Original Research Article

ALTERNATIVE SUBSTRATE WITH CUPUAÇU BARK PROMOTES MORPHOPHYSIOLOGICAL QUALITY IN YELLOW PASSION FRUIT SEEDLINGS

ABSTRACT

The use of agricultural residues for the production of alternative substrate is essential to reduce seedling production costs, as well as to reduce the environmental impacts resulting from the use of commercial substrates. Thus, the objective of this study was to evaluate the morphosiological performance of yellow passion fruit seedlings as a function of alternative cupuaçu bark substrates. The experiment was carried out in a screened nursery with sombrite of 50%, with a randomized block design with three replications and five plants per plot. The treatments consisted of the combination of ground and crushed cupuassu bark in different percentages. Liquid photosynthesis, stomatal conductance, internal CO_2 concentration, transpiration, plant height, stem diameter, main root length, number of leaves, dry and fresh shoot and root weight and Dickson Quality Index were evaluated. The morphological and physiological performance of passion fruit plants was influenced by the cupuaçu bark concentration. Substrates containing 20 to 40% cupuaçu bark resulted in better seedlings, as they promoted increased net photosynthesis, gas exchange, leaf number, higher root growth and development, and larger stem diameter and shoot height. Consequently, the Dickson quality index showed excellent values, which shows an improvement in the biometric and physiological characteristics of the passion fruit seedlings produced with alternative substrates based on cupuaçu bark.

Keywords: *Passiflora edulis*; Photosynthesis; Seedling production.

1. INTRODUCTION

The yellow passion fruit (*Passiflora edulis* Sims) has wide adaptation to tropical regions due to the edaphoclimatic conditions that are favorable to its cultivation. Due to the acceptance of its fruit for fresh consumption and for the fruit pulp industry, this fruit is highlighted by its economic and social importance [1]. Originally native to Brazil, which is the largest producer and consumer of this fruit tree in the world, with a production of 554,598.00 tons in the 2017 harvest on 110 hectares and an average productivity of 13.5 t ha^{-1} [2].

The seedling is the most important input in the implantation of a yellow passion fruit orchard [3], which produced with quality guarantee greater uniformity of the plants in the field and facilitate the productive process, while the use of low quality phytosanitary, genetic seedlings and nutritional compromises productivity, fruit yield and longevity of the crop [4].

In the production of passion fruit seedlings, sowing is usually carried out on commercial substrates, composed of expanded vermiculite and organic materials [5]. However, these substrates are expensive and do not provide all the physical, chemical and biological attributes necessary for the development of high quality seedlings [6].

The substrates can influence the development of plants, interfering with the maintenance, retention and amounts of water, in addition to the oxygen and nutrients available in the medium [7]. These factors in excess or deficiency, combined with the amount of irradiating light, promote stressful conditions that directly influence the physiological development of the seedling, mainly in the photosynthetic production of assimilates that are used for the growth and development of the plant [8].

As an alternative to the aforementioned substrates, research has been carried out with mixtures of organic materials, since these have appropriate physical and chemical properties for the development of quality seedlings, have low cost and are easily acquired [9, 10, 11], in addition to to provide less dependence on external inputs and reduced seedling production costs [12].

In Acre, the biggest limitation for the acquisition of commercial substrates is the distance from the production centers, which ends up making the production process more expensive or unviable. Thus, it becomes necessary to replace commercial substrates with alternatives produced from organic and regional materials available on the properties [13].

Given the above, the use of cupuaçu bark substrates, due to their physical and chemical characteristics and because of their high availability in various regions of the country, is a viable alternative and can meet the demand for the production of alternative substrates for the growth and development of high quality seedlings [14]. Therefore, the objective of this work was to evaluate the morphological and physiological performance of yellow passion fruit seedlings produced with alternative substrates based on cupuaçu bark.

2. MATERIAL AND METHODS

The experiment was conducted in a screened nursery with 50% shade, from June to August 2019, at the Federal University of Acre. The climate, according to the Köppen classification, is of the Am type, average annual temperature of 24.5 ºC, relative humidity of 84% and average annual rainfall ranging from 1,700 to 2,400 mm [15].

