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Growth rate, leaf area index, and productivity of jambu grown in a hydroponic system

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Abstract

Jambu (*Spilanthes oleracea* L.) is a leafy vegetable with medicinal properties used in food, cosmetics, and medicine. This work aims to analyze the growth of jambu plants grown in a hydroponic system. The experiments were conducted at a company site (B&A Hidroponia), using a nutrient film technique hydroponic cultivation system, in a protected environment. The experimental design was randomized with six treatments and three replications. The morphophysiological indices, culture growth rate, relative growth rate, net assimilation rate, and productivity were analyzed. Crecism analysis showed that the jambu plant has higher morphophysiological indices after the 39-day cycle in a hydroponic system and was directly influenced by the liquid assimilation rate, which in turn is influenced by the duration of the leaf area. The producer must pay attention to the handling of the nutrient solution. A productivity of 11.39 Kg / m^2 at 54 DAS of jambu cultivation was achieved using hydroponics.

Keywords: hydroponics, leaf yield, morphophysiological indices, *Spilanthes oleracea L.*

Introduction

Jambu (*Spilanthes oleracea* L.) is a widely consumed vegetable in the northern region of Brazil. In recent times, jambu has been used in natural medicines due to its chemical properties and the presence of important compounds like spilanthol, trans-caryophyllene, and germacrene D (Borges et al., 2012). Borges et al. (2015) and Borges et al. (2016) reported that jambu plants have flavonoids, vitamin C, total phenolics, carotenoids, and polyamines contents. According to Borges et al. (2019a) and Borges et al. (2019b), this high concentration of antioxidants in jambu has sparked the interest of cosmetic companies and exotic food restaurants. However, this vegetable remains invisible in the production statistics, despite the advances in research seeking information about its health benefits (Borges et al., 2020a).

In recent years, the consumption of healthier products rich in nutrients has become a trend. Thus, consumers' need for a tasty daily diet has boosted the consumption of leafy vegetables (Barbosa, 2009). Similar trends have been observed with the jambu, where consumers and lovers of Pará cuisine increasingly seek this vegetable. The hydroponic system of cultivation is being used to grow jambu to meet the increased demand throughout the year, with the aim of producing a sufficient quantity and quality (Martins, 2009; Homma et al., 2011).

According to Casais et al. (2020), the form of cultivation determines the size, health, and suitability of plants. A hydroponic system, a cultivation method without the use of soil, offers several advantages, like greater productivity and quality, reduced pests and diseases, greater control of plant development, and the opportunity of cultivation at different times of the year (Duarte & Santos, 2012).

According to Maia et al. (2014), olericulture

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accounts for most of the crops grown by hydroponics. With the growing demand for food and sustainable growing techniques, there are many studies regarding the use of medicinal and ornamental species in hydroponic cultivation. However, there are only a few studies on the growth analysis of jambu. Therefore, there is a need to analyze the growth and productivity of jambu in a hydroponic system.

This study aims to conduct growth analysis on jambu plants cultivated in a hydroponic system and contribute to the knowledge of growth kinetics in plant development.

Material and Methods

We conducted the experiment on the site of the company B&A Hydroponic between May 8 and July 1, 2018. This study site (latitude 3º 00' 16'' S, longitude 47º 24' 45'' W, altitude of 132 m) is located in the Rural Condominium of the municipality of Paragominas, in the state of Pará, which is about 8.5 km away from the city center. The climate of this region falls into the "Aw" category as per Köppen climate classification. It is tropical rainy with a well-defined dry season, with an average annual temperature of 26.5 °C, and relative humidity of 70% to 90% (Rodrigues et al., 2002).

The production was carried out in a nutrient film technique (NFT) hydroponic system. NFT comprises a nutrient solution reservoir, a pumping and return system from the nutrient solution to the reservoir, and growing channels.

