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Growth and development of Greek basil variety Medinette in greenhouses and shade netting

Crecimiento y desarrollo de albahaca tipo griega variedad Medinette en invernadero y malla sombra

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Abstract

Growth parameters were evaluated in plants of *Ocimum basilicum L.* variety Medinette, in two indoor production environments: a greenhouse and a shade net. Plant height, number of branches and leaves per plant, and leaf area were measured. Growth parameters such as leaf area index (LAI), relative growth rate (RGR) and net assimilation rate (NAR) were estimated up to 45 days after transplanting (ddt). The plant and its organs showed sigmoidal growth in the two protected environments. Growth kinetics, height, number of leaves and branches produced per protected environment showed significant differences (P≤ 0.05), these parameters being higher for plants grown in shade netting. The physiological efficiency parameters showed an IAF of 0.53 and 1.28 for plants grown in greenhouse and shade net, respectively. The CRT presented the maximum value (0.14 mg mg-1 day-1) at 35 ddt for plants grown in shade net. The TAN was 0.078 mg cm2 day-1 for plants in the shade net. Temperature and relative humidity conditions in the greenhouse caused a reduction in growth and physiological efficiency indices in basil.

***Ocimum basilicum L.*, Leaf area, Photosynthetic efficiency**

Resumen

Se evaluaron parámetros de crecimiento en plantas de *Ocimum basilicum* L. variedad Medinette, en dos ambientes de producción bajo cubierta: un invernadero y una malla sombra. Se midió la altura de planta, el número de ramas y hojas por planta, así como el área foliar. Se estimaron parámetros de crecimiento como el índice de área foliar (IAF), la tasa relativa de crecimiento (TRC) y la tasa de asimilación neta (TAN) hasta los 45 días después del trasplante (ddt). La planta y sus órganos mostraron un crecimiento sigmoidal en los dos ambientes protegidos. La cinética de crecimiento, la altura, número de hojas y ramas producidas por ambiente protegido mostraron diferencias significativas (P≤ 0.05), siendo estos parámetros superiores para las plantas cultivadas en malla sombra. Los parámetros de eficiencia fisiológica mostraron un IAF de 0.53 y 1.28 para las plantas cultivadas en invernadero y malla sombra, respectivamente. La TRC presentó el máximo valor (0.14 mg mg^{-1} $día^{-1}$) a los 35 ddt para las plantas en malla sombra. La TAN fue de 0.078 mg cm^2 $día^{-1}$ para las plantas de la malla sombra. Las condiciones de temperatura y humedad relativa en el invernadero ocasionaron una reducción en el crecimiento y los índices de eficiencia fisiológica en albahaca.

***Ocimum basilicum L.*, Área foliar, Eficiencia fotosintética**

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Introduction

The genus *Ocimum* consists of more than 60 species of medicinal and aromatic herbs of the Lamiaceae family in which basil stands out with a great variety of unique aromas, shapes, sizes and colours (Gonda *et al*., 2020), and its main active agent is the essential oil, which accumulates during the flowering period in 0.5 to 1.5 % based on cineol, metaclavicol, linalool, estragole, among others (Moncayo *et al*., 2015). *Ocimum* species also have a wide variety of antioxidant and phenolic compounds (Gonda *et al*., 2020).

Mexico has areas of high potential for the production of fine herbs, with basil being one of the species that stands out most for the area dedicated to its cultivation (389 ha) (SIAP, 2021) in which conventional and organic production is identified (Juárez *et al*., 2013). The main producing states are: Baja California, Baja California Sur, Guerrero, Morelos, Nayarit and Puebla (SIAP, 2021). Aromatic species are promising crops with high economic potential that are attracting more and more producers due to their commercialisation in international markets; however, their management during the production process can face different types of technological limitations (Combat *et al*., 2020). On the other hand, growth analysis techniques can be used in multiple situations and their use in intensive crops presents particular aspects that need to be taken into account (Di Benedetto and Tognetti, 2016) and the available information on aromatic herbs is scarce and scattered.

Despite the growing importance of fine herbs in Mexico and in the state of Nayarit, basic and applied information related to the performance of basil varieties in greenhouses and shade nets is incomplete. Hence, it is important to investigate the environmental effects of a protected site on the growth and development of basil plants to understand the nature of plant-environment interaction.

