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CONSTRUCTION OF AN AUTOMATED GERMINATION CHAMBER AND GERMINATION TESTS ON EUCALYPTUS GRANDIS SEEDS

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Keywords: Germinator; Arduino; Low-cost.

Abstract

The objective of this work was the construction and test of an automated germination chamber, capable to provide the proper ambiance to conduct germination tests. Thermoperiod and photoperiod were controlled by means of an Arduino microcontroller. Energy consumption, construction and operation costs were analysed and compared to a market available germination chamber. Four replications of germination tests using Eucalyptus grandis seeds, under 17.5 °C, 25.0 °C and 30.0 °C, air relative humidity higher than 90% and germination paper as substrate were conducted. The seeds attained average germination of 89.33 per replication, considering average seedlings. The results found were in-line to the document Rules for Seed Analysis. Economical evaluation indicate 62% higher operation costs for the alternative model, yet for financial analysis (taking into consideration equipment purchase costs), indicate similar costs (3% difference), what indicates that the alternative chamber would be a suitable choice for business with smaller demand in seed testing.

CONSTRUÇÃO DE CÂMARA DE GERMINAÇÃO AUTOMATIZADA E TESTES DE GERMINAÇÃO EM SEMENTES DE EUCALYPTUS GRANDIS

Palavras-chave: Germinador; Arduino; Baixo-custo.

Resumo

O objetivo com este trabalho foi a construção de um germinador de câmara automatizado. O fotoperíodo e o termoperíodo foram controlados com Arduino. O consumo energético e os custos de construção e operação foram avaliados e comparados com câmaras disponíveis no mercado. Testes de germinação com quatro repetições usando sementes de Eucalyptus grandis, temperaturas ambientes de 17,5 °C, 25,0 °C e 30,0 °C, umidade relativa do ar maior que 90% e substrato papel foram conduzidos. As sementes atingiram germinação média de 89,33, considerando plântulas normais. Os resultados encontrados foram considerados válidos, de acordo com as Regras para Análise de Sementes. A análise econômica demonstrou custos operacionais 62% maiores em relação às câmaras disponíveis no mercado. A análise financeira, considerando custos de aquisição dos equipamentos, revelou uma pequena diferença de custo entre as alternativas, na ordem de 3%. Podemos concluir que o equipamento apresentado neste trabalho é uma alternativa viável para testes em sementes.

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INTRODUCTION

Local environment influences seed germination success (COCHRANE, 2016). Eucalyptus spp. multiplication by seedling is applied by minor nurseries (CENTARSKI FILHO; CARVALHO, 2009). Knowledge about physiology of germination contribute to management, choice, and adaptation of planting areas (MARTINS; PEREIRA; LOPES, 2014). Germination test results are useful to estimate sowing rate, physiological quality and standards for seed business (AFFONSO et al., 2018).

The adoption of laboratory conditions guarantees uniformity on results obtained from germination tests (WILLIAN, 1987). Germination tests executed on germinator and greenhouse revealed high phenotypic correlation (ARMAKI, 2014). Works interested in conceiving an automated chamber use platform systems based on open source hardware (BISTÁK, 2019). Aulakh (2015) used a WiFi based wireless sensor network with Arduino to improve germination chambers.

The present work aims the construction of a low cost automated germination chamber. The equipment is foreseen to comply to the specifications stated at the Rules for Seed Analysis (RSA). The germinator must be able to control thermoperiod and photoperiod by the use of Arduino microcontroller. A minimum temperature test was done to assess its feasibility and observance of RSA regulations. Energy and economic evaluation were analysed and compared to a commercially available model. Four replications of germination tests on paper substrate were conducted on Eucalyptus grandis seeds under temperatures of 17.5 °C, 25.0 °C and 30 °C and air relative humidity greater than 90% and germination time was analysed.

MATERIAL AND METHODS

Following recommendations of RSA established in Brasil (2009), which is in agreement with the International Seed Testing Association (ISTA), the germination chamber stands as a 0.017 m^3 box made of expanded polysterene. Its measurements were 0.30 m height, 0.29 m length, 0.20 m width and 0.025 m wall thickness. Its internal measurements were 0.265 m length, and 0.175 m width.

