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Light environments and phosphorus doses in the growth of basil plants

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ABSTRACT: The objective of this work was to evaluate the development of basil plants cultivated in modified light environments with the use of color shading nets under different dosages of phosphate fertilization. The experimental design was a randomized block factorial design 4 x 3, with the treatments: 0, 50; 100 and 200 kg ha^{-1} P_2O_5 using shading nets in colors: blue and red, with 50% shading and full sun, and five replications. After 120 days of cultivation, analyzes of the growth of basil plants were carried out, in addition to the phosphorus content in the roots. There was a significant interaction between phosphorus doses and light environments for the number of leaves, leaf area, specific leaf area, leaf area ratio and leaf weight ratio. Basil plants grown in full sun at the maximum phosphorus dosage (200 kg ha^{-1} P_2O_5) showed significantly higher results than those grown under shade. However, it is worth noting that the shaded environment provided higher height and dry mass production, in addition to higher phosphorus levels in the roots. It was concluded that the interaction of color shading nets with the phosphate fertilization presented positive results in relation to the development of the basil plants.
Keywords: luminosity, medicinal plant, shading, *Ocimum basilicum* L.

Ambientes de luz e doses de fósforo no crescimento de plantas de manjericão

RESUMO: O objetivo do trabalho foi avaliar o desenvolvimento das plantas de manjericão cultivadas em ambientes de luz modificada com o uso de malhas fotoconversoras sob diferentes dosagens de adubação fosfata. O delineamento experimental foi em blocos ao acaso em esquema fatorial 4 x 3, sendo os tratamentos: 0;50; 100 e 200 kg ha^{-1} de P_2O_5, e três ambientes de luz utilizando malhas fotoconversoras nas cores : azul e vermelho com 50% de sombreamento e a pleno sol, com cinco repetições. Após 120 dias de cultivo foram realizadas análises de crescimento das plantas de manjericão, além do teor de fósforo nas raízes. Observou-se interação significativa entre as doses de fósforo e os ambientes de luz para as variáveis número de folhas, área foliar, área foliar especifica, razão de área foliar e razão de peso foliar. Plantas de manjericão cultivadas a pleno sol na dosagem máxima de fósforo (200 kg ha^{-1} P_2O_5) apresentaram resultados significativamente superiores em relação àquelas cultivadas sob sombreamento. Porém vale ressaltar que o ambiente sombreado proporcionou maior altura e produção de massa seca, além de maiores teores de fósforo nas raízes. Conclui-se que a interação das malhas fotoconversoras com a adubação fosfatada apresentou resultados positivos em relação ao desenvolvimento das plantas de manjericão.
Palavras-chave: luminosidade, planta medicinal, sombreamento, *ocimum basilicum* L.

1. INTRODUCTION

Basil (*Ocimum basilicum* L.*)*, an aromatic sub-shrub native to Asia and cultivated for spice and medicinal use, is considered a species of economic interest since its essential oil has a substance called linalool, which presents marketing importance mainly for perfumery, cosmetics, food and pharmaceutical industries (LORENZI; MATOS, 2008 AMARO et al., 2012). In addition, it presents a great medicinal potential, acting against problems in airways as a decongestant, antiseptic activity against bacterial infections, besides improving the digestion of foods. It also acts as a vermifuge on intestinal parasites (LORENZI; MATOS, 2008).

Knowledge about the reproductive biology of medicinal and spice species is essential to ensure the establishment of plants in the field. Despite several uses in popular culture, few studies have been carried out in relation to seedling production and cultivation of basil. A number of factors may influence plant growth, such as light and nutrient availability, whose deficiency or excess may promote a greater or lesser production of drugs using the plant (MARTINS et al., 2000).

Light is the main factor controlling the growth and development of plants, which are affected in complex ways by irradiance at all stages of growth. According to Peralta et al. (2002), plant responses to light include a variety of physiological and biochemical adaptations translated into growth rate, plant architecture and morphological characteristics.

In this sense, techniques that improve light quality such as the use of shading nets have contributed to changes in the light quality of the growing environment and improvement in photosynthesis, causing a greater efficiency of use (SOUZA et al., 2011). Such nets have the purpose of combining physical protection with differential filtration of solar radiation to promote specific physiological responses regulated by light (BRANT et al., 2009).

Another factor influencing the development of plants is mineral nutrition and, among nutrients, phosphorus deserves

to be highlighted by the great influence exerted on the production of biomass in plants. Phosphorus is one of the nutrients that limit plant growth the most, especially at the seedling stage, which presents an underdeveloped root system. The normal nutrient level in the soil should be higher for seedlings than for plants under production (CARMO et al., 2014). The beneficial effects of phosphorus on plant development depend on the amount of nitrogen available to the plant, in addition to the adequate dose of this nutrient (SANTINATO et al., 2014).

However, phosphorus deficiency causes immediate disturbances in plant metabolism and development, with a marked reduction in growth, delay in flowering and reduced leaf number (SILVA et al., 2010; SANTINATO et al., 2014).

