EFFECT OF DIFFERENT FERTILIZATION PRACTICES ON THE GROWTH OF TWO PLANT SPECIES: *Begonia* sp. AND *Petunia* sp.

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ABSTRACT: The study was carried out in a greenhouse, located in Griffin, Georgia Agricultural Experiment Station, University of Georgia. The experiment was arranged in a split-split plot design and aimed to verify the effect of the fertilizer concentration on Begonia (*Begonia semperfloresns-cultorum* Hort.) and Petunia (*Petunia hybrida* Hort. Vilm-Andr.) growth. It was verified that the dry weight varies with fertilizer concentration and over time. The fertilizer concentration that generated the maximum growth in dry weight was that with electrical conductivity (EC) around 1.5 dS/m. The EC values increased with fertilizer concentration and over time. The pH values decreased with fertilizer concentration and over time, reaching values that reduced the nutrient availability and limited the plant growth.

Key words: Fertilization, plant growth, split-split plot design, floriculture, ornamental plant.

EFEITO DE DIFERENTES PRÁTICAS DE FERTILIZAÇÃO NO CRESCIMENTO DE DUAS ESPÉCIES: *Begonia* sp. E *Petunia* sp.

RESUMO: *Este estudo foi conduzido em casa de vegetação, localizada em Griffin, Estação Experimental de Agricultura da Georgia, Universidade da Georgia. O experimento foi arranjado em um delineamento experimental em parcelas sub-sub divididas e objetivou verificar o efeito da concentração de fertilizantes sobre o crescimento de duas plantas ornamentais: Begônia (Begonia semperfloresns-cultorum Hort.) e Petúnia (Petunia hybrida Hort. Vilm-Andr.). Através dos resultados encontrados verificou-se que o peso seco varia com a concentração de fertilizante e com o tempo. A concentração de fertilizante que gerou um máximo crescimento em peso seco foi aquela com condutividade elétrica (EC) próxima a 1.5 dS/m. Os valores de EC aumentaram com a concentração de fertilizante e no tempo. Os valores de pH decresceram com a concentração de fertilizantes e no tempo, atingindo valores que reduziram a disponibilidade de nutrientes e limitaram o crescimento das plantas.*

Palavras-chave: Fertilização, crescimento de plantas, parcelas sub-sub divididas, floricultura, planta ornamental.

1 INTRODUCTION

The ornamental plant market has increased in a worldwide scenario. This economic activity includes the production and the commercialization of a wide range of plants, including flowers and other ornamental plants. The ornamental plant market in the United States is worth nearly $5 billion annually (STATPUB, 2005). The nursery-and-greenhouse industry now represent about 12 percent of the total U.S. agricultural product value, and is the fifth largest segment of U.S. agriculture (HODGES & HAYDU, 2003). Demand for floriculture and nursery products in the United States is increasing. Over the last 13 years, per-capita consumption has grown about 13 percent, or one percent annually (inflation-adjusted), to around $50 per capita, with roughly 61 percent for nursery products and 39 percent for floriculture (HODGES & HAYDU, 2003).

In Brazil, this market has grown faster in the last decade, mainly in the São Paulo State, becoming a profitable investment alternative, demanded small land area, short rotation (about three months) and allowing a fast capital flow (SILVEIRA & MINAMI, 1997). Moving an average R$ 6 million a month and offering over 5 thousand tons of products, the Flower Market at Ceasa-Campinas has been registering 24% per year

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growth in the volume of products commercialized, mainly in the sector of ornamental plants for gardening and landscaping (CEASA, 2005).

The suitable fertilizer application during the growth stage in greenhouse is important to produce health seedling, preventing nutritional deficiency, toxicity and a better development (FOLEGATTI et al., 2005; IERSEL et al., 1998). The fertilizer must be incorporated in the plant development in formulation, quantity, time and right place to help prevent nutritional deficiency and quality (IERSEL et al., 1998).

The best fertilization in ornamental plant production depends on the method, the irrigation frequency and the environmental conditions. Fertilizer recommendations for potted plants should include the fertilizer concentration to apply, the application method, and the desired growing medium nutrient levels, which can be expressed as growing medium EC (Electrical Conductivity) (KANG & IERSEL, 2001). Fertilizers are salts that contain one positively charged ion (cation) bonded to one negatively charged ion (anion). When a salt is placed into water, the two ions separate and dissolve. Fertilizer concentration of a solution can be determined by measuring the ability of a solution to conduct an electrical signal (FAUST & WILL, 2005).

