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EFFECTS OF PHOTOSELECTIVE SHADE NETS ON THE METEOROLOGICAL ELEMENTS, GROWTH AND RADIATION USE EFFICIENCY OF CUCUMBER

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CSBE101226 – Presented at Section II: Farm Buildings, Equipment, Structures and Livestock Environment ConferenceABSTRACT Crop growth is influenced by meteorological conditions. Thus, crops growing inside protected environments versus field conditions, are submitted to different meteorological conditions. This research was conducted under photoselective shade nets and field conditions in order to quantify the influence of radiation net (Rn) on growth rate, productivity, global radiation (SR), photosynthetically active radiation (PAR) and PAR use efficiency of local variety cucumber crop. The experiment was carried out in the spring of 2009 in a experimental area (Lat. 16°40’S, Long. 49°15’W and alt. 730 m) that consisted of three treatments, named: T1- field conditions; T2 - 30% red filter net in the visible and 30% transmission in the far red spectrum; T3 - 30% red filter net in the visible and 40% transmission in the far red spectrum. The best results in terms of growth rate, productivity, energy efficiency were obtained under T3 condition. Under these conditions, the reduction of global solar radiation was not limited for the cucumber growth below the nets, being that a crop growth rate of 0.431 g day^{-1}was observed with an average global solar radiation incident of 4.4 MJ m^{-2} day^{-1} and PAR use efficiency of 0.079 kg MJ dia^{-1}. Both red filter nets increased dry matter and chlorophyll content.

Keywords: *Cucumis sativus*, radiation net, photosynthetically active radiation, dry matter.

INTRODUCTION The plants perform the photosynthesis that consist a vital process to the vegetable life. The atmospheric CO_2 together water and solar energy is carboxylated through the photosynthesis and transformed in glucose that will be used in several process demanding energy, such as: growth, roots emission, grain filling, synthesis of actives principles and others.

The visible light is a primary energy source at the photosynthesis and has wavelengths arranged between 380 nm and 700 nm, that is, since violet until red. This range of electromagnetic radiation spectrum is also known as “photossinteticaly active radiation” (PAR). The main factors that change the photosynthetic action are light (quality and intensity), concentration of carbon dioxide, temperature, water and foliar morphology.

The light quality is represented by the. For instance, smaller wavelengths are more energetic, as blue light. However, bigger wavelengths are less energetic, as red light. These two types of lights are the more effectives on the photosynthetic activities (Figure 1).

The action spectrum of photosynthesis in plants; that is, the ability of light of different wavelengths to support photosynthesis is shown on Figure 1a. (b) The absorption spectra for three photosynthetic pigments (chlorophyll *a*, chlorophyll *b*, and β-carotene) is shown on Figure 1b. Each spectrum shows how well light of different wavelengths is absorbed by one of the pigments.