However, agronomic studies on the influence of phosphate fertilization and shading nets on medicinal plants, especially maize, are still scarce. Thus, the study of the influence of shading nets and phosphate fertilization on growth, yield and composition of basil essential oil aims to offer producers of these species more efficient alternatives to obtain significantly better economic results in the agronomic production of plants.

In this sense, the objective of this work is to evaluate the growth, physiological indexes and phosphorus levels in basil plants cultivated in light-modified environments using shading nets and different doses of phosphate fertilization.

2. MATERIALS AND METHODS

This study was carried out from December 2012 to April 2013 at the experimental field of the Federal University of the Recôncavo da Bahia. The soil used was the Cohesive Alic Yellow Latosol according to the Brazilian Soil Classification System.

Initially, a 0-20 cm soil layer sampling was performed, which was analyzed as for chemical composition. The chemical characteristics of the soil were pH in H_2O (6.65), P (18 mg dm^3), K (55 $mgdm^{-3}$), Ca (8.6 $cmol_c\ dm^{-3}$), Mg (3.9 $cmol_c\ dm^3$), Al (0 $cmol_c\ dm^{-3}$), H+Al (0.69 $cmol_c\ dm^{-3}$), CEC (13.56 $cmol_c\ dm^{-3}$), V (94.4%) and OM (21 g kg^{-1}), which were performed in the soil and nutrition laboratory of Embrapa Mandioca and Fruticultura, Cruz das Almas, Bahia.

Sowing for basal seedlings (*Ocimum Basilicum* L.) was carried out in plastic trays using washed sand + organic compound as substrate. The trays were kept in a greenhouse under 50% shading for 30 days. Subsequently, the seedlings were transplanted into plastic containers with a capacity of 4 liters: 3.8 liters of soil-based substrate, 0.2 liters of washed sand applied together. Irrigation was performed manually and daily for a good development of plants.

The experiment was completely randomized blocks in a 4 x 3 factorial design, and the treatments were 0, 50, 100 and 200 kg ha^{-1} of P_2O_5 under different lightness conditions (50% shading). Such shading was obtained by using photovoltaic nets: 1 - Red ChromatiNet net, 2 - ChromatiNet Blue net, 3 - Control: treatment in full sun (0% of shading). There were five replications, totaling 60 plants. The plants in pots remained in the field under the nets and in full sun for 120 days, during which time they were evaluated to obtain the results. The leaf material of basil plants was collected monthly, totaling four evaluations.

Linear and non-linear biometrics were measured. Non-linear biometric measurements were determined from leaf area, dry plant weight and leaf dry weight, according to Benincasa (2004), using the following formulas:

$$LAI = LAtotal/SA \quad \text{(Equation 01)}$$
$$SLA = LA/DMleaf \quad \text{(Equation 02)}$$
$$LAR = LAtotal/DMtotal \quad \text{(Equation 03)}$$
$$LWR = DMleaf/DMtotal \quad \text{(Equation 04)}$$

where: LAI = leaf area index; LA = leaf area; SA = soil area; DM = dry matter; SLA = specific leaf area; LAR = leaf area ratio; LWR = leaf weight ratio.

The total leaf area per plant was measured using a portable ADC leaf area meter "AM300 Area Meter". Linear biometric measurements were number of leaves, plant height and stem diameter. They were determined in both collections using a ruler and a pachymeter with an accuracy of 0.1 cm, respectively. After the last collection, the parts (root, stem and leaf) of the plants were separated and dehydrated in a greenhouse with forced air circulation at 65° ± 5°C for 72 hours to measure the dry matter in an precision analytical balance, and later grinding of samples for an appropriate chemical analysis.

The determination of the phosphorus levels of roots of basil plants was carried out at the Laboratory of Mineral Nutrition of Plants of the Federal University of the Recôncavo da Bahia, following the methodology of Murphy and Riley (1962) and Watanabe and Olsen (1965).

The data were submitted to analysis of variance, performing a progression study, and Tukey test ($P \leq 0.05$), using the statistical software SISVAR (Ferreira, 2008).

3. RESULTS

Analysis of variance revealed that there was a significance for the interaction between phosphorus doses and light environments to which the basil plants were submitted in relation to the number of leaves. There was an increase of 71% and 34% of this variable at the dose 100 kg ha^{-1} of phosphorus in plants grown in full sun compared to those cultivated under the red and blue nets, respectively. It is noteworthy that there was no significant difference among plants grown under nets (Table 1). The use of the doses 0, 50 and 200 kg ha^{-1} of phosphorus did not differ statistically for the variable number of leaves. However, the highest value (406.6) was obtained at the dose 100 kg ha^{-1} of P_2O_5 when grown in full sun (Table 1). This value reveals how much phosphorus had a positive effect on these plants.