It is possible to accomodate up to 36 rolls of germitest paper in the device. The chamber has no shelves and the paper rolls must be upright to achieve this maximum accomadation capacity. Aluminium foil was used as an insulating material, in order to block incoming visible light waves, besides collaborating with the maintenance of internal temperature. The second wall was made of black satin vynil foam and its thickness was 0.01 m. The approximated total cost of the chamber was R$ 73,00 (based on 2020 Brazilian market conditions). The chamber's sketch is shown on Figure 1.

The control system is based on Arduino Uno microcontroller, which receives data from temperature and air humidity sensor and clock. After processing these data, the microcontroller sends signals so that the relay could trigger the illumination and refrigeration systems. It has a SD card module to store the data. The whole control system had an approximate total value of R$ 149,00 (based on 2020 Brazilian market conditions).

The light was located at 0.15 m from the seeds. The LED light is cool white, 15 W, 1510 lm, 210° opening angle, colour rendering index greater than 80 and 6500 K. Sanoubar et al. (2018) verified the influence of LED versus fluorescent light on seed germination and concluded that LEDs were more efficient. The approximated total cost to the illumination system was R$ 38,00 (based on 2020 Brazilian market conditions), including the light and some accessories like cables and protoboard.

Jiang et al. (2019) used thermoelectric coolers to set temperature environment conditions in a plant miniature greenhouse. For the present work, two thermoelectric peltier coolers were employed along with its aluminium heat sinks. Two 1.8 W FAN coolers were placed on both top and bottom sides of the refrigeration set. The refrigeration system was composed by four FAN coolers and two 20 W peltier coolers.

The total cost of the refrigeration system was R$ 258,00 (based on 2020 Brazilian market conditions). The total cost of the germination chamber, along with its electric components was R$ 518,00.

The performance of the prototype was analysed through a minimum temperature test. Air relative humidity was kept greater than 90%, external temperature was 22 °C and illumination system impact was verified. Thus, the refrigeration system was triggered on its maximum power until the internal temperature was stabilized, indicating the minimum temperature reachable. Somwanshi, Mishra and Gaba (2020) studied the maximum degree of cooling for a box attached in a cooler tank.

The energy expenditure for the experiment was verified in its entirety and by repetition. The total installed power in the germinator, considering four FAN coolers and two peltier coolers is 47.2 W. The cost of energy was established according to the energy tariff of the power distribution company ENEL RJ. The amount was R$/MWh 270,90.

The economic analysis was made with the costs per tested samples (R$/samples). The financial analysis was made through cash flow method, applying the NPV (Net Present Value) for 5 years and assuming a rate of 6.6% per year. The final economical value was calculated considering test's minimum sale value to provide a NPV of zero for the 5th year, which is equivalent to the minimum selling price to remunerate the invested capital at the minimum attractiveness rate.