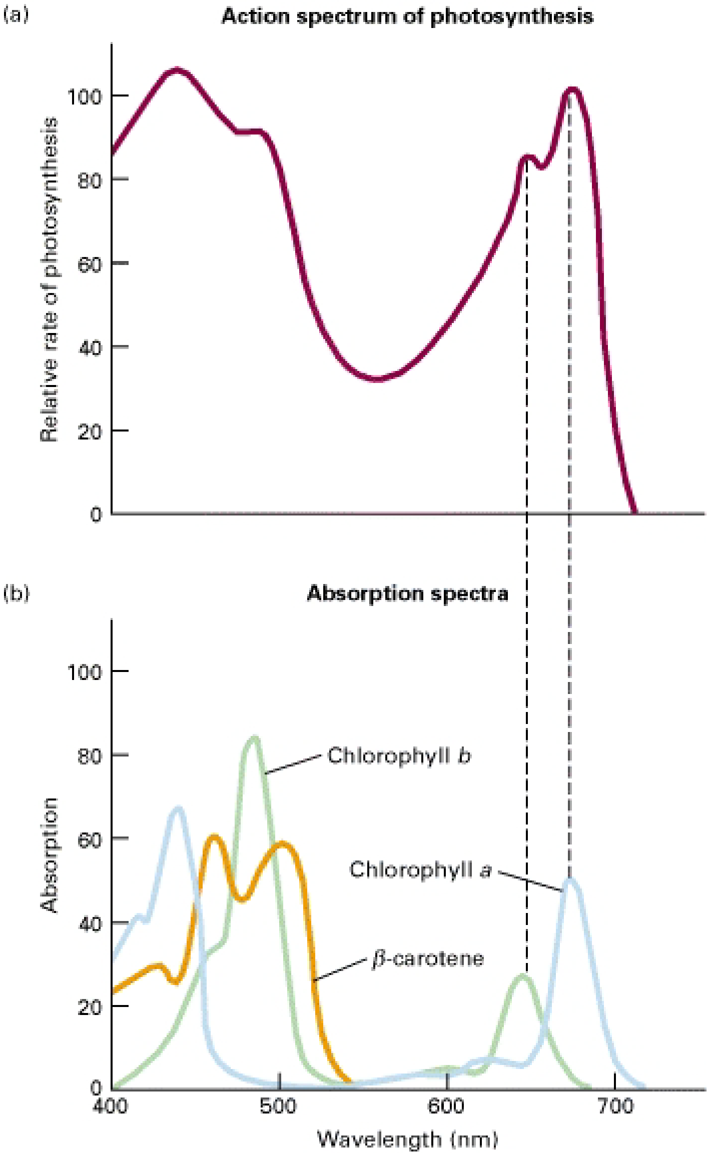


Figure 1. Photosynthesis at different wavelengths (LODISH, et al., 1999)

The best quality of incident solar radiation under photoselective nets can favor the photosynthetic process, resulting in a best plants development and, or, in a shortening of their cycle. This fact is very important for the farmers, because reduces the production costs and increases the aggregated value, and providing best profits.

In the same way, the relationship between the production of dry mass and the intercepted or absorved photossinteticaly active radiation has been largely use in order to define the radiation use efficiency by the crops (Sivakumar & Virmani, 1984; Costa et al., 1996). It is considered, in healthy plants, the net photosynthesis and the phytomass are proportional to PAR absorbed by the canopy (Monteith, 1977).

This research was conducted under photoselective shade nets and field conditions in order to quantify the influence under meteorological elements, growth rate and productivity of local variety cucumber (*Curcumis sativus*) crop under Brazilian tropical region.

METHODOLOGY

The research was conducted in an experimental area of the Agronomy and Food Engineering Faculty of the Goiás Federal University, Goiânia city, Brazil, located at 16° 40’ S and 49° 15’ W and 730 m of altitude during the spring of 2009.

According Köppen, the local climate is classified as Aw (hot and semi-humid with dry season defined between may to September, and 23ºC of annual average temperature, with 29.8°C e 17.9°C of maximum and minimum average temperature, respectively). The annual average precipitation is 1,575.9 mm and the annual total isolation is of 2,588.1 hours.

The experiment was conducted under three shade nets of 16.00 x 12.00 x 2.20 m^3 and in field conditions. The treatments corresponded to four environmental shading conditions, namely: T1- field conditions; T2 - 30% red filter net in the visible and 30% transmission in the far red spectrum; T3 - 30% red filter net in the visible and 40% transmission in the far red spectrum. Each environment was divided in five beds with 1.00 m of width and 12.00 m of length and 1.00 m between each bed.

The sowing was performed in September 2009 by direct sowing of local variety in two lines per bed with spacing of 0.60 cm each other. After 30 days the plants were tutored in order to prevent the tipping and to allow more penetration of the solar radiation and ventilation through the crop canopy.

The data of air temperature and relative humidity, global solar radiation, photossinteticaly active radiation were monitored between October 20th and November 24th. The data were collected each ten seconds and the average values were registered each 10 minutes from sensor coupled to a weather station (WatchDog 2000 series model Plainfield, Ilinois, EUA). The solar radiation (SR, in W m^{-2}) and the photossinteticaly active radiation (µmol s^{-1} m^{-2}) on T2 and T3 environments were obtained by the pyranometer and a quantum sensor, respectively.

The data of solar radiation of the field condition (T1) were obtained from the extraterrestrial solar radiation (Qo, em W m^{-2}) (Equations 1 to 3) and substitution of values on the Equation 4.

$$\mathrm{Qo} = 37{,}6\,(\mathrm{d/D})^2[\pi\,/180\,\mathrm{hn}\,\mathrm{sen}\phi\,\mathrm{sen}\delta + \cos\delta\,\mathrm{sen}\,\mathrm{hn}] \qquad (1)$$

Where:

$(d/D)^2$ = correction factor for SR determination due to continually variation of Earth-Sun distance (Equation 2);

hn = horary angle of sunrise (Equation 3);
NDY = number of days elapsed in the year.

$$(d/D)^2 = 1 + 0{,}033 \cos (360\ NDY / 365) \tag{2}$$

$$hn = \arccos [-\tan\phi \tan\delta] \tag{3}$$

Substituting (1) in (4):

$$SR = Qo\ (a + b\ n/N) \tag{4}$$

n = number of hours of solar bright (h)
N = diary photoperiod (h)

The *a* and *b* values express the factors that affect the absorption and diffusion process and vary according with the locality. For the Goiânia city, Goiás, Brazil, are admitted the values 0.27 and 0.49, respectively to *a* and *b*.