The experimental design was in randomized blocks with five treatments derived from the combination of cupuaçu bark and soil (substrate), in three replications and five plants per plot, totaling 75 sample units. The substrates used were: 100% soil; 20% cupuaçu bark + 80% soil; 40% cupuaçu bark + 60% soil; 60% cupuaçu bark + 40% soil; and 80% cupuaçu bark + 20% soil, with a complementary homogeneous distribution of 8 kg m^{-3} of slow release fertilizer (Osmocote) on all substrates. The analytical results of the chemical composition of the substrates are shown in Table 1.

Table 1. Chemical properties of the ground and crushed cupuaçu bark.

Substrate	pH	P	K	Ca	Mg	Al+	Al	OM	CEC
	H_2O	mg dm^{-3}	-------------cmol$_c$ dm^{-3}--------------					g kg^{-1}	pH7
Soil	5.40	27.64	0.75	6.25	1.25	0.71	0.01	22.44	9.01
cupuaçu bark	7.50	2.10	1.40	11.90	4.30	-	-	432.9	34.00

OM, organic matter; CEC, cation exchange capacity.

To evaluate the quality of the seedlings, were acquired seeds of *Passiflora edulis* cv. Giant Yellow in production area. Three seeds were distributed in plastic cups with a capacity of 300 mL containing the substrates. At 14 days after sowing, when the seedlings reached an average height of 5 cm, thinning was carried out, leaving only one plant of greater vigor. In conducting the experiment, manual irrigation was performed in two stages (morning and afternoon) and control of invasive plants manually.

At 72 days after sowing, when all plants in one of the treatments had tendrils, the morphophysiological characteristics were evaluated: net photosynthesis (PN), stomatal conductance (Gs), CO_2 intercellular content (Ci) and leaf transpiration (E), number of leaves (NL), seedling height (SH), stem diameter (SD), root length (RL), shoot fresh weight (SFW), root fresh weight (RFW), shoot dry weight (SDW) and root dry weight (RDW) and Dickson quality index (DQI).

Gas Exchange measurements were performed using an infrared gas analyzer - IRGA, LI-6400XT model (Li-Cor Inc. Lincoln, USA). The evaluations were carried out in a single day, at 10:00 am, in four plants for each treatment, totaling 20 samples.

The seedling height was determined with ruler graduated in cm, measuring from the base of the stem to the apex of the last leafe. The stem diameter was obtained with a digital caliper (mm) measuring the seedling diameter above 2 cm from the neck. The number of leaves was obtained by counting.

The plants were separated in shoot and root part, submitted to drying in forced-air circulation oven at 65ºC until they reached a constant weight. Subsequently, it was determined the shoot dry weight the root dry weight, in grams, by weighing on a precision analytical balance.

The Dickson quality index [16] was determined by the equation:

$$DQI=\frac{TDW\ (g)}{\left(\frac{SH\ (cm)}{SD\ (mm)}\right)+\left(\frac{SDW\ (g)}{RDW\ (g)}\right)}$$

TDW: total dry weight;
SH: seedling height;
SD: stem diameter;
SDW: shoot dry weight;
RDW: root dry weight.

The data were previously submitted to the verification of the presence of outliers by the Grubbs test, to the normality of errors by the Shapiro-Wilk test and to the homogeneity of the variances by the Cochran test. After verifying the assumptions, analysis of variance was performed using the F test and the data were submitted to regression analysis.

3. RESULTS AND DISCUSSION

The substrate with cupuaçu bark proportions showed a quadratic effect for PN, Ci, E and Gs (Figure 1A, 1B, 1C and 1D). It was found that the maximum point of net photosynthesis (9.99 $\mu mol\ m^{-2}\ s^{-1}$) was provided with 50.66% cupuaçu bark as a substrate conditioner. However, the gradual increase in the concentration of cupuaçu bark up to 80%, provided increasing rates of transpiration, internal CO_2 concentration and stomatal conductance in the seedlings.

