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# Photo-selective nets and potassium concentrations on *Costus lasius* crop

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**ABSTRACT:** The practice of using different photo-selective nets, associated with the technique of fertigation, represents a new agrotechnological concept that aims to promote specific physiological responses for growth and production, which are regulated by light. The aims of the study were to evaluate the effect of photo-selective nets and potassium concentrations in the fertigation solution on the horticultural performance of *Costus lasius*. The study was conducted at the Universidade de São Paulo, ESALQ, Piracicaba, SP, Brazil. Three experiments were carried out separately to evaluate five potassium concentrations in the fertigation solution (40, 80, 120, 160 and 200 mg $L^{-1}$) under three colours of photo-selective nets (red, blue and black) in a randomized block design, with five repetitions. The variables plant height and numbers of leaves, stems and flower buds were evaluated. The data were submitted to the joint analysis of experiments. The association between the $K^+$ concentration of 200 mg $L^{-1}$ and the black photo-selective net results in higher stem and inflorescence production.

**Key words:** ornamental flowers, potted flowers, fertigation

## Malhas fotoconversoras e concentrações de potássio no cultivo de *Costus lasius*

**RESUMO:** A prática da utilização de malhas de diferentes colorações, associada à técnica de fertirrigação, representa um novo conceito agrotecnológico que visa promover respostas fisiológicas específicas ao crescimento e à produção que são reguladas pela luz. Neste sentido, o objetivo da pesquisa foi avaliar o efeito, em cultivo protegido, de malhas fotoconversoras e de concentrações de potássio na solução de fertirrigação sobre o desempenho horticultural da *Costus lasius*. A pesquisa foi conduzida na Universidade de São Paulo, ESALQ, Piracicaba, SP. Foram realizados três experimentos separadamente, para avaliar cinco concentrações de potássio na solução de fertirrigação (40, 80, 120, 160 e 200 mg $L^{-1}$) em três colorações de malhas fotoconversoras (vermelha, azul e preta), no delineamento em blocos casualizados com cinco repetições. Foram avaliadas as variáveis altura de planta, número de folhas, caules e botões de flores. Os dados foram submetidos à análise conjunta de experimentos. A associação entre a concentração de 200 mg $L^{-1}$ de $K^+$ e a malha fotoconversora de cor preta resultou em maior produção de hastes e inflorescências.

**Palavras-chave:** flores ornamentais, flores de vaso, fertirrigação

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## Introduction

The Brazilian territory has promising prospects for floriculture, mainly due to climatic factors and a rich biodiversity (Paulino et al., 2013). In a market saturated by traditional crops, unusual species arouse curiosity and stimulate consumption (Siqueira, 2009). In this context, the species *Costus lasius* Loes, belonging to the Costaceae family, stands out and, despite having great potential for production and markets in Brazil, it is still a little studied species. This tropical plant, which serves to a restricted ornamentation market within floriculture, occurs naturally in Panama, Colombia, Peru and in Brazil, covering the Amazon region (Gonçalves et al., 2005). Although previously treated as medicinal, because of its beauty and exoticness, it has come to play prominent and innovative role in the Brazilian market. It has a variety of uses from landscaping to flower arrangements, resulting in original, lush and durable compositions.

The most attractive features of *Costus lasius* are the small yellow-gold inflorescences and a short spiral stem, characteristics that give grace in combination with potted plants. This species has a 12-month life cycle, short stature, an expanded habit and a high number of leaves/stems per plant, giving it a high capacity of soil cover (Castro et al., 2011). In addition, inflorescences have a long post-harvest life. As it has only recently been introduced into the national ornamental plant market, there are still difficulties in its cultivation due to the lack of technical and scientific information about production and management.

The use of photo-selective nets associated with fertigation in greenhouses represents a new agrotechnological concept, aiming at promoting specific physiological responses that are regulated by light (Brant et al., 2009). In horticulture, it has been increasingly common to use different net colours for *Eustoma grandiflorum* (Torres-Hernández et al., 2012, Almeida et al., 2016), *Catharantus roseus* (Melo & Alvarenga, 2009), *Anthurium* sp. (Nomura et al., 2009) and in arrangements with foliage (Stamps & Chandler, 2008).

