SOLAR TRANSMISSION PROPERTIES OF WOVEN FABRICS TO BE USED AS GREENHOUSE COVERING

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Abstract: Now a days high-tech poly films are used as Greenhouse covering materials, Nanoparticles or UV stabilizers added to it for the absorption and blocking of harmful UV Rays. The poly-films materials added with Nanoparticle also enable to increase the Photo-synthetically active radiation (PAR). The plastic-based poly films are very harmful to the environment due to their non-biodegradable in nature. It causes serious pollution of air and water and also the food chain. Generally, poly-film takes several years to decompose in a landfill. Researchers have found various composite materials added with textile fabrics for replacing poly films by cotton, jute, woven, non-woven and knitted textile fabrics. This work is aiming towards the development of Greenhouse covering materials made from woven textile fabric. Highlight various solar transmission properties of woven fabric.

Keywords: Greenhouse covering, Agro textile, Solar transmission, PAR, woven fabric, Cover factor**,** Spector photometer**.**

1. Introduction:

The greenhouse process is one such technology that can provide a suitable condition for cultivation. The possibility of cultivation will increase throughout the year. Greenhouse techniques are controlling greenhouse temperatures during warm weather. It can be added with a fan or lower ventilation and evaporative cooling system[1]. It also helps to reduce the chances of burning plant leaf due to the high temperature in the summer season. The heat load is created by the infrared (IR) wavelength (≥770 nm) of the radiant energy from the sun[2]. Plants are used photo-synthetically active radiation (PAR) in the blue to red range (380–700 nm) of the total light spectrum for photo synthesis. However, there is still a lack of information about accurate spectral optical properties for various plant growths. Today mostly plastic materials are used as greenhouse covering materials. These plastic poly films are known as harmful non-biodegradable substances for environment. Normally poly-film takes 500-1000 years to decompose in a landfill. The contaminants of micro-plastics are reducing soil fertility, creates problems to water entering soil, entering the food chain[3]. In a recent article found that the 300 million tons of plastic produced worldwide in till 2013. However, their production is poised to expand rapidly, with 4.2 million tons are produced in 2016, and 6.1 million tons being the projected production in 2021[4]. It is a big concern about environmental effects. While the possible uses of textile fabrics nets and several other woven or knitted fabric structures for Greenhouse covering material. So this is the main advantages are textiles fibre have vast properties and translucent materials. Wide ranges of woven fabric are available in the market. Many of them are suitable for fabric comfort which is used as a garment, and some of them may be used as Greenhouse covering materials for plants for providing suitable weather conditions. On my little survey, I have collected some fabric that can be suitable for greenhouse covering. After a brief analysis and testing result gives an idea how the solar transmitted is related to the textile materials properties. The textile materials can be an alternative solution to this situation[5].

2. Literature Review:

Solar radiation is the electromagnetic radiation with energy lie between 1.2 meV to 124 eV. This radiation contained a huge amount of energy of the photon and quantum particle, only the main three components of solar radiation reach the earth. These are ultraviolet radiation (UV), visible light radiation (light), and infrared (IR) radiation[5],. There are several facts happen when passing through the textile fabric. Solar radiation is electromagnetic radiation that is transmitted, absorbed, and reflected by the fabric. Some part of the radiation is absorbed by the fibres and converted into different energy level[6]. Another part of the radiation passes or transmitted directly through the gap of the fabric between the fibres and yarns, which is known as transmission. Some radiation is reflected or throws in various random directions by the fibres [7]. The use of textile fabrics (agro textiles) in agriculture gives significant benefits to the environment which is explained by carbon footprint[8].

