CHAPTER 2

LITERATURE REVIEW

2.1 Greenhouse

Greenhouse is a structure with walls and roof made chiefly of transparent material, in which plants requiring regulated climatic conditions are grown. These structures range in size from small sheds to industrial-sized buildings. The interior of a greenhouse exposed to sunlight becomes significantly warmer than the external ambient temperature Other than that, it also plays a role as a shelter for the plants inside it by providing additional warmth and protection from other elements. Other than that, it also prohibit heat from escaping by reflecting the energy back into the interior and inhibits winds from the outside to carry the heat away. This heat is functional for growing and propagating plants.

2.1.1 Cladding Material

Work by Zabeltitz (2011) shows that a suitable roof inclination are required for the refinement of light transmittance. Other than that, the commercial cladding materials also plays an important role in choosing the required spectral transmittance and energetic demand as it is available for many usage. Those features have to be valued in choosing the suitable cladding materials for different climatic regions. For example, in tropical, subtropical and arid climates countries, plastic film is the most applied cladding material. However, in some arid regions, they are using rigid plastic sheets and glass. Table 2.1.1

shows that the transmittance of direct and diffused light for several types of cladding material according to their thickness.

Table 2.1: Transmittance for direct and diffuse light of greenhouse cladding materials (Zabeltitz, 2011)

Material	Thickness (mm)	Direct light (%)	Diffuse light (%)
Glass	4	89–91	82
PE film UV	0.1–0.2	89–91	81
EVA film	0.18	90–91	82
PVC film	0.1–0.2	87–91	
ETFE film	0.1	93–95	85
PC double sheet	12	80	61
PMMA double sheet	16	89	76

The features of the cladding material influences the quality of transmitted light into the greenhouse and radiation transmittance can be improved qualitatively and quantitatively. Cladding materials for greenhouses should have, high transmittance of visible light and Photosynthetic Active Radiation (PAR) with wavelengths of 400–700 nm and low transmittance of Far Infrared Radiation (FIR) which is within the span of 3,000–20,000 nm of wavelength.

2.1.2 Far Infrared Radiation (FIR)

The transfer of heat by radiation from the crop throughout the cover of greenhouse is increased by the transmittance of FIR radiation with wavelengths of 3,000–20,000 nm with the effect of lower plant and air temperature with the temperature inversion (inside temperature is lower than outside). Temperature condensation along with fogs will occur if plant and air temperature dropped under the dew point, and thus plants will be prone to diseases. Glass is non transparent to FIR radiation. For greenhouses in subtropical and arid climates, thermic film with IR absorber or co-extruded PE and EVA film should be used to keep the temperature prominent. Fog and temperature change in the greenhouse can be prevented by early ventilation.

2.2 Shading Net

Shading nets affect environmental modification (humidity, light intensity and temperature) provides physical protection (birds, hail, insects, excessive radiation) and increases the relative percentage of diffused light as well as absorb different spectral bands, thus it affects the light quality. These may influence crops as well as the organisms connected with them. Moreover, shading net offers many environmental and economy advantage (Briassoulis, Mistriotis, & Eleftherakis, 2007). These shading nets are also used to reduce cooling loads for residential buildings all over the world (Kim, Lim, Lim, Schaefer, & Kim, 2012) and in agricultural sectors for plant and animal protection purposes.

2.2.1 Classification of Shading Net

Today, there are many types of shading nets which are currently available and being promoted in the market worldwide. These shade nets were classified into few main groups according to their applications namely anti-hails, insects, windbreak and shading nets (Briassoulis et al., 2007) .

For wind protection, darker colour net is used in the form of windbreaks with average range size of 1 to 3 mm. Black or green colour of shade nets were fitted above or below the greenhouse roof, in order to decrease the air temperatures inside the greenhouse during warm periods.

Besides that, shading nets were also used for covering structures, such as shade houses which protects plants from high temperatures and excessive solar radiation. The mesh size of this net is normally in the span of 0.6–4mm with light transmittance fluctuating from 20% to 70%.