Another way to check the fertilizer concentration is by measuring the pH in the solution, which control the uptake of nutrients. If the pH is not in the desire range, individual nutrients can not be taken up, creating a nutrient deficiency, or the nutrient can taken up too readily, resulting in a nutrient toxicity (FAUST & WILL, 2005). The main objective of this paper is to estimate the effect of different fertilization practices on the growth of *Begonia sp.* and *Petunia sp.*, and to generate guidelines for greenhouse growers.

2 METHODOLOGY

2.1 Data

The study was carried out in a greenhouse, located in Griffin, Georgia Agricultural Experiment Station, University of Georgia. The database was generated by sampling during 7 weeks for *Begonia* sp. and 5 weeks for *Petunia* sp. The experimental design utilized was split-split plot design with 6 benches for each species and two replications arranged in a randomized complete block design. Each bench, filled with MetroMix soilless media, was divided in two parts and each part received a different treatment. In the first treatment, plants were watered and fertilized daily with six different fertilizer concentrations based on Electrical Conductivity values in $dS.m^{-1}$ (0.5, 1.5, 2.5, 3.5, 4.5 and 5.5). In the second treatment, it was attempted to keep constant the fertilizer concentrations in the growing medium by using the same concentrations applied in the first treatment. This operation, sometimes difficult to control, was done by moving the plants to benches which were receiving the concentration as needed. Further, twice a week, were collected information of the growth medium electrical conductivity (EC) and Potential Hydrogen (pH) from three random plants. Also, information of the dry weight of two begonia and three petunia plants were recorded in the same day for EC and pH. For operational purpose, the information on the two species was taken in different days. The total measurements were 14 times for begonia and 10 times for petunia.

In the experimental terminology, considering a split-split plot design, we can describe as following: whole plot unit – each bench (6 bench with two replications, totalizing 12 benches for each specie); whole plot factor - fertilizer concentration (0,5; 1,5; 2,5; 3,5; 4,5 and 5,5); split plot unit – a half of bench (24 for each specie); split plot factor – fertilizer concentration and medium concentration; split-split plot unit – plant mean (336 for begonia and 240 for petunia); split-split plot factor – date. The design structure was randomized complete block for whole plot, split plot and split-split plot. The response variables were Dry Weight (Grams/plant), Electrical Conductivity of growing medium ($dS.m^{-1}$) and Potential Hydrogen (pH).

2.2 Statistical Model

The statistical model for the split-split plot, arranged in a completely randomized design, is the following:

$$Y_{ijkp} = \mu + \theta_i + \alpha_j + \varepsilon_{j(i)}^{W} + \gamma_k + (\alpha\gamma)_{jk} + \varepsilon_{k(ij)}^{S} + \beta_p + (\alpha\beta)_{jp} + (\gamma\beta)_{kp} + (\alpha\gamma\beta)_{jkp} + \varepsilon_{p(ijk)}^{SS}$$

where:
Y_{ijpk}= Response Variable;
μ = Overall mean;
θ_i = Effect of the i_{th} block;
α_j = Effect of j_{th} factor measured on the whole plots;
$\varepsilon_{j(i)}^{W}$ = Random effect of the whole plots;
γ_k = Effect of the k_{th} level of the factor measured on the split plots;
$(\alpha\gamma)_{jk}$ = Interaction effect of j_{th} factor measured on the whole plots and k_{th} factor measured on the split plot;
$\varepsilon_{k(ij)}^{S}$ = Random effect of the split plots (split plot error term);
β_p = Effect of the p_{th} level of factor measured on the split-split plots;
$(\alpha\beta)_{jp}$ = Interaction effect of j_{th} factor measured on the whole plots and p_{th} factor measured on the split-split plots;
$(\gamma\beta)_{kp}$ = Interaction effect of k_{th} factor measured on the whole plots and p_{th} factor measured on the split-split plots;
$(\alpha\gamma\beta)_{jkp}$ = Interaction effect of j_{th} factor measured on the whole plots, k_{th} factor measured on the split plots and p_{th} factor measured on the split-split plots;
$\varepsilon_{p(ijk)}^{SS}$ = Random effect of the split-split plots (split-split plots error term);
and the assumption are:

$\varepsilon_{j(i)}^{W} \sim N(0,\sigma_w^2), \varepsilon_{k(ij)}^{S} \sim N(0,\sigma_S^2), \varepsilon_{p(ijk)}^{SS} \sim N(0,\sigma_{SS}^2)$,

$\varepsilon_{j(i)}^{W}$, $\varepsilon_{k(ij)}^{S}$ and $\varepsilon_{p(ijk)}^{SS}$ are mutually independent.
i = 1, ..., r (r=2); j = 1, ..., w (w=6); k = 1, ..., s (s=2); and p= 1, ..., z (z=14 for begonia and z=10 for petunia).