The data were registered in µmol s^{-1} m^{-2} and converted in mol m^{-2} day^{-1}, adopting the Equation 5 (RADIN et al. 2003).

$$PAR = \Sigma_{daily}\left[\frac{PAR\left(\mu mol\ s^{-1}\ m^{-2}\right) x\ t(s)}{1{,}000.000}\right](mol\ of\ fotons\ m^{-2}\ day^{-1}) \tag{5}$$

For comparison purposes, the data were converted in MJ m^{-2} day $^{-1}$, using an only conversion value for the different environments, according Radin et. al. (2003), by Equation 6.

$$PAR = \Sigma_{daily}\left[\frac{PAR\left(\mu mol\ s^{-1}\ m^{-2}\right) x\ t(s) / 4{,}57}{1{,}000.000}\right](MJ\ m^{-2}\ day^{-1}) \tag{6}$$

Where, PAR is the photossinteticaly active radiation, t is the time between the collection, and 4.57 is the conversion value. All the values calculated each 10 minutes were added.

Around four weeks of sowing during the flowering it were collected samples of fruits after 0, 3, 6, 9 and 12 after the flowering in order to determined the followings variables: a) length (cm); b) diameter (cm); c) dry mass (g); and d) growth rate GR, in g day^{-1}), according the Equation 8.

$$GR = \left(\frac{D_{m2} - D_{m1}}{P}\right) \tag{8}$$

Where,
D_{s2} = dry mass at the last sampling (g);
D_{s1} = dry mass at the first sampling (g);
P = period between the samplings (days).

The crop productivity was obtained by the fresh mass of the fruits from all the ones harvest in each treatment. The relative productivity (RP, em %) were obtained by Equation 9.

$$RP = \frac{p}{P} x100 \tag{9}$$

Where,

p = productivity in each treatment, in kg m^{-2};
P = productivity in field condition, in kg m^{-2}.

In order to determined the effect of the quality of transmitted radiation spectrum in each environment, was use the parameter named PAR use efficiency. Thus, it was adjusted in a linear model, the dry mass total of the fruits (g m^{-2}) in function of the accumulated RFA. Therefore, the line angular coefficient represents the PAR use efficiency.

The experiment was designed in a randomized blocks. In order to perform the analysis of meteorological parameters, the replications and the blocks constituted to days and horary, respectively. The average values of variables were compared by Tukey test.

RESULTS AND DISCUSSION

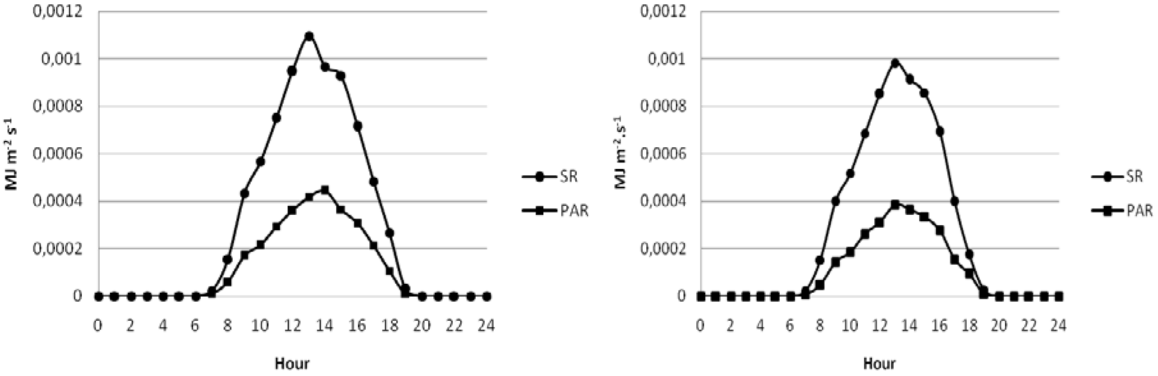
The field condition promoted more values of temperature, global solar radiation (SR) and photossinteticaly active radiation (PAR) than the photoselective shade nets as was expected (Table 1).

Table 1. Average values of the meteorological data obtained during the period between November 7th and 24th.

