



SUNTUF[®] *Plus*

Corrugated Polycarbonate Sheets for Greenhouses

Technical Guide

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I n t r o d u c t i o n

SUNTUF Plus is manufactured from polycarbonate, the strongest polymer known. It is sometimes called the “glass steel” because it is both clear and more impact resistant than steel relative to its weight. Polycarbonate is both tough and rigid, possessing an elastic modulus of 2,200 MPa.

SUNTUF Plus Features

- Corrugated Polycarbonate Sheet 0.8 mm Thickness
- Single Wall
- Outwardly exposed side UV protected by co-extruded protection (UV2 option - co-extruded UV protection on both sides)
- Inwardly exposed side will not allow condensation to accumulate due to a unique anti-condensation treated surface
- Possesses the highest light transmission of all greenhouse covering materials above 90% when dry and above 92% when wet
- Will withstand the impact of hailstones up to 80 mm in diameter (proven in Australia)
- Retains an extremely high level of light transmission after 12 years of service (demonstrated in the USA and Australia)
- The easiest, cheapest and most dependable greenhouse covering to install
- A record of no failures during the last 20 years of intensive service around the world
- Over 25 million square meters have been installed around the world under various climatic condition with temperatures ranging from -30°C to $+50^{\circ}\text{C}$.

Solar Transmission Properties

SUNTUF Plus corrugated polycarbonate panels transmit approximately 90% of visible, PAR and near infrared radiation. Essentially 0% of UVA and UVB below 380 nm is transmitted (see Figures 1 and 2 below). The high transmission of solar radiation which is responsible for heat generation in the greenhouse, ensure that even on cloudy days there will be a great amount of heat collection in the greenhouse covered with SUNTUF Plus.