In addition, shading nets which are highly meshed with anti-virus vector insect nets are known as bio-nets generally used for the protection of plants mainly in greenhouses. The net mesh size is made upon the species of insects against which the net is designed to protect crops, and the size is approximately 0.5 mm.

2.2.2 Coloured Shading Net

The manipulation of plant structure and physiology using coloured shade nets throughout the decades, mainly in greenhouse environments (Wilson and Rajapakse 2001). Coloured nets portrays a new agro-technological concept, which intends to combine physical preservation with different treat of solar radiation. Furthermore, these coloured nets are vigorously being tested due to their power to change the spectra of radiation which reaches the crops below (Figure 2.2.2(a)). These nets may allow increase of light scattering up to 50% or more and this alone can affect the plant growth and development (Figure 2.2.2(b)).

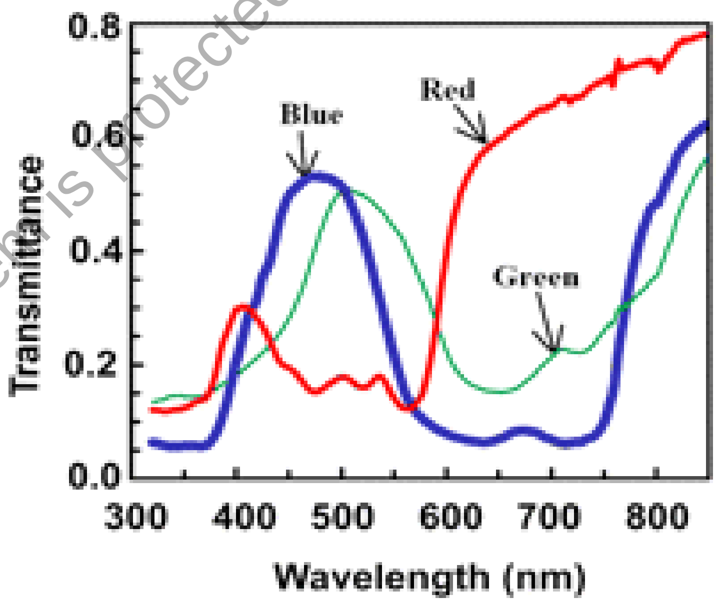

Figure 2.1: Transmittance Spectra of Three Coloured Shade Nets (Oren Shamir et al., 2001)

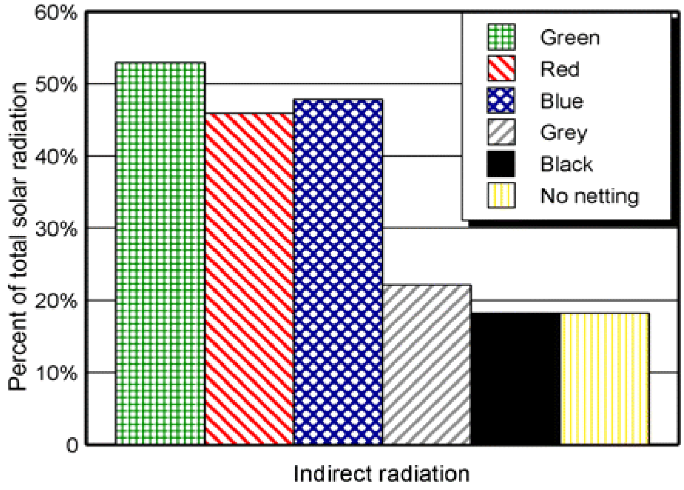

Figure 2.2: Scatters of Light under Coloured Shade Netting Compared to No Net (Oren-Shamir et al., 2001)

The coloured net products are different from one another based on its' diverse chromatic additives, reflective elements and light dispersive elements which is manufactured into the nets. These nets are aimed to distinguish various spectral elements of solar radiation along with the change of direct light into scattered light. The changes of spectral radiation is designed to assist desired physiological responses, while the scattering enhance the piercing of the modified light to the interior part of the plant body.