Textile fabrics are mainly classified into three types according to the manufacturing process of fabric: woven, knitted, and non-woven[9]. Among of them woven and knitted are basically use as Fabric product, Knitted fabrics have lower solar transmission than woven fabrics. Which includes the type of weaving and weave density, cover factor, porosity, fabric weight (GSM) and thickness. All these factors are inter-correlated and influence each other solar transmitted of fabrics or knitted fabrics to have a higher cover factor than other traditional fabrics[10]. Since the cover factor is expected to have a positive influence on the transmission of solar radiation. The fabric construction parameter ends per inch and picks per inch is a determination of cover factor of woven fabric. Generally, woven fabrics have a higher cover factor than knitted fabrics, due to the frequent weaving of threads. The pores between the yarns are basically larger in case of woven. The optical properties of fabric depending upon various textile properties like yarn spinning method, linear density, yarn evenness, yarn hairiness, amount of twist on the yarn, color or shade of fabric, fibre composition of the yarn, fabric weight, fabric density, and cover factor. Darker color fabric tends to absorb more solar radiation than lighter colors, including whites and pastels, but bright colors like red can also substantially absorb solar radiation[11]. Fabric weight is one of the useful factors for solar transmittance. It is difficult to determine how much fabric weight is providing the required amount of transmittance by observing the fabric. Yarn hairiness was the dominant factor for the IR and visible portions of the solar radiation spectra. Increasing the yarn hairiness decreases the transmittance in the VIS and IR portion of the solar spectra[7].

1) **Weave:** If a fabric is very tightly woven or knitted there are reduce holes or pore size then less amount of solar radiation transmitted through the fabric.
2) **Color:** Color or shade of fabric has a significant effect on the solar transmission. The structure of dyes used in fabrics absorbs some amount of solar radiation. It's also depending on the concentration of the dyes. Darker shades absorb more solar radiation than lighter color or un-dyed fabrics provide a better transmission of solar radiation. Lighter colors reflect visible light but shows good transmission through the fabric and easily reach to the plant. After several times uses as a greenhouse covering materials can slightly reduce the solar transmission of the fabric.
3) **Weight:** The high GSM means thicker and denser fabrics absorb more solar radiation and reduce transmission of the solar radiation than the thinner or lower weight of the fabric. So the lower GSM fabric can be used as a greenhouse covering material.
4) **Stretch:** When the fabric gets stretched out, the holes between the yarns open up and the solar radiation can easily pass through the fabrics. The solar radiation will be changed with the level of stretch experiments showed that the solar radiation of test stretch fabric decreased compared with the textile fabric in the normal state[14].
5) **Moisturizing:** It found that solar transmission through the wet fabric is significantly lower than the same fabric measured in the dry condition. The water increases the surface smoothness, reduces the pore size and reduces the scattering effect increase transmittance of the fabric.
6) **Construction:** The higher cover factor or densely weave gives minimum spaces between yarns which in turn less amount of solar radiation that can pass through the fabric. Some tightly constructed use vents to increase air circulation and help the textile fabric stay cool.
7) **Design:** The asymmetric overlap roof shape (AORS) in the E-W direction receives minimum solar radiation in the summer season and receives maximum radiation in the winter season would be more preferable. Hence, this type of construction should be preferred.
8) **Treatments:** Chemicals treatment and finishing are given more effective transmitting of solar radiation during fabric processing.
9) **Fibre composition:** The chemical structure of polyester have excellent in case of disrupting sunlight (due to hydrogen and carbon-based benzene rings within the polymer molecular chain). The chemical structure of nylon fibre showing not so good in case of solar transmission. Wool and silk are moderately effective. Cotton, rayon, flax, and hemp fabrics (natural fibres composed of cellulose, hemicellulose materials like lignin and wax) often score low solar transmission without added any treatments[15].
10) **Condition:** Worn or faded fabrics are less effective in solar radiation.
11) **Age:** solar radiation transmitting capacity decreases with increasing along with the service life of the textile fabric[12].

3. Materials and Methods:

A UV-VIS Shimadzu UV-2600 Spectrophotometer is used for measuring the optical behavior of the fabrics. This testing instrument was equipped with a double beam system and two detectors, a photomultiplier tube (PMT) detector used for the UV and visible region. The two detectors were connected to an integrating sphere (60 mm inner diameter) with an interior barium-sulfate coating, which is able to evaluate the total spectral reflectance and transmittance of the scattering material. Ultraviolet and visible spectrum transmission, reflection, and absorption parameters were calculated according to the EN 410 standard method. The transmission and absorption were measured, and reflation was calculated according to Equation (1) in the EN 410 standard method. The transmission percentage was measured at wavelength intervals of 5 nm or less in the spectral range 282.5–800 nm[16]. The UV (282.5–377.5 nm), VIS light (380–780 nm), Photo synthetically active radiation (PAR) solar light (300–800 nm) and various regions of the electromagnetic spectrum measured according to the TS EN 14500 Part-B standard testing method. The standard testing method excluded the UV-C part, as this radiation does not reach Earth, because of UV-C is absorbed by the ozone layer in the stratosphere region. The visible portion is responsible for visual comfort, whereas the IR portion is related to thermal comfort. The UV part is taken into consideration in two ways. This measurement should also be made in the transmission and reflection modes. The absorption properties calculated by using the equation in the EN 410 standard test method[7]. Analysis of the changes of light intensity transmitted through woven fabric. Higher levels of incident light intensity generate a larger amount of the transmitted light. Smaller values of pattern fabric cover because larger differences between in light intensity for the subsequent wavelength. The curves of the relation of light transmission as the function of the wavelength have the character of a poly nominal [17].

