETFE double layer inflated to benefit from the high light transmission and energy saving (picture P.A.T.I. S.p.A.).

Greenhouse plastic films are subjected to degradation due to exposure to solar radiation. The degradation is accelerated by the absorption of chemicals used during cultivation.

When the plastic sheets can no longer be used, they have to be removed from the greenhouse structures and wasted or preferably recycled. The environmental impact of the plastic covering sheets can be reduced by increasing the actual life time or by using materials suitable for an easier recycle.

The average service life for commonly used plastic films in horticulture ranges from some months up to three to four years, relative to the thickness of the plastic film and to the degree of stabilisation. *Table 1* shows the expected service life of a film in three ranges of solar radiant exposure. The desired service life of a film can be obtained to some extent by choosing the basic polymer, the thickness and then including in the formulation a suitable combination of additives, i.e. antioxidants, UV-absorbing chemicals and stabilisers against the solar radiation, mainly in its UV range. The different classes of plastic film durability are based on the WOM test, which is a European standard for measuring. The effects of exposure to chemicals are not included in these tests. The most advanced commercially available products of the E Class can reach a lifespan of three years in southern Italy and in the central Mediterranean area.

Sophisticated architecture

Not included in the classes in the *Table* is the film made of

ETFE, which refers to ethylene-tetrafluoroethylene copolymer. This material is already on the market for more than 20 years and is mainly used in sophisticated architectural constructions, as in the Allianz Arena in Munich, Germany and the Olympic Swimming Stadium in Beijing. But ETFE has also been used in greenhouses. There have been several examples of greenhouses covered by fluoropolymeric films, ETFE mainly, but the commercial development has always been hampered by the cost of the material, which is about ten times higher than polyethylene film.

But for the extra investment, ETFE offers a number of advantages such as the durability, which is regarded to be more than 20 years. This is due to the intrinsic UV stability of the polymer, without the need of any UV stabiliser. Moreover, the material is known for its low chemical reactivity, which is an extra advantage for greenhouses.

A side effect of the long duration is the reduction of waste, which is gaining importance because of the growing focus on sustainable production methods all over the world. Another advantage of the durability has to do with the expected increase of oil costs. Since costs of plastic are closely related to the costs of oil, an increase can be expected. This can make a heavy investment now profitable in the long term. Another advantage of ETFE is that there is only a little loss of PAR light transmittance when the cover gets older. Moreover, long durable film reduces the cost of replacing plastic film, which as a rule costs the same as the traditional film itself. As a conclusion, the high investment in ETFE film can be beneficial, if calculated over the long term.

Evaluate environmental impact

Because of the actual advantages of ETFE, plastic film producer P.A.T.I.S.p.A from Italy researched the characteristics of the product cooperation with the universities of Padova and Bari. In order to evaluate the environmental impact of the use of plastic covering films in terms of volumes of waste generated per hectare and per year, it was necessary to consider the real average period of replacement and the technical and economic feasibility of the waste materials recycle. The period of replacement is affected not only by the quantity of solar energy absorbed by the plastic sheets but also by the effect of chemical contaminants, that can deactivate the stabilisers and accelerate the film ageing reactions.

The aim of this research is to study the sensitivity of commercial greenhouse films to solar radiation and to a few commonly available phytochemicals. In order to estimate their actual lifetime in a practical situation, field and laboratory tests were carried out.

The field tests took place twice (in 2006 and 2007) at the experimental farm of the University of Bari in Valenzano (Italy) in low tunnels. During each set of experiments, four different EVA plastic films have been tested together with one ETFE film, all manufactured by P.A.T.I. S.p.A.. Each film was used as covering of two low tunnels, one of which was sprayed with the agrochemicals while the other one was not sprayed and used as reference. The plastic films, mounted on steel arches, were exposed to the atmospheric agents and to the chemicals. A water solution containing sulphur, iron and chlorine was sprayed weekly on each film. During the field tests, samples of the films were taken periodically and tested in the laboratory and the solar radiation falling on the films was measured. The cumulative solar radiation for the different exposure intervals was calculated.

