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Influence of multilayer photoselective polymeric films on technical crops

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Abstract. In recent decades, the climate has undergone dramatic changes that have led to global ecological damage. Therefore, it was necessary to practice agriculture to provide biological protection of plants and soil. Currently, due to its advantages "plasticulture" gained a special scale. Covering greenhouses with polymeric films, protects crops against rain, extreme temperatures and pests. Using polymeric films modified by including additives for selective transmission of sunlight results in the control of heat and light energy, having a great influence on crop productivity and precocity. The amount of solar radiation and modifying the visible spectrum of solar radiation influences vegetative mass. Harvest and its biological requirements are basic conditions for systems of crop land covering, which should provide an internal environment conducive to plant growth compared to the natural environment outside. These films can be defined as "photoselective" if the incorporation of specific additives, are able to transmit selectively the sunlight in UV-VIS and IR.
Key Words: high tunnels, photosynthetically active radiation, plasticulture, technical crops.

Introduction. Cultivation of agricultural products in areas protected by polymeric films, or "plasticulture", has gained special amplitude both internationally and domestically due to their advantages (Hodges & Brandle 2010).

Lately, the diversity of coverings for greenhouses and other elements of their construction were greatly extended, as a result of development of new types of plastic materials and improving of existing materials, also of the growing demand for technological improvements in the control environment of the agricultural industry, being in full expansion.

Greenhouses are building used for agricultural production, enabling better conditions for plant growth than in the open field (Arthurs et al 2013). Greenhouses change the indoor climate, ensuring optimum conditions for plant growth, such as: temperature, light, protection against wind and weather, etc. Thus, it ensures superior quality, productivity and precocity of vegetables.

In countries with intense sunlight, it is important to use agricultural film with long-term stabilizers, which protect against photodegradation and chemicals, such as pesticides, insecticides or soil disinfection agents. Therefore, new requirements for stabilizers it refers primarily to resistance to chemicals that may affect the long-term properties of films.

The role of polymeric photoselective foils used in high tunnels for cropping technical plants. Multilayer polymer films designed and constructed to cover greenhouses and tunnels effectively ensure optimal microclimate in order to monitor morphological crops (Siwek & Libik 2012).

Polymeric sheets made to cover crops in order to protect them, are defined as "photoselectives" because, by incorporating specific additives, they are able to absorb a band range of light and reducing the passage of visible radiation within specific band of wavelength.

Changing the visible spectrum of solar radiation provides an improved control over the microclimate, pathogens and pests.

Production systems in controlled environment allows possibility to achieve the production of horticultural superior qualitatively and quantitatively (Wissner 2012).

Traits that confer a high quality of films include:

- very good optical clarity boost plant growth;
- superior optical properties by embeding UV and IR barrier additives, improving transmission of PAR light;
- good resistance to dust and keep clean sheet preserving transmission properties of sunlight over a long period of time;
- good resistance to breakdown in contact with the metal brackets that are installed.

When designing agricultural films it must take into account the type of culture and its biological requirements, which contain many individual components that are in mutual relationship (Upson 2012).

Greenhouse structures must be in accordance with the production system, providing good working conditions and managerial, optimal microclimate and minimize perturbation from the external environment.

Polymers have revolutionized the greenhouse industry by simplifying construction and reducing costs (International Labour Office 1999).

Multilayer photoselective polymeric films influence positively the crop quality and predictability by:

- the possibility of obtaining very early vegetable products;
- increased production per unit area cultivated;
- carried out several successive crops;
- avoiding negative effects of weather on crops;
- providing of precocity of crops with 15-20 days in the spring time;
- fall crops can be maintained until November.

Photoselective multilayer polymeric films are used to build greenhouses and tunnels to protect crops. The structure and thickness of multilayer photoselective polymer films allow them to cover greenhouses and tunnels both in tropical areas and in cold climates.