The structural part of the system consisted of greenhouses built with iron and wood, with a right foot of 4 m. The roof was constructed on supporting arches made of galvanized steel with a lantern, and it was covered using an AV Blue type plastic film. A red Cromatinet® leno screen, 8 m wide and 30 m long with 35% shade, was used to close the side openings completely.

The pump house comprises 5000 L capacity containers with nutrient solution and pumping and control structures. The average temperature inside the greenhouses was 30 °C, and the pH of the solution was maintained at around 5 to 7. The benches were composed of polyethylene gutters specific for hydroponics, profile type, Hidrogood brand, with a length of 11.5 m and a slope of 10%, so that the solution returns to the reservoir by gravity. The system was managed by a timer that kept the solution circulating for 5 min and resting for the next 10 min during the daytime. At night, the solution was stirred for a period of 10-min after every 180 min.

The nutritive solution used in the system was designed by the producers, who obtained their own formulation through experimental tests carried out on the site. During the production process, the same solution was used for all nutritive lettuce crops. The main source of macronutrients was Dripsol® Lettuce fertilizer, which contains good nitrogen, phosphorus, potassium, and small concentrations of magnesium, boron, iron, and sulfur. It is carefully balanced with the macro and micronutrients necessary for high productivity and quality.

Iron was introduced through the Kelamyth® MP6 fertilizer, an iron-based (6%) powder product chelated by EDDHA, and calcium through Calcinit® calcium nitrate, which is composed of 19% Ca and 15.5% N.

The nutrient solution was prepared using 650 g/1000L Dripsol Lettuce, 650 g/1000L Calcinit, 20 g/1000L Kelamyth MP6, and 10 g/1000L. The solution was renewed every 20 days for two renewals, and in each renewal the pH and electrical conductivity parameters remained at 5 to 7 and 1.2 S/m, respectively.

The seeds were distributed in individual cells with the help of a special pressure-type sowing machine. The tray was moved to a closed and dark structure, which helped in the emergence and then in the pre-growth of the seeds in the hydroponic nursery until they reached the ideal size to be transferred to the next stage of cultivation, which was the separation of the seedlings, leaving only one individual cell.

The transplanting of the seedlings from the nursery to the growing channels, where they began to receive the nutritive solution, was carried out 23 days after sowing. It was carried out manually and consisted of the removal and separation of the seedlings from the phenolic sponge, leaving behind only one individual cell for each plant. These cells were later inserted separately into the spaces between the troughs.

The statistical design was entirely randomized with six treatments (six collections) and three repetitions. A total of six samplings were performed after sowing at intervals of 5 days, i.e., on days 29, 34, 39, 44, 49, and 54. The hydroponic jambu from the bench under analysis had a cycle of 55 days.

Soon after the harvest, the plants were taken to the laboratory of the Federal Rural University of the Amazon-Paragominas campus for growth analysis. Fresh mass (in grams) was obtained by weighing the aerial part of the plants on a digital scale. The unit value of the number of leaves was obtained by manual counting at each repetition, followed by taking the average of the values. The leaf area (LA in cm^2) values were obtained using the Area Meter, Model AM350.

The jambu plants were then packed in Kraft paper bags, each identified with their treatments, and placed to dry in a forced air circulation oven at an average temperature of 60 °C for 48 h until they reached a constant weight. Then, the dry mass weight (g) was determined by weighing on digital scales. The leaf area index (LAI), a dimensionless quantity, was obtained by dividing the LA of the repetition by the total number of repetitions used, expressing the results in m² of leaf area per m² of usable area.

Crop growth rate (expressed as g m-² day-¹) was obtained by dividing the result of the dry mass delta (g) by the result of the delta on the day after germination, expressing the results in dry mass (g) per m² of area per day. The relative growth rate (indicated as g g-¹ day-¹) was obtained by dividing the result of the crop growth rate by the dry mass value (g), expressing the results in dry mass (g) per original mass (g) per day.

