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A new substrate medium mixture can improve the initial growth of *Hylocereus costaricensis* (Haw)

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Abstract

Dragon fruit is an exotic species that has currently shown great relevance in the world market. Hence, the demand for materials with high genetic potential has increased. Genetic propagation allows selecting materials with high yield and climatic conditions adaptation. The substrate selection influences the seedling quality, providing adequate conditions for germination and root development. This study evaluated the seedling emergence and initial growth of dragon fruit cultivated in different substrates under nursery conditions. The experiment was carried out in a completely randomized design, with 11 treatments, four replications, and 25 seeds per replication. The treatments used were composed of the washed sand; organic compost; Tropstrato®; coconut fiber; organic compost + Tropstrato® (1:1); coconut fiber + organic compost (1:1); coconut fiber + Tropstrato® (1:1); coconut fiber + Tropstrato® + organic compost (1:1:1); washed sand + Tropstrato® (1:1); washed sand + coconut fiber (1:1); washed sand + organic compost (1:1); washed sand + organic compost + Tropstrato® (1:1:1). Data of shoot length, stem diameter, root length, shoot dry matter, and root dry matter were recorded at 88 days after emergence. The treatment of washed sand + coconut fiber and Tropstrato® provided a higher emergence percentage and emergence speed of dragon fruit seeds. The treatment of coconut fiber + Tropstrato® + organic compost allowed better means for stem diameter, shoot dry matter, and root dry matter. Conversely, the treatments of washed sand + Tropstrato® and Tropstrato® resulted in greater root system growth.

Keywords: dragon fruit, seedlings production, seedlings vigor, seed propagation

Introduction

Brazil is one of the world's largest fruit producers, behind China and India (Food and Agriculture Organization, 2017), due to the edaphoclimatic conditions and diversity of genotypes. Dragon fruit is a promising fruit that has recently aroused the interest of many producers and researchers.

Dragon fruit (*Hylocereus costaricensis* Haw), also known as pitaya, is an exotic fruit species that has stood out in several countries, such as Israel, the United States, Australia, Thailand, Taiwan, Malaysia, Nicaragua, Vietnam, and more recently, Colombia, Ecuador, and Brazil (Food and Agriculture Organization, 2017). This fruit's success is mainly due to its ease of adaptation to different cultivation conditions compared with other fruit trees. This culture explores diverse horizons of the market and can be consumed *in natura* or processed in the forms of sweets, ice cream, and jelly.

Pitaya fruits have excellent physicochemical quality, with soluble solids values above 13 °Brix, low acidity, and pH (Menezes Cordeiro et al., 2015). In addition, the red pitaya fruit has in its composition red pigments known as betalains, phenolic compounds, and antioxidants, stimulating the organism in the digestive processes, preventing cancer and cardiorespiratory disorders (Esquivel & Araya Quesada, 2012), and has proven to be an excellent source for pharmaceutical products, as the fruits contain vitamins and minerals (Abreu et al., 2012).

Due to its current success in domestic and international markets and its high commercial value, the demand for materials with high genetic potential has increased. Seedling production is the most commonly used technique for propagating plant species due to the low cost of production (Ortiz-Hernández & Carrillo-Salazar, 2012). However, seed propagation becomes

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advantageous due to the species' variability, allowing selecting materials with desirable traits, such as high yield and climatic conditions adaptation (Andrade et al., 2008).

Dragon fruit is commonly vegetatively propagated using cladodes. Seed propagation requires the knowledge of internal factors (dormancy state, seed quality, and germination potential of the species) and external factors (water, temperature, gases, and light) interfering with the germination, emergence, and seedling development processes. Sexual propagation is used for genetic improvement and is considered a very efficient tool for high-diversity species.

The substrate choice also deserves attention, influencing the seedlings' production directly. A worthy substrate must be readily available and provide favorable conditions for germination and subsequent initial seedling development. In producing dragon fruit seedlings, Santos et al. (2016) concluded that sand+manure mixture provided higher phytomass accumulation in the shoots and the dragon fruit root system. For Marques et al. (2012), the treatment containing Plantmax® showed the best results for rooting.

Studies on the best substrate for the emergence and initial development of dragon fruit are scarce in the literature. The few available ones were performed under laboratory conditions and have only evaluated the germination percentage and germination speed (Alves et al., 2011; Alves et al., 2012; Andrade et al., 2008; Oliveira Júnior et al., 2015).

However, despite their satisfactory results, the existing works were carried out under laboratory conditions, controlling the factors that influence germination and emergence. Therefore, this work evaluated the emergence, and initial growth of dragon fruit (*H. costaricensis*) cultivated in different substrates under nursery conditions.

Materials and Methods

Description of the experimental area

The experiment was carried out in a greenhouse located at the Federal Rural University of the Semi-Arid (UFERSA), in the municipality of Mossoró (lat. 5°11'S; long. 37°20'W; alt. 18m asl).

