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Sprouting of pre-sprouted sugarcane seedlings and micrometeorological variables under photo-selective nets

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ABSTRACT: Sugarcane is a grass species that stands out worldwide in the production of ethanol. Brazil is the world's largest producer and leader in exports, responsible for more than 50% of the products that are marketed worldwide. The objective of this study was to investigate the effect of photo-selective nets on micrometeorological variables and on sprouting of pre-sprouted sugarcane seedlings. The experiment was carried out in a protected environment at Universidade Federal Rural de Pernambuco - UFRPE, in a completely randomized design. Seedlings of cultivar RB92579 were obtained by the technique of production of pre-sprouted seedlings. The protected environment was divided into four modules corresponding to the treatments: covered with anti-UV low-density polyethylene plastic: + Solpack® red ultranet net, + Solpack® white net, + Solpack® freshnet net and without shade net. Micrometeorological data of air temperature and substrate temperature were recorded in each module. The first count of emergence, sprouting speed index and sprouting percentage were calculated. Principal component analysis was used to verify the association between the cultivation modules and the micrometeorological and sprouting variables of the seedlings. Air temperature in the protected environment was 8.7% higher than that in the external environment. The white net led to sprouting of 78.93%. The substrate temperature above 30.4 °C favored seedling sprouting. The modules with white net and red ultranet net favored seedling sprouting.

Key words: *Saccharum officinarum*, protected environment, shade net, propagation of seedlings

Brotação de mudas pré-brotadas de cana-de-açúcar e variáveis micrometeriológicas sob malhas fotosseletivas

RESUMO: A cana-de-açúcar é uma gramínea que se destaca mundialmente na produção de etanol. O Brasil é o maior produtor mundial e líder na exportação, responsável por mais de 50% dos produtos derivados que são comercializados no mundo. Objetivou-se averiguar a influência de malhas fotosseletivas nas variáveis micrometeorológicas e na brotação de mudas pré-brotadas de cana-de-açúcar. A pesquisa foi realizada em ambiente protegido na Universidade Federal Rural de Pernambuco, em delineamento inteiramente casualizado. As mudas da cultivar RB92579 foram obtidas pela técnica de produção de mudas pré-brotadas. O ambiente protegido foi dividido em quatro módulos, correspondentes aos tratamentos: coberto com plástico polietileno de baixa densidade anti-UV + malha ultranet vermelha Solpack®, + malha branca Solpack®, + malha freshnet Solpack® e sem malha de sombreamento. Foram registrados os dados micrometeorológicos de temperatura do ar e temperatura do substrato em cada módulo. Foram calculadas a primeira contagem de emergência, o índice de velocidade de brotação e a porcentagem de brotação. Foi utilizada a análise multivariada de componentes principais para verificar a associação entre os módulos de cultivo e as variáveis micrometeorológicas e de brotação das mudas. A temperatura do ar no ambiente protegido foi 8.7% maior em relação ao ambiente externo. A malha branca proporcionou 78,93% de brotação. A temperatura do substrato acima de 30,4 °C favoreceu a brotação das mudas. Os módulos com malha branca e ultranet vermelha favoreceram a brotação das mudas.

Palavras-chave: *Saccharum officinarum*, ambiente protegido, malha de sombreamento, propagação de mudas

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Introduction

Sugarcane is a monocotyledon, allogamous and perennial plant probably native of New Guinea, from where it was taken to Asia, initially used in the form of syrup. Global sugarcane production surpasses 1700 million tons in 24 million hectares. Brazil is the largest sugarcane producer in the world, with 735 million tons (FAOSTAT, 2016).

In this scenario, it is necessary to develop new technologies that increase the profitability for the producer. One of these technologies is the production of pre-sprouted seedlings (PSS), which is an alternative to conventional planting, allowing greater control of seedling quality, vigor and health (Landell et al., 2013).

It is known that sugarcane sprouting is a characteristic of the varieties, and each one shows a different response according to the environmental conditions, especially luminosity and temperature. Sprouting of culms of pre-sprouted sugarcane seedlings in protected environment is also influenced by bud position and propagule formation age (Manhães et al., 2015; Maqbool et al., 2016; Ram et al., 2017).

Therefore, through the management of global solar radiation it is possible to maintain the other micrometeorological elements within a range that favors seedling production. The air temperature ranging from 25 to 33 ºC is the most adequate for sugarcane growth (Ferreira Junior et al., 2012), substrate temperature in the range from 23 to 32 ºC leads to sprouting percentage above 90% (Clementes, 1940), and the red spectrum strongly affects the vegetative growth, photosynthesis, flowering and sprouting (Singh et al., 2015).