Net assimilation rate (LAR, g m-² day-¹) was obtained by dividing the result of the growth rate of the crop by the value of the LAI, expressing the results in dry mass per (g) per m² of leaves per day. The specific leaf area (cm² g-¹) was obtained by dividing the leaf area result by the leaf dry mass value, expressing the results in m² of area per g of leaves. The leaf area ratio (RAF) (expressed as dm-² day-¹) was obtained by dividing the LA by dry mass value of the plant, expressing the results in m² of leaves per g of the plant.

The duration of leaf area (DAF) (dm-² day-¹) was obtained from the integral of the leaf area by the result of the derivative of the day after sowing the plant, expressing the results in m² of leaves per m² of usable area per day. The quantity of water in the aerial part (QWAP) (g/plants) was obtained through the difference between the value of the fresh mass of the plant and the value of the dry mass of the plant, expressing the results in g per set of plants. The productivity (Kg/m²) was obtained through the multiplication of the fresh mass of the leaves by the number of plants collected in each repetition, expressing the results in g per set of plants.

All obtained data were statistically analyzed using variance analysis and an F-test. Regression analysis was performed (1%) to compare means when the collection factor was significant. All analyses were performed by the software program SISVAR (Ferreira, 2011), and the graphs were plotted using Microsoft Office Excel.

Results and Discussion

For fresh mass (Figure 1), until 34 DAS, there was slow growth. At 39 DAS, we observed an accentuated development. We speculated that this growth could be related to the root development of the plants, which enabled a better absorption of nutrients by the plants.

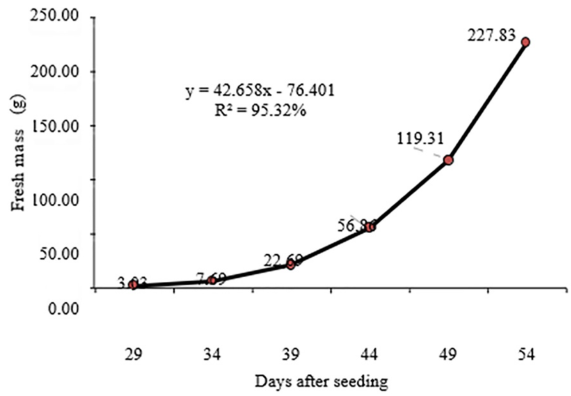

Figure 1. fresh mass of jambu plants grown in hydroponic system.

Due to the unavailability of a jambu-specific solution in the market, we used a lettuce nutrient solution for growing jambu in a hydroponic system. Based on the accelerated development from 39 DAS, it is possible to infer that the producer does not need a standard solution with the same amount of nutrients at the beginning of the plant cycle. This nutrient solution can be reduced by half, and only after 39 DAS, the solution can be maintained with the standard amount of nutrients for the culture. According to Borges et al. (2020b), the standard nutrient solution for lettuce used to grow jambu is inadequate, preventing the crop from reaching its maximum productive potential.

At the end of the cycle, a great increase in the fresh mass of jambu in the hydroponic system was observed. At 49 days, the yield was 119.31 g. The production doubled at 54 DAS with a yield of 227.83 g. Rodrigues et al. (2014) emphasized that in Pará, the production of leaves and flowers (fresh plant material) can vary between 6 to 10 bundles, equivalent to about 300 to 500 g per m² of bed.

Figure 2 shows that the values obtained until 34 DAS are initially slow. According to Caron et al. (2012), the dry mass of plants is related to their ability to fix atmospheric CO2 by photosynthesis, and this is higher when the LA is greater.

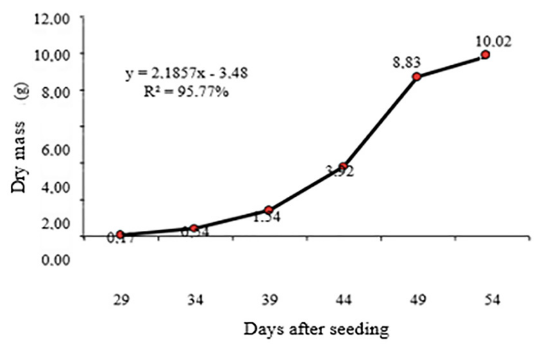

Figure 2: Dry mass of jambu plants grown in hydroponic system.