Experimental. It was performed photoselective three-layer polymeric film by coextrusion-blowing technology (Mueller et al 2000). To obtain physical-mechanical and optical properties, the three layers coextruded films had the following configuration:

- the outer layer consisting of low density polyethylene (LDPE) sort OKITEN 245 S with good optical properties and UV stabilizing additive 100566 (2%);
- an intermediate layer composed of low density polyethylene linear structure (LLDPE), sort DOWLEX 2022.01E, which contributes to increasing the tear and impact strength. It contain additive UV Barrier 100 645 (2%) for selective transmission of light in the UV range;
- the inner layer consists of low density polyethylene of higher molecular weight type LDPE 150, in order to obtain improved mechanical properties, and two additives: IR barrier 100 218-A (3%) that transmits selectively the infrared sunlight, and the other, antifog additive called COP AF 100023-B (2%), as an additive helping the formation of a continuous film of condensed water droplets on the inner side of the sheet.

The role of specific additives embedded in each layer of polyethylene is:

- combating the degradation of the material under the action of environmental conditions;
- resistance to specific factors of cold areas of culture:
    - poor ventilation, high humidity during the night, the lack of carbon dioxide during the day,
    - aggression of chemicals: fertilization, pesticides substances,
    - resistance to mold, etc.
- selective transmission of light within the UV – VIS range (PAR light transmission), with antivirus and antiblackening effect of the petals;

- selectively transmitting light in the infrared, with heating effect;
- achieving properties of antifog and antidrop;
- melt processing additive.

Due to their physical and mechanical properties, photoselective multilayer polymeric film are more resistant to mechanical stress.

Photoselectivity additives confer the following properties to polymeric films:

- shelf life of 5 years without significant changes of characteristics;
- efficient transmission in the visible light energy with a wavelength range between 400 and 700 nm;
- efficient transmission of caloric solar energy in the near infrared range at wavelengths from 700 nm to 2100 nm;
- reduced transmission of heat energy radiating black body, in the range of 7000 nm to 14000 nm.

It was revealed the influence of phototselective multilayer polymeric film morphology by monitoring technical crop experimentation in the research field of the Faculty of Horticulture from USAMV Bucharest. The greenhouses were of two types:

- greenhouse covered with monolayer film from LDPE without additives considered witness;
- greenhouse covered with photoselective multilayer polymeric film from three sort of LDPE with additives, considered experimental.

Standard requirements on physical, mechanical and optical properties of low density polyethylene films used to cover greenhouses are:

1. <u>aspect</u>: photoselective multilayer polymeric films of uniform thickness with smooth surface, non-porous, free from impurities or perforation (nongelled points), no wrinkles, no folds;
2. <u>color</u>: natural or colored, according to sample standard as agreed between the beneficiary and the manufacturer;
3. <u>dimensions</u>:
- width: 1200 mm or 4200 mm,
- thickness: 140–180 μm;
4. <u>tensile strength</u>:
- longitudinal: 13.7 ... 17.9 N/cm^2,
- transverse: 15.4 ... 19.7 N/cm^2;
5. <u>elongation at break</u>:
- longitudinal: 140 ... 660%,
- transverse: 400 ... 500%;
6. <u>tear resistance</u>:
- longitudinal: 7.9 ... 8.5 N/cm,
- transverse: 7.8 ... 8.4 N/cm;
7. <u>water absorbtion</u>: 0 ... 0.042%;
8. <u>density</u>: 0.9175 ... 0.9582 g/cm^3;
9. <u>opacity</u>: 24.25 ... 26.59%;
10. <u>contraction in warm</u>:
- longitudinal: -2...-3%,
- transverse: +1%;
11. <u>sunlight transmission</u>: in the range UV-VIS.

Photoselective multilayer polymeric films have been fitted on metal semicircular frames fixed in the ground, to perform experimental greenhouses. When installing multilayer photoselective films it was took into account the positioning of the layers in the correct direction (i.e. indoor or outdoor) as installation instructions. Positioning the film was made with the layer containing the additive antifog toward the interior of the tunnel.

The films were installed in the early morning when the ambient temperature was lower (15-23^{o}C) and not beat wind. When the films were positioned of, it were strained tightly enough to resist wind action. The installation of the films was performed carefully to avoid the damage of materials. The method of assembling the films was dropping them on top of the metal frame and further their running.