The field tests had mainly the aim of simulating the process of external contamination. Additional tests were carried out to simulate aging by a SAIREM SEPAP unit that provides a more intensive treatment and shortens the testing time by 30% in comparison with the WOM method.

No significant changes

The ETFE film did not show significant changes, even after an exposure of 9,800 hrs in the SAIREM SEPAP 12/24 apparatus. The test was corresponding to at least nine years in a 130-160 kLy climatic area. The tensile strain was still very far from the limit of 50% of the original

Table 1: Expected service life of film for different solar radiation exposure

Film class	WOM exposure[1]	70-100 kLy/yr[2]	100-130 kLy/yr	130-160 kLy/yr
N	≥ 400 hours	< 1 year	« 1 year	« 1 year
A	≥ 1700 hours	≈ 1 year	< 1 year	« 1 year
B	≥ 3200 hours	≤ 2 years	> 1 year	≤ 1 year
C	≥ 4600 hours	> 2 years	< 2 years	> 1 year
D	≥ 6000 hours	> 3 years	> 2 years	< 2 years
E	≥ 7300 hours	> 4 years	≤ 3 years	≤ 2 years

[1] WOM = test according to European standards

[2] 1 kLy = 41.84 MJ/m²

Table 2: Waste quantity of plastic covering sheets for 1 ha of multi-span greenhouse according to the class of duration of the plastic films in a climatic situation corresponding to southern Italy.

Film type	Cumulated film surface area (m²/ha)	Cumulated waste quantity range (kg/ha)
LDPE or EVA, B Class	195 000	22 669 - 27 203
LDPE or EVA, C Class	130 000	18 135 – 21 158
LDPE or EVA, D Class	91 000 – 104 000	14 810 – 19 344
LDPE or EVA, E Class	65 000	12 090 – 13 601
ETFE	13 000	2 210 – 2 431

Table 3: Chemical contamination of EVA and ETFE films after an exposure in the experimental field of 60 days.

	New films			Sprayed films		
	S (ppm)	Cl (ppm)	Fe (ppm)	S (ppm)	Cl (ppm)	Fe (ppm)
reference EVA film, no additives	45	< 20	10	5200	440	20
ETFE film, Dyneon 6235	40	30	40	60	35	40


Blow extrusion pilot plant at P.A.T.I S.p.A.

value. Furthermore, tests carried out at the CEMAGREF research institute (Montpellier, France) confirm that an ETFE film under evaluation since 1987 is still usable, with a total transmission loss of about 10% of the PAR (390-700 nm). An expected service life of 15 years for this type of material appears therefore to be conservative.

The chemical contamination of the ETFE film after two months was limited in comparison with the reference EVA film sprayed in the same way (see *Table 3*). The comparison of surface tension measurements gave an indication of the fouling tendency for the two reference materials and of the ease of rinsing the surfaces. This is important both in relationship with the long term preservation of the total PAR transmission and with an easy washing of the waste material during the recycling process.

Calculations of waste

In the end, calculations were made of the amounts of waste generated by the replacement of the plastic covering sheets for 1 ha of multi-span greenhouses (*Table 2*). Several working assumptions were made, such as a location in a climatic area with a solar radiant exposure of 130-160 kLy and no damage occurred due to severe climatic events or overexposure to phyto-chemicals. The surface area of film needed for 1 ha, including side walls, is 13,000 m^2 and the period of time considered is 15 years.

The preliminary results of the research confirmed the initial hypothesis that the use of ETFE films as covering material for greenhouses can significantly reduce the quantity of waste generated in the medium to long term. The calculated reduction ratios were between five to ten times in a period of 15 years. It seems reasonable to assume that this is a significant value for ETFE films, as waste is reduced and environmental contamination will be limited.

However, the research showed that more prolonged tests and studies are required, with several targets such as repetition of the artificial ageing tests to confirm the final time for ETFE films. ■