Figure 2: Dry mass of jambu plants grown in hydroponic system

At 39 DAS, we documented the increase in the dry mass of the crop, resulting from the ability of the culture to absorb and synthesize its own reserves, thus entering a phase of rapid reserve accumulation of metabolites absorbed both by the nutrients in the solution and by photosynthesis. Borges et al. (2014) obtained in the Cultivar Jambuarana 30.51 g of DM, while Borges et al. (2010), working with the same cultivar, obtained 16.62 g of DM, These values are above than those observed in the present study.

Figure 3 shows a gradual increase in the number of leaves, and from 39 DAS, there is a significant increase in the number of leaves, which reached 54 DAS with a value of 497 leaves. Silva et al. (2020) obtained values between 279.66 and 791.86 of NL in hydroponic jambu, which are different from those obtained in the present study. Golçalves et al. (2018) showed that the number of leaves and LA was directly related to the photosynthetic capacity of the plant.

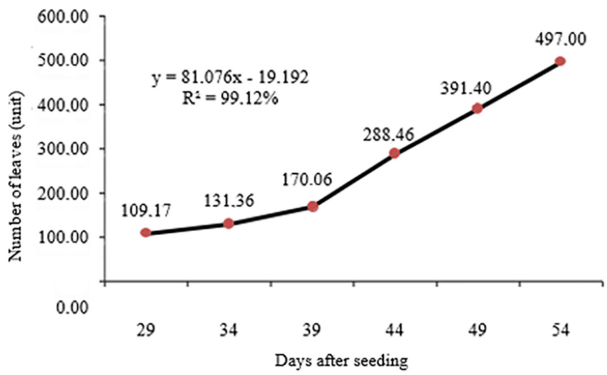

Figure 3: Number of leaves of jambu plants grown in hydroponic system.

Figure 4 shows an increase in LA from 49 DAS, reaching a value of 4623.30 cm^2 of AL at the end of the cycle at 54 DAS. These results were close to those found by Silva et al. (2020), 4314.24 30 cm^2 of AF in hydroponic jambu. According to Zuffo et al. (2016), plants with a greater photosynthetic area will have a more significant production of photo assimilates, resulting in growth and development. Taiz et al. (2017) observed that the leaf area is a designative growth characteristic of productivity because the photosynthetic process depends on the interception of light energy and its conversion into chemical energy.

In the characteristic LAI, as observed in Figure 5, values increase in the same proportion as the AF values, thus following the growth of the plant, reaching 54 DAS with a high index value of 9.25. In comparison, when morpho-physiological indices and productivity of jambu cultivars were evaluated, Borges et al. (2014) obtained lower values of 3.60 and 2.36 from the cultivars Jambuarana and Nazaré, respectively.

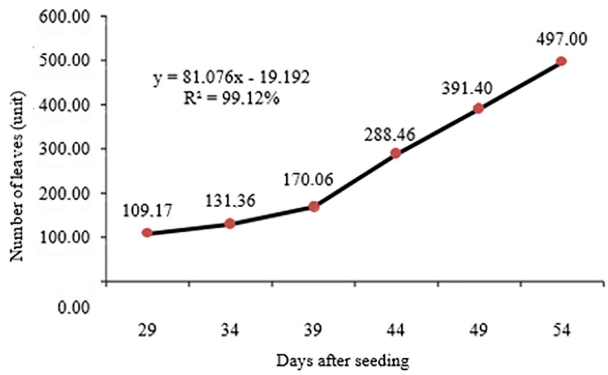

Figure 4. leaf area of jambu plants grown in hydroponic system.

