Colegio de Postgraduados

Estimation of fig (*Ficus carica* L.) yield in fertigation using linear regression

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ABSTRACT

Objective: To estimate the fig (*Ficus carica* L.) yield in fertigation, through the use of linear regression, under the conditions of the Mixteca region of Puebla.

Design/Methodology/Approach: The plants were established in 10-L black polyethylene bags, using pine sawdust as a substrate. The treatments consisted of 6 variations of the following nutrient solution: 1.52 mg L^{-1} of potassium nitrate, 0.08 mL L^{-1} of phosphoric acid, and 0.38 mg L^{-1} of magnesium sulfate. Plant height, number of fruits per plant, and growth speed (cm day^{-1}) were determined. A completely randomized experimental design was used and the levels of nutrient solution and orthogonal contrasts were subjected to a linear regression analysis, through the SAS® On Demand for Academics statistical package.

Results: The linear model describes the behavior of the data with an alpha of 0.01. A 60% nutrient solution level has a greater effect on growth and generates highly significant differences in both the plant height increase rate and plant height variables.

Study Limitations/Implications: This study includes only preliminary results; therefore, a longer period is necessary for data collection. Additionally, the following variables must also be included: yield and the content of nitrogen, phosphorus, potassium, magnesium in plant tissue.

Findings/Conclusions: Plant growth (height) can be estimated through the application of a linear model. An increasing linear behavior was observed in height with respect to the levels determined 50 days after the experiment was established. There are highly significant differences between the 60% dose and the rest of the treatments.

Keywords: Mixteca, productive reconversion, dry tropics.

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INTRODUCTION

The genus *Ficus* L. comprises approximately 800 species, the most important of which is *F. carica*. Although this crop is mainly grown in temperate regions, it adapts to tropical and subtropical regions. In the Mediterranean, annual production reaches ≈1,064,784 tons, which are harvested from 311,080 hectares. Seventy percent of this production is distributed in Turkey, Egypt, Iran, Greece, Algeria, and Morocco, while the United States contributes only 4% of world production (Moniruzzaman *et al.*, 2020). Fig is considered a

crop with high economic potential, that it thrives in arid and semi-arid conditions, with high temperatures and poor soils. Furthermore, it has been established with densities of 500 to 1,000 trees ha^{-1}, obtaining yields of 5.1 t ha^{-1} to 11.6 t ha^{-1} (Kurubar *et al.*, 2017; Chithiraichelvan *et al.*, 2017). In Mexico, its expansion has been driven by export demand (Del Sol-Rodríguez, 2021). The consumption of figs constitutes an important source of polyphenolic antioxidants, anthocyanins (aglycone 99-85%), and cholesterol-free fats, among other compounds (Ercisli *et al.*, 2012). In addition, the waste generated during fig production constitutes an alternative for the production of biofungicides (Istúriz-Zapata *et al.*, 2019).

Protected agriculture is used for the intensive management of figs: a population density of 1.25 plants m^2 in 40-L containers, localized irrigation, and Steiner fertilization (Mendoza-Castillo *et al.*, 2019). In the state of Puebla, this species is planted in the municipalities of Xochiapulco, Coatzingo, Zacapoaxtla, Izúcar de Matamoros, and Teziutlán (SIAP, 2022).

In the Mixteca region of Puebla, the tropical deciduous forest predominates; its main economic activities are the grazing of goats and cattle, extraction of firewood, production of agricultural instruments, and exploitation of materials for the construction of rural homes. The deterioration of regional ecosystems is very noticeable: there is accelerated soil erosion, loss of biodiversity, fragmentation of ecosystems, and depletion of aquifers (Guízar-Nolazco *et al.*, 2010). Based on all of the previously mentioned factors, the objective of this research was to estimate fig yield in fertigation, through the use of linear regression, under the conditions of the Mixteca region of Puebla.