Light Transmission of SUNTUF Plus as a Function of Wavelength

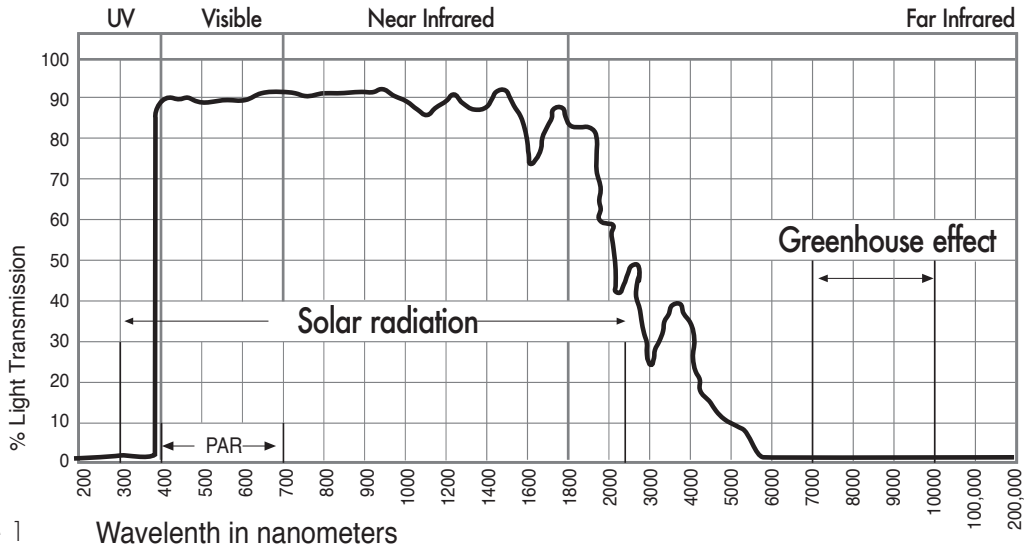


Figure 1

SUNTUF Plus and Sun spectrums

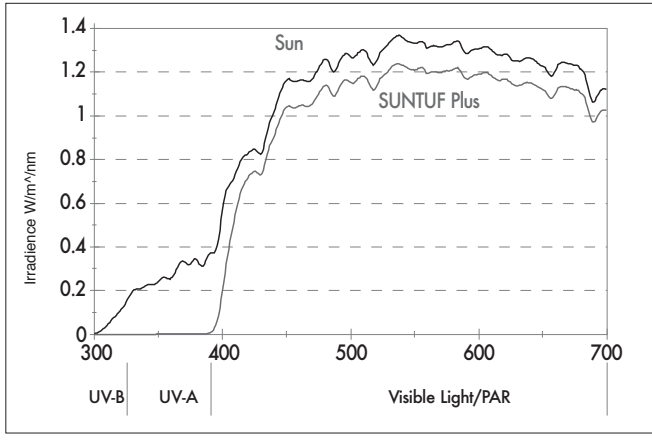


Figure 2

Light Diffusion

SUNTUF Plus LDT (Light Diffusing Texture) offers high transmission (90%) while 20% of the transmitted light is diffused, helping to spread light throughout the greenhouse and reduce shadows around the plants. The effect is demonstrated in Figure 3 below.

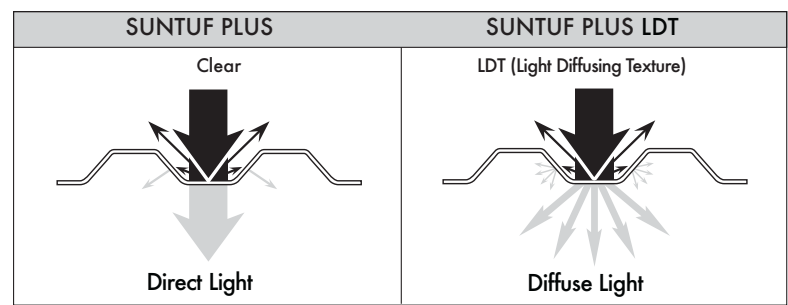


Figure 3

Comparison of light transmission for SUNTUF PLUS and SUNTUF PLUS LDT

Comparison to Flat Glazing

The corrugated profile of SUNTUF Plus results in greater light transmission in the critical early morning and late afternoon hours than is the case for flat twin wall or glass panels, as indicated in Figure 4 below.

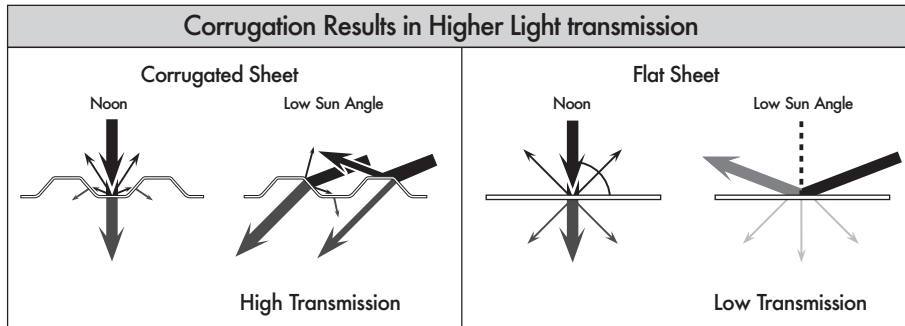


Figure 4

No Construction Shading

SUNTUF Plus sheets require light construction and only a few metal purlins to support the sheets. SUNTUF Plus transmits 6% more light than flat glazing with dense metal construction.

Proven Condensation Control

When outdoor temperatures are lower than the temperature of the greenhouse and the relative humidity of the air in the greenhouse is high, a wet "film" of small droplets of condensed water is created on untreated covers of greenhouses. The "film" reflects the light out. SUNTUF Plus is treated with a built-in layer which prevents the formation of the small droplets. The condensed water flows on the sheet without screening the light and without dripping on the plants avoiding contamination and disease.