Results. Photoselective multilayer film and monolayer characterization were performed according to standard methodology. Polymeric films were tested prior to installation in the field and after removing greenhouses.

The utility of the model was demonstrated in two ways:

- photoselective multilayer polymer films reliability resulting from the analysis of physical-mechanical and optical properties;
- influence on crops by protecting and morphological monitoring.

The values obtained for the multilayered films before and after the exposure to the natural environment are shown in Table 1.

Table 1

Comparison of photoselective multilayer film properties before and after exposure in the experimental field

Characteristics	*Values obtained*		*Percentage variation of property (%)*
	Photoselective multilayer polymeric film before exposure in the experimental field	*Photoselective multilayer polymeric film after exposure in the experimental field*	
Aspect	Film of uniform thickness, with smooth surface, exhibit thin flowing lines on processing direction, no pores, no folds, no creases, no wrinkles, no impurities or perforation (nongelled points), no foreign parts	Translucent to opalescent tint film with slight scratches and dirt	-
Color	Transparent	Translucent to opalescent tint	Change of the transparency
Thickness, mm	0.18	0.18	0
Tensile strength, N/cm^2			
- longitudinal	14.7	15.8	17
- transverse	14.2	16.55	14.2
Elongation at break, %			
- longitudinal	480	460	- 4.2
- transverse	500	440	- 12
Tear resistance, N/cm			
- longitudinal	8.2	8.0	- 2.4
- transverse	8.1	7.45	- 0.8
Water absorbtion, %	0.042	0.036	- 14.3
Density, g/cm^3	0.938	0.943	0.5
Opacity, %	24	29	17.2
Contraction at heat, %			
- longitudinal	- 2 ... - 3	- 2 ... - 3	0
- transverse	+1	+1	0

Physical and mechanical properties of single layer LDPE sort OKITEN 245 S are presented in the Table 2.

Transmission of sunlight through the films:

- RANGE UV - multilayer foil shields UV-B radiation, in the range of 290-380 nm, providing sunlight transmitance beetwin 30-60%. Shielding of radiation UV-B lead to antivirus effects by inhibition of spores release by pathogenic fungi, such as *Botrys cinerea*, and by obstruction of insects entrance in greenhouse, those visibility is situated within radiation band UVB. Also, by shielding of UVB radiation it can be obtained petals blossoming antiblackening effects;
- RANGE VIS – multilayer polymeric film provides efficient transmission of light energy in the visible, which corresponds to wavelengths between 400 and 700 nm. The transmittance in this range increases from about 70% to a value of 80%;

- RANGE UV – monolayer film provide sunlight transmitance of 65% in the range of 290-380 nm;

- RANGE VIS – monolayer film provide sunlight transmitance of 78% in the range of 400–700 nm.

Table 2

Physical and mechanical properties of LDPE monolayer for covering greenhouse witness

Characteristics	*Values*		*Percentage variation of property (%)*
	Monolayer polymeric film before exposure in the experimental field	*monolayer polymeric film after exposure in the experimental field*	
Color	Natur	Opalescent tint	-
Aspect	Film of uniform thickness, with smooth surface, no pores, no folds, no creases, no wrinkles, no impurities or perforation (nongelled points), no foreign parts	Translucent to opalescent tint film with slight scratches and dirt	-
Tensile strenght, N/cm^2			
- longitudinal	13.6	16.0	15
- transverse	12.8	14.0	8.6
Elongation at break, %			
- longitudinal	600	350	- 41.7
- transverse	550	300	- 45.5
Tear resistance, N/cm			
- longitudinal	6.0	5.1	- 15
- transverse	5.0	4.7	- 16
Opacity, %	18	20	10
Water absorbtion, %	0.05	0.04	- 20
Density, g/cm^3	0.924	0.933	0.1
Contraction at heat, %			
- longitudinal	- 1 ... - 2	- 1 ... - 2	0
- transverse	+1	+1	0

Tensile strength*.* The values of the tensile strength of the multilayer polymeric film are better than those of single-layer film of low density polyethylene. The values obtained show that the multilayer film has a good resistance to mechanical stress and handling. After exposure in the field, tensile strength increased on longitudinal and transverse with an average value 14% and 17%, that reflect very poor degradation (due to few crosslinking in the material under the action of sunlight). Property variations ranks within the limits of ± 25% admitted.