MATERIALS AND METHODS

The experiment was established at the Instituto Tecnológico Superior de Acatlán de Osorio (18° 12' 08" N and 98° 02' 54" W, at 1,180 m.a.s.l.), located in the municipality of Acatlán de Osorio. The plant material was obtained from the vegetative propagation of mother plants from family gardens. Semi-woody cuttings with an ≈10-cm long vegetative bud were used, adding radix 10000. The rooting substrate consisted of a mixture of Agrolita® substrate with peat moss (2:1 ratio); this stage lasted 66 days. Once they had established roots, the cuttings were transplanted in 10-L black polyethylene bags, using pine sawdust as a substrate. In the conditioning stage, two applications of 100 g of triple 17 were used as fertilizer. The application of the fertilization treatments began 141 days after rooting, using six variations (60%, 50%, 40%, 30%, 20%, and 10%) of the following nutrient solution: 1.52 mg L^{-1} of potassium nitrate, 0.08 mL L^{-1} of phosphoric acid, and 0.38 mg L^{-1} of magnesium sulfate. To decrease the pH of the nutrient solution, 0.91 g L^{-1} of ferrous sulfate was added to the treatments. The nutrient solution was irrigated daily during the application of the treatments.

A completely randomized experimental design was used. Each treatment consisted of three repetitions and each repetition included one plant. Plant height, number of fruits per plant, and growth speed (cm day^{-1}) were measured from the beginning of the treatment application, until 195 days after rooting. In the regression analysis, the levels of nutrient solution (%) were considered as the independent variable and the increase in height (cm) was considered as the dependent variable. The effect of each level of nutrient solution on the increase in height (cm) in relation to time (days after rooting) was analyzed individually. A linear regression analysis and orthogonal contrasts were used to analyze the data, along with the SAS® On Demand for Academics statistical package.

RESULTS AND DISCUSSION

The effect of the dose levels of the nutrient solution applied to the fig plants on the response variables were determined 50 days after the start of the application. The preliminary results are only shown for the 60%, 50%, 40%, and 30% levels, since no vegetative development was registered during that period for the 20% and 10% treatments.

Linear regression analysis

Based on the results of the linear regression analysis for the nutrient solution levels on height increase variable, the model does describe the behavior of the data (α=0.01) for the interval under study. The 60% nutrient solution applied for this interval has a greater effect on growth (Figure 1).

Linear regression analysis for the 60%, 50%, 40%, and 30% levels of nutrient solution

Using the linear regression model to describe the behavior of the increase in height with the application of the 60% dose, a height increase rate of 0.9621 cm day^{-1} was obtained, while the 50%, 40% and 30% levels recorded height rates of 0.7523, 0.3716, and 0.5091 cm day^{-1}, respectively (Figure 2).

According to these results, a decreasing trend is apparent in the growth speed during the period under study, since as the amount of fertilizer applied decreases, a decrease in growth is recorded.

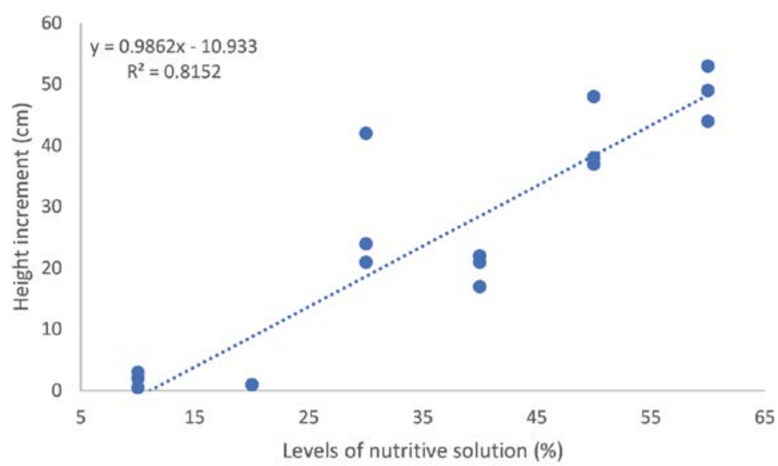

Figure 1. Effect of nutrient solution levels on height increase.