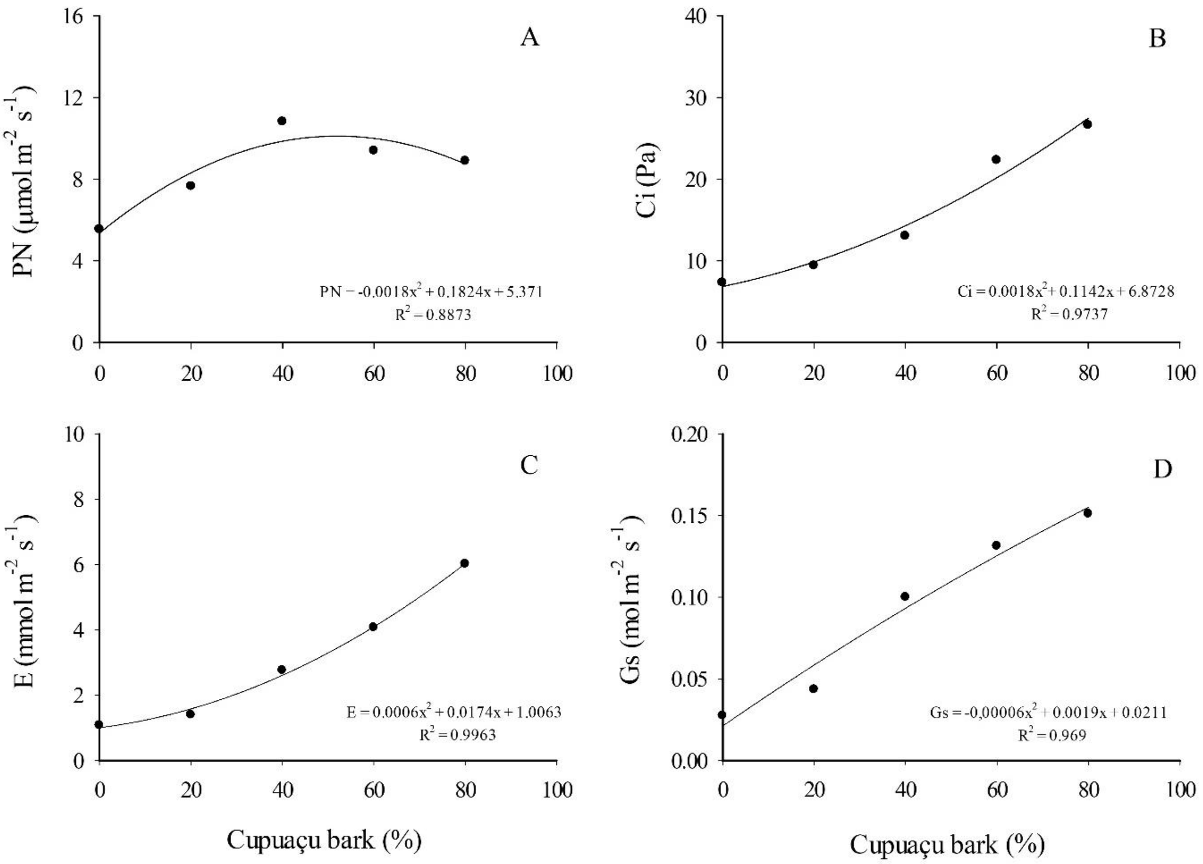

Figure 1. Net photosynthesis (A), internal CO_2 concentration (B), leaf transpiration (C) and stomatal conductance (D) of yellow passion fruit seedlings produced on an alternative substrate based on cupuaçu bark.

At high levels of stomatal conductance, gas exchange is consequently facilitated [17], which justifies the increasing order of transpiration and internal CO_2 concentration of seedlings submitted to the highest percentages of cupuaçu bark (60% and 80%). It is worth mentioning that high rates of gas exchange are obtained in the environment that provide better conditions for the vegetative development of seedlings, which favors the availability of essential resources for physiological activities [18].

However, even though there are interrelationships between the components of gas exchange, their high rates do not always reflect greater liquid photosynthesis by the plant, because the low internal CO_2 concentrations are a direct consequence of the high carboxylation efficiency of rubisco for the production of photoassimilates [19]. In addition, high values of gas exchange at a given rate, can provide a decrease in liquid photosynthesis due to biochemical limitations [20]. In this study, the ideal gas exchange conditions for the passion fruit seedlings to perform greater photosynthetic efficiency were provided by the mixture of 20% to 40% of cupuaçu bark with soil.

For the biometric characteristics of leaf number (NL), seedling height (SH), stem diameter (SD), and root length (RL) (Figure 2), a quadratic behavior was observed between the percentages of cupuaçu bark as substrate conditioner. It is noteworthy that between 15 and 30 cm in height the yellow passion fruit seedlings are suitable for planting [21], a condition observed in this study in all percentages of cupuaçu bark mixed with the soil. However, greater efficiency in seedling growth was found in low (0 to 40%) concentrations of cupuaçu bark.

