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RESEARCH ON PHOTOMETRIC PROPERTIES AND TRANSPARENT PHOTOSENSITIVE MATERIALS USED IN THE CONSTRUCTION OF GREENHOUSES

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Abstract: *This paper approach the aspects of the influence that the construction materials used in greenhouses have, and the photometric and photosensitive properties of their which influence both solar radiation that penetrates the greenhouse and heat loss through these materials. Regarding photosensitivity of the transparent material that is covering the greenhouse, over time have been done researches in many countries with have very interesting results, some of them studying the influence of the color of the material used over plant growth.*
Keywords: *photosensitivity, photometric properties*

1. INTRODUCTION

For coverage of greenhouses is used glass in areas where culture is practiced in the cold season, where the construction is warmed artificially and various plastics are used in areas where growing vegetables is suitable in greenhouses heated by the sun or mild heating with adequate facilities. The transparent material which is covering the greenhouse, becomes a determining factor in crop production, they contributed, together with other elements, to create a favorable microclimate, especially to ensure optimal light conditions[1].
That's the reason why knowing the photosensitivity and photometric properties not only theoretically but also practically, presents a higher importance for both the manufacturing industry and for vegetable growers. With a thoroughgoing study over the penetration phenomenon and light transmissivity the glass manufacturers can make new types of glass and plastics with superior quality of photosensitivity and photometric properties [2].
It is well known that the solar radiation that reaches the surface does not fully penetrate the roof of the greenhouse, a large part of it is reflected and absorbed by the covering surface. The types of glass and other materials to cover not only reduce emissions intensity of solar radiation, but also have a selective effect. From a theoretical standpoint, the most suitable material for covering greenhouses is considered one that changes the least penetrating rays of the solar spectrum.

2. PHOTOMETRIC AND PHOTOSENSITIVE PROPERTIES OF MATERIALS

The decrease in radiation intensity due to absorption by the glass or plastic is in function of the sun position above the horizon [3]. Direct solar radiation intensity varies considerably in the greenhouse, during a year also during a day. Reflections of the sun rays due to glass or plastic is under a combined angle between the incidence angle of the rays towards a horizontally plan and face of the same plan, reported also to greenhouse orientation. Regarding photometric materials properties Nisen (1976) defines three categories of factors: spectral (transmissivity, bright and energetic reflectivity), Total (of different kinds) and Global which constitutes somehow the extension and synthesis of the first two factors. As global factors it defines average light transmission factor (T), the solar factor (S) and efficiency factor of the glazing (R).
The average light transmission factor (T) is the ratio of the light amount that enters a room through a transparent panel and the amount of light that enters the room through the same if it were not transparent panel:

$$T = \frac{T_{30^0} + T_D}{2} \quad (1)$$

Where:

T_{30} – is the luminous transmission factor of direct sunlight with an incidence angle of 30°

T_D - total light transmission factor of diffuse solar radiation on a clear sky

The solar factor S is the ratio between the amount of solar energy that penetrates into a room through a glazing material and the amount of solar energy that penetrates in the same room if the material is not glazed.

Is defined as follow:

$$S = \frac{T_{30^0 sol} * \phi_D + T_{D\,sol} * \phi_d + K\,(t_s - t_i)}{\phi_D + \phi_d} \quad (2)$$

Where:

ϕ_D – It is the light energy of the direct solar radiation corresponding to a normal spectral distributions (according to Moon) for an atmospheric mass equal to 2 in an the incidence of 30° (658 W/m^2);

ϕ_d – is the light energy of diffuse solar radiation (= 47 W/m^2);

$\phi_D + \phi_d$ – Global solar flux received from a glazing panel (705 W/m^2)

$T_{30^0 sol}$ – Total light transmission factor of the diffuse radiation on the ground in case of clear sky

$T_{D\,sol}$ – Total light transmission factor of the diffuse radiation on the ground in case of clear sky

K – Heat transfer coefficient of the glazing in w/m^2

t_i – Ambient temperature of the greenhouse (admitted = 25°C)

t_s – Equivalent temperature, fictive temperature that the outside air should have in order that the heat transmission between the panel and the two environments to be the same without solar radiation and in real case with solar radiation.