The research of ornamental plants, which is cultivated under shade nets exhibit prominent responses to the red, yellow, blue, grey and pearl nets, compared with the usual black nets of the same shading factor. These responses include stimulated vegetative dwarfing, branching, leaf variegation and the flowering time.

2.2.3 Temperature and Relative Humidity

Shade nets are used to reduce heat stress (Shahak et al., 2004). However, during the day temperature in enclosed shade house is slightly elevated than the outside temperature (Pérez et al., 2006; Stamps, 1994) and it is moderate during the night.

However, for relative humidity it is usually elevated under shade netting even when temperatures under the netting are higher (Stamps, 1994). This is due to water vapour being transpired by the plants and reduction of inside air mixing with drier air outside the netted area.

2.2.4 Radiation

Shading nets and film covers propagates a substantial volume of beam radiation during transmission. The further scattering and dispersion elements of solar radiation transmitting through shading net have been investigated and proved that more radiation will be blocked significant to the increase of shading factor. Temperature and relative humidity is affected due to reductions in radiation (Stamps, 1994). Furthermore, Shading net can scatter ultraviolet radiation because it is made up using plastic which is resistant to ultraviolet (Wong, 1994). It is shown that, shading net which does not affect the light spectrum but increases light scattering do increase the branching, plant compactness, and the number of flowers per plant (Nissim-Levi et al., 2008).

2.2.5 Air movement

Shade nets reduces wind run along with wind speeds (Stamps, 1994). These movement affect the temperature, relative humidity and gas concentrations sequel from reductions of air mixing. These changes may give impact on photosynthesis, transpiration and respiration. The results on air movement depends on the physical location and porosity of the netting.

2.3 Effects of coloured shade on plants

2.3.1 Number of Yield

Total marketable yield of Capsicum was elevated with 40% shading level and then reduced with 50% shade. Black net treatment gives the lowest total yield (Medany et al. 2008). Other than that, the coloured netting concept was tested under high solar radiation in greenhouse for four different coloured shade-nets (pearl, red, blue and black) with different relative shading (40% and 50%). Shading of pepper plants gives effects on both fruit yield and quality, where total marketable yield elevated with 40% shading level and then reduced with 50% shade.

2.3.2 Height of Plants

In summer season which is off season for Spinach, crop showed poor growth under control due to high temperature, but under coloured shading nets Spinach had good growth compared to control. Spinach grown under green shading net had maximum growth and was found to be nearly double as compared to control.

Regardless the decrease in total biomass especially the root part, cultivation of O. selloi under blue or red shading had led to an increase in the development of inflorescences compared to plants grown without shading nets. This phenomenon is explained by the survival strategy of the plant. For example, under critical conditions plants are likely to save energy spent on biomass production in order to support its' reproductive functions.(Larcher, 2000). In addition, work by Rajapakse et al. (1992) and Brown et al. (1995) on seedlings where three different light treatments are maintained (full sunlight, red and blue coloured shade netting). For coloured shade-grown plants, it were taller compared to those which were grown without shading.

Blue netting decreased and red netting increased branch lengths of Variegated Pittosporum (Oren-Shamir et al. 2001). The aluminet, grey and red netting increases branching compared to the black netting. Despite that, the productivity of commercial branches (used by florists) was decreased under blue netting. In a 3-year study, production of Pittosporum tobira 'Variegata' branch yield was prominent under red, intermediate under grey, and least under black and blue netting (Stamps, 2008).

2.3.3 Width of Plants

Net shade had prompt the changes in physiological behaviour of the coffee plants, such as enhancing leaf area index, having better photosynthesis performance and produced bigger and heavier fruits with better bean quality.

On the other hand, Spinach which was grown under red shading net had leaf length of 62-93% higher as compared to control. Meanwhile, Spinach grown under black shading net had 15-40% higher value and under white shading net had 8-17% higher value as compared to control. In rainy season the root length, leaf length and total length of Spinach was found to be more in control followed by under green, red, white and black shade net.