The objective of this study was to investigate the effect of photo-selective nets on micrometeorological variables and on sprouting of pre-sprouted sugarcane seedlings.

Material and Methods

The study was carried out at the Universidade Federal Rural de Pernambuco (UFRPE), in the municipality of Recife, PE State, Brazil, at the coordinates 8º 4' 3" S and 34º 55' 0" W, at altitude of 13 m. The climate is characterized as megathermal (As'), with mean annual temperature of 25.2 ºC according to Köppen's classification (Pereira et al., 2002).

A protected environment with an arched structure was used. It was covered with low-density polyethylene (LDPE) plastic with anti-ultraviolet (anti-UV) additive, 50% shade net on the sides, and dimensions of 21 m length, 7 m width, 3 m ceiling height, 4.5 m total height and 147 m².

The seedlings were obtained by the technique of production of pre-sprouted seedlings (PSS) adapted from the methodology proposed by Landell et al. (2013), but the sprouting stage in the present study was carried out in a protected environment. Such modification consisted in planting mini-setts of the sugarcane cultivar RB92579 on 15-cell trays, using coconut powder as substrate in the conduction of the sprouting processes in the same protected environment where seedlings were grown.

The trays were placed in protected environment, where irrigations were performed every 2 days until the beginning of the sprouting process, in order to prevent the propagative material from rotting.

Seedling production was conducted under sub-irrigation system, which consists of a cultivation platform with a water tank, a submerged pump and an analog timer. The timer was programmed to turn the pump on every day at 7 h, pumping the nutrient solution for 15 min to the highest part of the cultivation platform, which was conducted by capillarity through the substrate to the roots.

The experiment was set up in a completely randomized design, with four treatments (modules) and five repetitions, which totaled 20 experimental units constituted by 75 seedlings, with a total of 1500 seedlings.

The protected environment was divided into four modules: anti-UV LDPE + Solpack® red ultranet net with 35% shading (anti-UV LDPE + red ultranet), anti-UV LDPE + Solpack® white net with 50% shading (anti-UV LDPE + white), anti-UV LDPE + Solpack® freshnet thermo-reflective net with 50% shading (anti-UV LDPE + freshnet) and anti-UV LDPE without shade net (anti-UV LDPE). The nets were positioned at 0.15 m height from the trays, until 12 days after planting (DAP).

Energy availability from the external environment was characterized using sensors, which allowed continuous recording of air temperature (Tair; °C), connected to a datalogger (Campbell® - CR1000 model).

Substrate temperature (Tsubs, °C) and air temperature (Tair, °C) in each cultivation module were recorded using HOBOware® mini-dataloggers. The sensors were installed in the geometric center of the cultivation modules, which were 1.0 m wide, 1.75 m long and 0.15 m high, i.e., half the length, half the width and at a 1.0 m height from the soil. The data were measured every second and means were recorded at 15-min and daily, until obtaining the seedlings for transplanting.

The effect of the photo-selective nets was evaluated based on global solar radiation, photosynthetically active radiation, air temperature, relative air humidity, substrate temperature and on sugarcane sprouting variables.

The substrate temperature (TSUBS, °C), air temperature (TAIR, °C) and relative air humidity (RH, %) of each cultivation module were recorded by mini-dataloggers from HOBOware®. The data of global solar radiation (GSR; CMP3 Pyranometer LI200/R sensor; 400-1100 nm) and photosynthetically active radiation (PAR; LI190SB Quantum sensor; 400-700 nm) were recorded by connected sensors to a data logger from Campbell® (CR1000 model). The sensors were installed in the geometric center of the cultivation modules.

The following analyses were carried out since the beginning of the sprouting process until emergence stabilization: First count of emergence (FCE) - emerged plants were counted, considering as emerged those whose epicotyl was above the substrate level at 4 days after planting (DAP); Sprouting speed index (SSI) - calculated according to the methodology described by Nakagawa (1994) until 12 DAP; Sprouting percentage (%S) - ratio between the number of emerged seedlings and the number of buds planted until stabilization at 12 DAP.

The association between cultivation modules, micrometeorological variables and sugarcane sprouting variables was assessed by principal component analysis based on the matrix of correlation between the variables.

Results and Discussion

The air temperature (Tair) in the internal environment was 7.7% higher than in the external environment (Table 1), because inside the protected environment Tair is a function of the amount of radiation entering and the amount of energy retained due to the presence of the covering plastic. Reis et al. (2013) observed that air temperature in the protected environment was 7.2% higher than that recorded in the external environment.