Equivalent temperature is, in fact, after Nissan, effective temperature obtained under the influence of solar radiation in an environment in contact with a surface whose absorption coefficient and surface exchange are known.

Effectiveness factor of the glazing panel (R) is defined as the ratio of the two previous global factors, that is, the average light transmission factor (T) and the solar factor (S).

$$R = \frac{T}{S} = \frac{T_{30^0} + T_D}{2S} \quad (3)$$

A high factor represents a transparent roof that let in plenty of natural light in the greenhouse and less solar energy. Some of the values T, S, R are given in Table 1:

Table 1. Factors that characterize the photometric properties of glass for greenhouses (according to Mănescu B., 1977)

The glass type	***T***	***S***	***R***
Clear glass with 6 mm thickness	0,852	0,813	0,019
Transparent panel with double transparent glass 2 X 6 mm thickness	0,785	0,752	1,043
Green absorbent panel (sunscreen)	0,718	0,609	1,179
Double transparent panel: 6mm glass + green absorbent glass	0,644	0,478	1,346
Absorbing gray glass panel (sunscreen	0,410	0,535	0,645
Reflective glass panel (6mm x 2)	0,358	0,250	1,430

Effectiveness factors of the glass panels appears as complex parameters that allow proper comparison between the size of energy and light entering the greenhouses covered with different types of plastic or glass.

When referring to the photosensitivity of material transparencies that is covering greenhouse, over time have done research in many countries with very interesting results [4].

In the visible radiation with wavelengths between 360 and 760 nm the absorption for common types of glass goes from 1.6 to 2.5%, depending on its thickness. A 5 mm thickness glass absorbs 7-15% of total global radiation (Ogura, 1968). The reflected radiation for the same material varies according with the wavelength of rays and their angle of incidence, time and season. In Table 2 are given by Ogura as percentages the transmission, reflection and absorption of the glass for different angles incidents of radiation.

Nissan (1959), analyzing the penetration of sunlight through a glass with a smooth and through one corrugated, found out that reflected radiation largely depends on the angle of incidence [5]. Considering rays coming from the right with the positive sign and coming from the left with a negative sign, it is observed that when studied all positive beam those refracts once, then without hindrance gets through and reaches the crop grown in the greenhouse. The rays with a negative sign that are falling at a greater angle are suffering a near-total face wavy reflection. Some come in the front of incidence, while others end up crossing the glass sheet after going through a journey of 5-6 cm through.

Table 2. Coefficients of transmissivity, reflection and absorption of a glass sheet (according to Ogura, 1968)

Angle of incidence (0)	Thickness of 3 mm			Thickness of 5mm		
	Transmissivity %	Reflection %	Absorption %	Transmissivity %	Reflection %	Absorption %
5	87,69	7,82	4,48	85,20	7,62	7,16
20	87,54	7,86	4,58	85,00	7,65	7,33
40	86,23	8,81	4,95	83,54	8,57	7,88
50	83,84	10,87	5,27	81,10	10,05	8,33
60	78,04	16,08	5,87	75,36	15,62	9,00
70	64,38	28,09	6,3	62,07	27,34	10,57
80	35,00	52,00	6,5	33,70	51,06	15,22
Sky radiation	79		5	77		7

There are differences of transparency, depending on the wavelength radiation between laminated windows (those of ordinary windows) and the molded ones. The molded glass have a reflection effect more pronounced than the laminate ones. In Fig. 1 are given after Seemann (1952) the evolution during a clear days for the two curves of radiant energy, in relative value, in two greenhouses identical as construction and orientation in which one is covered with laminated glass and the second with molded glass. The variations due to opaque parts are more intense for greenhouse that is covered with laminated glass greenhouses and attenuated for the one covered with molten glass.

