Names and Properties of Cover Materials For Greenhouses

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Greenhouses are in essence a system for accumulating solar energy throughout the day. Within the greenhouse, the rays of sunlight are absorbed by the plants, while the rest are converted to heat. Practically speaking, most of the sun's rays that arrives at the greenhouse is converted to heat. If we look at the greenhouse as a solar system, then the cover material's properties with regard to radiation are of utmost importance.

There is a difference in terminology between radiation and light, where light refers to visible radiation, namely wavelengths between 390 and 760 nm. Radiation, or electromagnetic radiation, is characterized by its wavelength and amplitude. There are three generally accepted units of measurements for a wavelength:

1. The micrometer, \( \mu m \), is a very small unit of length, which is one thousandth of a millimeter, or a millionth of a meter. Also known as a micron.
2. The nanometer, nm, is even smaller, and is one thousandth of a micrometer.
3. The angstrom, A, is one tenth of a nanometer.

The wavelength is generally used as the defining property of radiation. Note that frequency \( f \) of a photon may be used in place of its wavelength \( \lambda \) using the equation \( f = c/\lambda \), where \( c \) is the speed of light. This equation indicates that there is an inverse relationship between the wavelength and the frequency. In other words, as the wavelength increases, the frequency decreases. The frequency is used much less frequently, albeit occasionally, describe the radiation.

The second characteristic of electromagnetic radiation is its amplitude. There are many ways to define a photon's magnitude, based on energy, surface area, wavelength, or frequency. Being that this article only discusses cover material for greenhouses and not electromagnetic radiation, we will not get into the analysis of the amplitude of radiation; we will only characterize it by its wavelength. When classifying different types of radiation, we view radiation with different lengths as completely separate entities.

The behavior of radiation at one wavelength is not at all similar to the behavior of radiation of a different wavelength. Any behavior shared occasionally by radiation of different wavelengths is considered an exception to the norm. The behavior of a photon changes as its wavelength changes. For example, radiation of 450 nm will appear yellow. This is an example of differentiation between red and yellow light based on wavelength alone. There are obviously different intensities of red light, which is a measure of the red light quantity per unit area, and reflects the amplitude of the radiation.

One should note that a difference of only 130 nm dramatically changes the sensation of the human eye, even when dealing with long-wavelength radiation. When categorizing different types of cover materials for greenhouses, we use a much coarser classification of wavelengths than that of colors. The general categories are:
a) ultraviolet radiation (U.V.), of a wavelength less than 380 nm (“ultra” referring to its high frequency) 
b) visible radiation (V.I.), of a wavelength between 390 nm and 760 nm 
c) infrared radiation, (I.R.), of a wavelength longer than 780 nm (“infra” referring to its low frequency. I.R. radiation itself is further divided into near infrared, around 1 μm, and far infrared, defined as a global frequency.

This discussion was necessary to better understand electromagnetic radiation in order to categorize the different properties of cover materials. The standard categories of cover materials used by farmers are:

1. U.V. plastic  
2. I.R. plastic  
3. reflective plastic  
4. dispersive plastic  
5. anti fog (A.F.) plastic  
6. transparent plastic

The cover material has three properties:

1. transmissivity 
2. reflectivity 
3. absorptivity

Transmissivity is the ability of the material to have radiation pass through it. It is expressed as either a fraction or a percentage. As mentioned earlier, this property is relevant to the type of incoming radiation and its wavelength. Some highly transmissive materials can have 95% of radiation at certain wavelengths pass through them. One should expect, though, the transmissivity to vary with different wavelengths, and it will not be 95% for all wavelengths.

Reflectivity is the ability of the material to reflect incoming waves. The reflectivity is mostly affected by the surface properties of the cover material. Materials that include additional elements within the plastic layer will reflect rays from within the material. As with transmissivity, reflectivity will vary for different wavelengths.

Absorptivity is the ability of the material to absorb radiation that arrives or is diverted toward the material. Materials with high absorptivity are used as protection against radiation by preventing its penetration. In a sense, the reflectivity and absorptivity are similar in that both prevent radiation from passing through. There is, however, a fundamental difference between them: Highly reflective material does not heat up upon exposure to radiation, while highly absorptive material does. Absorptivity, too, varies for different wavelengths. Material that is highly absorptive will also emit much radiation. We can thus define a new property: emissivity. The emissivity percentage is equal to the absorptivity. The relation between the three quantities may be expressed mathematically as:

transmissivity + reflectivity + absorptivity = 100%
or, transmissivity + reflectivity + emissivity = 100%

This relation enables one to easily calculate the third quantity if the other two are known. Distinguishing the individual properties, however, is a more difficult task. For example, while the reflectivity of a material results in radiation emerging from its surface and around it, so does its emissivity. As another example, both reflectivity and absorptivity block radiation from passing through.
Both apparently similar properties, but functionally and existentially different. These two examples highlight the difficulty in classifying the radiative properties of materials.

