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# SCALPE 2.0: SISTEMA DE CONTROLE AUTOMATIZADO PARA SUPLEMENTAÇÃO LUMINOSA EM CULTIVOS PROTEGIDOS

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## 1 RESUMO

Este trabalho descreve o desenvolvimento de um sistema automatizado para controle de intensidade e proporção espectral de lâmpadas LED aplicadas em cultivos protegidos. O sistema SCALPE 2.0 utiliza lâmpadas RGB para melhorar a fotossíntese das plantas, controlando a iluminação de acordo com a demanda de diferentes cultivos. O *hardware* do sistema foi testado com sucesso, demonstrando um controle de proporção e intensidade luminosa. O projeto também inclui um aplicativo de controle remoto via *Bluetooth*, facilitando a gestão da iluminação. Os resultados indicam que o sistema pode reduzir custos e aumentar a eficiência energética em cultivos protegidos.

**Palavras-chave:** automação agrícola, iluminação suplementar, LED.

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## 2 ABSTRACT

This study describes the development of an automated system for controlling the intensity and spectral ratio of LED lamps in protected cultivation. The SCALPE 2.0 system uses RGB lamps to optimize plant photosynthesis by adjusting the lighting according to the demand of different crops. The system hardware was successfully tested, demonstrating control of the proportion and light intensity. The project also includes a remote control app via Bluetooth, facilitating lighting management. The results show that the system can reduce costs and increase energy efficiency in protected cultivation.

**Keywords:** agricultural automation, supplemental lighting, LED.

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## 3 INTRODUÇÃO

Family farming in Brazil is essential for the production of vegetables and fruits, representing up to 80% of this market (Hoffmann, 2014). To increase productivity and optimize resources, many farmers have adopted protected cultivation practices in greenhouses. This method has grown in recent years because of its advantages, such as less use of planted areas, proximity to urban centers and greater efficiency in the use of resources (He *et al.*, 2016; Maham *et al*.). 2020). However, the need for light supplementation has become a challenge, especially when there is competition for sunlight between plants, which impacts photosynthesis and, consequently, productivity, as Boonman noted. *et al* . (2006).

Studies indicate that LED lamps are effective at providing light supplementation for protected crops (Brazaitytė *et al*., 2010; Xiaoying *et al*., 2012), with bands close to red (~660 nm) and blue (~450 nm) being the most suitable. However, most systems use fixed spectra, limiting their adaptation. Supplemental lighting with LEDs allows precise control of the intensity and spectral ratio, increasing productivity (Pereira *et al*., 2022; Gomez *et al*., 2013; Pinheiro, 2016). SCALPE 2.0 was developed to optimize these parameters, offering an automated and affordable solution for farmers, especially in protected cultivation areas.

The objective of this project was to develop a control system for light supplementation via LEDs, allowing the customization of lighting according to the specific needs of each crop.

## 4 MATERIALS AND METHODS

The development of SCALPE 2.0 began with research into the effects of supplemental light on protected crops, identifying the need to control the light intensity and spectral ratio. The system was designed with RGB LED lamps, which offer flexibility in choosing the colors emitted (red and blue), and an ESP32 microcontroller for control.

Development stages:

- Student training: Training was provided in analog and digital electronics, with a focus on circuit assembly and the use of ESP32.
- Circuit construction: The circuit was designed on the basis of light control and automation technologies and uses transistors and resistors. Pulse *width modulation - pulse width modulation* (PWM) was used to control the lamps.
- *Software* development: An application was created at *MIT App Inventor* to allow remote control of the system via *Bluetooth*, thus facilitating the operation of the equipment by distant users.
- Laboratory tests: The system was tested in the laboratory to ensure the controllability of the lighting parameters, determine the energy efficiency and determine the feasibility of controlling the light intensity and spectral proportion.

## 5 RESULTS AND DISCUSSION

Light intensity and proportion control tests revealed that SCALPE 2.0 is an efficient solution for light supplementation in protected crops. Other studies have shown several tests carried out with mini tomatoes, revealing a 16% increase in the production of fruits suitable for commercialization compared with that of crops without light supplementation (Pinheiro, 2016), as shown below.