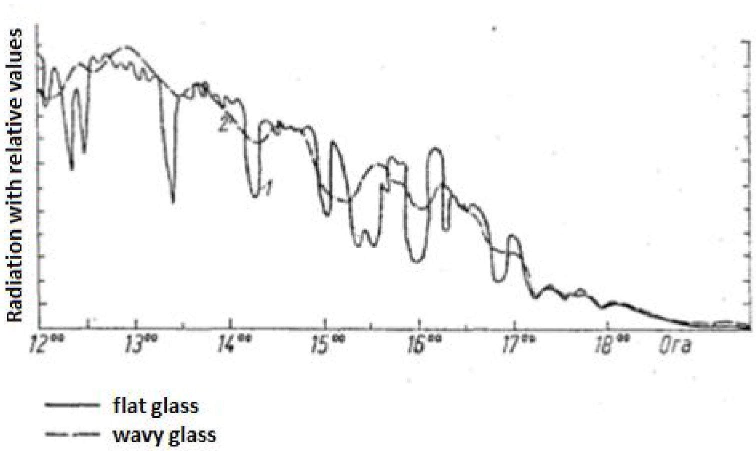

Figure. 1 The variation of radiation intensity in two greenhouses covered with different types of glass, in a clear day (according to Seeman)

As a consequence it can be recommended the use of a 4 mm thickness white sheet and the semi-crystal glass threated with lead oxides, which gives greater strength and better illumination

A wide spread in all countries that are producing vegetables, is the use of plastics, which broke new ground in vegetable cultivation, and essential changes to the process. Tensile strength, flexibility, high transparency, convenience in being handled, the simplicity of operation are qualities that make plastics gradually to replace glass, metal and wood in construction of greenhouses.

At the Leningrad Agricultural Institute of Physics have been studied three types of plastics in the form of films acetate, polyethylene and polyamide. The experiences showed that all films are transparent at a rate of 89-90% for the visible spectrum rays. Compared with glass, the plastic films let pass the active ultraviolet rays; with biological wavelength of 295 nm. In the infrared spectrum acetate film it is different than glass and the polyamide film is more transparent. The polyethylene film is very transparent to infrared rays.

The absorption of rigid plastics material, for example, methyl methacrylate (Plexiglas) and polyester panel is substantially different from that of the glass. In Figure 2 the data of transmissivity as a percentage for the solar radiation spectrum, depending on the wavelength, are given, for polyester with 1.2 mm thickness, polyvinyl chloride (PVC) 1.6 mm thickness, and Plexiglas, as compared to the usual glass from silicate having 3.8 mm thick.

In the visible range of the spectrum, the selected plastic materials do not have different transmissivity, regarding to wavelength and glass. The polystyrene allows the sunlight to pass up to 90% in the range of 700-1700 nm compared with the glass which provides a passageway of the radiation only in a proportion of 82%.

Reinforced polyester is generally less transparent to ultraviolet rays of 300-350 nm, and the 380-780 nm visible spectrum, but in terms of penetration it is slightly lower or equal to the glass. Rigid materials are transparent to infrared rays 770-2 000 nm, and those with wavelengths of 200-300 nm are opaque. It should be noted that the diffusion strength of the polystyrene is great. The light rays after crossing the plaque are distributed in all parts. The refractive index of the light that falls on the plaque of polyester as a whole is equal to that of glass (n = 1.5), but varies to some extent depending on the chemical structure and the wavelength of the material.

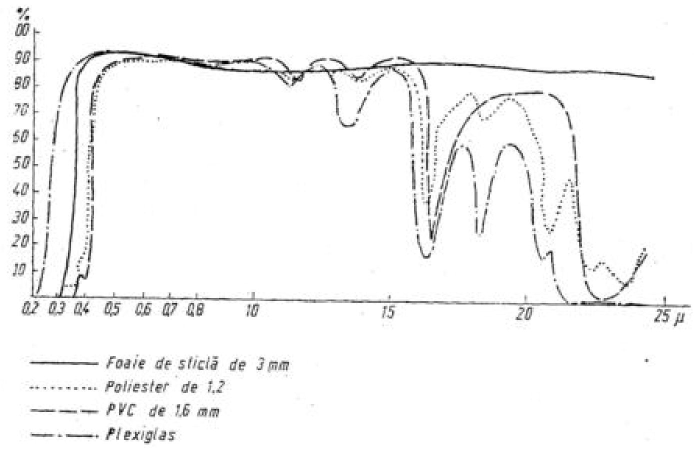

Figure 2 Spectral transmissivity of radiation for various transparent materials (by Seeman)