Theoretical framework

The current market for aromatic and medicinal plants has prompted the study of factors affecting their yield and quality in order to improve the productivity of production systems.

It is desirable that the intensive cultivation of plants under a protected environment favours their rapid production and that the plants are healthy and vigorous. In this sense, the yield of a crop is determined by the capacity to accumulate dry matter in the organs intended for harvesting (Morales *et al*., 2015).

Growth is defined as an irreversible increase in the dimensions of a plant, which can be determined by measuring changes in volume. However, taking these measurements can generate practical difficulties, which is why it is determined with related variables such as weight accumulation, variations in height or diameter and changes in leaf area (Di Benedetto and Tognetti, 2016). The analysis of plant growth can be analysed through the calculation of efficiency indices that allow for the accurate estimation of fundamental processes of productivity. In this context, efficiency indices can be determined with dry weight (Sedano *et al.*, 2005) and leaf area as a function of time (Morales *et al*., 2015), and their use and interpretation provides elementary information about crop performance in specific production environments (Di Benedetto and Tognetti, 2016).

Leaf Area Index (LAI) is a growth component that represents the leaf surface per unit area occupied by the plant; it increases with crop growth until it reaches a maximum value at which the maximum capacity to intercept solar energy is obtained (Carranza *et al*., 2009). This information is useful for agronomic and commercial management, as it allows growers to know how the crop behaves with climate and crop management under different production conditions (Colorado *et al*., 2013). Since it is impossible to take data from the same plant at different times (as the tests are destructive) these parameters are estimated from sampling different plants throughout the experimental period (Di Benedetto and Tognetti, 2016).

Relative growth rate (RGR) is defined as the increase in dry matter per unit dry matter present per unit time and its value is affected by the production environment (López *et al*., 2018). Net assimilation rate (NAR) is a parameter that indicates the efficiency of a plant's foliage as a source of photoassimilates in dry matter production (Morales *et al*., 2015).

Method and tolos

The research was conducted at the Academic Unit of Agriculture of the Autonomous University of Nayarit, located in Xalisco, Nayarit (21° 25' LN and 104° 53' LO). The experiment was set up in two protected production environments, one in a modified tunnel type greenhouse with passive lateral and zenithal ventilation, with a milky plastic cover with 30 % shade with high light diffusion and the other in conditions of shade netting made of monofilament of 3.5 x 4.5 threads per cm^2 with 35 % shading and the other in a greenhouse with a shading net of 3.5 x 4.5 threads per cm^2 with 35 % shading and the other in a greenhouse of 3.5 x 4.5 threads per cm^2 with 35 % shading. Temperature was recorded with a HOBO® data logger. The standard nutrient solution (Steiner, 1984) was used at 75 % concentration in all its ions and the Medinette variety of Greek basil (O. basilicum var minimum) which were obtained from seeds and transplanted in the experimental sites when they were 5 cm high was evaluated.

Black flexible plastic containers of 20 X 20 cm were used. The substrate used was red tezontle with a grain size of 0.3-0.7 mm. A completely randomised design was used in two protected environments: greenhouse and shade netting. Sampling was carried out at 15, 25, 35, 35, 45 and 55 days after transplanting (ddt). Periodic sampling of five plants per experimental unit was used to determine the height (with a flexometer graduated in cm), the number of green leaves and branches per plant, and the leaf area was determined by measuring the surface area of the leaf laminae in cm2 with a CI-202 CID Bio Science Inc. model integrator.

A digital balance with a sensitivity of 0.01 g was used to quantify the dry biomass accumulated in the leaf lamina and stem. These parameters were evaluated after the material was placed in a drying oven at 80 °C until it reached a constant weight (g) without including the root system, with these data the leaf area index (LAI) was determined (Morales *et al*., 2015) using the following equation:

$$IAF = \left(\frac{\text{åleaf area per plant} \times \text{population density}}{\text{Surface unit}}\right) \quad (1)$$

With the values of dry biomass and leaf area per plant, the relative growth rate (RGR) was calculated in accordance with the formulas indicated by Morales *et al*).

$$TRC = \frac{logPS_2 - logPS_1}{t_2 - t_1}$$

The net assimilation rate (NAR) was determined according to the methodology reported by Morales *et al.* (2015), using the following relationship:

$$TAN = \left(\frac{PS_2 - PS_1}{AF_2 - AF_1}\right)\left(\frac{logAF_2 - logAF_1}{t_2 - t_1}\right)$$

Where: PS2 and PS1 are dry weight, AF2 and AF1 are leaf area, log is the natural logarithm of leaf area and t^2 and t1 are time, CRT is expressed in mg.mg-1.day-1 and TAN is expressed in $mg.cm^2.day-^1$.