On the other hand, fertigation has been highlighted as one of the technologies with the greatest impact on crop production in greenhouses, enabling the correct distribution of nutrients during the crop cycle, according to the nutritional needs of the plants, reducing unnecessary fertilizer use and avoiding environmental contamination (Oliveira, 2011). Potassium, a macronutrient, plays essential roles in enzymatic activation, photosynthesis, water use efficiency, cell turgidity control, starch formation and protein synthesis (Stino et al., 2011). Thus, controlling the application of this nutrient may be a way to improve flower quality and facilitate its entry into the national market.

In view of the above, this study aimed to evaluate, under greenhouse cultivation, the effect of different photo-selective nets and potassium concentrations in fertigation solution on the horticultural performance of *Costus lasius.*

## Material and Methods

The research was conducted in a greenhouse, located at ESALQ, Universidade de São Paulo, Piracicaba, SP, Brazil (22º 42' S, 47º 37' W, and altitude of 550 m), with a single span of 6.4 m width and 36 m length, north-south orientated, covered with a polyethylene diffuser film, with 100% transmissivity. Different nets for the type of transmitted light were hung 3.5 m from the ground, arranged in the colour sequence red, blue and black, with a thickness of 5 mm and a shading index of 50%. To avoid interference between treatments, the plants were placed in the geometric centre of each area, thus avoiding direct interference of the light from one treatment onto another.

Three experiments were carried out separately to evaluate five potassium concentrations in the fertigation solution (40, 80, 120, 160 and 200 mg $L^{-1}$, based on the standard recommendation of Hoagland & Arnon (1950)), under photo-selective nets of three colours (red, blue and black) in a randomized block design, with five repetitions.

The species used in the study was *Costus lasius* Loes., a new one, already adapted to the State of São Paulo, Brazil, and obtained from the Agência Paulista de Tecnologia do Agronegócio (APTA), the Unidade de Pesquisa e Desenvolvimento de Ubatuba (UPDU), in Ubatuba, SP, Brazil. The standard 10 cm cuttings were planted in trays of 72 cells, with commercial substrate composed of peat, corrective, vermiculite, charcoal and pine bark, and grown until they achieved a satisfactory root system (Figure 1A).

The seedlings were maintained approximately six months in the trays, when they reached the two leaf stage (Figure 1B), and two seedlings were transplanted to a 2-$dm^3$ pot. The second growth cycle in the pots lasted one year, and finally, the flowering phase lasted four months. A drip irrigation system was used, with pressure-compensating emitters with a nominal flow rate of 4 L $h^{-1}$, coupled to the irrigation lines, composed of 16-mm-diameter polyethylene pipes, with one dripper for each pot.

Fertigation with potassium using potassium chloride as the fertilizer was carried out in all irrigations, with the concentrations pre-established by the treatments. For the other elements, the applications were kept constant during daily irrigations. Irrigation quantity was controlled by the gravimetric method, where one of the pots (located in the geometric centre of the bench) from each treatment was monitored by weighing. During the first 60 days after transplanting (DAT), one daily irrigation was carried out and, from 60 to 180 DAT, two daily

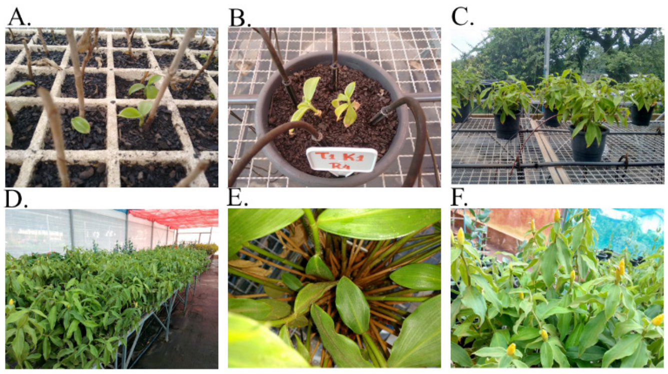



**Figure 1.** Seedlings production from cuttings (A), transplantation of the seedlings into the pots (B), arrangement of plants in the development phase and number of leaves counting period (C), arrangement of plants for the flowering phase (D), number of stems per plant (E), and leaf arrangement and inflorescence counting in the final stage of the crop (F)

irrigations were performed to follow plant growth. At 180 DAT, due to the increased demand by the plants in the vegetative and reproductive developmental phases three irrigations per day were carried out until the end of the experiment at harvesting.