3 RESULTS AND DISCUSSION

The results are presented in ANOVA tables for Begonia and just commented for Petunia. The response variables are Dry Weight, Electrical Conductivity for Medium and pH for Medium.

3.1 Split-Split Plot Analysis

The ANOVA (Table 1) shows, for Begonia, that EC (whole plot) had a significant effect on dry weight (p-value = 0,0001), i.e., by changing the EC value (fertilizer concentration) the response variable changes significantly. Also, the split plot and split-split plot factors had significant effect on plant growth (p-value = 0,0001). When the plants received fertilizer by watering or by constant concentration of the growing medium, the dry weight variable tends to be significant different and, by changing the date, the dry weight variable also changes significantly.

Table 1 – Analysis of variance for begonia with dry weight as response variable.

Tabela 1 *– Análise de variância para begônia com peso seco como variável resposta.*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP	1	0.01434720	0.01434720	-	-
EC	5	101.74228759	20.34845752	254.26	0.0001
Error (a)	5	0.40014720	0.08002944	-	-
TREA	1	12.04296326	12.04296326	59.82	0.0001
EC*TREA	5	2.27875439	0.45575088	2.26	0.2210
Error (b)	6	1.20811011	0.20135169	-	-
DATE	13	1230.78353978	94.67565691	996.53	0.0001
EC*DATE	65	119.29874282	1.83536527	19.13	0.0001
TREA*DATE	13	15.00806083	1.15446622	12.04	0.0001
EC*TREA*DATE	65	14.03607263	0.21593958	2.25	0.0001
Error (c)	156	14.9657	0.09589740	-	-

Considering the interactions of the factors, the main interactions had significant p-value, suggesting that the dry weight growth over time has different trend for each treatment. The same results were verified when the variable response was Medium Electrical Conductivity (Table 2). But, when the variable response was pH, the interactions between the treatments over time do not have significant effect, meaning that the pH has the same varying pattern over time for both treatments (Table 3). Roughly, the same results were obtained for the specie Petunia.

A valuable information in this experiment is to know the fertilizer concentration that generate maximum growth. Figure 1 shows that the treatment Medium with concentration 1,5 generated the maximum dry weight.

Table 2 – Analysis of variance for begonia having Medium Electrical Conductivity response variable.

***Tabela 2 –** Análise de variância para begônia tendo a condutividade elétrica média como variável resposta.*

Source	DF	Type I SS	Mean Square	F Value	Pr > F
REP	1	0.823	0.82325100	-	-
EC	5	1718.789	343.75786001	1987.23	0.0001
Error (a)	5	0.865	0.17304604	-	-
TREA	1	185.617	185.61776853	560.23	0.0001
EC*TREA	5	63.828	12.76560253	38.34	0.0001
Error (b)	6	1.985	0.33087451	-	-
DATE	13	124.249	9.55764356	79.32	0.0001
EC*DATE	65	98.772	1.51957351	12.65	0.0001
TREA*DATE	13	99.610	7.66232611	63.76	0.0001
EC*TREA*DATE	65	54.103	0.83235768	6.93	0.0001
Error (c)	156	18.746	0.120	-	-

Table 3 – Analysis of variance for begonia having pH as response variable.

***Tabela 3 –** Análise de variância para begônia tendo pH como variável resposta.*

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
REP	1	0.00044115	0.00044115	-	-
EC	5	18.47531873	3.69506375	38.35	0.0001
Error (a)	5	0.48147785	0.09629557	-	-
TREA	1	0.25236132	0.25236132	11.06	0.0001
EC*TREA	5	0.53995093	0.10799019	4.73	0.0001
Error (b)	6	0.13688507	0.02281418	-	-
DATE	13	110.66062861	8.51235605	494.04	0.0001
EC*DATE	65	6.09440546	0.09376008	5.44	0.0001
TREA*DATE	13	0.15557676	0.01196744	0.69	0.7667
EC*TREA*DATE	65	1.2575474	0.01924238	1.12	0.2878
Error (c)	156	2.68825288	0.01723239	-	-

Considering the effect of the fertilizer concentrations and days after transplanting (Figure 2), the maximum growth occurred at the age 50 days and concentration 1,5 dS.m^{-1}. This information is compatible with that showed on Figure 1. It can be seem that 20 days after transplanting the growth tend to differentiate by fertilizer concentration. When the fertilizer concentrations increase the dry weight tends to be smaller. This tendency will be discussed further based on pH values.

Figure 3 shows that the pH values decrease over time and with decreasing on fertilizer concentration. This tendency certainly affected the plant growth. The recommended range of water pH for irrigation and substrate solution pH for production depends on the crop being grown, but, in general, pH should range from 5.2 to 6.8 for irrigation water and 5.4 to 6.3 for substrate solution (BAILEY & BILDERBACK, 1998). This information explains the reduction of the dry weight verified with the fertilizer concentration increases and, consequently, the pH values decrease. In the concentration of 4.5 dS.m^{-1} , the pH value reach the minimum, almost 4.0, which is very drastic to the plant growth. The fact that concentration lines through the days are not parallel explains the significance of the interaction between EC and DATE.