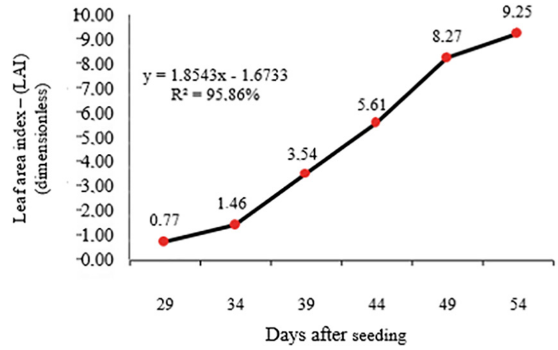

Figure 5: Leaf area index of jambu plants grown in hydroponic system.

As indicated in Figure 6, the growth rate of the crop is initially slow. However, from 34 DAS, we observed an accelerated growth, with a maximum peak at 44 DAS obtaining a value of 0.981 $g\ m^{-2}\ day^{-1}$. After this period, a sharp decrease is observed, probably caused by the translocation of nutrients from the plant to its inflorescences.

Figure 7 shows the values of the Relative Growth Rate (RGR). These values initially present high values, which represent the accelerated metabolism of the culture.

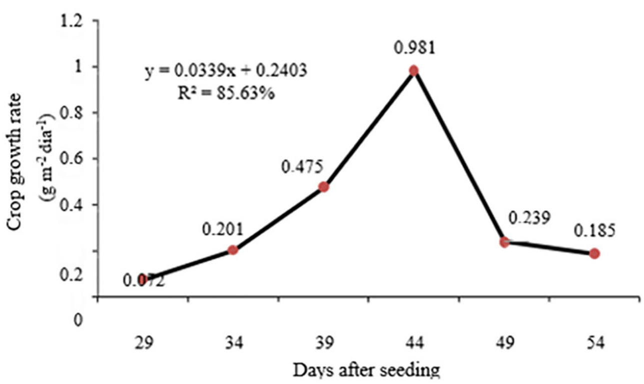

Figure 6: Crop growth rate of jambu plants grown in hydroponic system.

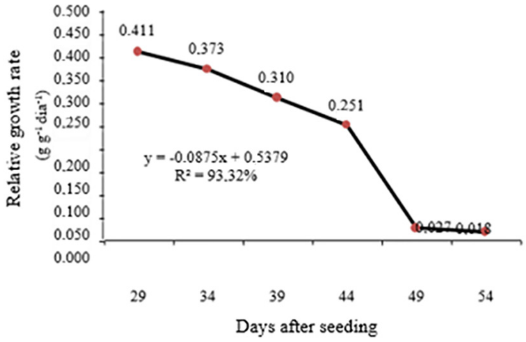

Figure 7. Relative growth rate in jambu plants grown in hydroponic system.

As of 44 DAS, there was a very sharp drop, from 0.251 g g-¹ day-¹ to 0.027 g g-¹ day-¹ at 49 DAS, and reaching 0.018 g g-¹ day-¹ at 54 DAS, indicating a possible stabilization. According to Benincasa (2003), the RGR expresses the increment in dry matter mass per unit of initial weight in a time interval (g g-¹ day-¹).

The LAR (Figure 8), according to Benincasa (2003), indicates the correlation between LA and total dry matter. As shown in Figure 8, at the beginning of the cycle, there was an increase in the values of LAR. However, at 44 days of DAS, we observed a maximum peak of 0.174 g m-² day-¹. After this date, there was a decrease in these values, probably indicating shading in the culture, either by increasing the LA of the culture or by factors such as light intensity in the period, affecting the culture sharply. Therefore, an increase in the spacing between the troughs for jambu plants is recommended for better LAR.