For Pittosporum under the green and red netting, higher percentage of larger size leaves (15 to 30 cm^2) and a lower percentage of small leaves (less than 10 cm^2) were produced compared with the conventional black netting.

2.3.4 Chlorophyll Content

According to Meena et. al (2014), chlorophyll content depends on light. Coloured shade nets modifies light concentration which affect the chlorophyll concentration. Chlorophyll content measured by the dimethyl sulfoxide (DMSO) method showed that Spinach grown under black colour shading had 12 to 31% more chlorophyll, under white shading net had 19 to 35% more value, under green shading net had 52 to 62% more value and under red shading net 54 to 67% more value as compared to control. In rainy season control had more chlorophyll content then coloured shading net.

For Ocimum Selloi, absorbtion of light by chlorophyll is highest under the red portion of the spectrum. Yet, biomass production in O. selloi was not elevated under red shading. This situation is explained by the fact that plants cultivated below red shading need supplementation with blue radiation (Brown et al., 1995). Moreover, according to Kim et al. (2004) there is a reduction in the value net photosynthetic rate of plants submitted to blue and blue-far red light treatment.

2.3.5 Vitamin Content

The amount and intensity of light during the growing season influences the amount of vitamin C formed in Capsicum plant. Significantly higher vitamin C content was observed in pepper under red shade netting than in pepper without colour nets. Favourable impact of the red net on pepper productivity were also acquired by the group of Fernández-Rodriguez for plastic tunnel cultivation in Almeria, Spain (Shahak et al. 2004b).

For Coffee, a research by Bote & Struik, (2011), shaded plants had more biochemical and physiological potential for high dry matter production which will assist them to preserve high coffee yields in the longer span of time. In addition, according to Muschler (2001) shade net had delayed the maturation of coffee beans which gave a good bean filling and larger bean size.

Other than that, for Tomatoes, shade netting decreases the sugar content (Davies and Hobson 1981), ascorbic acid (Giovanelli et al, 1999) and pigments (carotenoids) (Davies and Hobson 1981) of tomato fruit. Regarding sucrose contents, there were no differences detected between fruits produced in the field and fruits produced in the protected environment. Shading did not affect the content of sucrose in the fruits.

2.3.6 Post Harvest Quality

In research published in Scientia Horticulturae in 2013, other scientists found that growing sweet peppers under pearl-and red nets improved the post-harvest quality of the fruit, compared with the same crop grown under black nets. The peppers had firmer, more elastic flesh, and had greater levels of ascorbic acid and antioxidants. While the air temperature and humidity under both the black and the pearl nets were relatively the same, the pearl netting's ability to increase certain wavelengths of light and their intensity made a significant difference in how the sweet peppers fared once picked.

Other research has determined vast differences between coloured netting. Blue netting reduces red and far-red light values, results in plants with darker, more compact foliage and a delayed bloom. Such traits are desirable to commercial growers who need to ship ornamental plants and cut flowers that can blossom while on display in retail stores. Interestingly, red netting tends to cause the opposite effect of the blue netting: a high growth rate. The root systems are more developed, stems are longer, plants flower earlier, and plants yield larger fruit that ripen more quickly.

2.3.7 Pest Attraction

Understanding how coloured nets affect plants, pests and beneficial insects could lead to more widespread use of these techniques, even in the home garden. In a study published by Ben-yakir, et al (2012) it is reported that, even though whiteflies landed on a yellow net 40 more times than on a black or red net, only half of them passed through to the tomato plants below. The result was an 80-fold protection from whitefly infestation for the tomatoes under the yellow net. In addition, the tomato plants grown under red, yellow and pearl nets used in the study had 15% -40% higher fruit production compared with plants under the black net. Moreover, yellow netting is irresistible to most insects. Yellow is a very attractive colour for the landing of insects, because they perceive it as a dark green.