Treatments	Temperature (°C)	RH %	SR (MJ m^{-2} dia^{-1})	PAR (MJ m^{-2} dia^{-1})
T1	25.58 a[1]	72.94 b	19.08 a	9.54 a
T2	24.57 b	84.53 a	16.71 c	7.00 c
T3	25.18 ab	83.61 a	15.49 b	5.95 b

[1] At the column, average followed by the same letter does not differ each one by the Tukey test ($p < 0.01$).

Both the SR and PAR flux were more in the T2 than in the T3 conditions. Thus, the more global solar radiation attenuation was reached by T3 treatment. However the SR and PAR presented similar behavior in all environment conditions (Figure 2).



(a) (b)

Figure 2. Average values of global solar radiation (SR) and photossinteticaly active radiation (PAR) in field conditions and under T2 (a) and T3 (b) treatment during November 17th.

The Table 2 presents the average values of fruits characteristics collected on different shade nets and on field condition with 27 days harvest duration. The more average values of length, diameter and fresh mass were proportioned by the T3 photoselective net.

Table 2. Average values of fruits characteristics collected on different shade nets and on field condition.

Treatments	Days[1]	Length (cm)	Diameter (cm)	Fresh Mass (g)
T1	1	13.62	4.51	1905
	3	12.17	4.04	2570
	7	12.55	4.21	4016
	10	12.73	4.35	3310
	15	13.19	4.61	3670
	17	11.84	3.98	2435
	20	12.76	4.31	2065
	24	13.01	4.14	2010
	27	12.83	4.58	3645
	Average	12.74	4.30	2847.33
T2	1	13.78	4.68	755
	3	12.21	4.30	1150
	7	13.00	4.37	4798
	10	12.39	4.61	1070
	15	14.28	4.83	8650
	17	13.4	4.39	1310
	20	13.2	4.21	990
	24	13.76	4.52	2935
	27	12.22	4.25	1880
	Average	13.14	4.46	2615.33
T3	1	12.65	4.15	240
	3	11.11	3.71	1390
	7	13.56	4.51	5573
	10	12.75	4.36	2725
	15	13.96	4.86	7445
	17	13.03	4.08	2815
	20	12.56	4.18	1675
	24	13.89	4.66	4415
	27	12.27	4.00	330
	Average	12.86	4.34	2956.44

[1] Days after fruits reached the commercial size.

The productivity of crop followed the same behavior of the fruits characteristics. The best productivity was reached by the T3 treatment with an average of 11.09 kg m^{-2} (Table 3).

Table 3. Average values of crop productivity and relative productivity.

Treatment	Productivity	
	Per area (kg m^{-2})	Relative (%)
T1	10.68	100.00
T2	9.81	91.85
T3	11.09	103.84

The Figure 3 presents the productivity of cucumber (kg m^{-2}) as function of the accumulated photossinteticaly active radiation (MJ m^{-2} day^{-1}). The line angular coefficient was used in order to explained the PAR use efficiency by the cucumber. The PAR use efficiency was superior on T2 and T3 photoselective net than the field conditions (T1 environment). The presence of the net shade promoted better uniform distribution of radiation through the vegetable canopy. This favored the foliar expansion and, consequently, the radiation use efficiency. According the results the best efficiency was promoted by the T2 and T3 photoselective nets, respectively 0,057 and 0,079 kg MJ^{-1} day^{-1}.