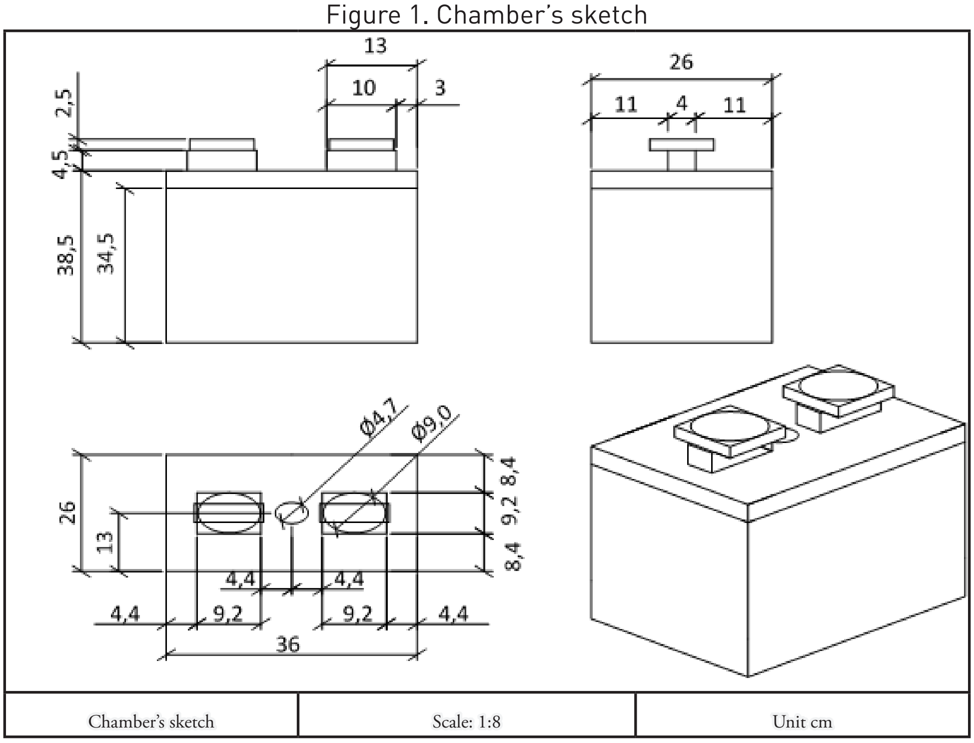
The economic analysis was made through comparison between the Low-Cost Germination Chamber (LCGC) and a Market Germination Chamber (MGC). The MGC consisted of a 0,12 m^3 germination chamber; dimensions 0.54 m height, 0.48 m length and 0.42 m width; inner chamber coated with precast polymer; working range from -10 °C to 60 °C; 4 lights of 10 W and power of 200 W; 2 shelves and 1 plastic drawer. The expected cost of this germination chamber is R$ 4.789,00 (based on 2020 Brazilian market conditions).[1]

In order to demonstrate the application of the germinator elucidated on this paper, there were executed germination tests on Eucalyptus grandis seeds. The part of the seed lot from Eucalyptus grandis species acquired was provided by Bentec Sementes e Insumos Company. Its provenance is a seed orchard situated in a seed production area with selected matrices. The part of the seed lot used weighted 0.100 kg, containing about 10000 seeds with a declared germination rate of 80%.

Cardoso (2016) performed germination tests during 20 days on Eucalyptus grandis seeds on paper. The greatest average germination speed was found under 25.3 °C. For the present work, the germination tests were executed on paper substrate. The space between seeds adopted was close to 2.0 times the width of seeds, according to Brasil (2009).

The germination tests were performed under constant temperatures of 17.5 °C, 25.0 °C and 30.0

Figure 1. Chamber's sketch



Fonte: Autores, 2022.

°C, internal air relative humidity greater than 90% and 8 hours photoperiod. Outside the chamber, the temperature ranged between 22.0 °C and 28 °C and the air relative humidity ranged between 61% and 88% during the execution of the tests. The water volume employed was 2.25 times the weight of the dry paper. Germination tests lasted 14 days.

In addition, germination time with the same temperatures was analysed, in order to verify if the germinator chamber comply a wider temperature range. The tests comply standards set with Rules for Seed Analysis. The germination time was calculated use the Edmond & Drapala expression (1958).

RESULTS AND DISCUSSION

The total amount spent for LCGC was close to R$ 518,00. Bento and Moraes (2018) constructed a germinator with recycled materials and compared its value with the ones available on the market costing between R$ 4460,00 and R$ 5736,67. The Low-Cost Germination Chamber (LCGC) after assembled is shown in Figure 2.

As the device has a clock, the user determines the exact moment for the system to turn the light on and off. Similarly, the user determines the temperature inside the chamber which is controlled by its own sensor and refrigeration system.

The user must regulate the device before starting the tests. In order to do that, the user should connect Arduino Uno microcontroller to a computer, open the code and choose temperature and photoperiod. The user must also carry out the procedures for preparing the samples prior to the test. In this research, the pre-test procedures were in accordance with the methodology proposed by RSA.