From the information obtained, a factorial analysis with repeated measurements was carried out and the mean values were compared with Tukey's test ($p \leq 0.05$) using the SAS statistical programme, version 9.0 (2002). Growth curves were made in a MS Excel® spreadsheet.

Results

During the period evaluated, the mean temperature was 25.34 °C in the shade net and 32.2 °C in the greenhouse. The mean relative humidity was 77.98 % for the shade net and 61.62 % in the greenhouse. The dynamics of biomass accumulation in basil variety Medinette was sigmoidal. Growth kinetics, height, number of leaves, branches and leaf area per protected environment were different (Table 1). This can be explained by the fact that plants produced in shade netting had a rapid growth after transplanting and presented the highest leaf area due to the temperature and photosynthetic irradiation conditions that allowed them to intercept a high percentage of radiation and increase the efficiency in the use of this resource.

Treatment	Plant height (cm)	Number of branches ($plant^{-1}$)	Number of leaves ($plant^{-1}$)	Leaf area (cm^2)
Shade house	48.16 a	72.95 a	935.33 a	910.02 a
Greenhouse	40.0 b	44.77 b	483 b	547.55 b

Means with the same letter between columns are equal (Tukey $P \leq 0.05$).

Table 1 Effect of shade netting on growth parameters of Greek basil variety Medinette

The IAF presented its maximum range of 1.28 at 45 ddt in shade netting, decreasing by 24.5 % at 55 ddt. In the greenhouse its maximum yield was 0.53 (Figure 1). These results are affected by the sampling dates.

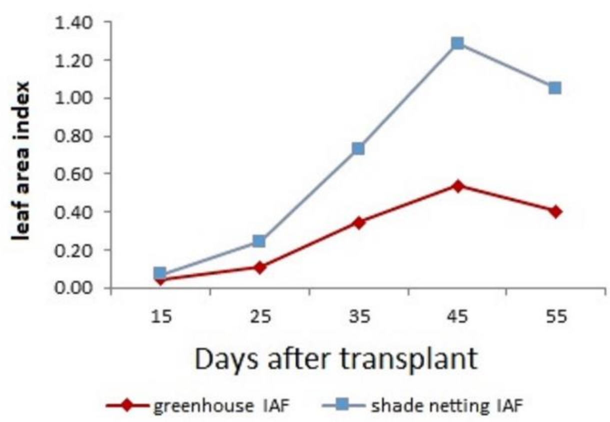

Figure 1 Leaf area index (LAI) of Greek basil plants Medinette variety in greenhouse and shaded netting

The CRR under greenhouse conditions remained constant and under shade net conditions showed a positive trend until 35 ddt when it reached 0.14 mg.mg-1.day-1, which contributes to a higher yield expression of the evaluated plants and decreased throughout the evaluation period until it reached 0.02 mg.mg.mg-1.day-1 at 55 ddt, which is considered a normal process during the development of the crop (Figure 2). The TAN was 0.078 mg.cm2.day-1 at 35 ddt in shaded conditions, which is related to the number of leaves and leaf area per plant (Figure 3), which depend on the age of the plant.