Inside the protected environment, the highest value of Tair (30.78 °C) was recorded in the module covered with anti-UV LDPE and the lowest mean value (29.82 °C) in the cultivation module covered with anti-UV LDPE + freshnet (Table 1). Tair values recorded in the modules remained within the range from 25 to 33 °C (Figure 1), which is the most adequate for sugarcane growth (Ferreira Junior et al., 2012). Air temperatures below 20 °C cause physiological rest and growth stoppage.

The mean substrate temperature (Tsubs) was higher in the module with anti-UV LDPE + white (33.58 °C) and lower in the module covered with anti-UV LDPE + freshnet (28.52 °C), compared to the other cultivation modules (Table 1). The ideal range of soil temperature to reach bud sprouting percentage above 90% is between 23 and 32 °C. In turn, soil temperatures below 21 °C strongly limit plant growth and sprouting; above this temperature, there is a progressive increase in sprouting (Clementes, 1940). Silva et al. (2013) report that the thermo-reflective net promotes lower substrate temperature and, therefore, better conditions for the development of seedling radicles, elevating seedling emergence speed.

There were high coefficients of determination between Tair and Tsubs in the modules covered with anti-UV LDPE + red ultranet and anti-UV LDPE + white (R^2 > 0.90), evidencing high linear association between the two variables (Figure 2). The similarities between the Tsubs-Tair relationships observed in the regressions with data of 15 min and Tsubs-Tair relationships found with mean data confirm the results obtained in Table 1.

The angular coefficients of the equations denote that Tsubs was 9.8% higher than Tair in the module with anti-UV LDPE + white (Figure 2B), and 0.62, 5.53 and 5.97% lower than Tair in the modules with anti-UV LDPE + red ultranet (Figure 2A), anti-UV LDPE + freshnet (Figure 2C) and anti-UV LDPE (Figure 2D), respectively.

The first and second principal components explained 48.3 and 27.7% of the total data variation, respectively (Figure 3).

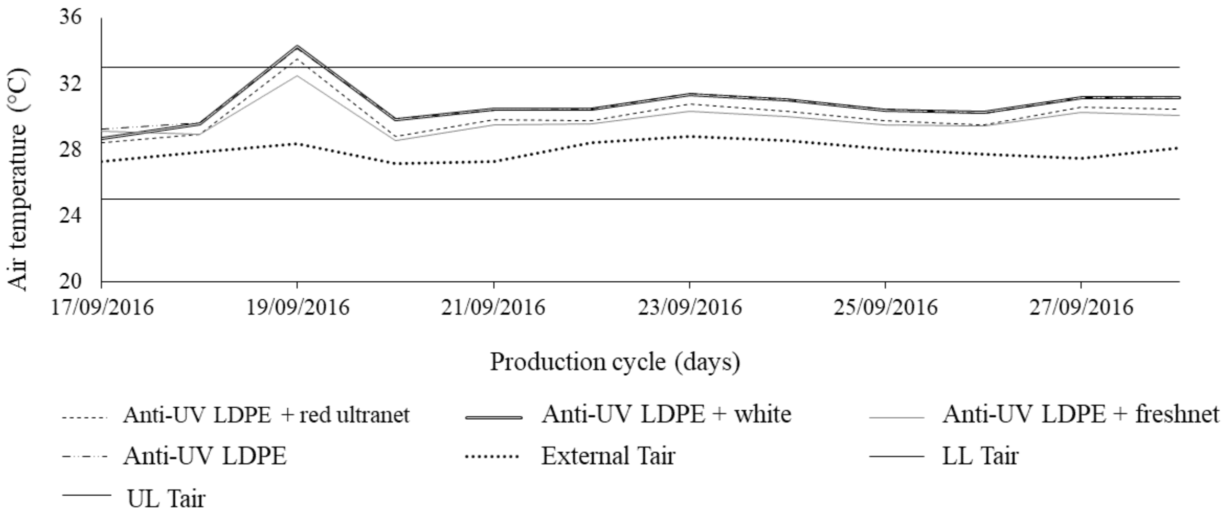
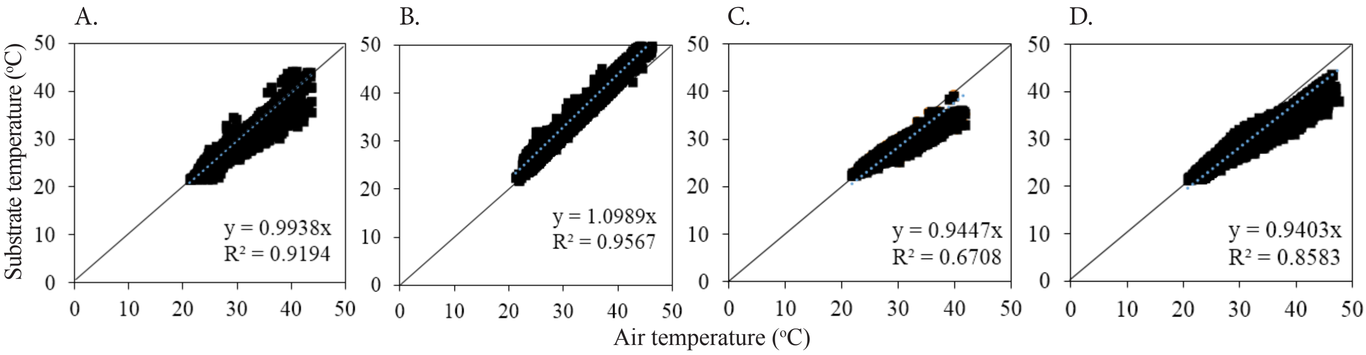