The derivation of the regression equation indicates that the optimum dose, estimated at 118.5 kg ha^{-1} of P_2O_5, allowed a maximum number of leaves (371 leaves) for plants grown in full sun (Figure 1). In relation to stem diameter, no significant effect was observed for the interaction of phosphorus doses and colored nets. However, regardless of the dose used, plants grown in full sun, both in absence and presence of phosphorus, presented results significantly higher than those grown under shading using red and blue nets (Table 1). There was no significance at doses 0, 50 and 200 kg ha^{-1}. However, plants cultivated with 100 kg ha^{-1} of phosphorus had a significant effect when compared to the different conditions of luminosities studied, showing that plants grown under full sun presented higher values (0.54 cm).

Table 1. Mean values for number of leaves, stem diameter and leaf area of basil plants cultivated under different light conditions in function of phosphorus doses.
Tabela 1. Valores médios das variáveis número de folhas, diâmetro do caule e área foliar de plantas de manjericão cultivadas nas condições de luminosidade em função das doses de fósforo.

Number of Leaves				
Luminosity	Doses of P_2O_5 (kg ha^{-1})			
	0	50	100	200
Blue net	323.1 a	254.6 a	304.0 b	258.2 a
Red net	264.4 a	300.0 a	238.2 b	323.6 a
Full Sun	301.4 a	291.6 a	406.6 a	331.2 a
Stem diameter (cm)				
Luminosity	Doses of P_2O_5 (kg ha^{-1})			
	0	50	100	200
Blue net	0.44 a	0.48 a	0.48 ab	0.40 a
Red net	0.40 a	0.44 a	0.38 b	0.44 a
Full Sun	0.48 a	0.40 a	0.54 a	0.50 a
Leaf area (cm²)				
Luminosity	Doses of P_2O_5 (kg ha^{-1})			
	0	50	100	200
Blue net	1,035.66 a	918.42 a	964.3 ab	771.9 b
Red net	762.38 ab	846.00 a	709.28 b	849.64 b
Full Sun	728.06 b	834.70 a	1,172.88 a	1,222.38 a

Means followed by the same letters in rows and lines do not differ statistically by Tukey test at 5% significance.

Plants cultivated under full sun presented higher values of leaf area (LA) at the doses 50, 100, 200 kg ha^{-1}, evidencing that, when submitted to different light conditions, basil plants have higher values of leaf area at 0% shading (Table 1).

Plants cultivated under full sun presented higher values of leaf area (LA) at the doses 50, 100, 200 kg ha^{-1}, evidencing that, when submitted to different light conditions, basil plants have higher values of leaf area at 0% shading (Table 1).

In the unshaded environment, plants cultivated under omission of phosphorus differed statistically from the other doses, presenting a lower value (728.06 cm²) of leaf area. However, at high concentrations of phosphorus, plants grown under full sun had 58% greater leaf area values than those under blue net, and 44% higher than under red net (Table 1).

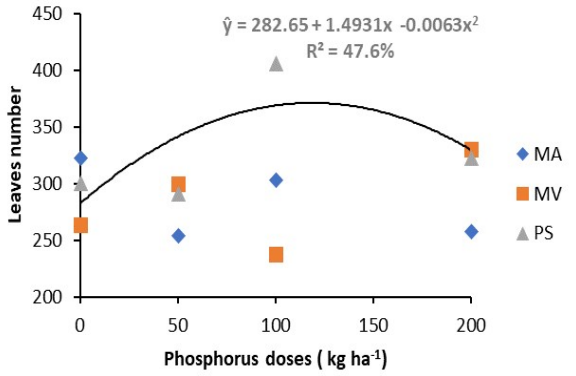

Figure 1. Mean values of the number of leaves per basil plants, submitted to the interaction between nutrient phosphorus and different light qualities. Where: MA = Blue mesh, MV = Red mesh, PS = Full sun.
Figura 1. Valores médios do número de folhas por plantas de manjericão, submetidas à interação entre o nutriente fósforo e diferentes qualidades de luz. Onde: MA= Malha azul, MV= Malha vermelha, PS= Pleno sol.

By analyzing the variable plant height, there was no significant effect for the interaction between phosphate fertilization and light quality. A significant effect was observed only when light conditions were compared.

Basil plants cultivated under blue light were higher (47.85 cm) than those grown under red net and full sun (Table 2). There was a 35% increase in the height of plants cultivated under blue net in relation to plants grown in full sun. There was a lower height in plants cultivated in full sun, showing that basil plants cultivated under intense radiation tend to present a lower production of photoassimilates, and consequently a lower growth.

Table 2. Mean height values of basil plants grown under different light conditions.
Tabela 2. Valores médios da altura das plantas de manjericão cultivadas em diferentes condições de luminosidade.

Luminosity	Plant height (cm)
Blue net	47.85 a
Red net	41.27 b
Full Sun	35.47 b

Means followed by the same letters in rows do not differ statistically by Tukey test at 5% significance.

A linear increase in LA was observed, presenting better results (1,222.38 cm²) at the maximum dose used (200 kg ha^{-1} of P_2O_5) (Figure 2A), indicating that this variable may respond to an increase in phosphorus doses in the system.