In this equation-1, 2 and 3, photo synthetically active radiation (PAR) transmitivity coefficient is T for perpendicularly incident radiation, can be defined as

$$T = \frac{\sum_{\lambda=380nm}^{\lambda=780\ nm} T_\lambda P_\lambda D_\lambda \Delta\lambda}{\sum_{\lambda=380\ nm}^{\lambda=780\ nm} P_\lambda D_\lambda \Delta\lambda} \tag{1}$$

Where, T is average solar transmittance, P_λ is direct normal spectral irradiance at λ (W/m2 nm), D_λ is account for the relative photosynthetic yield in different wavelengths, T_λ is the measured transitional spectrum of the fabric or spectral transmitivity, λ is wavelength (nm) and $\Delta\lambda$ is the bandwidth (nm) quantity of solar energy required to yield [18].

$$R = \frac{\sum_{\lambda=380nm}^{\lambda=780\ nm} R_\lambda P_\lambda D_\lambda \Delta\lambda}{\sum_{\lambda=380\ nm}^{\lambda=780\ nm} P_\lambda D_\lambda \Delta\lambda} \tag{2}$$

And, similarly R is average solar reflectance coefficient and R_λ is spectral reflectivity

$$A = \frac{\sum_{\lambda=380nm}^{\lambda=780\ nm} A_\lambda P_\lambda D_\lambda \Delta\lambda}{\sum_{\lambda=380\ nm}^{\lambda=780\ nm} P_\lambda D_\lambda \Delta\lambda} \tag{3}$$

And, the same as A is the average solar absorbance coefficient and A_λ is spectral absorbency.

According to Kirchoff's relationship, The sum of the average solar transmission coefficient, average solar reflectance coefficient, and the average solar absorption coefficient is one [19].

$$T + R + A = 1 \tag{4}$$

Then from the equation-(4), the average reflectance coefficient is given by the equation (5)

$$R = 1 - (T + A) \tag{5}$$

4. **Result and discussion:** In this study, we assume that air transmission is 100% as reference the test is conducted on the seven type different covering materials. Hear glass and poly films are already using as established greenhouse covering materials. The remaining five samples are different plain-woven fabric. These are a Polyester multifilament woven fabric, Polyester monofilament woven fabric, Polyester-cotton blended woven fabric, and two different GSM plain weave cotton fabrics[20].

Table 1: The properties of Greenhouse and textile materials.

Sample Code	**Materials**	**Materials Type**	**Yarn** (Warp ×Weft) in tex	**Fabric Density** (EPI×PPI)	**GSM**	**Thickness** (mm)
AIR-1	Air (Reference)	-	-	-	-	-
GR-2	Glass	Rigid	-	-	3379.73	1.40
PF-3	Poly-film	Film	-	-	200	0.20
PET-4	Polyester multi filament	Plain Woven Fabric	7.35×8.33	120×82	63.3	0.10
PET-5	Polyester monofilament	Plain Woven Fabric	10.54×12.96	73×49	58.8	0.12
PC-6	Polyester-Cotton blends	Plain Woven Fabric	22.12×22.97	74×65	128.5	0.14
CO-7	Cotton-1	Plain Woven Fabric	13.60×15.29	94×64	100.7	0.12
CO-8	Cotton-2	Plain Woven Fabric	14.05×14.05	104×79	122.7	0.14

All the materials in table no-1 are taken to check their physical properties (i.e. - Type of materials, yarn count, fabric density, GSM and Thickness) according to standard testing method and optical properties (i.e.- Transitivity, Absorptivity, and reflectivity) by spectrophotometer according to EN 410 method. Each sample size is 1×4 sq inch. The table -2 showing the average value of transmittance, absorbance, and reflectance. After plotting the result in origin pro-2018 software, getting separately transmission (Figure: 01), reflectance (Figure: 02), and absorbance (Figure: 03), graph of all seven types of covering materials [21]. The trends of the graph showing that Glass and poly films (consecutive transmission 74 % and 60%) which is already being used as covering materials for plants is less transmission in the UV region spectrum but good transmission in PAR(Photo synthetically active radiation) region. In this case of fabric showing that polyester (transmission 48 %) fabric have better result among the other fabric and follow the same trends like glass and poly films. The small difference of the cover factor found changes in large amounts of light intensity by changing the fabric density (EPI or PPI)[22].