According to Koppen's classification, the region's climate is 'BSWh' (warm, semiarid, rainy summer, with dry season lasting nine to ten months). The average annual rainfall is about 673.9 mm. The period from February to May is the most humid, and the period from August to November is the driest (Alvares et al. 2013).

Seeds were collected from ripe fruits from a commercial orchard in Baraúna/RN, using the methodology recommended by Alves, Godoy, and Oliveira (2012). After removing the mucilage from the seeds, sowing was carried out in 8 x 16-cm polystyrene trays containing 128 cells, with one seed per cell, at 1 cm depth. The substrates were irrigated twice a day with a watering can.

Experimental design

The experiment consisted of a completely randomized design, with 11 treatments, four replications, and 25 seeds per replication, distributed in a completely randomized design. The following treatments were tested: washed sand; organic compost; Tropstrato®; coconut fiber; organic compost + Tropstrato® (1:1); coconut fiber + organic compost (1:1); coconut fiber + Tropstrato® (1:1); coconut fiber + Tropstrato® + organic compost (1:1:1); washed sand + Tropstrato® (1:1); washed sand + coconut fiber (1:1); washed sand + organic compost (1:1); washed sand + organic compost + Tropstrato® (1:1:1).

After mixing the substrates, samples from each treatment were chemically analyzed, and the results are shown in Table 1.

Table 1. Chemical analysis of the different substrates and their mixtures used for dragon fruit seedlings production, Mossoró/RN, 2017.

Substrates	pH	EC	N	P	K^+	Na^+	Ca^{2+}	Mg^{2+}	SB (%)
	(Water)	dS m^{-1}	gkg	mg dm^3		.......cmolc dm^3.......			
Organic compost + Tropstrato®	6.92	0.02	6.02	28.67	48.52	26.8	6.78	4.62	11.64
Coconut fiber + organic compost	6.97	0.02	8.54	129.8	79.2	29.89	10.3	8.58	19.21
Coconut fiber + Tropstrato®	5.78	0.01	4.06	209.1	53.47	14.43	8.71	5.32	14.23
Coconut fiber + tropstrato® + Organic compost	6.74	0.01	5.74	452.8	81.18	25.77	9.89	7.92	18.13
Coconut fiber	5.98	0.01	4.62	72.15	58.42	14.43	3.26	2.36	5.83
Washed sand	-	-	-	-	-	-	-	-	-
Washed sand + Tropstrato®	6.72	0	0.28	186	16.84	12.36	8.28	5.29	13.67
Washed sand + Coconut fiber	7.21	0.01	1.4	33.51	23.77	11.33	3.34	2.89	6.34
Washed sand + Organic compost	7.78	0	0.7	190.3	23.77	12.36	6.76	4.41	11.28
Washed sand + Organic compost + Tropstrato®	7.32	0.01	1.4	305.3	43.57	21.64	7.97	6.91	15.09
Tropstrato®	6.28	0.01	4.2	131.1	37.63	15.46	14.7	12.07	26.96

* Chemical analysis was not performed for treatment #6 (only washed sand). EC: Electrical conductivity; N: Nitrogen; P: Phosphorus; K: Potassium; Na: Sodium; Ca: Calcium; Mg: Magnesium; SB: Sum of bases. Source: Authors, 2017.

Variables analyzed

Emergence percentage was evaluated daily by counting until up to 50 days after sowing when the emergence of all treatments stabilized. The first emergence count was performed five days after sowing. Subsequently, results were expressed as emergence percentage (E), calculated according to the rule for seed analysis.

$$E = \left(\frac{N}{A}\right) * 100 \quad \text{(Eq. 1)}$$

Where: emergence percentage – E; total number of emerged seedlings – N; number of sown seeds - A.

Emergence speed index (ESI) was calculated based on the formula described by the rule for seed analysis Maguire (1962).

$$ESI = \frac{E1}{N1} + \frac{E2}{N2} + \cdots + \frac{En}{Nn} \quad \text{(Eq. 2)}$$

Where: emergence speed index - ESI; E1, E2, and En are the number of normal seedlings that emerged in the first, second, and last count; and N1, N2, and Nn are the number of days to the first, second, and last count.

The mean time and relative emergence frequency were evaluated by the formula proposed by (Lima et al. 2006):

$$Tm = \sum ni \ ti / \sum ni \quad \text{(Eq. 3)}$$

Where: number of emerged seedlings per day - ni, and ti is the evaluation time (days).

$$Fr = ni / \sum ni \quad \text{(Eq. 4)}$$

Where: total number of seedlings emerged - ni, and Σni is the number of emerged seedlings per day.