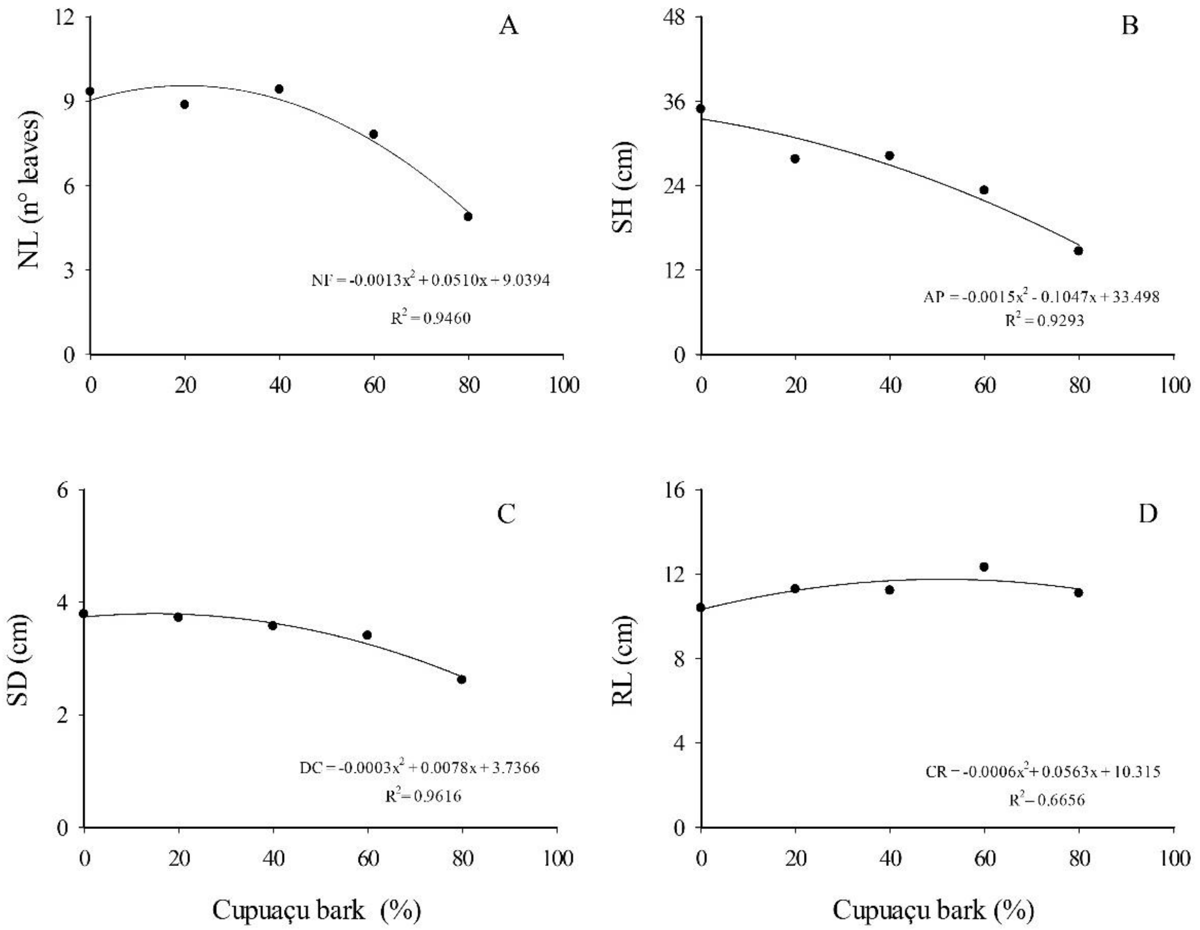

Figure 2. Number of leaves (A), seedling height (B), stem diameter (C) and root length (D) of yellow passion fruit seedling produced on an alternative substrate based on cupuaçu bark.

The addition of 20% to 40% of cupuaçu bark to the substrate provided ideal conditions for optimum development of NL (Figure 2A) and SD (Figure 2C) of passion fruit seedlings. In isolation, the largest root lengths (Figure 2D), to the detriment of height, were observed with the addition of up to 50% crushed cupuaçu bark. The stem diameter, as well as the greatest root growth, are considered measures of the vigor and robustness of the seedlings, being related to their growth after planting, as well as resistance to adverse climatic conditions, being able to predict transplant survival [22].