There were studied colorful transparent materials, with photosensitive properties that absorb radiation of a well-defined spectral bands according to their color and prevent or reduce their passage towards the plants. From this principle Favilla (1966) started, covering with plastic colored the greenhouse, inaugurating thus a new technology in growing vegetables,. Accordingly cultivated plants react promptly by changes in the life cycle, especially fruiting phase, allowing for earlier harvests and even higher crops.

Studying the transmission of light radiation from different colored plastics, it found that it varies depending on the angle of incidence of the light beam and coloring pigments used during the manufacturing process. Overall, coloration for simple materials reduce the permeability of visible radiation at a rate of 12-54%. Regarding rigid material differences between colorless and colored panels are much lower. It was established that in the field of infrared radiation with a wavelength of 1500 nm is highlighted in some cases a reduction in light transmission capacity, and at wavelengths greater differences disappear completely

Biometric records made in experimental greenhouses show that the vegetative growth of the tomato plants under the blue and red color film is enhanced. Note that under blue film growth began immediately after planting, and under red tape at 30 days after planting. Significant difference was observed, and the production of vegetables (Fig. 3).

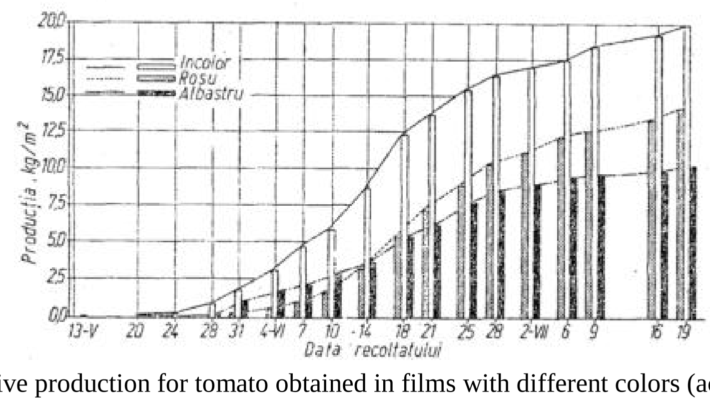

Figure 3 Cumulative production for tomato obtained in films with different colors (according Favilla)

In order to determine the reaction of the colors in the plastic regarding transparency selectivity of the infrared, experiments were made in Romania by Cobîlaş (1977). UV Pictograms with transmissivity between 2500 and 25 000 nm (Fig. 4) shows that polyethylene colored in blue, orange yellow and white are less transparent than wavy polyvinyl chloride (PVC). Only mat green coloring for polyethylene with 0.10 mm thick maintain a better transparency. Overall curves shapes are depending on the wavelength is square, regardless of color.

For various coloration intensities and different thicknesses of the same material is also observed the maintenance of curve shape, transparency is stronger in lighter stains and thinner films. The same phenomenon have been observed in other analyzed samples with the difference that wavy polyvinyl chloride (PVC) of 1 mm thickness is almost opaque between 6 300 and 25 000 nm.

