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UV radiation transmission of common greenhouse glazing materials

When you plan to build a greenhouse, selection of glazing materials is a critical process as it significantly affects light environment (intensity, quality, and uniformity) as well as the structure type and construction costs. Greenhouse glazing materials have high transmission in photosynthetically active radiation (PAR, 400-700 nm). However, the transmission in UV radiation range (300-400 nm) is largely different for different materials. This article briefly summarizes the effects of glazing on UV radiation available in the greenhouse.

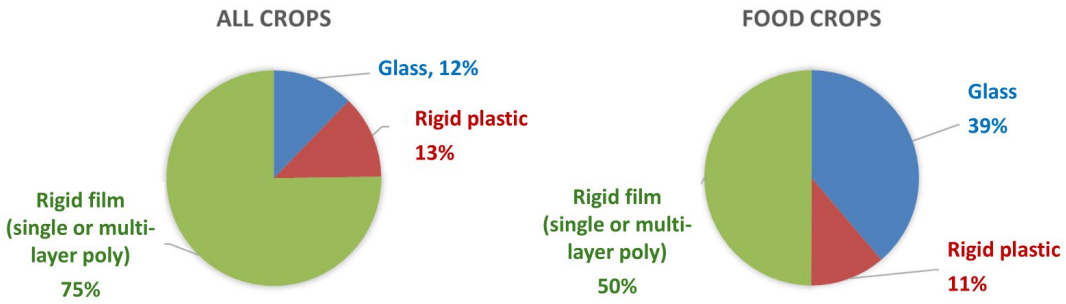

Figure 1. Percentages of greenhouse areas under specific glazing types for all crops and food crops. (Source: USDA NASS, 2020).

USDA NASS (2020) reported that 75% of US greenhouse acreage was covered by plastic film (single or multiple layer poly) (Figure 1). Glass and rigid plastic covered greenhouses are only 12 and 15%. However, among US food crop production greenhouses, percentage of glass covered greenhouses is 39%, a higher percentage compared to that for all crop types. As Both and Faust (2017) review, glass has various advantages including high and stable transmission in PAR range, and long lifespan (30 years). However, for various reasons, users are choosing alternative glazing materials that meet their requirements.

Most commercially available glazing materials used for greenhouses are highly transmittable in PAR (photosynthetically active radiation) range (400-700 nm). Because PAR is similar to a human's visible radiation (~380 – ~780 nm), differences in spectral transmission outside of PAR range are difficult to visually notice without having more specific measured information. Sunlight contains radiation with wavelengths starting around 300 nm. These wavelengths shorter than PAR are referred to as ultra violet (UV) radiation and they are further classified into UV-A (320-400 nm) and UV-B (280-320 nm) radiation. Plants sense this radiation and it induces specific responses. Therefore, we consider UV-A and UB-B radiation as part of biologically active radiation for plants. While glazing materials influence UV radiation transmission, the information is very limited. Depending on the crops grown, selection of a wrong type of glazing could cause a permanent, significant impact on your product quality.

One of well-known responses of UV-radiation is development of leaf color. Anthocyanins are a class of pigments of blue, purple, and/or red colors. Figure 2 shows lettuce plants (a red-leaf cultivar) grown under three different light quality environments altered by different glazing materials. Plants were all grown for the same duration of time in a greenhouse with high UV radiation with additional covering materials about 30 cm above the crop canopy. The light intensity received by the plants was adjusted to be similar and the only outstanding difference was the amount of UV radiation that reached the plants, as affected by the type of glazing. Polycarbonate is a widely used material in a form of twin-wall sheet and its advantages include high impact resistance and nonflammable characteristics. What is not known widely