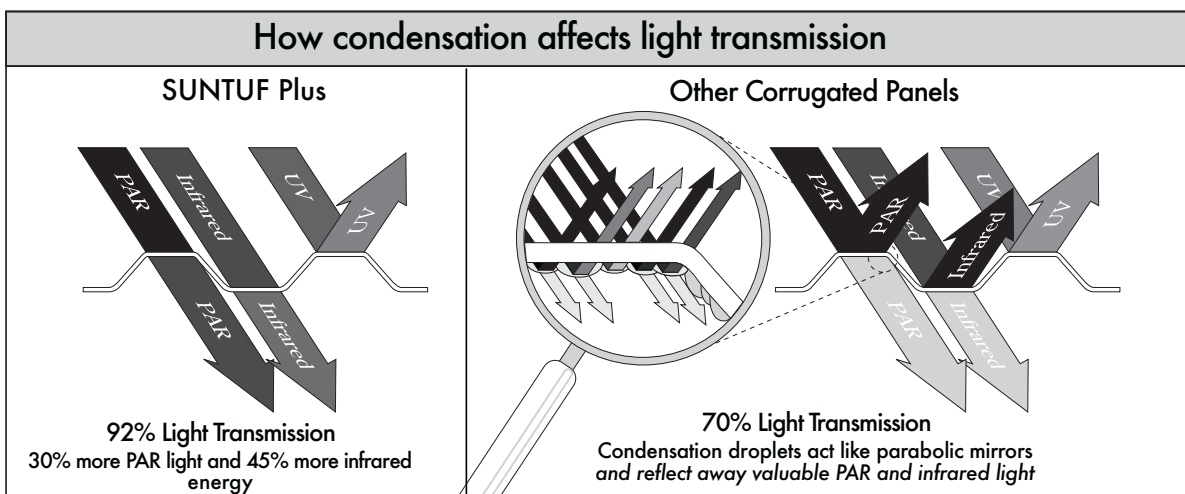


Figure 5

SUNTUF Plus versus Untreated Polycarbonate under Condensation (Wet) and Sun Spectrums

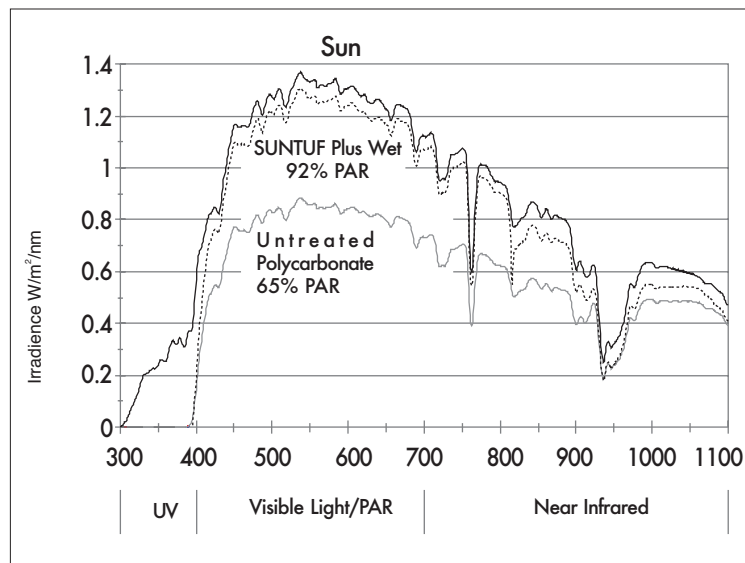


Figure 6

UV Resistance

SUNTUF Plus exhibits exceptional resistance to the negative effects of UV radiation. Integrated co-extruded UV protection on the outer side of the sheet protects SUNTUF Plus from degradation, loss of light transmission and yellowing.

20 years after the introduction of UV protected SUNTUF in 1985, SUNTUF has never encountered a claim for yellowing or loss of light transmission. The growers are fully satisfied. Accelerated laboratory QUV tests indicate that SUNTUF Plus can be expected to perform well much longer than that.

SUNTUF Plus is supplied with a 10 year warranty against loss of light transmission or yellowing due to UV radiation (provided upon request).

Impact Strength

SUNTUF Plus is lightweight and flexible, yet it is virtually unbreakable. SUNTUF Plus carries a solid 5-year warranty against breakage due to hail (supplied upon request). Laboratory tests have been carried out to demonstrate that 8-year old SUNTUF Plus is at least more than 30 times more impact-resistant than 3 mm tempered glass. In these tests, the equivalent of a 60 g (50 mm in diameter) hailstone striking the panel with an energy of 68 J did not break or star SUNTUF PLUS. It only dented it slightly. The results are depicted in more detail on the next page.