Plant height (cm) was measured monthly, from September 2015 to August 2016, to monitor the growth of the stems, totalling 12 evaluations. At each evaluation of plant height, two stems of each pot were randomly selected and measured from its basal part to the apical meristem using a ruler. At the end of each evaluation, the arithmetic mean was calculated for each treatment.

Leaf counting was carried out monthly, during the same period, for each of the experimental plots, totalling 12 evaluations (Figure 1C). Production was evaluated by combining the leaf count and number of flowers in each treatment, photo-selective nets and K concentrations. The counting was carried out at harvesting time, on November 11, 2016, for the three photo-selective nets, when the flower buds had already formed (Figures 1D, E and F). Before performing the statistical analysis, the data were transformed using square root to satisfy the assumptions of the mathematical model.

After testing the data for normal distribution, an individual statistical analysis was performed for each net used. Subsequently, joint analysis was carried out using the data from the five concentrations of potassium and the three nets. The means of the nets were compared by Tukey test ($p \leq 0.05$) and those of potassium concentrations by regression analysis. The statistical analyses were performed using the SAS System 9.3.

## Results and Discussion

The analysis of variance for plant height showed that there was a significant interaction ($p \leq 0.05$) between the treatments for the evaluations performed at 60 and 90 DAT, but there was no similar effect for the rest of the periods (Table 1). By analysing the nets separately, it was possible to note that there was a significant effect on plant height for all evaluations. The effects of the $K^+$ concentrations were not statistically significant ($p > 0.05$).

The average plant height, at 60 and 90 DAT, showed a significant interaction with the potassium concentrations and the photo-selective nets (Table 1). At 60 DAT, comparing the red and blue nets, no significant differences were observed, while the black net at the K160 concentration led to the highest height. The average $K^+$ concentrations did not fit to the models studied in the regression and showed low determination coefficients for the red ($Y = 0.00001^{ns}x^2 - 0.0053^{ns}x + 6.69$, $R^2 = 0.0273$), blue ($Y = 0.0003^{ns}x^2 - 0.062^{ns}x + 8.948$, $R^2 = 0.90$) and black nets ($Y = -0.00026^{ns}x^2 + 0.0573^{ns}x + 6.042$, $R^2 = 0.33$). At 90 DAT, plant growth remained constant with little difference between the treatments. The $K^+$ concentrations did not differ under the red net and, under the black net, the K160 concentrations remained statistically different from the others (12.07). In this period, under the blue net the K200 concentration was different only from the concentration K120, with average heights of 11.12 and 6.90 cm, respectively. At 90 DAT, the regression data also did not showed good fits to the quadratic models for the red ($Y = 0.000031^{ns}x^2 - 0.01136^{ns}x + 8.060$, $R^2 = 0.10$), blue ($Y = 0.000475^{ns}x^2 - 0.1046^{ns}x + 12.768$, $R^2 = 0.91$) and black nets ($Y = -0.000252^{ns}x^2 + 0.0523^{ns}x + 8.364$, $R^2 = 0.31$).

Based on the difference in the interaction between the means for the nets (Table 1), within each $K^+$ concentration, it was observed that in the two periods evaluated, for K120 and K160 concentrations, the black net showed averages that were statistically different from and higher than those found under the red and blue nets. On the other hand, at 90 DAT, the average K200 concentration under the blue net was higher than those obtained under the other nets (11.12 cm). The plants showed reduced growth in the initial phase of the experiment and, for this reason, the differences found at 60 DAT cannot be solely attributed to the potassium concentrations in the initial part of the experiment. The absence of statistically significant differences between the averages is probably more closely related