Figure 2. Red-leaf lettuce plants grown under glazing with high transmission (ETFE), moderate transmission (acrylic panel) and no transmission (polycarbonate). Acrylic panel UV radiation transmission is known to be equivalent to standard float glass. (Photo by C. Kubota)

for polycarbonate is the low or almost no transmission in the range of UV radiation. Of interest, the red-leaf lettuce did not develop any visible red color under polycarbonate sheet and leaves were bright green (Figure 2). Glass and acrylic sheets are known to have moderate UV radiation transmission (with mostly in UV-A range). Of course, the actual transmission at different wavelengths is product specific. In general, both glass and acrylic materials have lower transmission in UV-B range than UV-A range. Lettuce plants in our demonstration developed a moderate degree of red color under acrylic sheet (Figure 2). The highest transmission (higher than glass) can be achieved by ETFE film. ETFE (ethylene tetrafluoroethylene) is a relatively new glazing option in North America. However, one outstanding characteristic of ETFE film is the selective transmission in UV range. A highly transmittable type (or UV-open type) has reportedly nearly 90% transmission in entire UV range (300-400 nm) when measured at the perpendicular beam angle (zero degree of incident beam angle). The lettuce leaves developed more intensive red color under this light quality provided under ETFE film (Figure 2).

Another UV-mediated plant response is the disorder called intumescence or oedema occurring on leaves and stems. Some plant species such as tomato develop intumescence severe enough to negatively influence the growth when UV-B radiation (280-320 nm) is limited in the growing environment (Kubota et al., 2017).

So what about poly film? Polyethylene itself can transmit UV-radiation "very well". However, to extend the lifespan (to reglaze every four years instead of one year, for example), polyethylene film used for glazing high tunnels and greenhouses is UV-rated, with additives absorbing UV radiation harmful to the polyethylene material. This significantly reduces the UV transmission.

How to check the UV radiation transmission? Ideally, the manufacturer directly or greenhouse builder indirectly provides the needed information when UV radiation transmission is the concern. Accurate measurements require a specialized setting employing an integrating sphere. Without that, transmission measured is not accurate due to the light scattering caused by the film itself. Wageningen University LightLab in the Netherlands offers unique measurement services for greenhouse glazing materials. Unfortunately, I am not aware of any services similar to them in North America.

Table 1. Advantages and disadvantages of common glazing materials. Information was gathered from various sources.

Materials	UV transmission	Advantages	Disadvantages
Polyethylene (PE) film	Varied transmission: UV-rated long-life PE film does not transmit UV radiation.	Lowest costs	Lower PAR transmission than other glazing materials, flammable, short lifespan (3-4 years), low overall thermal transmission (single layer)
Polycarbonate sheet (twin-wall)	No UV radiation transmission	Less flammable than PE or acrylic sheet, moderate lifespan (15 years), moderate PAR transmission, high impact resistance	Discoloration (yellowing) over time
Acrylic sheet (twin-wall)	Moderate UV-A radiation transmission similar to glass	Good lifespan (20 years), good PAR transmission, similar transmitted light quality as glass, no discoloration	Flammable (if not treated to be less flammable), relatively low impact resistance
Glass	Moderate UV-A radiation transmission, Low UV-B radiation transmission	Very good lifespan (30 years), high PAR transmission, low transmission in thermal radiation, consistent quality, diffuse glass option, nonflammable, chemical resistance	Low impact resistance, heavy weight (more load requiring more structural support), higher costs, need to mechanically clean the surface to maintain the high transmission
ETFE (ethylene tetrafluoroethylene) film	Selective UV A+B radiation transmission (high, moderate or no transmission) without affecting PAR transmission	Very good lifespan (30 years), high PAR transmission, diffuse option, high impact resistance, non-stick surface (self-cleaning), relatively consistent quality, light weight, nonflammable, chemical resistance	Higher costs, requirement of specialized roofing system

Most glazing except polyethylene films is more or less a permanent installation. Polycarbonate and acrylic sheets have a minimum of a 15 year or greater lifespan. Glass and ETFE are known to be much longer. Glazing selection affects many other design aspects of greenhouse (e.g., style, frame material, structure strength, and equipment size). Therefore, greenhouse constructors are recommended to fully discuss the pros and cons of glazing with users so that there will be no surprise caused by misunderstanding after construction.

Figure 3. Controlled Environment Agriculture Research Complex (CEARC) at the Ohio State University. Two glazing materials (glass and ETFE) are used for Venlo-style greenhouses. (Photo credit: Brad Feinknopf)

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