These tests were carried out by shooting a round projectile of a given mass (g) at a measured velocity (m/s) at panels under controlled conditions. The relationship between the energy (J), mass and velocity of the projectile is depicted in the equation below:

$$E = 1/2 \times m \times v^2$$

As can be seen in the table below, the energy of standard hail (according to ASTM Method E822-81) as simulated by the projectile increases both with the mass and velocity of the projectile.

Std Hail Diameter (mm)	Std Hail Mass (g)	Std Hail Velocity (m/s)	Energy (J)
25	7.4	30.0	3.33
38	25.8	33.7	14.65
51	58.8	37.3	40.90

Hail Resistance

Evaluation of Hail Resistance of Panels in Hail Simulator

Panel	Projectile Type Mass (g)	Projectile Velocity (m/s)	Energy (J)	Result
Regular Glass	Plastic - 9.8	10	0.5	Brittle Break
Safety Glass - 3 mm	Plastic - 9.8	18	1.6	No Break
	Plastic - 9.8	20	2.0	Brittle Break
Safety Glass - 4 mm	Plastic - 9.8	25	3.1	No Break
	Plastic - 9.8	30	4.4	Brittle Break
SUNTUF Plus after 8 years of service	Aluminum - 38	60	68.4	No Break

Summary of the Results

- 1 - All the glass panels broke upon impact with moderate to heavy hail simulator projectiles.
- 2 - SUNTUF Plus was not affected by a hail simulator projectile striking with an energy up to 68 J which possesses 1.7 times the energy of an actual hail stone 50 mm in diameter. (The simulator cannot be safely operated above this energy.)
- 3 - The SUNTUF Plus panel evaluated was taken from a greenhouse in California, USA after 8 years of service. There was a ductile depression at the point of impact.

The Ideal Heat Gain

Each greenhouse cover has its advantages and disadvantages.

Twin wall polycarbonate has good insulation properties but its light transmission is limited. Glass has a high light transmission but its dense metal supports block part of the light from the plants during the day and the glass itself transmits the long IR outward during the night.

Flat covers like glass, polyethylene, twin wall, etc. reflect the sun rays during critical hours of the morning and late afternoon.

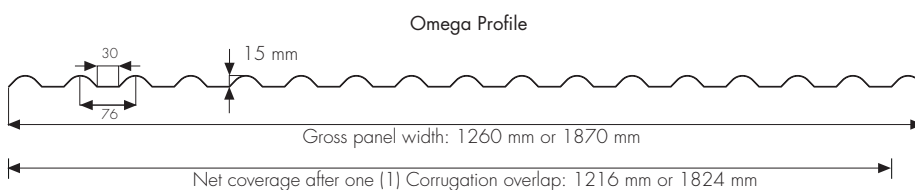
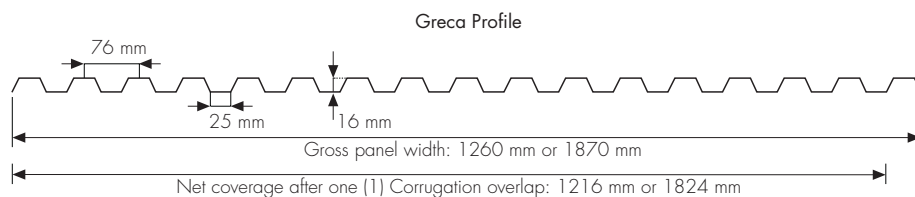
Only SUNTUF Plus allows maximum light to enter the greenhouse from early morning to late afternoon.

The minimal construction, the high transparency, the profiled shape and the anti-condensation treatment make SUNTUF Plus the ideal cover for gaining maximum heat in the greenhouse. The solution is completed by installation of a thermal curtain together with the SUNTUF Plus sheet to prevent heat loss during the night and also as shading option for hot sunny days.

Growers who use the ideal solution of SUNTUF Plus in combination with an automatically controlled thermal curtain report saving up to 50% of heating energy compared to IR polyethylene film covers.

Panel Dimensions

SUNTUF Plus is recommended for use in greenhouse covers in either the Greca or Omega profile. The two are available in glossy, clear and LDT (light diffusion texture) finish. Both profiles are available in either widths of 1260 mm (1216 mm net width after one corrugation overlap) or 1870 mm (1824 mm net width after one corrugation overlap).