**Table 1.** Analysis of variance for plant height (PH); interaction between plant height means at 60 and 90 days after transplanting (DAT); and general comparison between the average height of the *Costus lasius* plants throughout the experimental period

| SV | DF | Mean squares - PH - DAT | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 | 360 | 390 |
| Block/Nets | 12 | 31.2 | 37.7 | 36.4 | 24.5 | 17.2 | 10.7 | 7.6 | 4.8 | 12.3 | 7.0 | 10.7 | 15.9 |
| Nets | 2 | 29.3* | 55.3* | 101.7* | 109.4* | 81.3* | 58.2* | 16.1* | 12.3* | 34.2* | 44.0* | 87.5* | 142.1* |
| $K^+$ | 4 | 2.5$^{ns}$ | 3.8$^{ns}$ | 7.1$^{ns}$ | 11.2$^{ns}$ | 6.9$^{ns}$ | 7.3$^{ns}$ | 0.5$^{ns}$ | 0.9$^{ns}$ | 0.6$^{ns}$ | 1.2$^{ns}$ | 1.2$^{ns}$ | 2.2$^{ns}$ |
| Nets × $K^+$ | 8 | 8.8* | 12.9* | 8.6$^{ns}$ | 5.8$^{ns}$ | 4.2$^{ns}$ | 5.8$^{ns}$ | 5.2$^{ns}$ | 2.6$^{ns}$ | 7.1$^{ns}$ | 8.5$^{ns}$ | 9.6$^{ns}$ | 5.6$^{ns}$ |
| Error | 48 | 3.8 | 4.7 | 7.2 | 6.2 | 6.0 | 4.4 | 4.3 | 3.2 | 8.3 | 7.9 | 10.1 | 9.0 |
| Total | 74 | | | | | | | | | | | | |
| CV (%) | | 27.18 | 25.09 | 22.96 | 17.13 | 13.85 | 10.42 | 8.53 | 6.08 | 8.01 | 7.21 | 7.74 | 6.89 |

| Nets | Interaction between plant height means (cm) - 60 DAT | | | | | 90 DAT | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | K40 | K80 | K120 | K160 | K200 | K40 | K80 | K120 | K160 | K200 |
| Red | 6.82 a | 5.43 a | 7.17 a | 5.97 a | 6.22 a | 8.06 a | 6.20 a | 8.15 a | 6.83 a | 6.95 a |
| Blue | 6.73 a | 6.55 a | 5.51 a | 6.95 a | 9.02 a | 9.01 ab | 8.15 ab | 6.90 b | 7.67 ab | 11.12 a |
| Black | 8.56ab | 7.86 ab | 8.85 ab | 10.35 a | 6.54 b | 10.87 ab | 9.36 ab | 10.86 ab | 12.07 a | 7.88 b |

| Nets | General average plant height (cm) - DAT | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 | 360 | 390 |
| Red | 9.6 c | 12.4 c | 15.6 b | 18.4 b | 23.8 b | 29.6 ab | 37.1 a | 40.5 a | 43.2 a | 46.0 a |
| Blue | 11.6 b | 14.7 b | 18.3 a | 20.7 a | 25.4 ab | 30.5 a | 36.0 ab | 39.0 ab | 40.9 b | 43.5 b |
| Black | 13.7 a | 16.6 a | 19.0 a | 21.3 a | 24.4 a | 29.1 b | 34.8 b | 37.9 b | 39.4 b | 41.3 c |
| Error | 1.69 | 1.58 | 1.55 | 1.33 | 1.33 | 1.15 | 1.83 | 1.79 | 2.02 | 1.90 |

* Significant at $p \leq 0.05$; $^{ns}$ Not significant; Means followed by the same letter in the columns do not differ by the Tukey test at $p \leq 0.05$; SV - Source of variation; DF - Degrees of freedom

to the lack of uniformity between transplanted seedlings, which had a greater effect on their initial growth rates than any other factor. However, as the experiment progressed the effect of the potassium concentrations and the photo-selective nets could be clearly seen through the rest of the experimental period until flowering.