Figure 1. Air temperature (Tair; °C) in the protected environment and substrate temperature (Tsubs; °C) in the modules covered with: anti-UV LDPE + red ultranet; anti-UV LDPE + white; anti-UV LDPE + freshnet; anti-UV LDPE, and lower limit (LL Tsubs) and upper limit (UL Tsubs) of Tsubs for sugarcane growth and sprouting until 12 days after planting

Table 1. Mean values of air temperature (Tair), substrate temperature (Tsubs), variation of air temperature relative to the external environment (ΔTair), variation of substrate temperature relative to air temperature (ΔTsubs-Tair), global solar radiation (Rg), photosynthetically active radiation (PAR), relative air humidity (RH), first count of emergence (FCE), sprouting percentage (%S), sprouting speed index (SSI) in the modules covered with anti-UV LDPE + red ultranet, anti-UV LDPE + white net, anti-UV LDPE + freshnet and anti-UV LDPE, and in the external environment until 12 DAP

Module	Anti-UV LDPE + red ultranet	Anti-UV LDPE + white net	Anti-UV LDPE + freshnet	Anti-UV LDPE	External environment
Tair (°C)	30.06	30.72	29.82	30.78	27.92
Tsubs (°C)	30.44	33.58	28.52	29.26	
ΔTair (%)	5.33	6.28	4.07	7.92	
ΔTsubs-Tair (%)	1.22	8.52	4.56	5.19	
Rg (MJ m^{-2} d^{-1})	7.05	8.60	5.07	11.39	19.52
PAR (MJ m^{-2} d^{-1})	2.74	2.40	1.85	4.02	
RH (%)	67.61	68.71	67.64	65.14	70.64
FCE (%)	1.33	2.40	2.67	1.60	
%S (%)	76.80	78.93	68.80	60.27	
SSI	5.87	6.33	5.46	4.80	

Anti-UV LDPE – low-density polyethylene with anti-ultraviolet additive



Anti-UV LDPE – low-density polyethylene with anti-ultraviolet additive

Figure 2. Relationship between substrate temperature (Tsubs) in the studied modules and air temperature (Tair) in the protected environment. (A) in the module covered with anti-UV LDPE + red ultranet; (B) in the module covered with anti-UV LDPE + white; (C) in the module covered with anti-UV LDPE + freshnet and (D) in the module covered with anti-UV LDPE