There was a linear increase in leaf area ratio (LAR) in the full sun condition, with a higher value (83.62 cm² g^{-1}) at the maximum dose applied. However, by analyzing the blue net environment, a decrease in LAR values was observed (Figure 2C) as the applied phosphorus doses increased.

The increase in phosphorus doses favored the increase of LAR in plants grown in full sun, presenting values 72% higher in relation to the blue net and 61% higher by plants grown under red net (Figure 2C).

However, conflicting results were observed with respect to this variable, since plants cultivated under blue net and full sun differed statistically from each other, not differing from those cultivated under the red net (Table 3).

Figure 2D shows the mean values of leaf weight ratio (LWR) in function of the dose of P_2O_5 used. There was a significant effect only in plants cultivated in full sun, where linear increases were observed with the increase in the doses of P_2O_5. The higher the LWR values, the better the crop performance, indicating that there is a greater production of photoassimilates.

Under full sun, basil plants only showed lower results when submitted to the minimum dosage of P_2O_5, i.e., in the absence of phosphorus, presenting higher values of LWR (0.57) at the dose 100 kg ha^{-1} (Table 3).

LWR is important because it is related to the performance of the crop, as it expresses the dry matter fraction that is not exported to the rest of the plant. A greater or lesser export of the leaf material can be a genetic characteristic influenced by environmental variations.

Fertilized plants with doses of 50 and 100 kg ha^{-1} presented better SLA results regardless of the luminosity condition used (Table 4). Under the red and blue nets, the plants did not statistically differ at the doses 0, 50 and 100 kg ha^{-1}, but differed from plants cultivated in full sun.

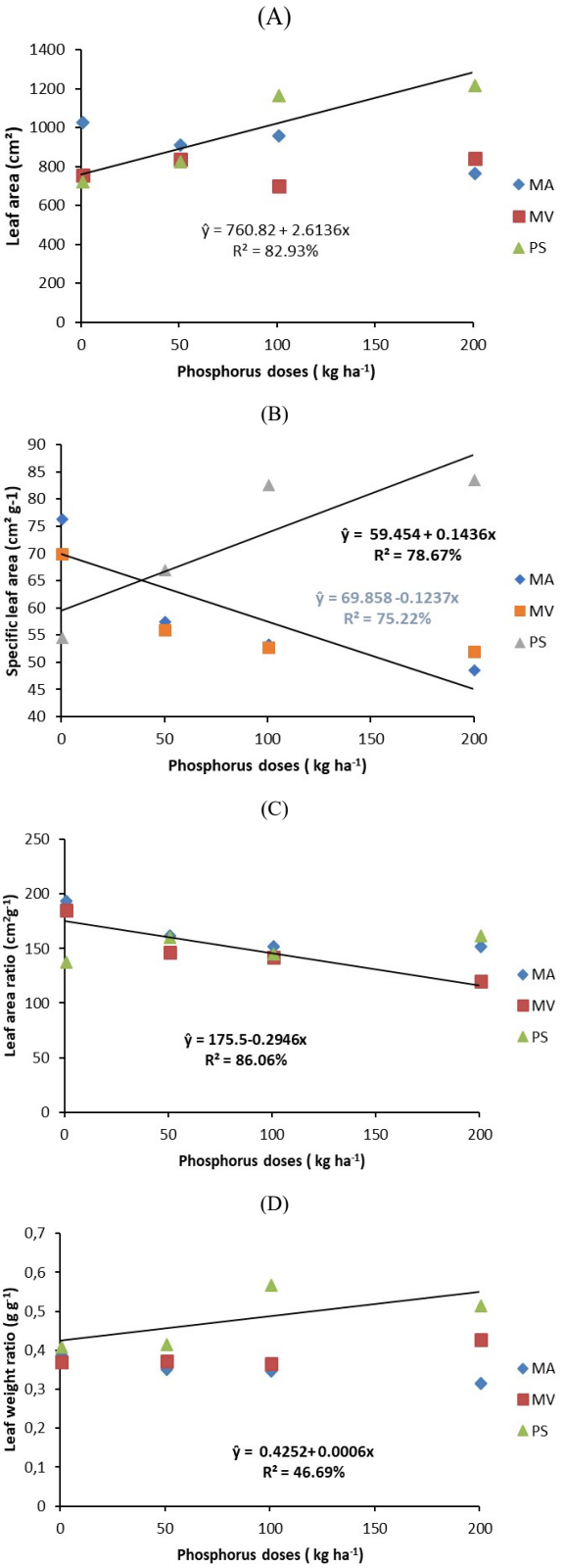

Figure 2. Mean values of leaf area (cm^2g^{-1}), specific leaf area (cm^2g^{-1}), leaf area ratio (cm^2g^{-1}) and leaf weight ratio ($g\ g^{-1}$) of basil plants, submitted to the interaction between nutrient phosphorus and different light environments. Where: MA = Blue mesh, MV = Red mesh, PS = Full sun.