The physical properties of the substrate, including particle size distribution, water availability, air space and nutrient retention, influence seedling performance and growth [23]. In these conditions, the addition of up to 50% of the cupuaçu bark provided greater retention and availability of water for the seedlings, which favored the excellent root growth, larger diameter of the neck and maintained the number of leaves of the seedlings. Such results demonstrate the benefits of using cupuaçu bark as an alternative substrate for the production of high quality and low cost yellow passion fruit seedlings.

For shoot fresh weight (SFW) and shoot dry weight (SDW), the highest averages were observed in the treatment without the addition of cupuaçu bark (Figure 3A, 3C), followed by the treatment composed of 20% of this substrate, showing a decrease after that value. The addition of 20% to 40% of cupuaçu bark provided a greater increase in the root fresh weight (RFW) and root dry weight (RDW) (Figure 3B, 3D). It is noteworthy that, among other aspects, the root dry matter is an important parameter in estimating the seedling survival rate, since the greater the development of the root system, the greater the chances of establishment in the field, regardless of height of the shoot [24].

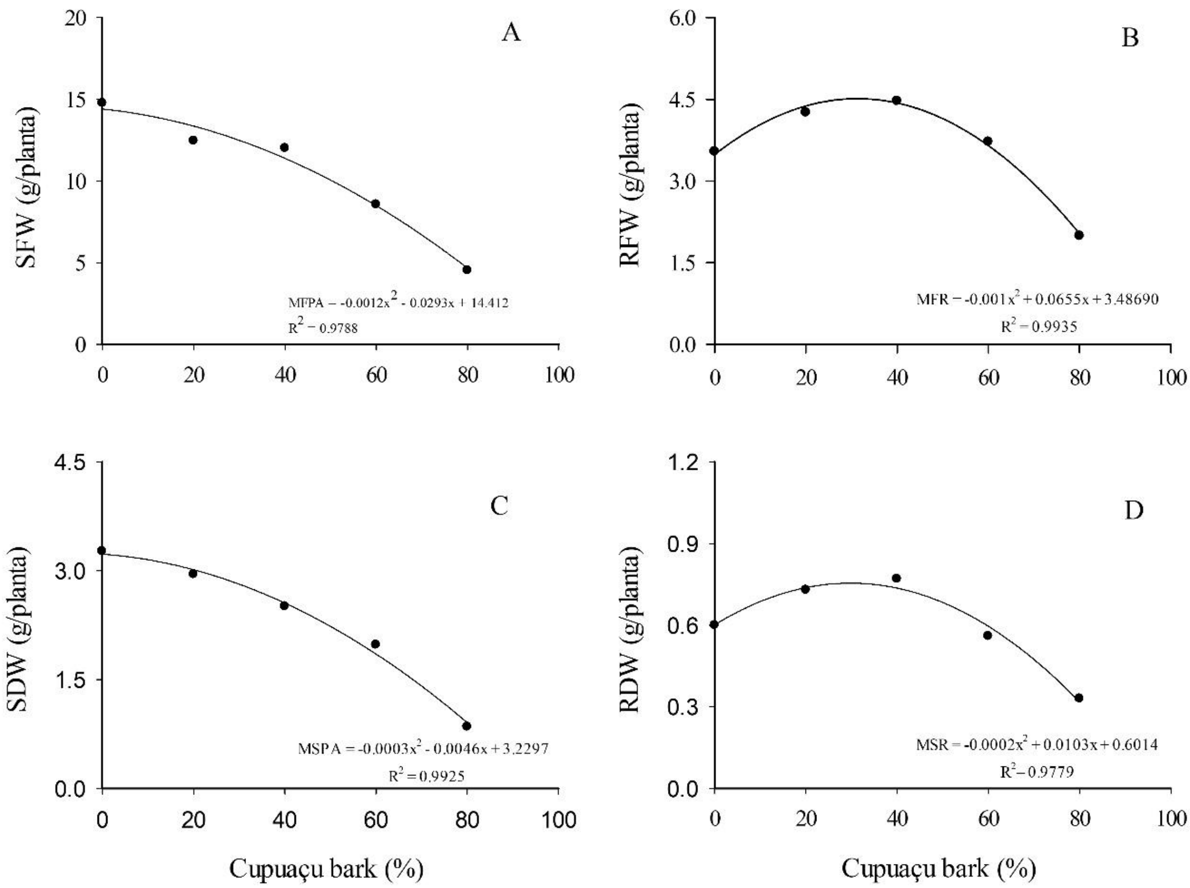

Figure 3. Shoot fresh weight (A), root fresh weight (B), shoot dry weight (C) and root dry weight (D) of yellow passion fruit seedlings grown on substrates based on cupuaçu bark.