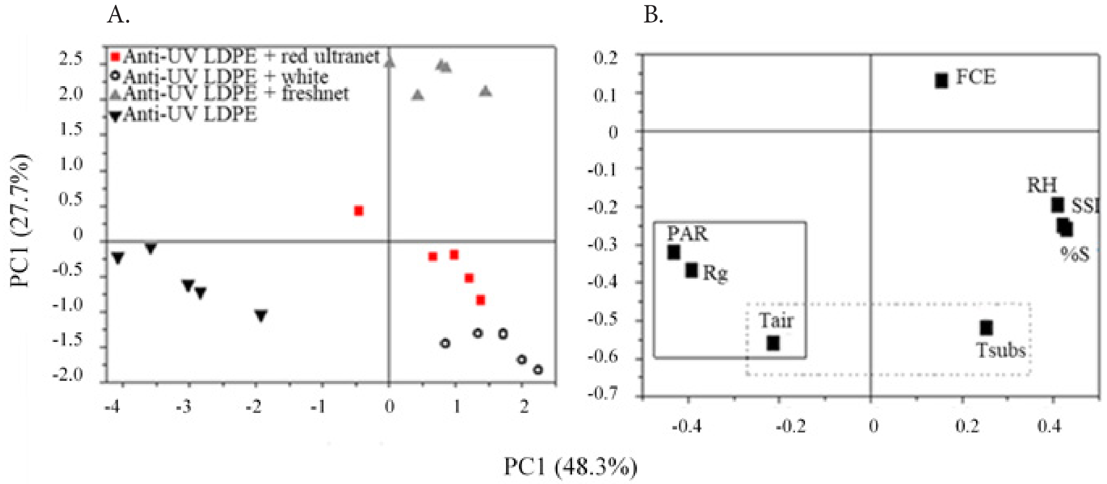


Figure 3. Scores of the principal component 1 (PC1) and principal component 2 (PC2) of the modules (A; objects) and sprouting variables (B; loadings): first count of emergence (FCE); sprouting speed index (SSI); sprouting percentage (%S); substrate temperature (Tsubs); air temperature (Tair); relative air humidity (RH); global solar radiation (Rg); photosynthetically active radiation (PAR) until 12 DAP

The first count of emergence (FCE) was higher in the module covered with anti-UV LDPE + freshnet, due to the similarity in the location of these components in the graphs of the modules (Figure 3A) and of the variables (Figure 3B). FCE was negatively correlated with the variables global solar radiation (Rg) (r = - 0.32), photosynthetically active radiation (PAR) (r = - 0.28) and air temperature (Tair) (r = - 0.11).

Thus, the higher the values of Rg, PAR and Tair in the cultivation module, the longer the time required for seedlings to start emerging. Nascimento et al. (2011) reported that very high temperatures compromise the beginning of the germination, reducing germination speed and final percentage, due to the inactivation of some enzymes directly linked to this process.

In addition, the module covered with anti-UV LDPE + freshnet reduces the time required for bud sprouting because it possibly accumulates higher percentage of the red spectrum (625-740 nm) of the solar radiation and this spectrum is characterized by strongly affecting sprouting (Singh et al., 2015).

Modules covered with anti-UV LDPE + red ultranet and anti-UV LDPE + white showed greater association with the variables sprouting speed index (SSI), sprouting percentage (%S), relative air humidity (RH) and substrate temperature (Tsubs) (Figures 3A and B). Average Tsubs of 30.2 and 32.9 °C were recorded in these modules, respectively.

The ideal range of soil temperature for adequate sugarcane growth is between 25 and 33 °C (Aude, 1993). Soil temperatures below 21 °C strongly limit bud sprouting (Clementes, 1940). Oliveira et al. (2012) emphasize that the white shade net conserves greater amount of energy from solar radiation, which increases Tair by up to 1.3 °C, and such increment may also be related to the increase in Tsubs in this cultivation module.

SSI was more influenced by the micrometeorological variables relative humidity (RH) (r = 0.64) and substrate temperature (Tsubs) (r = 0.56). The highest SSI values were obtained in the modules covered with anti-UV LDPE + white (6.33) and anti-UV LDPE + red ultranet (5.87) (Figure 3). Matoso et al. (2016) observed SSI between 3.54 and 3.79 for different sugarcane cultivars.

As occurred with SSI, %S was more influenced by RH (r = 0.73) and Tsubs (r = 0.55) (Figure 3B). Silva et al. (2004) observed sprouting percentage above 74% under conditions of average RH of 80%. The highest Tsubs in the modules with anti-UV LDPE + red ultranet and anti-UV LDPE + white favored the SSI and %S of pre-sprouted sugarcane seedlings, which occurred because the temperature interferes with sprouting speed, percentage and uniformity, biochemical reactions, cell differentiation and action of enzymes which perform cell division (Arrigoni-Blank et al., 2014; Silva et al., 2016).

Conclusions

1. The module covered with anti-UV LDPE + freshnet promoted the lowest transmittance of Rg and PAR. Air temperature in the protected environment was 8.7% higher than that in the external environment.

2. The module covered with anti-UV LDPE + freshnet reduced the time required for seedlings to start sprouting.

3. White net led to sprouting of 78.93%. Substrate temperature within the range from 30.44 to 33.58 °C favored seedling sprouting.

4. Modules with white net and red ultranet favored seedling sprouting.

Acknowledgements

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