Figura 2. Valores médios da (A) área foliar (cm^2g^{-1}), (B) área foliar específica (cm^2g^{-1}), (C) razão de área foliar (cm^2g^{-1}) e (D) razão de peso foliar ($g\ g^{-1}$) de plantas de manjericão, submetidas à interação entre o nutriente fósforo e diferentes ambientes de luz. Onde: MA= Malha azul, MV= Malha vermelha, PS= pleno sol.

The mean values for specific leaf area (SLA) were significant only for plants cultivated under the red net (Table 3), which presented a decrease in the SLA values as the doses of phosphate fertilizer increased (Figure 2B). For the variable leaf dry matter (LDM), increases were observed in basil plants cultivated under red net and in full sun, both reaching maximum values (7.1 and 7.7 g, respectively) at the dose 200 kg ha^{-1} of P_2O_5 (Figure 3), according to the number of leaves found, where plants grown in full sun had a higher leaf quantity.

The spectral quality of the radiation transmitted by the blue net caused an increase in root dry matter in plants grown in this environment (10.56 g), and lower values in plants grown in full sunlight (7.38 g) (Table 4).

Table 3. Mean values for leaf area ratio, specific leaf area and leaf weight ratio of basil plants cultivated under light conditions in function of phosphorus doses.

Tabela 3. Valores médios das variáveis razão de área foliar, área foliar específica e razão de peso foliar de plantas de manjericão cultivadas nas condições de luminosidade em função das doses de fósforo.

Luminosity	Leaf Area Ratio ($cm^2\ g^{-1}$)			
	Doses of P_2O_5 ($kg\ ha^{-1}$)			
	0	50	100	200
Blue net	76.64 a	57.99 a	53.39 b	48.69 b
Red net	69.93 ab	56.01 a	52.80 b	52.01 b
Full Sun	54.65 b	67.14 a	82.66 a	83.62 a
Luminosity	Specific Leaf Area ($cm^2\ g^{-1}$)			
	Doses of P_2O_5 ($kg\ ha^{-1}$)			
	0	50	100	200
Blue net	194.94 a	162.96 a	153.2 a	53.03 ab
Red net	186.9 a	148.12 a	143.23 a	121.15 b
Full Sun	138.61 b	161.42 a	146.2 a	63.11 a
Luminosity	Leaf Weight Ratio (gg^{-1})			
	Doses of P_2O_5 ($kg\ ha^{-1}$)			
	0	50	100	200
Blue net	0.39 a	0.35 a	0.35 b	0.31 b
Red net	0.37 a	0.37 a	0.37 b	0.43 a
Full Sun	0.41 b	0.41 a	0.57 a	0.51 a

Means followed by the same letters in rows and lines do not differ statistically by Tukey test at 5% significance.

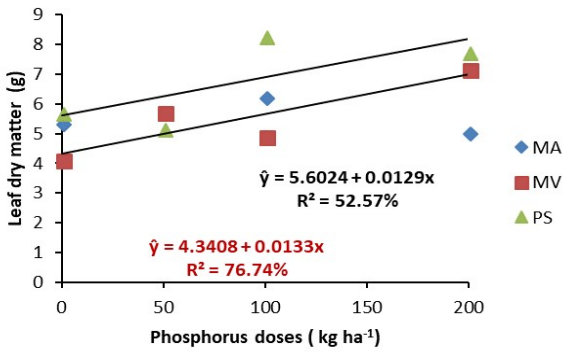

Figure 3. Average values of the dry mass of the basil leaf, submitted to the interaction between the nutrient phosphorus and different qualities of light. Where: MA = Blue mesh, MV = Red mesh, PS = Full sun.

Figura 3. Valores médios da massa seca da folha de manjericão, submetidas à interação entre o nutriente fósforo e diferentes qualidades de luz. Onde: MA= Malha azul, MV= Malha vermelha, PS= pleno sol.

Table 4. Average values of the variable dry mass of the root (g) in basil plants grown under different light conditions.
Tabela 4. Valores médios da variável massa seca da raiz (g) em plantas de manjericão cultivadas em diferentes condições de luminosidade.

Luminosity	Root dry matter (g)
Blue net	10.56 a
Red net	8.73 ab
Full Sun	7.38 b

Means followed by the same letters in rows do not differ statistically by Tukey test at 5% significance.

Regarding the analysis of phosphorus in the roots of basil plants, the macronutrient phosphorus presented a higher quantity under conditions of low light intensity, that is, under shading conditions, with the use of colored nets, especially the blue net, when the macronutrient was found at the highest quantity (1.77 g/kg) (Table 5).

The phosphate ion is not very mobile in the soil, and its absorption is related to root length since it occurs by root diffusion. In this sense, plants cultivated under the blue net showed higher levels of phosphorus since they had a longer root length.

Table 5. Mean values of the macronutrient phosphorus (g kg^{-1}) extracted from the roots of basil plants in the light conditions.
Tabela 5. Valores médios do macronutrientes fósforo (g kg^{-1}) extraído das raízes das plantas de manjericão nas condições de luminosidade.