Panel Width Advantage

Most corrugated greenhouse panels provide a net coverage of 1000 - 1200 mm, after a one or two corrugation overlap. This results in from 5 to 11% of the panel area overlapping. Some of this overlap results from useless side flaps, which only serve to increase the cost of the panel. SUNTUF Plus panels are cut before the corrugation flattens out. Therefore, for 1260 mm panel, you receive 1226 mm of net coverage, or only 3.5% overlap. For the 1870 mm panel, the % overlap is minimized to minimal value of 2.5%. As a result, less SUNTUF Plus is required to cover a given greenhouse, as indicated in the table below for a 1000 square meter (4 m x 250 m) of a greenhouse roof or wall.

Covering	No. Sheets Required	Sheet Dimension	Sheet Area Required	% Overlap Material Required
SUNTUF Plus	137	4m x 1870mm	1025 m ²	2.5
Other Corrugated Polycarbonate	209	4m x 1265mm	1058 m ²	5.8
PVC	250	4m x 1120mm	1120 m ²	12.0

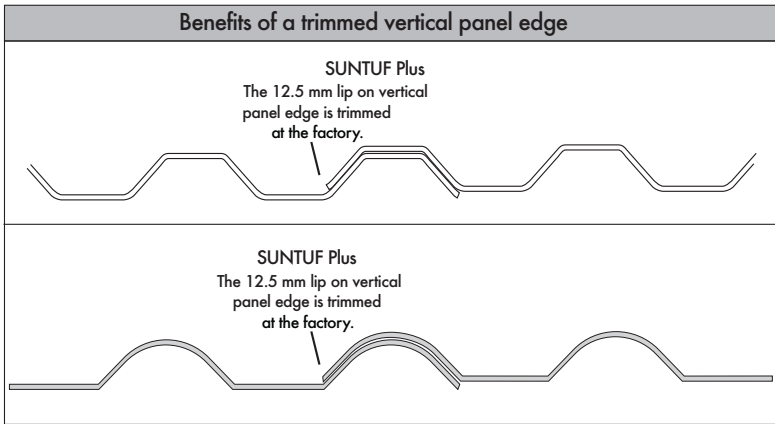


Figure 8. Benefits of a Trimmed Vertical Panel Edge for Greca Profile

Furthermore, this added width serves no purpose and over time dirt can accumulate under it reducing light transmission. Light transmission is less through all overlap areas. Utilizing the unique SUNTUF Plus 1870 mm panel, can reduce this area of reduced light transmission to a quarter of the amount you receive with competing products.

Chemical Resistance

It is important to remember, that although SUNTUF Plus is resistant to a wide variety of chemicals employed in normal greenhouse operations, some may attack polycarbonate. If possible, every effort should be made to avoid bringing chemicals used in the growing process in contact with SUNTUF Plus.

Shade Compounds

PALRAM Industries recommends that you contact your sales representative before using shade compounds. Certain compounds can attack polycarbonate. The main laboratory of PALRAM Industries has the facilities to perform testing, and will test any material forwarded free of charge. **Special care should be taken not to use solvent based shading compounds or solvent based caning agents.**

Shade and Energy Curtain Fabrics

Most exterior webbed shade fabrics will not damage SUNTUF Plus. However, here again it is recommended that you consult with your sales representative. If the material is not on our approved list, he will submit the fabric for testing and approval prior to use. Most energy/shade curtain fabrics are compatible with SUNTUF Plus, but some have problems to be incompatible.

Note:

The list of recommended materials to be used in contact with SUNTUF Plus will be supplied upon request.

Cleaning and Care of Suntuf Plus

It is recommended that the exterior of SUNTUF Plus panels be washed and rinsed annually to provide maximum performance and extended service life.

Cleaning Procedures

1. Cleaning may be carried out using high pressure water. A mild detergent or soap may be added to the stream. Steam or hot water may also be employed.
2. Brooms or brushes with soft bristles may be used. Do not use hard bristles that may abrade the surface.
3. Soft cotton rags (no paper) or sponges are ideal.
4. Be sure to rinse away any soap or detergent that is applied.
5. Drying with a soft cotton cloth will prevent water spotting.