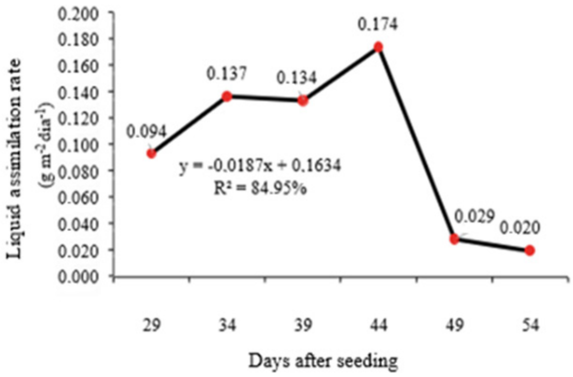

Figure 8. Net assimilation rate in jambu plants grown in hydroponic system.

Figure 9 shows that the values obtained for specific leaf area correlate the leaf surface area with the dry mass of the leaf itself, indicated by the high values at 29 DAS, caused by the increase in leaf expansion and less biomass in the leaves.

Throughout the cycle, there are increments and decrements in the values of specific leaf areas, which may be related to the periods of leaf expansion. Borges et al. (2014), evaluating jambu cultivars, obtained 282.94 cm² g-¹ in the cultivar Jambuarana at 90 DAS, a value higher than that found in the present study at 54 DAS of 230.99 cm² g-¹; this difference is probably due to the fact that the authors' work was with a longer cycle.

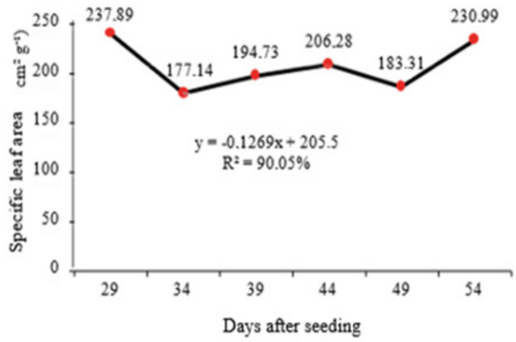

Figure 9. Specific leaf area in jambu plants grown in hydroponic system.

For the RAF, Figure 10 showed decreasing values from 29 DAS with 218.03 dm-² g-¹ to 54 DAS with 46.41 dm-² g-¹. As the cycle of jambu culture advanced, there was a noticeable reduction in the RAF influenced by the interference of the upper leaves in relation to the lower leaves, thus decreasing its useful LA. For Gonçalves et al. (2018), the RAF decreased with increasing self-shading, which was related to the results of leaf number and LA in this study.

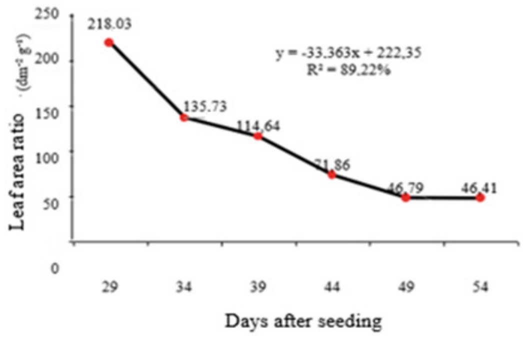

Figure 10. Leaf area ratio in jambu plants grown in hydroponic system.

For the DAF, it was observed in Figure 11 that at 54, DAS there was an increase, reaching at 12482.92 dm-² day-¹. Peixoto & Peixoto (2009) reported that the DAF was indicative of the persistence of the assimilatory surface of a plant and can be calculated before and after flowering. This is described by Silva et al. (2015) in their work on leaf analysis of radish, where most species showed greater DAF after flowering, which possibly occurred at 54 DAS in this work, explaining the reason for the substantial increase.