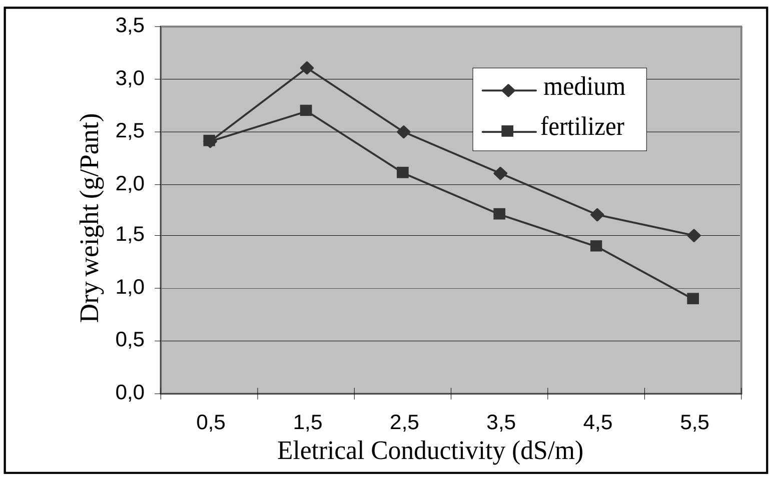

Figure 1 – Effect of the two methods of fertilizer application on Begonia growth .

***Figura 1 –** Efeito de dois métodos de aplicação de fertilizantes no crescimento de Begonia.*

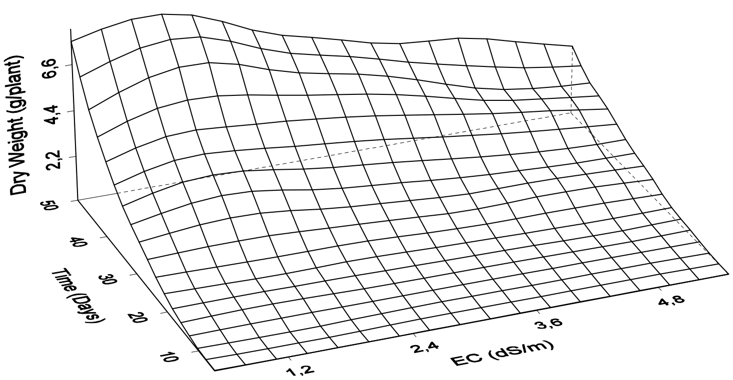

Figure 2 – Effect of the fertilizer concentration on plant dry weight over time.

***Figura 2 –** Efeito da concentração de fertilizante sobre o peso seco das plantas no tempo.*

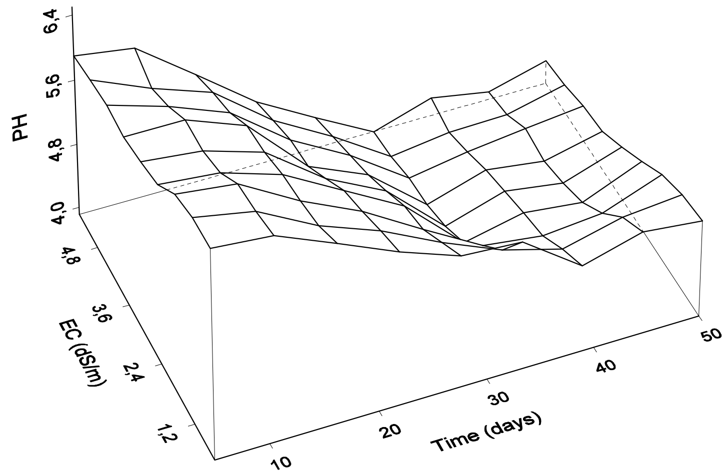

Figure 3 – Variations on pH values as function of fertilizer concentrations and time.

Figura 3 – *Variações nos valores de pH em função da concentração de fertilizante e do tempo.*

5 CONCLUSION

The dry weight changed significantly by both fertilizer application method and over time.

The dry weight growth and the Medium Electrical Conductivity over time had different trend for each treatment in both plant species. But, for pH, it was verified the same pattern over time.

The maximum growth occurred on 50 days after transplanting, at a fertilizer concentration of 1.5 dS.m^{-1}. When the fertilizer concentrations increase the dry weight decreased.

The pH values decreased over time and when the fertilizer concentration decreased.

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