Table 2: Transmission, absorption, and reflectance of different woven fabric.

Fabric Code	**Transmittance** (%)	**Absorption** (%)	**Reflectance** (%)
Glass	73.97	0.65	25.38
Poly films	59.75	0.62	39.63
PET-4	45.04	0.48	54.48
PET-5	48.14	0.34	51.52
PC-6	28.56	0.58	70.85
CO-7	39.70	0.41	59.88
CO-8	35.40	0.46	64.14

The trend of the graph (Figure-1, Figure-2, and Figure-3) is describing the transmission, absorption, and reflection of light in Ultra violation (UV) and visible region. The optical properties of different covering materials and fabric in the Ultraviolet (UV), visible weave length on the transmittance, absorbance and reflectance can be clearly observed. Fig.-1 shows that Glass has low ultraviolet transmittance, and the transmittance of the visible spectrum has been increased gradually [23]. The solar radiation transmittance and reflectance of glass or poly-films have a larger percentage than textile woven fabric. In all the textile fabrics only polyester woven fabric showing good result and follow the same trends of graph. If ends per inch will increase the more light will be passed through the fabric. Hence, the optimum transmission can get for batter plant growth[24].

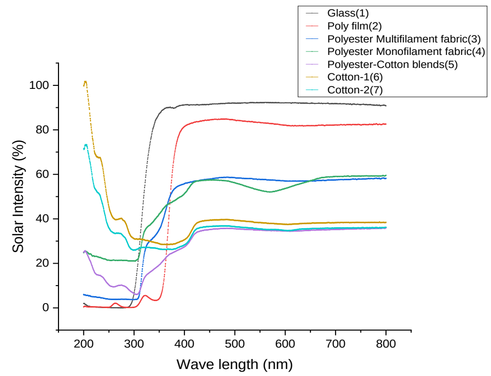

Figure 1: Solar transmission through different materials

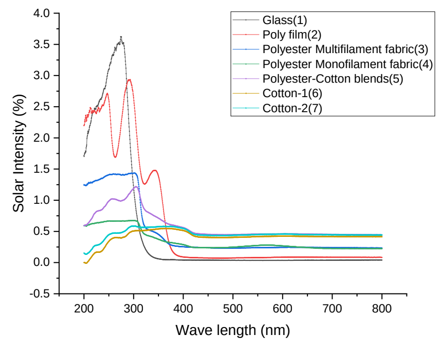

Figure 2: Solar absorption by different materials

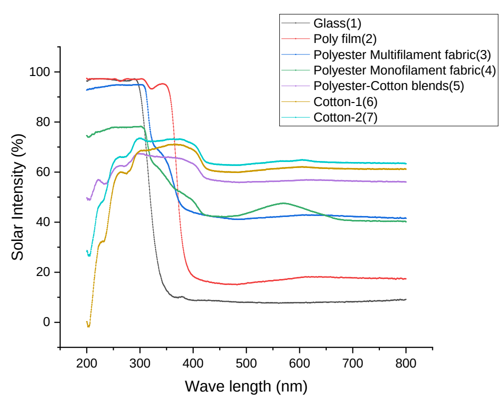

Figure 3: Solar reflectance by different materials

5. **Conclusion:** This study will lead to the development of effective, low cost and high durability Greenhouses materials for growing vegetables or fruits and increasing the awareness of the farmer about the use of greenhouses was the main target of this experiment. The above result showing that polyester woven fabric found more suitable for use as a greenhouse covering material. Because of the polyester fabric has better transmission and passes the photo synthetically active radiation (PAR) easily. Also, synthetic polyester fabric served long service life due to sustaining against photo degradation and harsh weather condition. This idea gives ecologically and economically advantage in food production.

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