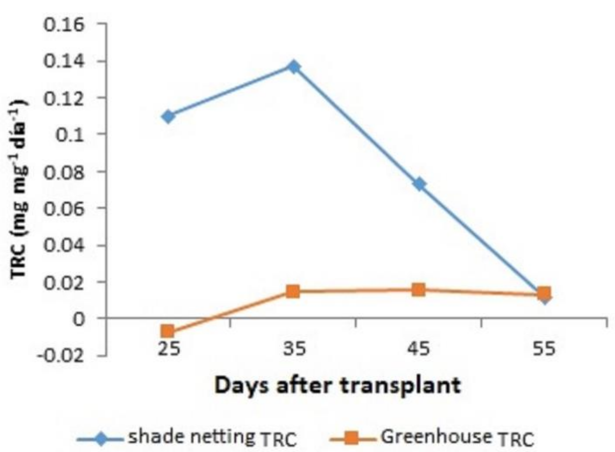

Figure 2 Relative growth rate (GRR) of Greek basil plants Medinette variety in greenhouse and shade net

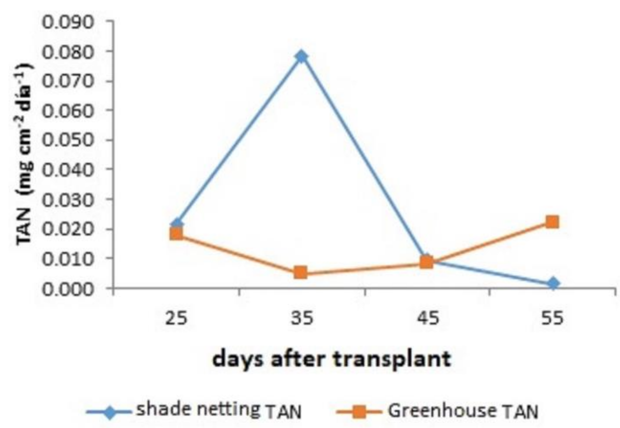

Figure 3 Net assimilation rate (NAR) of Greek basil plants of the Medinette variety under greenhouse and shade netting

Discussion

Factors such as temperature and relative humidity in production environments promote plant growth and development. In this sense, Ruiz *et al*. (2008) showed that there is a relationship between temperature and relative humidity with yield, being at 32 °C and a RH of 58 % when higher productivity is obtained in basil plants. However, these results are affected by the variety of basil grown.

Plant height is variable according to the cultivar produced. In this regard, Chiquito *et al*. (2018) reported plant heights of basil var. Nufar, between 32 and 41 cm, in this study an average height of 48 cm was observed. In this sense, it was determined that the growth dynamics was similar to that obtained in epazote (Chenopodium ambrosioides L) by Aguilar *et al*. (2021). With respect to the leaf area of the cultivated plants, the results obtained coincide with those reported by (Chiquito *et al*., 2018) who indicate that this parameter, together with the accumulation of fresh and dry biomass, are important characteristics for obtaining quality plants for sale on the international market.

On the other hand, a larger leaf area increases the production of photoassimilates, which are exported to the organs of economic interest (Escalante and Kohashi, 2015). In this regard (Di Benedetto and Tognetti, 2016) indicate that the expansion of leaf area is a critical variable for crop productivity and the curve consists of an exponential stage, a linear stage and a stage of decreasing increments.

However, it is important to note that in the commercial management of basil, several cuts are made during its growing cycle, so its growth and development will be variable. The relative growth rate is the central concept of plant growth analysis, during the first days of growth it usually has an exponential biomass accumulation dynamics (Di Benedetto and Tognetti, 2016), in this study the data obtained coincide with that reported by Colorado *et al*. (2013) who reported that the maximum CRR occurs at five days ddt (0.1082 g g-1d-1) and that it decreases as the plant grows and reaches 61 ddt (0.022 g g-1d-1) (Figure 1). This effect has also been reported in other species such as Physalis in which CRT has its maximum value at the beginning of the cycle, subsequently becoming constant and decreasing with plant age (López *et al.*, 2018).

With regard to TAN, Colorado *et al*. (2013) indicate that this parameter in basil has a decreasing behaviour due to the development of the crop during the production cycle. This is related to the number of leaves and leaf area per plant, since basil has little leaf senescence compared to other species such as beans, squash and sunflower (Sedano *et al*., 2005; Morales *et al*., 2015). Derived from these statements it can be said that a higher production of basil variety Medinette can be achieved with a higher photosynthetic efficiency.

Conclusions

Growth, biomass production and its physiological components are affected by the conditions of the production environment.

Shade netting conditions allowed the highest expression of the parameters IAF, TRC and TAN which resulted in higher plant yields.

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