According to the general comparison of the averages (Table 1), the photo-selective nets differed statistically in all evaluations of plant height, remaining constant until the final developmental stage. During the initial and development phases, the nets had different effects on the plants. From the initial period of evaluation until 180 DAT, the black net led to higher average heights, in relation to the photo-selective nets (blue and red). Significant differences between the blue and red nets occurred from 120 DAT, when the effects of the different concentrations of potassium were apparent. From 210 DAT differences between the nets began to appear, continuing up to 390 DAT, with heights of 40.90 and 39.49 cm, respectively. In the initial stage of flowering, all the nets were significantly different, and the red net resulted in the highest average plant height (46.09 cm), followed by the blue net (43.56 cm) and black net (41.33 cm).

The variation between the effects of the nets during the experiment on plant growth can be explained by the fact that these plants grow in an environment with predominantly red shading. This is explained by the activation of the auxin synthesis by red and far-red wavelengths, which are intensified under the red net, while the blue net partially retains these wavelengths, allowing only the greater penetration of the spectrum in the range from green to blue; the black net does not change the incident light spectrum. Taiz et al. (2017) reported that the regions of the spectrum ranging from 1,000 to 720 nm, relative to the red and far-red range, are the wavelengths that exert most effect on plant growth. Light in this range of wavelengths improves the quality of diffuse light and promote greater rooting and plant development and production. Findings by Scaranari et al. (2008) further support this, suggesting that internode elongation and flowering control are promoted.

There are several studies demonstrating that under red enriched wavelengths plants have higher growth rates when compared to blue enriched and normal wavelengths (Oren-Shamir et al., 2001). Shahak et al. (2004) reported that, compared to the black net, red significantly stimulated vegetative growth and the blue caused dwarfism in plants. Shahak et al. (2002) also observed a delay in the plant growth under blue-green wavelengths when cultivating *Aspidistra elatior*, *Aralia* sp., *Asparagus officinalis* and *Monstera deliciosa*. However, the same authors observed an acceleration of vegetative growth under the red net when compared to the black one. Similar results were obtained in studies with lisianthus (Almeida et al., 2016), *Pitosporo variegata* (Oren-Shamir et al., 2001, Stamps & Chandler, 2008), *Catharanthus roseus* (Melo & Alvarenga, 2009) and seedlings of *Coffea arabica* (Henrique et al., 2011). Arthurs et al. (2013) report that responses by different plant species are often variable when subjected to modified light conditions induced by different nets.

The analysis of variance for the number of leaves detected a significant effect ($p \leq 0.05$) of the photo-selective net at all observed times, except for the evaluations performed at 270 and 390 DAT (Table 2). No significant differences between the concentrations of potassium or the interaction were observed.

By comparing the number of leaves between the net treatments (Table 2), it was observed that the average number of leaves (NL) for the red and blue nets were not statistically different up to 270 DAT. The black net resulted in higher NL compared to the others before 270 DAT, when it led to an average number of leaves of 98.60, which is not significantly different from the values for the red and blue nets (94.10 and 90.60, respectively). However, from 300 DAT, the red net led to the highest average number of leaves, maintaining this difference until 390 DAT, when flowering began.

Calaboni (2014), working with *Heliconia ortrotricha* under different photo-selective nets reported similar results to those obtained in this study. The same has been observed in studies with *Lisianthus* (Almeida et al., 2016) and *Pittosporum* (Stamps & Chandler, 2008), in which the leaf numbers of the plants under the red net were higher than those of the plants under black or blue nets, respectively. Kasperbauer & Hamilton (1984) justified that exposure to red and far-red wavelengths during leaf growth and development influences the development of chloroplasts, ensuring more efficient plant growth. Costa et al. (2011) reported that red net or absence of net cover may have resulted in an