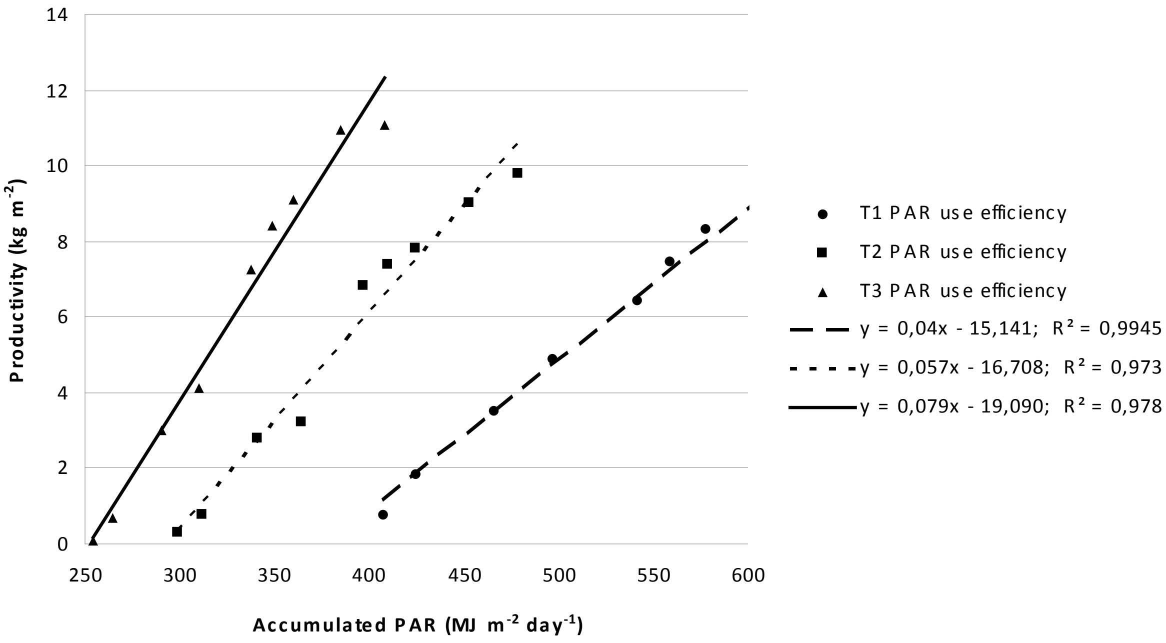


Figure 3. Photossinteticaly active radiation use efficiency explained by the productivity promoted on the different environments.

Although the environmet T1 had received more incident PAR, the biomass produced was lesser than that produced by T2 and T3 photoselective nets (Figure 3). In these last case, it there was more production of biomass with lesser disponibility of solar radiation. According the Figure 1, the superior photosynthesis rate promoted by the more infrared exposition can explained that difference between the treatments.

Papadopoulos and Ormrod (1988) and Hammer and Vanderlip (1989) obtained similar results and considered the more PAR use efficiency under plastics is explained by the increase of diffuse radiation. Aikman (1989) verified the increase of diffuse radiation promoted more uniformity of radiation through the canopy. It did the inferior leafs increased the efficiency of PAR interception and consequently promoted the increase of radiation use.

Sinclair and Horie (1989) verified the radiation use efficiency varies between the same species and that saturated leafs by radiation are less efficient than shaded ones. The more uniform distribution of solar radiation through the canopy tends does not saturate the most of leafs. This can justify the linear response of dry mass accumulation in function of PAR total (Russel et al., 1989).

The results of the crop growth rate (Figure 4) present a more stability of production for T3 condition. In this case the maximum crop growth rate was reached earlier than the others treatments at the sixth day of harvest beginning with 0,823 g day^{-1}.

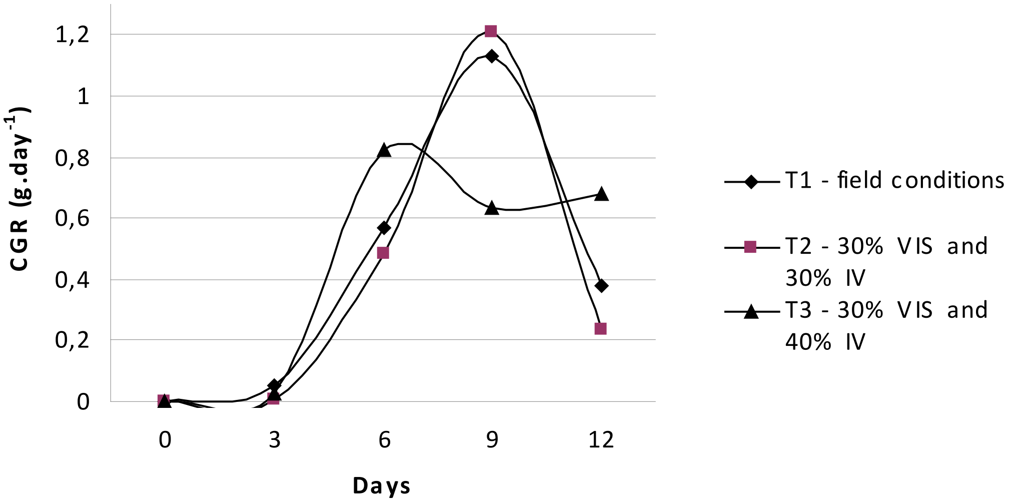


Figure 4. Crop growth rate (CGR, in g day^{-1}) of cucumber under different environmental conditions.

CONCLUSION

1. Both photoselective shade net promoted significant changes on the meteorological elements.
2. The 30% red filter net in the visible spectrum and 40% transmission in the far red spectrum (T3) promoted more uniform growth during the crop cycle and the best results in terms of production.
3. At the final of cycle, the 30% red filter net in the visible spectrum and 40% transmission in the far red spectrum (T3) promoted the best PAR efficiency, since it was reached the best productivity for the less intercepted photossinteticaly active radiation.

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