**Table 1.** Productivity of mini tomatoes with and without the application of light supplemented with LEDs.

| MINI TOMATO PRODUCTIVITY | | | |
|---|---|---|---|
| **LED** | **COMMERCIAL PRODUCT** | **NON-COMMERCIAL PRODUCT** | **P TOTAL** |
| | Kg/m² | | |
| **WITH** | 16,9 | 1,7 | 18,7 |
| **WITHOUT** | 14,5 | 2,5 | 17 |
| **GAIN** | 16,6% | -32% | 10% |

**Source:** Adapted from Pinheiro (2016).

**Figure 1.** Mini tomato with and without the application of light supplemented with LEDs.

**Source:** Adapted from Pinheiro (2016).

Additionally, the use of light supplementation in lettuce crops resulted in more robust plants, with better development when exposed to a combination of red and blue light (Mello, 2016), as shown in Figure 2.

**Figure 2.** Comparison of lettuce cultivation for different types of light proportions.


**Source:** Adapted from Mello (2016).

The flexibility of the SCALPE 2.0 system, which allows for precise adjustments in the intensity and spectral ratio, distinguishes it from other lighting systems, such as the LED *Grow Light*. This refined control is greatly facilitated by the intuitive *touchscreen interface*, which gives users the ability to quickly customize lighting parameters to their specific growing needs, as noted below.

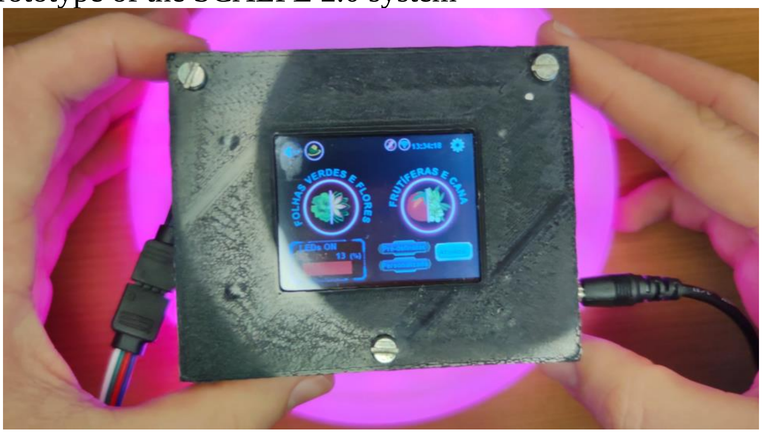
**Figure 3.** Screens designed for the *display*


**Source:** Authors.

Touch screens ensure easy and efficient interaction, increasing *the* precision of light level adjustment.

Furthermore, the final prototype of SCALPE 2.0 was developed with a focus on practicality and efficiency, featuring a compact and robust design that facilitates installation and maintenance. The system demonstrated superior cost-effectiveness, with lower energy consumption and greater operational control, making it a viable solution for SMEs. Below are images of the final prototype and *touchscreen* interface, highlighting the accessibility and innovation of the system.

**Figure 4.** Final prototype of the SCALPE 2.0 system



**Source:** Authors.

The SCALPE 2.0 system features advanced technical features for controlling 5050 RGB LED strips, such as precise adjustment of the red-to-blue color ratio, ranging from 0--100%, and full control of LED power, adjustable from 0--100%. In addition, the system integrates with sunlight, using geographic coordinates to automatically adjust lighting schedules on the basis of sunrise and sunset via a *Wi-Fi connection*.

Designed for protected cultivation environments, SCALPE 2.0 provides high flexibility and energy efficiency and is able to operate up to 200 meters of LED strips, with a maximum current of 0.76 A and a voltage of 12 V DC, which ensures lower energy consumption and greater operational safety. Compared with LED *Grow Light systems*, which operate on alternating current and have limitations in covered area and flexibility, SCALPE 2.0 offers precise adjustments without the need to change equipment, in addition to remote control via apps.

In terms of cost, SCALPE 2.0 is more affordable, with a typical investment of between $1,230.00 and $1,898.00 for 20 LED strips, whereas LED *grow light* systems require a higher investment of between $1,552.00 and $4,404.00 to cover the same area. The combination of lower cost, greater flexibility and superior control makes SCALPE 2.0 a more technically efficient and cost-effective solution for a variety of growing applications.

## 6 CONCLUSIONS

SCALPE 2.0 offers an innovative technological solution for supplemental lighting in protected crops, with the potential to increase productivity and reduce farmers' operating costs. The ability to remotely control lighting and adjust the spectral ratio according to the needs of each crop makes the system a valuable tool for different types of agricultural production. The implementation of technological improvements, such as the use of RGB LEDs and control via an app, has provided greater flexibility and efficiency in the use of supplemental lighting.

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