The treatments with 60% and 80% cupuaçu bark provided less fresh and dry weight of the root system (Figure 3B, 3D), possibly due to the size of the particles of the cupuaçu bark, since rooting occurs more quickly in substrates thinner, in addition, substrates with high density decrease drainage and, consequently, aeration, creating an environment not favorable to the development of roots [25].

According to Figure 4, there was a quadratic effect for the Dickson quality index (DQI) of passion fruit seedlings developed on substrates with varying concentrations of crushed cupuaçu peel, reaching values between 0.16 to 0.32 of index. The highest DQI index was achieved with 26% substrate, a percentile that promoted an improvement in the efficiency of gas exchange parameters, reflecting in better development and growth of yellow passion fruit seedlings.

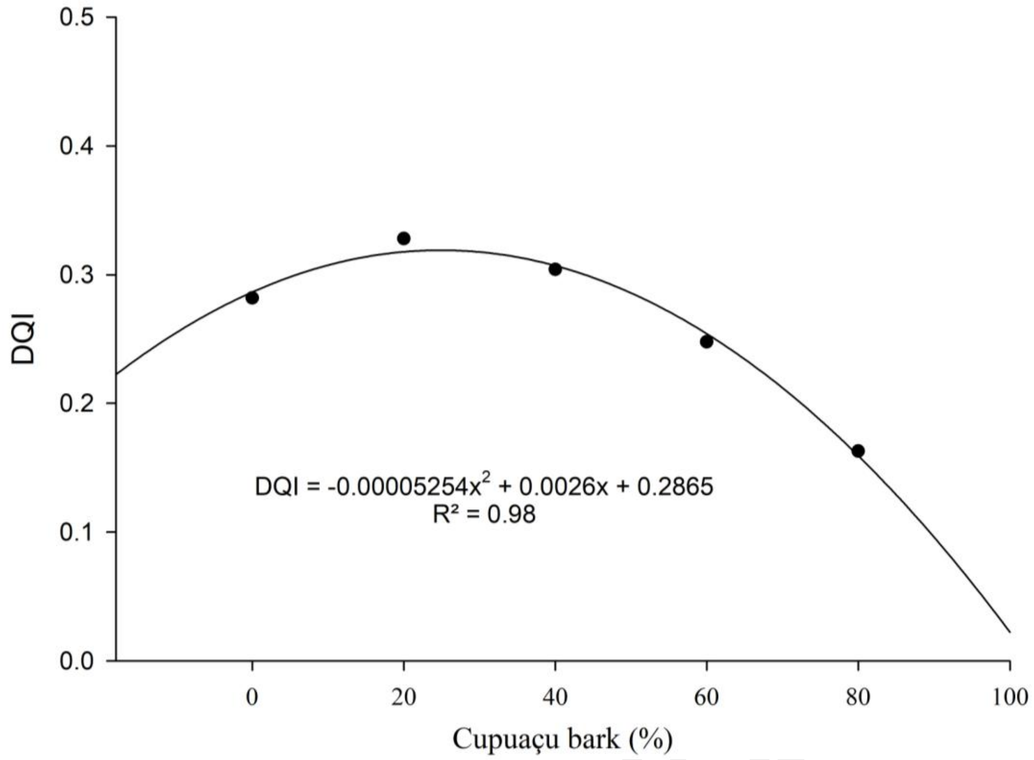

Figure 4. Dickson quality index (DQI) of yellow passion fruit seedlings produced on an alternative substrate based on cupuaçu bark.