**Table 2.** Analysis of variance and comparison between the means for the number of leaves (NL) at different Days After Transplanting (DAT) of the *Costus lasius* plants, submitted to potassium concentrations and photo-selective nets

| Sources of variation | DF | Mean squares | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of leaves - DAT | | | | | | | | | | | |
| | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 | 360 | 390 |
| Block/Nets | 12 | 4.5 | 18.7 | 72.5 | 97.4 | 111.3 | 149.8 | 177.9 | 302.2 | 547.5 | 694.1 | 578.7 | 1434.7 |
| Nets | 2 | 25.4* | 135.6* | 639.6* | 675.6* | 905.4* | 1084.1* | 1031.6* | $409.9^{ns}$ | 1679.5* | 2970.8* | 3813.8* | 4517.7* |
| Concentrations of $K^+$ | 4 | $2.2^{ns}$ | $13.3^{ns}$ | $56.8^{ns}$ | $77.5^{ns}$ | $101.5^{ns}$ | $117.2^{ns}$ | $174.4^{ns}$ | $505.7^{ns}$ | $1485.3^{ns}$ | $807.7^{ns}$ | $1442.8^{ns}$ | $809.4^{ns}$ |
| Nets x $K^+$ | 8 | $2.1^{ns}$ | $4.7^{ns}$ | $36.7^{ns}$ | $63.2^{ns}$ | $77.2^{ns}$ | $100.7^{ns}$ | $185.3^{ns}$ | $443.5^{ns}$ | $368.3^{ns}$ | $1120.2^{ns}$ | $674.1^{ns}$ | $836.7^{ns}$ |
| Error | 48 | 2.3 | 9.6 | 30.7 | 51.3 | 79.3 | 136.2 | 225.9 | 369.8 | 528.2 | 670.8 | 730.2 | 1197.7 |
| Total | 74 | | | | | | | | | | | | |
| CV (%) | | 27.9 | 35.2 | 33.6 | 29.7 | 26.0 | 24.3 | 23.0 | 20.4 | 21.8 | 20.3 | 19.5 | 21.3 |
| Nets | | Table of averages - DAT | | | | | | | | | | | |
| | | 60 | 90 | 120 | 150 | 180 | 210 | 240 | 270 | 300 | 330 | 360 | 390 |
| Red | | 5.0 b | 7.0 b | 12.5 b | 18.8 b | 29.6 b | 43.2 b | 62.4 ab | 94.1 a | 103.6 ab | 136.3 a | 151.1 a | 177.9 a |
| Blue | | 4.8 b | 7.8 b | 14.9 b | 22.5 b | 32.1 b | 45.4 b | 60.8 b | 90.6 a | 98.1 b | 130.6 ab | 126.8 b | 154.9 ab |
| Black | | 6.6 a | 11.4 a | 22.1 a | 29.9 a | 41.1 a | 55.6 a | 72.6 a | 98.6 a | 114.2 a | 115.2 b | 134.8 ab | 154.4 b |
| Error | | 0.97 | 1.95 | 3.51 | 4.53 | 5.63 | 7.38 | 9.51 | 12.16 | 14.54 | 16.38 | 16.97 | 21.87 |

DF - Degrees of freedom; CV - Coefficient of variation; * Significant at $p \leq 0.05$; $^{ns}$ Not significant; Means followed by the same letter in the columns do not differ by the Tukey test at $p \leq 0.05$

**Table 3.** Analyses of variance and comparison between the means of the total number of stems (NS) and flowers (NF) of the *Costus lasius* plants submitted to concentrations of potassium under photo-selective nets

| Sources of variation | DF | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | NS | NF | | | | |
| Block/Nets | 12 | 125.01$^{ns}$ | 22.72$^{ns}$ | | | | |
| Nets | 2 | 839.89* | 77.45* | | | | |
| $K^+$ | 4 | 44.65$^{ns}$ | 78.59* | | | | |
| Nets × $K^+$ | 8 | 20.14$^{ns}$ | 49.19* | | | | |
| Error | 48 | 93.82 | 17.98 | | | | |
| Total | 74 | | | | | | |
| CV (%) | | 15.43 | 43.16 | | | | |
| | | Means | | | | | |
| Nets | | NS | NF 40 (mg $L^{-1}$) | NF 80 (mg $L^{-1}$) | NF 120 (mg $L^{-1}$) | NF 160 (mg $L^{-1}$) | NF 200 (mg $L^{-1}$) |
| Red | | 61.44 b | 12.80 a | 6.50 a | 8.40 a | 10.00 a | 10.40 b |
| Blue | | 57.76 b | 7.80 ab | 6.00 a | 9.20 a | 8.00 a | 10.20 b |
| Black | | 69.12 a | 5.40 b | 9.60 a | 11.00 a | 13.20 a | 19.40 a |

DF - Degree of freedom; CV - Coefficient of variation; * Significant at p ≤ 0.05; $^{ns}$ Not significant; Means followed by the same letter in the column do not differ by the Tukey test at p ≤ 0.05

increase in photosynthetic capacity of the strawberry plants, when compared to the blue and metallic nets.