Then, the user should just place the samples inside the chamber and turn on the device. There is no need for the user to monitor the performance of the equipment during the execution of tests, since it is automated. Once the intended period has passed, the user must remove the samples from the equipment and verify the results.

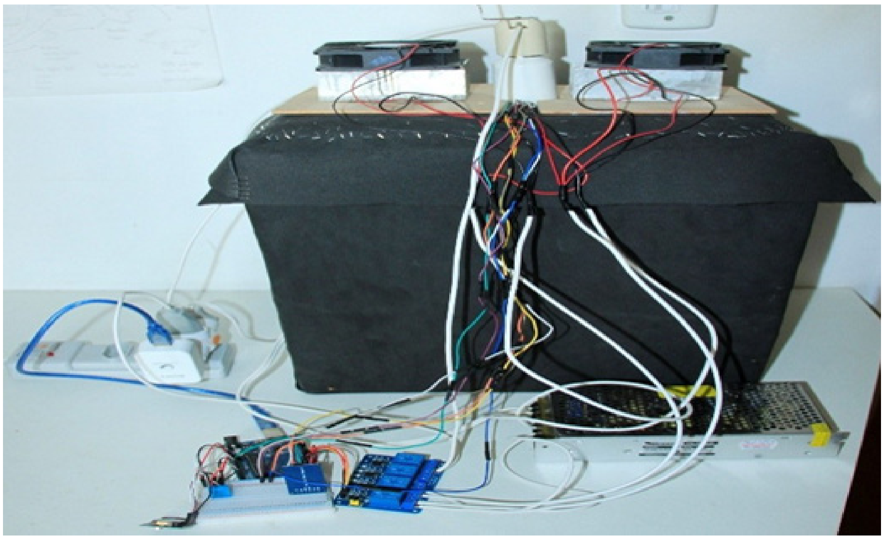
López et al. (2019) constructed a prototype with a similar control system, reaching similar results and according to the recommendations proposed by ISTA and Food and Agriculture Organization (FAO) for the evaluation of seeds.

Temperature performance

The performance analysis revealed that the device can attain a minimum temperature close to 11 °C, considering the internal air relative humidity greater than 90% and room temperature about 22 °C. Under these ambiance conditions, the equipment needs around 60 minutes to reach this minimum temperature and keep it constant.

The control system proposed in this work is based on an Arduino Uno microcontroller loop that works

Figure 2. Low-Cost Germination Chamber (LCGC)



Fonte: Autores, 2022.

[1] Source: _ https://www.cirurgicaestilo.com.br/camara-germinadora-com-fotoperiodo-120-litros-solidsteel-p15751/_____

every minute so that the temperature during the tests remains constant. Similarly, Marinelli et al. (2017), used a fuzzy control system embedded on an Arduino board to control thermoperiod and photoperiod for germination tests.

According to Brasil (2009), the internal air temperature cannot vary more than 2 °C during tests and internal air relative humidity must remain greater than 90%. The control system proposed in this work proved to be effective, considering these requirements.

Financial results

The numbers of samples per year that each device can attain were estimated considering germination tests lasting 14 days, 29 working days per month and 12 months for year. For LCGC, 36 samples were adopted every 14 days. For MGC, 230 samples were adopted every 14 days. MGC has a capacity 6.4 times greater than LCGC.

Table 1 shows energy consumption and costs calculated for the Low-Cost Germination Chamber (LCGC) and estimated to a Market Germination Chamber (MGC).

According to these values, it is noticed that the operation per batch of MGC is more expensive than LCGC. However, when we compare energy costs and energy consumed for both chambers per repetition, these finds changes. The higher operating cost of LCGC is diluted in the larger number of samples that MGC can carry out. Economically, MGC has a cost per processed sample 62.5% lower than LCGC.

The financial analysis through Net Present Value for LCGC indicated that a minimum selling price per test batch of R$235,50 leading to a minimal financial selling cost of R$0,26 per sample. The financial analysis through Net Present Value for MGC indicated that indicate a minimum selling price per test batch of R$ 1.566,50 leading to a minimum selling financial price of R$ 0,27 per sample.