The DQI is considered an integrated measure of morphological characteristics, in addition to being an excellent indicator of seedling quality because its calculation considers several important parameters, such as height, diameter and dry matter and their relationships [26]. Therefore, the higher the DQI, the higher the quality of the yellow passion fruit seedlings, since they are more vigorous when transplanted to the field, however when minimum values such as 0.20 for the index are obtained, the ideal is that the seedlings have height equal to or greater than 17 cm and number of leaves equal to or greater than nine, to guarantee the quality and survival of plants [27].

It is worth mentioning that the yellow passion fruit seedlings, even showing a decline in IQD with the increase in the percentage of cupuaçu bark in the substrate, their values were higher than 0.20, showing seedlings with excellent qualities to go to the field, which may reflect in less production time and, consequently, reduced input and labor costs.

4. CONCLUSIONS

Substrates constituted by the combination of 20% to 40% of cupuaçu bark and soil are an alternative for the production of yellow passion fruit seedlings, since they provide better biometric and physiological characteristics.

References

1. Lima LKS, Soares TL, Souza EH, Jesus ON, Girardi EA. Initial vegetative growth and graft region anatomy of yellow passion fruit on Passiflora spp. rootstocks. Scientia horticulturae. 2017; 215 (1): 134-141.

2. Instituto Brasileiro de Geografia e Estatística [IBGE]. (2017). Sistema IBGE de Recuperação Automática (SIDRA). Agricultural production. Portuguese. Retrieved on Out. 29, 2019 from https://sidra.ibge.gov.br.

3. Andrade FHA, Alves AS, Araújo CSP, Sousa VFO, Oliveira DS, Neto MAB, Morais RR. Cattle manure and liquid biofertilizer for biomass production of yellow passion fruit seedlings. African Journal of Agricultural Research. 2017; 12 (17): 1430-1436.

4. Santos GL, Almeida JF, Santos AS, Sousa VFO, Suassuna CF, Santos APL, Mesquita EF. Formation of Yellow Passion Fruit Seedlings under Different Substrates and Water Blades. Journal of Experimental Agriculture International. 2018; 27 (2) 1-8.

5. Miyake RT, Furlaneto FP, Narita N, Takata WHS, Creste JE. Economic analysis of the production of yellow passion fruit in an area with virose incidence and fertilized with NPK. Journal of Agricultural Science. 2018; 10 (5), 303-311.

[6] Miyake RTM, Takata WHS, Guerra WEX, Forli F, Narita N, Creste J E. Effects of potassium fertilization and commercial substrates on development of passion fruit seedlings under greenhouse condition. African Journal of Agricultural Research. 2016; 11 (39): 3720-3727. DOI: 10.5897/AJAR2016.11509

[7] Gruda NS. Increasing sustainability of growing media constituents and stand-alone substrates in soilless culture systems. Agronomy. 2019; 9 (6): 298. DOI: 10.3390/agronomy9060298

[8] Hussain HA, Hussain S, Khaliq A, Ashraf U, Anjum SA, Men S, Wang L. Chilling and drought stresses in crop plants: implications, cross talk, and potential management opportunities. Frontiers in plant science. 2018; 9 (4): 1-21. DOI: 10.3389/fpls.2018.00393

[9] Cavalcante AG, Araujo RC, Cavalcante ACAP, Silva AB, Neto MAD, Matos BF, Zuza JEFAC. Production of yellow passion fruit seedlings on substrates with different organic compounds. African Journal of Agricultural Research. 2016; 11 (12): 1086-1091. DOI: 10.5897/AJAR2015.10777

[10] Silva-Matos RRS, da Silva Júnior G B, Marques AS, Monteiro ML, Cavalcante ÍHL, Osajima JA. New organic substrates and boron fertilizing for production of yellow passion fruit seedlings. Archives of Agronomy and Soil Science. 2016; 62 (3): 445-455. DOI: 10.1080/03650340.2015.1050000

[11] Valle KD, Pereira LD, Barbosa MA, Chaves VBS, de Souza PHM, dos Reis EF, da Silva DFP. Development and root morphology of passion fruit in different substrates. Revista Colombiana de Ciencias Hortícolas. 2018; *12* (2): 514-520. DOI: 10.17584/rcch.2018v12i2.7779

[12] Pascual JA, Ceglie F, Tuzel Y, Koller M, Koren A, Hitchings R, Tittarelli F. Organic substrate for transplant production in organic nurseries. A review. Agronomy for Sustainable Development. 2018; 38 (3): 35. DOI: 10.1007/s13593-018-0508-4

[13] Simões AC, Alves GKEB, Ferreira RLF, Araujo Neto SE. Qualidade da muda e produtividade de alface orgânica com diferentes condicionadores de substrato. Horticultura Brasileira. 2015; *33* (4): 521-526. DOI: 10.1590/S0102-053620150000400019

[14] Oliveira JMF, Souza ADG, Smiderle OJ, Santos JL, Dall'agnese L. Seedling production Cattleya eldorado in substrates with nutritive solution under shading screens. Acta Iguazu. 2017; 6 (4): 114-125.