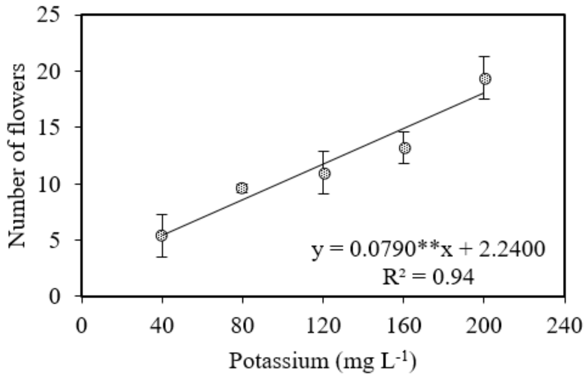
The results of the ANOVA presented in Table 3 showed a significant effect (p ≤ 0.05) of the photo-selective net only on the number of stems (NS). However, for the number of flowers (NF), a significant interaction (p ≤ 0.05) among the two factors was observed.

The black net resulted in a higher mean for NS (62.12 stems per plant), differing significantly from the other photo-selective nets, with no significant difference between red and blue, with means of 61.44 and 57.76, respectively (Table 3). These results are higher in comparison to the ones presented by Castro et al. (2011), where the species *Costus lasius* had 40 stems per plant, regardless of the growing environment.

Significant differences between the nets were observed only at the $K^+$ concentrations of 40 and 200 mg $L^{-1}$. For the lowest concentration applied, 40 mg $L^{-1}$ (K40), the stems under the red and blue nets produced mean numbers of flowers of 12.80 and 7.80, respectively, with no significant difference between them, but the red net was superior to the black net (5.40). For the highest concentration, 200 mg $L^{-1}$ (K200), the mean values for the blue and red nets were not significantly different (10.40 and 10.20 flowers, respectively). On the other hand, the mean for the black net was higher and significantly different from the others (19.40), the highest value in the study.

When comparing the different concentrations of $K^+$ under each type of net, for the red and blue nets it was not possible to fit the data to any statistical model, and means of 12.8 (40), 6.5 (80), 8.4 (120), 10.0 (160), 10.4 (200 mg $L^{-1}$) and 7.8 (40), 6.0 (80), 9.2 (120), 8.0 (160), 10.2 (200 mg $L^{-1}$) were obtained for the number of flowers, respectively. In contrast to the red and blue nets, under black nets the $K^+$ concentrations linearly increased the number of flowers, a 234% increment at the highest concentration compared to 40 mg $L^{-1}$ (Figure 2).

The increasing response to potassium concentrations showed a maximum estimated value of 19.40 stems at 200 mg $L^{-1}$, which is recommended to obtain a greater number of flowers without interference of the light spectrum. Rodrigues et al. (2008), studying potassium in chrysanthemum production, showed that the highest recommended concentration of the treatment (400 mg $L^{-1}$ of $K^+$) promoted the largest number and




** Significant at p ≤ 0.01 by F test

**Figure 2.** Number of flowers of *Costus lasius* plants as function of potassium concentrations in the fertigation solution, under a black net

diameter of the inflorescences. Gruszynski (2001) concluded that as the potassium concentration is closely related to the number of stems, this consequently affects the final number of inflorescences. Kittas et al. (1999) explain that nets that decrease the light intensity inside the greenhouse significantly affect some of the wavelengths, especially in the blue range.

## Conclusion

The association between the $K^+$ concentration of 200 mg $L^{-1}$ in the fertigation solution and the black photo-selective net resulted in higher stem and inflorescence production.

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