During absorption, the electromagnetic energy is converted into heat energy, which heats up the absorbing material, thereby, emitting radiation. By the law of energy conservation, the emissivity and absorptivity must be equal in equilibrium, and are thus equivalent and interchangeable. Where a material is labeled by a property, such as U.V. plastic, it denotes high absorptivity in the U.V. Range. This means that blocks ultraviolet light from passing through, thereby protecting the greenhouse from ultraviolet radiation. This protection prevents the blackening of the plants and prevents certain diseases from taking hold. Regular glass 4 mm thick naturally possesses this ability of ultraviolet radiation blockage, and so in glass greenhouses, roses do not blacken. Where polyethylene is used for greenhouse cover, components must be added to the material to achieve the desired protection from ultraviolet radiation. Every manufacturer zealously keeps their method of cover sheet manufacture private, and rightfully so.

When the sheet material is denoted by I.R., it refers to its high absorptivity of particularly infrared radiation, around 12 μm wavelength. This global wavelength is the wavelength at which radiation is emitted from the Earth's surface throughout the day.

When the sheet material is denoted as dispersive, it refers to its ability to disperse rays that pass by it and through it. This obviously increases it absorptivity, thereby diminishing its transmissivity. This is a very important property where uniform distribution of radiation is required on the entire plant.

In greenhouses with highly scattered radiation, more parts of the plant are productive during absorption than plants in a greenhouse without a light scattering component. The reason is simple: Scattered light does not cast shadows, and so the upper leaves do not cast shadows on the lower leaves, which would otherwise be expected on leaves exposed to unscattered light. Light scattering is an important and wide-ranging topic in its own right, and will not be discussed here any further.

When the sheet material is denoted as anti fog (A.F.), it refers to its ability to highly disperse water droplets, preventing the accumulation of droplets on the sheet. Droplets that accumulate on the sheet result in a higher absorption and reduce the amount of sunlight that passes through. Water dripping on the plants fester diseases resulting from free water on the leaves (e.g. botrytis). The dispersal capability of A.F. Material causes the water on the sheet to runoff into the gutters, where there is one drip stream. This stream may easily be removed if so desired by collecting the water drops. The water can then be removed from the undersides of the plants and support beams of the greenhouse, or from the entire greenhouse completely.

When the sheet material is denoted as reflective, it refers to its ability to reflect. This is a very important quality when dealing with sheets used for thermal insulation, especially from global radiation of 12 μm. This increases the energy efficiency of the heating process.
This article hopefully helps to crack the code of complexity surrounding the problem of radiation in greenhouses. The problem is even worse during the cultivation period, being that their properties are time variant. For example, the U.V. absorptivity is weakened by sulfide vapors. This problem is even more serious for roses, and results in blackened leaves among sensitive breeds.

Figure 2 indicates that ozone gas absorbs U.V. radiation from 0.28 μm. At 0.35 μm, radiation reaches the Earth's surface at high intensities, causing much damage, in particular to agriculture. The U.V. absorptivity of cover materials enables them to absorb the U.V. radiation, namely, radiation below 0.38 μm. For example, if red roses are shielded from U.V. radiation below 0.38 μm, the risk of blackening is dramatically reduced, which is why cover material is recommended especially for roses.

Investigating the absorptivity of sheets as a function of wavelength may be carried out by a spectrometer. This is an expensive piece of equipment and should not be purchased with the meager salaries of farmers. Instead, it is recommended to file a request to a laboratory equipped with a spectrometer that is capable of measuring absorptivity at wavelengths between 0.24 and 0.7 μm. User friendly graphs will denote the wavelengths in micrometers or nanometers and the transmissive intensity in percentages.

Figure 3 is an example of a test conducted in Neve Ya'ar with a computerized laboratory spectrometer. The test was carried out on green polyethylene that acts as a green filter, which works by absorbing all wavelengths other than that of green light, and allowing to pass through green light, i.e. radiation with a wavelength of around 530 nm. The graph clearly indicates that the green film passes through itself radiation with a wavelength of 530 nm; radiation with a longer wavelength is absorbed, while radiation of a shorter wavelength is absorbed less. The plastic appears bright green, indicating that the green polyethylene was manufactured with additive material that absorbs radiation at a wavelength between 0.76 and 5.8 μm and between 0.38 and 0.5 μm.

In order to inspect and follow up on the properties of cover sheets, it is recommended...
for farmers to keep samples of the sheets throughout the plant cultivation period. These samples will be of use to the farmer should any problem arise. The sheet sample should be around 0.5 m^2, and should include labels such as the manufacturer and the supplier. It should be kept in a large paper envelope in a cold, shady place. This will enable the farmer to identify a problem that results from a change in the radiative properties of the cover sheet during plant growth, or conversely, to check the sheet used and its compliance with the original properties. It is recommended to conduct these tests in cooperation regional greenhouse mechanization director.

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References:
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