Luminosity	Phosphorus (g kg^{-1})
Blue net	1.77 a
Red net	1.70 a
Full Sun	1.09 b

Means followed by the same letters in rows do not differ statistically by Tukey test at 5% significance.

4. DISCUSSION

The analysis of variance revealed that there was a significant interaction between phosphorus doses and light environments to which the basil plants were submitted in relation to number of leaves, leaf area, specific leaf area, leaf area ratio and leaf weight ratio, while for the other variables analyzed, no significant effects were observed for the interaction studied.

In relation to stem diameter, no significant effect was observed for the interaction of phosphorus doses and colored nets. However, regardless of the dose used, plants grown in full sun, both in absence and presence of phosphorus, presented results significantly higher than those grown under shading using red and blue nets (Table 1).

Growth in diameter depends on the exchange activity, which in turn is stimulated by carbohydrates produced by photosynthesis and translocated hormones from apical regions. Therefore, the base diameter is a good indicator of net assimilation, since it depends more directly on photosynthesis.

Similar results were found by Souza et al. (2012), who, with the objective of evaluating the effects of phosphate fertilization and spectral light quality transmitted by colored nets on biometric characteristics of lemongrass, concluded that plants grown in full sun presented a larger base diameter than plants grown under blue and red nets, showing that the reduction in light intensity, without changing the spectral quality, provides plants with a thinner stem.

The statistical study showed that basil plants under different light environments and doses of phosphate fertilization showed a different behavior in relation to leaf area (LA), that is, plants grown in full sun presented higher values of this variable in relation to plants grown under red and blue nets, with an increased phosphorus dose (Table 1).

Similar results were observed for Japanese mint and melissa, cultivated under different nets. The authors attributed the increase in leaf area in plants more to the intensity than to the spectral quality of the light (COSTA et al., 2012; BRANT et al., 2009).

It was visually observed that plants grown under blue net were broader than those grown in full sun, showing an adaptive strategy of plants for one light intensity, increasing the leaf area and its light uptake. This light energy absorption and phytomass production depend on an adequate leaf area in time and space, as well as on the plant's the efficiency of producing photoassimilates.

Martins et al. (2008) found conflicting results in a work carried out with *Ocimum gratissimum* L. grown under colored nets. They revealed that the cultivation of basil ("alfavaca") under colored nets provided greater leaf areas than the cultivation in full sun. Corroborating with Martins et al. (2008), Costa et al. (2012) found the lowest leaf area ratio for plants grown in full sun and increased LA under red thermo-reflective nets, reaching the maximum in black and blue nets.

Abreu et al. (2013) verified that basil plants grown in full sun and under a red net did not differ statistically among them; however, they presented a greater leaf area development in relation to the blue net. Such results indicate that blue light limits the total photosynthetic activity of basil plants, and therefore generates a lower yield of photoassimilates.

Similar results were found by Martins et al. (2008), who, working with *Ocimum gratissimum* L., pointed to a greater development of plants when cultivated under a blue net, which promoted a higher growth in height during the whole conduction of the experiment. This is because the blue net allows a greater transmission for wavelengths within the range of distant blue and red (OREN-SHAMIR et al., 2001).

Concerning the height of basil plants, a significant effect was observed when compared to luminosity conditions, where plants grown under shading were higher in relation to the full sun condition. The same behavior was observed for the variable root dry matter.

By evaluating the growth and biomass production of basil ("alfavaca") plants cultivated under colored nets, Souza *et al.* (2011) concluded that there was a linear increase in the height of “alfavaca” plants cultivated under a blue net; the lowest height was observed in plants grown in full sun, corroborating with the results obtained in this study.

Colored nets provided plants with a greater efficiency in the acquisition of biomass. Martins et al. (2008) concluded that plants grown in full sun had higher root dry matter gains and total dry matter gains than plants grown under a black net. Pegoraro et al. (2010), working with *Mentha piperita* L., observed that light intensity and substrate nutrition significantly influenced plant biomass. They also concluded that the increase in biomass, both in shoots and roots, was proportional to the increase in light intensity.

These results are in agreement with the values found for the variable plant height: there was a greater increase in

plants cultivated under a blue net. The higher the root dry matter values, the higher the efficiency of biomass acquisition. Thus, roots would require a sufficient quantity of nutrients.

In this study, there was a linear increase in leaf area ratio (LAR) in the full sun condition, with higher values (83.626 $cm^2\ g^{-1}$) at the maximum dose of P_2O_5 applied (Figure 2C).

The LAR is the parameter that expresses the leaf area useful for photosynthesis. Therefore, the higher the LAR, the greater the photosynthetic capacity of the plant, and consequently the greater the carbohydrate production.

Conflicting results were found by Martins et al. (2008), who, working with *Ocimum gratissimum* L., verified that the values of LAR of plants cultivated under colored nets did not differ statistically. However, they were higher than those of plants grown in full sun. According to the author, the increases in LAR are an adaptation of the plant to low luminosity, representing a greater proportion of photosynthetically active tissue in the form of leaf area.