We can observe on Table 2 that the cost per sample of LCGC is lower when compared to MGC. Economically, MGC has 62.5% lower costs than LCGC. Financially, LCGC presents 4.2% lower costs than MGC.

Table 1. Energy consumption and costs per batch and per repetition.

	LCGC	MGC
Total energy consumed per batch (kWh)	35.08	71.68
Total energy cost per batch (R$)	9.50	19.42
Total energy consumed per repetition (kWh)	0.49	0.31
Total energy cost per repetition (R$)	0,13	0,08

Table 2. Cost per sample comparison

	Costs per Batch (R$)	Samples precessed per year	Cost per sample (R$/sample)
LCGC	235,35	895	0,26
MGC	1566,65	5717	0,27

Germination and germination time tests

According to Binotto (2004), temperatures between 20º and 30º are the most recommended for germination tests. Table 3 shows the influence of temperature on germination and germination time.

For germination time, the lower the value obtained, the greater the vigor of the seeds. As can be seen in Table 4, there is less difference for the germination time, between the temperatures of 25°C and 30 °C,

Table 3. Analysis of variance of Eucalyptus grandis seeds in different temperatures

		Mean square	
Source of variation	DF	Germination	Germination Time
Temperatures	2	6,25 ^{ns}	2,29*
Residual	9	11,31	0,02
CV(%)		36%	6,73%

Ns, Not significant; * Significant at 0.05 probability levels by F test.

Table 4. Germination and germination time of Eucalyptus grandis seeds

Temperatures(ºC)	Germination	Germination Time
17,5	89a	6,83a
25	88a	5,41b
30	91a	5,69b

Means followed by the same letter in the column do not differ each other, by Tukey's test, at 5% probability.

when compared to the temperature of 17.5 °C.

The values found for germination and germination time for E. phaeotricha presented by Affonso et al. (2018), show that for low temperature and humidity values, the vigor tests also present low results, indicating a lower vigor. The same behavior can be seen in the analyzes by Filho and Carvalho (2009) for E. Dunnii.

The RAS indicates 25°C, for germination tests, for 40% of the mentioned Eucalyptus species, temperature where the values with greater vigor are observed for the seeds in the physiological tests. According to Labouriau (1983) the optimal temperature range is the one that presents maximum germination in the shortest average time.

According to Carvalho and Nakagawa (2000), the effects on germination speed and total germination differ, and for temperatures below the optimum for total germination, they tend to reduce the speed of the process, exposing the nascent seedling for a longer period of time to adverse environmental factors. This effect can be observed in the time to consider the experiment concluded, which for a temperature of 17.5 °C was higher.

For all tests executed, the difference between higher and lower quantity of germinated seeds from replications were lower than the tolerance, according to the document Rules for Seed Analysis (2009). Therefore, this Eucalyptus grandis seed lot meet the minimum standards and the results of both germination tests can be considered as valid. These results are compatible with the ones reported by Cardoso (2016). He found similar values for germination of the same species, temperature, distilled water and substrate.

CONCLUSION

1) The germination chamber constructed provides proper conditions to fulfil the condition imposed for the execution of germination tests. In additional, the tests performed and results obtained, show that chamber is able to work in a temperature range 20-30ºC, that comprise the range indicated by RAS of most species.

2) Low-Cost Germination Chamber presents 4.2% lower costs than the market germination chamber, therefore, due its low initial cost, it is a real alternative for commercial use. The low-cost of this solution compared to standard ones will allow its implementation for producers and buyers of seeds as well as researchers.

3) Open platforms for automation, such as microcontroller Arduino, presented indications that could be used on automation of germination tests. Furthermore, it enables the possibility of using other platforms to similar applications in the future. The use of an automated system might simplify the work of the operator involved on germination tests execution and credit the results obtained.

4) The result accomplished on this work about the germination of Eucalyptus grandis seeds are similar the results obtained by others researchers and might contribute to the researchers that follow this line of investigation.

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