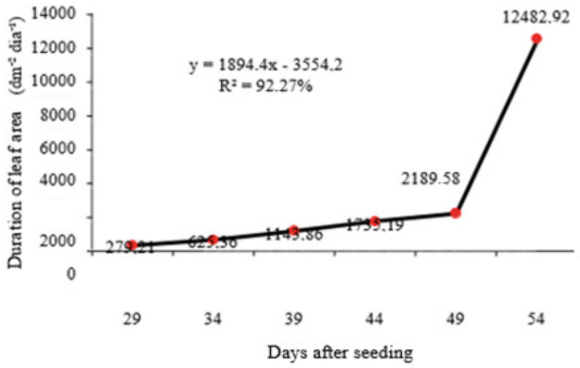

Figure 11. Duration of leaf area in jambu plants grown in hydroponic system.

Figure 12 shows that there was an exponential growth in the QWAP, arriving at 54 DAS, with a value of 217.81 g. Borges et al. (2013b), evaluating the growth of jambu plants as a function of fertilization, obtained an average of 106.81 g, a value lower than that found in the present study. In another study, Borges et al. (2014), evaluating jambu cultivars, obtained 216.33 g for the cultivar Jambuarana, a value close to that found in the present study.

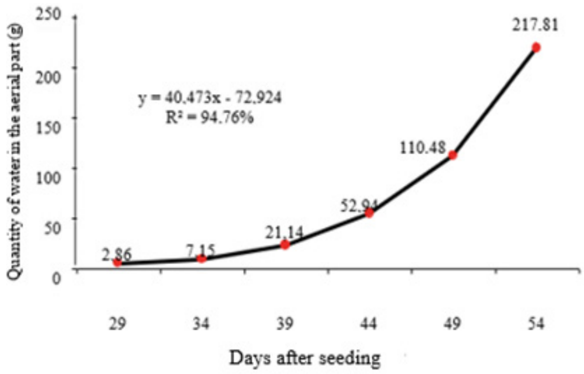

Figure 12. Quantity of water in the aerial part of jambu plants cultivated in hydroponic system.

Regarding the productivity characteristic, Figure 13 shows slower initial growth, but after 39 DAS, it grows exponentially, indicating a better use of the nutrient solution by the plant, verifying the productivity of jambu plants grown in soil. Borges et al. (2013b) found that jambu has a productivity of 3.37 kg/m2 and Borges et al. (2014) obtained values of 2.61 kg/m² in cultivar Jambuarana. However, Silva et al. (2020) obtained from 743.06 to 901.61 g planta^{-1} of hydroponic jambu productivity. One of the main features evaluated in any crop of economic interest is productivity, and in this culture, the jambu was obtained with excellent values since the 39 DAS that began a significant increase in the values of this feature, which reached the 54 DAS with values of 11.39 kg/m², an increase of 10 times when compared to the 39 DAS.

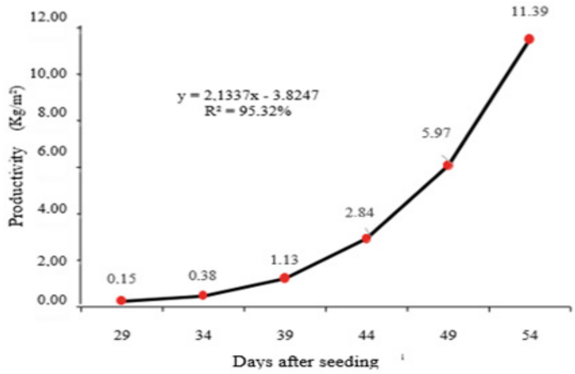

Figure 13. Productivity in jambu plants grown in hydroponic system

From this characteristic, it is possible to infer the high importance of this production system. If it is well managed, it can lead to a reduction in the crop cycle and greater financial return for the producer, which are factors of high relevance to all producers.

Conclusions

The growth analysis showed that the jambu plant in the hydroponic system presented higher morphophysiological indices starting at 39 days of the cycle and were directly influenced by the LAR. Due to the great influence of the leaf area length, the producers should be careful about the nutrient solution management. A productivity of 11.39 Kg / m² at 54 DAS of jambu cultivation was achieved using hydroponics.

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