Different results than those of this study were found by Melo et al. (2009), who, evaluating the effects of solar radiation changed by blue and red nets on aspects of the vegetative development of vinca plants, concluded that plants grown in full sun had a significantly reduced leaf area and lower LAR and LWR values in relation to shading treatments.

The high LAR observed in basil plants in the treatment in full sun can be considered as malefic, since a greater amount of vegetal material is exposed to any damage caused by the high intensity of light, as for example inhibition of plant growth. Corrêa et al. (2012), working with oregano plants, indicated that the leaf area was influenced by cultivation environment. Therefore, the highest LAR was obtained in plants grown under blue screen and lower LAR in plants cultivated in full sun.

These physiological growth rates are strongly influenced by various factors such as intensity, quality and duration of radiation, as well as by mineral nutrition, which reflects on anatomical and morphological changes of leaves (BENINCASA, 2004). It is emphasized that, under shading, the growth of plants is compromised because plants require a larger leaf area for the production of one gram of dry matter in comparison to the others.

Lima et al. (2013) found different results, where the values of LAR of plants grown under colored nets did not differ statistically; however, values were higher than those of plants grown in full sun.

Abreu et al. (2013) concluded that the leaf area ratio (LAR) of basil plants did not differ in relation to the incidence of blue and red light. However, significant responses were shown by plants grown under red net when compared to plants grown in full sun.

The specific leaf area (SLA) of basil plants showed the best results at the doses 50 and 100 kg ha^{-1} of P_2O_5 regardless of the brightness condition used.

Abreu et al. (2013) verified that the SLA of basil plants grown in full sun showed lower results and were significantly different from plants grown under a blue net. Souza et al. (2011) verified that basil ("alfavaca") plants submitted to 90 kg ha^{-1} without shading showed the highest values of SLA. With the increase in the P dose, the plants showed a slight decrease. They also concluded that plants without the presence of this nutrient presented a lower and more constant SLA during the cycle.

With respect to the P contents found in the roots of basil plants, this macronutrient was found at a greater quantity in plants grown under shading using red and blue thermo-reflective nets.

This can be explained because thermo-reflective nets decrease room temperature, consequently reducing the temperatures of the substrate and the plant, which improves the nutrient absorption conditions and the root development in the substrate.

The phosphate ion is not very mobile in the soil, and its absorption is related to root length since it occurs by root diffusion. In this sense, plants cultivated under the blue net showed higher levels of phosphorus since they had a longer root length.

5. CONCLUSIONS

Basil plants grown in full sun at the dose 200 kg ha^{-1} of phosphorus presented significantly better results than those grown under shading nets.

There was a linear increase in total leaf area in plants grown under full sun (58% higher than under blue net, and 44% higher under red net), showing better results at the maximum dose used. This variable may respond even more to an increase in the dose of phosphorus in the system.

The light environment modified by the use of blue and red shading nets provided a greater height and dry matter production in basil plants.

The levels of P found in the roots of basil plants were positively influenced by the different shading nets.

6. REFERENCES

ABREU, C. B.; SANTOS, A. S.; SOUZA, G. S de; OLIVEIRA, U. C.; LIMA, J. S. Qualidade de luz no crescimento inicial de plantas de manjericão (*Ocimum Basilicum* L.) em ambiente controlado. **Enciclopédia Biosfera**, Goiânia, v. 9, n. 16, p. 1855-1862, 2013.

AMARO, H. T. R.; ASSIS, M. O.; DAVID, A. M. S. S.; SILVEIRA, J. R.; SILVA NETA, I. C.; MOTA, W. F. 2012. Superação de dormência em sementes de manjericão (*Ocimumbasilicum* L.). **Revista Brasileira de Plantas Medicinais**, Botucatu, v. 14, n. esp., p. 218-223, 2012.

BENINCASA, M. M. P. **Análise de crescimento de plantas:** noções básicas. Jaboticabal: FUNEP, 2004. 42p.

BRANT, R. S.; PINTO, J. E. B. P.; ROSA, L. F.; ALBUQUERQUE, C. J. B.; FERRI, P. H.; CORREA, R. M. Crescimento, teor e composição do óleo essencial de melissa cultivada sob malhas fotoconversoras. **Ciência Rural**, Santa Maria, v. 39, n. 5, p. 1401-1407, 2009.

CARMO, D. L.; TAKAHASHI, H. Y. U.; SILVA, C. A.; GUIMARÃES, P. T. G. Crescimento de mudas de cafeeiro recém-plantadas: efeito de fontes e doses de fósforo. **Coffee Science**, Lavras, v. 9, n. 2, p. 196-206, 2014.

CORRÊA, R. C.; PINTO, J. E. B.; REIS, E. S.; MOREIRA, C. M. Crescimento de plantas, teor e qualidade de óleo essencial de folhas de orégano sob malhas coloridas**. Global Science Technology**, Rio Verde, v. 5, n. 1, p. 11-22, 2012.