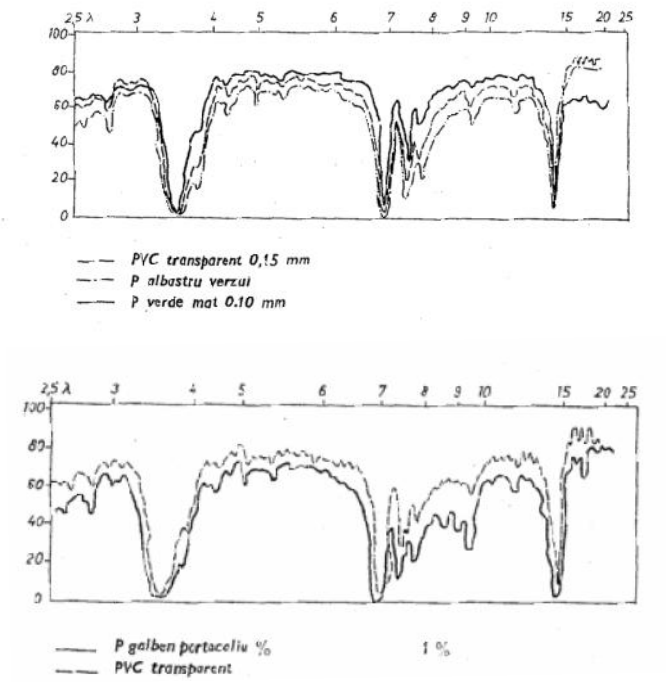

Figure 4 Pictograms for transparent radiation I.R. for colored polyethylene and transparent P.V.C. (wavy) 1 mm thickness (according Cobîlaş)

The transmissivity in the visible between 380-770 nm, presents in relation to the different colorations more differentiated spectrum (Fig. 5). The differences appear more visible, depending on the wavelength of the radiation between transparent and colored film. It should be noted that these differences are not related to a concordance between the dye and the respective color of the specific wavelength. The most transparent colors remain bright yellow, blue and green-light, and this regardless of wavelength. The least transparent is yellow-orange.

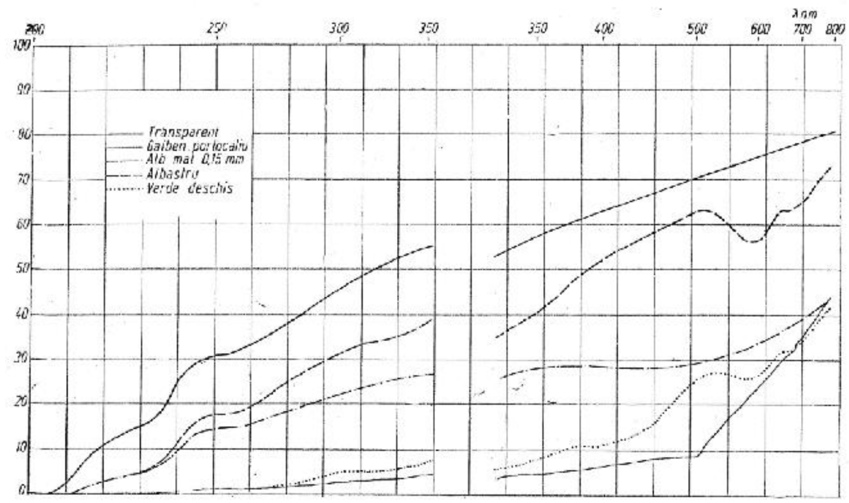

Figure 5 Transmissivity spectrograms for the visible radiation for the various dyes and thickness of polyethylene and PVC (according Cobîlaş)

The decrease of transmissivity for plastic materials over the years is one of their deficiencies. The transparency of materials during a long use changes sensitively. Thus, within two months of operation the film reduce the transparency for the ultraviolet rays by 20%. Duncan and Walker (1974) shows that the most durable is the Plexiglas plastic with 90-95% transmissivity from received solar radiation.

3. CONCLUSION

1. Direct solar radiation intensity varies considerably in the greenhouse, during a year also during a day.

2. In the visible radiation with wavelengths between 360 and 760 nm the absorption for common types of glass goes from 1.6 to 2.5%, depending on its thickness
3. The molded glass have a reflection effect more pronounced than the laminate ones.
4. Compared with glass, the plastic films let pass the active ultraviolet rays; with biological wavelength of 295 nm. In the infrared spectrum acetate film it is different than glass and the polyamide film is more transparent. The polyethylene film is very transparent to infrared rays.
5. The decrease of transmissivity for plastic materials over the years is one of their deficiencies. The transparency of materials during a long use changes sensitively.

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