Never: use or do the following

1. Abrasive cleaners.
2. Hand brushes.
3. Never scrape with razor blades or other sharp implements.
4. Benzene, gasoline, acetone or other solvents.

Treatment of Fresh Paint Splashes, Contact with Grease and Glazing Compound Removal

Before they dry, these conditions can easily be remedied by rubbing lightly with a good grade of VM&P naphtha, isopropyl alcohol, or butyl cellosolve. Afterwards, clean following the instructions above.

Label and Sticker Removal

Kerosene, VM&P naphtha, standard solvents or petroleum spirits can be used locally to assist in the removal of labels and stickers. A warm wash and rinse should always follow the use of these products.

In cases where the sticker material, such as vinyl, does not allow the penetration of solvent, the application of heat (a hair dryer, for example) will soften the adhesive and promote removal. However, caution should be exercised as the excessive heat may cause surface damage.

SUNTUF Plus Sheet

Typical Properties

Property	Conditions	ASTM Method ^c	Units - SI	Value
Physical				
Density		D-1505	g/cm ³	1.20
Water Absorption	24 hr. @ 23°C	D-570	%	0.15
Mechanical				
Tensile Strength at Yield	10 mm/min	D-638	MPa	62
Tensile Strength at Break	10 mm/min	D-638	MPa	65
Elongation at Yield	10 mm/min	D-638	%	7
Elongation at Break	10 mm/min	D-638	%	>80
Tensile Modulus	1 mm/min	D-638	MPa	2,300
Flexural Modulus	1 mm/min	D-790	MPa	1,890
Flexural Strength at Yield	1 mm/min	D-790	MPa	93
Shear Strength			MPa	42
Izod Impact Strength Notched (23 °C)		D-256	J/m	800
Impact Failing Weight		ISO /6603/1 ^a	J	50
Rockwell Hardness		D-785	R scale	118
Thermal				
Heat Deflection Temperature	Load: 1.82 MPa	D-648	°C	135
VICAT Softening Temperature	Load: 1 kg	D-1525	°C	150
Coefficient of Linear Thermal Expansion		D-696	10 ⁵ cm/cm °C	6.5
Thermal Conductivity		C-177	W/m K	0.21
Specific Heat Capacity		C-351	kJ/kg K	1.3
Service Temperature			°C	-40 to 120 °C
K Value		C-236	W/m ² K	5.6
Optical				
Haze		D-1003	%	<0.5
Light Transmission		D-1003	%	90
Refractive Index		D-542		1.57
Yellowness Index		D-1003		<1

SUNTUF Plus Sheet

Typical Properties (continued)

Property	Conditions	ASTM Method ^a	Units - SI	Value
Electrical				
Dielectric Constant	1 kHz	D-150		2.6
	1 MHz	D-150		2.4
Dissipation Factor	1 kHz	D-150		0.005
	1 MHz	D-150		0.02
Dielectric Strength - Short Time	500 V/s	D-149	kV/mm	20.3
Surface Resistivity	Ketley	D-257	Ohm	4.1 x 10 ¹⁵
Volume Resistivity	Ketley	D-257	Ohm-cm	1.7 x 10 ¹⁷

^aAll the results depicted in this table were obtained by following the indicated ASTM method except where another method is indicated by the appearance of this symbol

Flammability of SUNTUF PLUS Corrugated Polycarbonate Sheet

Standard	Classification*
DIN 4102	B-1
NFP 92501, 4, 5	M-1
UL 723	4.7, 47.0
Los Angeles Building Code	CC2 (Section 2603)
UNI 9177, 9176	Class 2

* For additional information, please contact your SUNTUF Plus distributor

General Information

SUNTUF Plus is unsurpassed in the ease with which it is installed on all types of greenhouse framing systems. Nevertheless, there are some important guidelines that need to be followed in order for panel installation to be accomplished quickly and properly. These are depicted in a separate publication: "SUNTUF Plus Corrugated Polycarbonate Sheets for Greenhouses - Installation Instructions." (Note: Palram Industries shall not be responsible for problems arising from a failure to observe those instructions and the recommendations in this pamphlet.)

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