COSTA, A. G.; CHAGAS, J. H.; BERTOLUCCI, S. K. V.; PINTO, J. E. B. P. Crescimento vegetativo e produção de óleo essencial de hortelã-pimenta cultivada sob malhas. **Pesquisa Agropecuária Brasileira**, Brasília, v. 47, n. 4, p. 534-540, 2012.

FERREIRA, D. F. **Manual do sistema Sisvar para análise estatística.** Lavras: Universidade Federal de Lavras, 66p. 2008.

LIMA, J. C.; OLIVEIRA, U. C.; SILVA, J. S.; SOUZA, G. S. Adubação fosfatada e qualidade de luz na produção de biomassa do capim-limão. **Enciclopédia Biosfera,** Goiânia, v. 9, n. 16, p. 45-55, 2013.

LORENZI, H.; MATOS, F. J. A. **Plantas medicinais no Brasil:** Nativas e Exóticas. Nova Odessa (SP): Instituto Plantarum, 2. ed., 2008. 544 p.

MARTINS, E. R.; CASTRO, D. M. de; CASTELLANI, D. C.; DIAS, J. E. **Plantas Medicinais**. Viçosa: UFV. 2000. 220p.

MARTINS, J. R.; ALVARENGA, A. A.; CASTRO, E. M.; PINTO, J. E. B. P.; SILVA, A. P. O. Avaliação do crescimento e do teor de óleo essencial em plantas de *Ocimum gratissimum* L. cultivadas sob malhas coloridas. **Revista Brasileira de Plantas Medicinais,** Botucatu**,** v. 10, n. 4, p. 102-107, 2008.

MELO, A. A.; ALVARENGA. A. A. Sombreamento de plantas de *catharanthus roseus* (l.) g. don 'pacifica white' por malhas coloridas: desenvolvimento vegetativo**. Ciência e Agrotecnologia**, Lavras, v. 33, n. 2, p. 514-520, 2009.

MURPHY, J.; RILEY, J. P. A modified single solution method for the determination of phosphate in natural waters. **Analytica Chimica Acta**, v. 27, p .31-36, 1962. DOI: https://doi.org/10.1016/S0003-2670(00)88444-5

OREN-SHAMIR, M.; GUSSAKOVSKY, E. E.; SHPIEGEL, E.; NISSIM-LEVI, A.; RATNER, K.; OVADIA, R.; GILLER, Y. E.; SHAHAK, Y. Coloured shade nets can improve the yield and quality of green decorative branches of *Pittosporum variegatum.* **The Journal of Horticultural Science and Biotechnology,** v. 76, n. 3, p. 353-361, 2001.

PEGORARO, R. L.; FALKENBERG, M. B.; VOLTOLINI, C. H.; SANTOS, M.; PAULILO, M. T. S. Produção de óleos essenciais em plantas de Menthax Piperita L. var.piperita (Lamiaceae) submetidas a diferentes níveis de luz e nutrição do substrato. **Revista Brasileira de Botânica**, São Paulo, v. 33, n. 4, p. 631-637, 2010.

PERALTA, G.; PEREZ-LLORENS, J. L.; HERNANDEZ, I.; VERGARA, J. J. Effects of light availability on growth, architecture and nutrient content of the seagrass Zostera noltii Hornem. **Journal of Experimental Marine Biology and Ecology**, v. 269, p. 9-26, 2002.

SANTINATO, F.; CAIONE, G.; TAVARES, T. O.; PRADO, R. D. M. Doses of phosphorus associated with nitrogen on development of coffee seedlings. **Coffee Science**, Lavras, v. 9, n. 3, p. 419-426, 2014.

SILVA, L. D.; MARCHIORI, P. E. R.; MACIEL, C. P.; MACHADO, E. C.; RIBEIRO, R. V. Fotossíntese, relações hídricas e crescimento de cafeeiros jovens em relação à disponibilidade de fósforo. **Pesquisa Agropecuária Brasileira**, Brasília, v. 45, n. 9, p. 965-972, 2010.

SOUZA, G. S.; SILVA, J. S.; SANTOS, A. R.; GOMES, D. G.; OLIVEIRA, U. C. Crescimento e produção de pigmentos fotossintéticos em alfavaca cultivada sob malhas coloridas e adubação fosfatada. **Enciclopédia Biosfera**, Goiânia, v. 7, n. 13, p. 296-310, 2011.

SOUZA, G. S.; SILVA, J. S.; OLIVEIRA, U. C.; LIMA, J. C.; SANTOS, A. R. Rendimento de biomassa de plantas de erva-cidreira (*melissa Officinalis* L.) cultivada sob diferentes ambientes de luz e doses de fósforo. **Enciclopédia biosfera**, Goiânia, v. 8, n. 15, p. 1516-1526, 2012.

WATANABE, F. S.; OLSEN, S. R. Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soils. **Soil Science Society of America Journal**, Madison, v. 29, p.677-678, 1965.