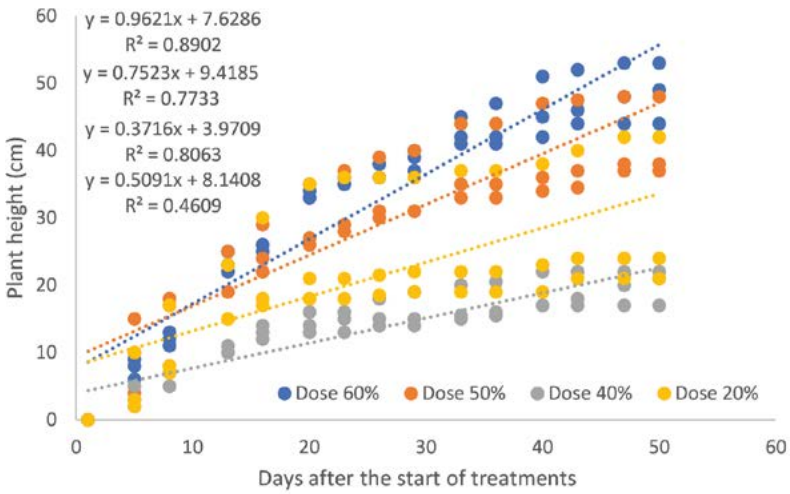

Figure 2. Growth dynamics with the application of 60%, 50%, 40%, and 30% of the nutrient solution.

Analysis of variance of the linear regression

Analysis of variance of the linear regression was applied for each of the nutrient solution levels, 50 days after the start of the experiment, to determine the increase in height in the fig plants. In the case of the dependent variable (increase in height), the regression model used does describe the behavior of the data for the four levels of the nutrient solution applied (α=0.01) (Table 1).

The use of linear regression as a tool to predict biomass increases is based on the correlation between plant structures (Lai *et al.*, 2013). In the case of alfalfa meadows, the height variable has a strong correlation with dry matter yield. If the correlation coefficients are high (>0.80), this variable can be considered to determine yield. In this sense, the crop growth rate (GR) is an approximation of the accumulation of plant biomass over time (Montes-Cruz *et al.*, 2016).

Orthogonal contrasts analysis

The orthogonal contrast test recorded highly significant differences between the plant height increase rate and plant height variables, with the comparison of the 60% nutrient solution with the 50%, 40%, and 30% solutions. When contrasting the 50% nutrient solution with the 40% and 30% nutrient solutions, significant differences were found for the plant height increase rate and plant height variables (Table 2).

Table 1. Analysis of variance of the linear regression of nutrient solution levels on height increase.

Source of variation	Degrees of freedom	Nutritive solution (60%)	Nutritive solution (50%)	Nutritive solution (40%)	Nutritive solution (30%)
Regression	1	9342.5**	5711.3**	1393.8**	2615.8**
Error	43	26.8	38.9	7.8	71.1
Total	44				
r^2		0.89	0.77	0.81	0.46

Table 2. Orthogonal contrasts analysis.

Contrast	Degrees of freedom	Rate of increase in plant height (cmdia^{-1})	Plant height (cm)	number of fruits per plant
Nutritive solution at 60% versus 50%, 40%, 30%	1	0.391**	784**	40.111^{ns}
Nutritive solution at 50% versus 40%, 30%	1	0.192*	544.5*	117.556^{ns}
Nutritive solution at 40% versus 30%	1	0.027^{ns}	121.5^{ns}	6.000^{ns}
Error	8	0.0213	48.333	55.167
Total	11			
r^2		0.78	0.79	0.27
CV		22.52	20.05	64.59

CONCLUSIONS

The application of a linear model allows the estimation of plant growth (height) during the period under study. Regarding the nutrient levels applied 50 days after establishing the experiment, a linear increasing behavior in height was observed. Finally, highly significant differences were recorded between the 60% dose and the rest of the treatments, regarding the plant height increase rate and plant height variables during the same period.

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