[15] INMET. Instituto Nacional de Meteorologia. Banco de Dados Meteorológicos para Ensino e Pesquisa. 2018. Retrived on Set. 14, 2019 from http://www.inmet.gov.br/portal/ index.php ?r=bdmep/bdmep.

[16] Dickson A, Leaf AL, Hosner JF.Quality appraisal of white spruce and white pine seedling stock in nurseries. Forestry Chronicle. 1960; 36 (1): 10-13. DOI:10.5558/tfc36010-1.

[17] Bucci SJ, Silletta LMC, Garré A, Cavallaro A, Efron S T, Arias N S, Goldstein G, Scholz F G. Functional relationships between hydraulic traits and the timing of diurnal depression of photosynthesis. Plant, Cell & Environment. 2019; 42 (5): 1603-1614. DOI: 10.1111/pce.13512

[18] Mateus SN, Ferreira OEV, Junior JCA., Domec JC, Jordan-Meille L, Gonçalves MJL, Lavres J. The ideal percentage of K substitution by Na in Eucalyptus seedlings: Evidences from leaf carbon isotopic composition, leaf gas exchanges and plant growth. Plant Physiology and Biochemistry. 2019; 137 (4): 102-112. DOI: 10.1016/j.plaphy.2019.02.006.

[19] Santos ALF, Mechi IA, Ribeiro LM, Ceccon G. Eficiência fotossintética e produtiva de milho safrinha em função de épocas de semeadura e populações de plantas. Revista de Agricultura Neotropical. 2018; *5* (4): 52-60. DOI: 10.32404/rean.v5i4.

[20] McClain AM, Sharkey TD. Triose phosphate utilization and beyond: from photosynthesis to end product synthesis. Journal of experimental botany. 2019;70 (6): 1755-1766. DOI: 10.1093/jxb/erz058.

[21] Junghans T, Jesus O. Maracujá do cultivo à comercialização. Brasília, DF: Empresa Brasileira de Pesquisa Agropecuária; 2018.

[22] Alonso JM, Abreu AHMD, Melo L A D, Leles PSDS, Cabreira, GV. (2018). Biosolids as substrate for the production of *Ceiba speciosa* seedlings. Cerne, 24 (4), 420-429. DOI: 10.1590/01047760201824042568.

[23] Munroe R, McGrath D, Henry J. Increasing amounts of coir dust in substrates do not improve physical properties or growth of tree seedlings in a novel air-pruning propagation tray. Journal of Environmental Horticulture. 2018; 36 (3): 92-103. DOI: 10.24266/0738-2898-36.3.92.

[24] Grossnickle SC, MacDonald JE. Why seedlings grow: influence of plant attributes. New forests. 2018; 49 (1): 1-34. DOI: 10.1007/s11056-017-9606-4.

[25] Chenot J, Gaget E, Moinardeau C, Jaunatre R, Buisson E, Dutoit T. Substrate composition and depth affect soil moisture behavior and plant-soil relationship on Mediterranean extensive green roofs. Water. 2017; 9 (11): 817. DOI: 10.3390/w9110817.

[26] Lin KH, Wu CW, Chang YS. Applying Dickson quality index, chlorophyll fluorescence, and leaf area index for assessing plant quality of *Pentas lanceolata*. Notulae Botanicae Horti Agrobotanici Cluj-Napoca. 2019; 47 (1): 169-176. DOI: 10.15835/nbha47111312.

[27] Posse RP, Valani F, Gonçalves AMS, de Oliveira EC, Louzada JM, Quartezani WZ, Leite MCT. Growth and quality of yellow passion fruit seedlings produced under different irrigation depths. Journal of Experimental Agriculture International. 2018; 22 (4): 1-11. DOI: 10.9734/JEAI/2018/40948.