Elongation at break*.* The values of elongation at break of the multilayer polymeric film are smaller than the single-layer film of low density polyethylene. This shows that the multilayer film exhibit good elastic properties, but does not deform when it is used for covering crops.

From the experimental measurements it can observe that after exposure in the fields, the elongation at break of the film in the longitudinal direction is decreased with 4.2%, while in the transverse direction is reduced by approximately 12%, values which fall within the limits permitted by 25%.

Tear resistance*.* The photoselective polymeric multilayer film exhibits good tear resistance properties. Values for tear resistance of the multilayer film are greater than in the case of monolayer film of low density polyethylene. The experimental data show that after exposure in the field, the longitudinal tear strength of the film decreases by about 2.4% and in the transverse direction lowered with 2.2%.

Water absorbtion. Initially, photoselective multilayer polymeric film presented very low water absorption, so that it can be used to cover greenhouses and low tunnels as practical material does not absorb water. After the exposure in the field, water absorption decreased by about 14.3%, which was expected, because the action of the environment, however, there have been some cross-linking in the material. Due to these changes, the film has taken a slightly more compact structure, which reduces the water absorption capacity.

Contraction-expansion. The results show that the multilayer polymeric film exhibit small shrinkage in the longitudinal direction -2...-3% and small expansion in the transverse direction 1%. After the exposure in the field multilayer polymeric film maintains the same characteristics of contraction-expansion which means that the film exposed to the natural environment, under the action of solar heat preserves almost constant its dimensions.

Influence of photoselective multilayer polymeric films on technical crops. The results of the experiment demonstrated the followings:

- the use of low density polyethylene to protect technical plants affect their growth, photoselective multilayer polymeric film determining strong growth inhibition of stems with 42% and internodes curtailment with almost 50% in comparison with technical crops from greenhouse witness;
- the total number of leaves per plant increased with 24%; there were large differences compared to the control sample because of the increased number of leaves harvested at the base and middle of the plant, instead at the top of the plant the number of leaves decreased;
- multilayer polymeric film causes some changes in leaf characteristics: size reduction, increased shape index, decreasing of leaf area by 12% and average weight diminution to 16%;
- total production of fresh leaves increased by 6% and those of the dry leaves with 15% in greenhouse protected with photoselective multilayer polymeric films in comparison with technical crop from greenhouse witness;
- protecting of the technical crops with photoselective multilayer polymeric film influenced favorably production by harvesting crops early and achieving quantitative growth of 14% in comparison with greenhouse withness;
- in the greenhouse covered with photoselective multilayer film, biochemical content of the leaves changed by:
    - decrease of the water content, which has positive impact on the drying efficiency improvement,
    - increase in dry matter content with favorable effects on the yields,
    - decrease in total chlorophyll content and decrease in ratio of the different types of pigment of the leaves, with consequences of harvesting precocity.

Conclusions. The influence of covering greenhouse with photoselective multilayer polymeric films, on harvesting crop of technical plants was studied.

Polymeric film performed by coextrusion-blowing technology, consisted of three layers of different sorts of LDPE, that embedded additives for selective transmission of sunlight in the UV-VIS and IR in order to ensure microclimate necessary for technical plant cultivation. Also, it were embedded additives stabilizers and antifog, to avoid water condensation on inner surface of greenhouse covering and to impede dripping condensation on the leaf surface.

There were built two greenhouses: witness greenhouse covered with LDPE single layer film, without additives and greenhouse covered with photoselective trilayer polymeric film with additives. It were reported variation of physical and mechanical properties of photoselective film before and after exposing in the experimental film and the influence of photoselective film on the precocity and quality of technical plants crops.

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