Shoot length (cm), stem diameter (mm), root length (cm), and shoot dry matter (g seedling^{-1}) were evaluated at 88 days after sowing. Shoot length, root length, and stem diameter were measured with a millimeter ruler (cm) and a digital caliper (0.01 mm precision). Afterward, the material was separated by parts (shoot and root), placed in paper bags, and oven-dried at 60 °C until reaching a constant weight. Subsequently, samples were weighed on an analytical scale (0.001 g accuracy), and results were expressed in (g seedlings).

Statistical analysis

Results were subject to analysis of variance, and when significant, the qualitative data were subject to the Scott-Knott's test, at a 5% probability level. Analyses were performed in the R Core Team (2020) software.

Results and Discussion

Percentage, first emergence count, and emergence speed index

The substrates washed sand + coconut fiber, and Tropstrato® showed the best means for emergence percentage, with 92% and 91% of emerged seedling at 50 days of evaluation, respectively, and did not differ statistically by the Scott-Knott's test at 5% probability level (Table 2 and Figure 1).

Table 2. Emergence percentage (% EMERG), First Emergence Count (FEC), and Emergence speed (ES) of dragon fruit (*H. costaricensis*) seeds on different substrates. Mossoró/RN - Brazil, 2017.

Treatments	%EMERG	FEC	ES
Organic compost + Tropstrato®	17 d	2 c	0.085 d
Coconut fiber + organic compost	37 c	7 b	0.185 c
Coconut fiber + Tropstrato®	27 d	2 c	0.135 d
Coconut fiber + Tropstrato® + organic compost	67 b	9 b	0.33 b
Coconut fiber	72 b	21 a	0.36 b
Washed sand	7 d	2 c	0.04 d
Washed sand + Tropstrato®	68 b	11 b	0.34 b
Washed sand + Coconut fiber	92 a	10 b	0.46 a
Washed sand + organic compost	47 c	2 c	0.23 c
Washed sand + organic compost + Tropstrato®	45 c	3 c	0.24 c
Tropstrato®	91 a	7 b	0.45 a
CV (%)	21.36	41.64	21.24

Means followed by the same lowercase letter in the column do not differ from each other by the Scott-Knott's test, at 5% probability.

Substrates composed of washed sand + coconut fiber and Tropstrato® provided a higher emergence percentage due to favorable characteristics such as good texture and structure, temperature homogeneity, and excellent moisture retention. These properties directly influence seed germination and emergence. Alves, Godoy, and Oliveira (2012) evaluated the effect of mucilage removal on dragon fruit seeds in the laboratory and obtained similar results for emergence percentage (92% of emergence).

Andrade, Silva, and Martins (2008) tested different substrates for pitaya seeds germination percentage in the laboratory and claimed that washed sand had the lowest means for germination percentage (9%). Those results are due to the excessive drainage of the substrate. The authors observed germination percentage peaks when using coconut fiber in the first weeks, in agreement with the present study results. Conversely, Alves, Godoy, and Corrêa (2011) studied different substrates and temperatures in the laboratory and obtained the best germination percentage (66%) using washed sand as substrate at 25 °C.

For the first emergence count (Table 2), the substrate coconut fiber had the best emergence percentage mean, statistically differing from the other treatments by the Scott-Knott's test, at a 5% probability level. The substrates organic compost + Tropstrato®, coconut fiber + Tropstrato®, washed sand, and washed sand + organic compost showed the lowest means in the first emergence count. Coconut fiber provided favorable conditions to the seeds and expressed its maximum physiological potential for seed emergence. This result is due to the moisture retention and aeration, allowing rapid water absorption and accelerated and uniform initial germination and emergence.

For the emergence speed, washed sand + coconut fiber and Tropstrato® had similar responses to the emergence percentage, with higher means than the other substrates. Also, they did not statistically differ by the Scott-Knott's test, at the 5% probability level (Table 2).

The Washed sand + Coconut fiber and Tropstrato® had the highest initial emergence speed (ES) among the treatments. Coconut fiber is a phytopathogen-free substrate, has no physical impediment, and has excellent moisture retention. These factors, combined with the excellent porosity, good drainage, and aeration of the sand, provide an excellent environment for the seedlings to emerge faster. Moura et al. (2016) claimed the inexistence of a standard substrate for fruit species. They recognized that each species has its particularities. However, the substrate's composition should be readily available, pathogen-free, and have good water retention and nutrient availability, which will provide seedling development during seedling production.

Dragon fruit seedlings' emergence was analyzed by its temporal distribution by the relative emergence frequency (Figure 3). Distribution patterns were ununiform, showing more than one peak over the 50-day evaluation, characterizing a polymodal behavior. For most treatments, peaks occurred between the fourth and the 24th and the 30th evaluation day. Only washed sand had an emergence concentration from the fourth to the 12th day after emergence. This treatment also resulted in the highest peak of relative emergence frequency (28.57%), and consequently in a longer mean emergence time.

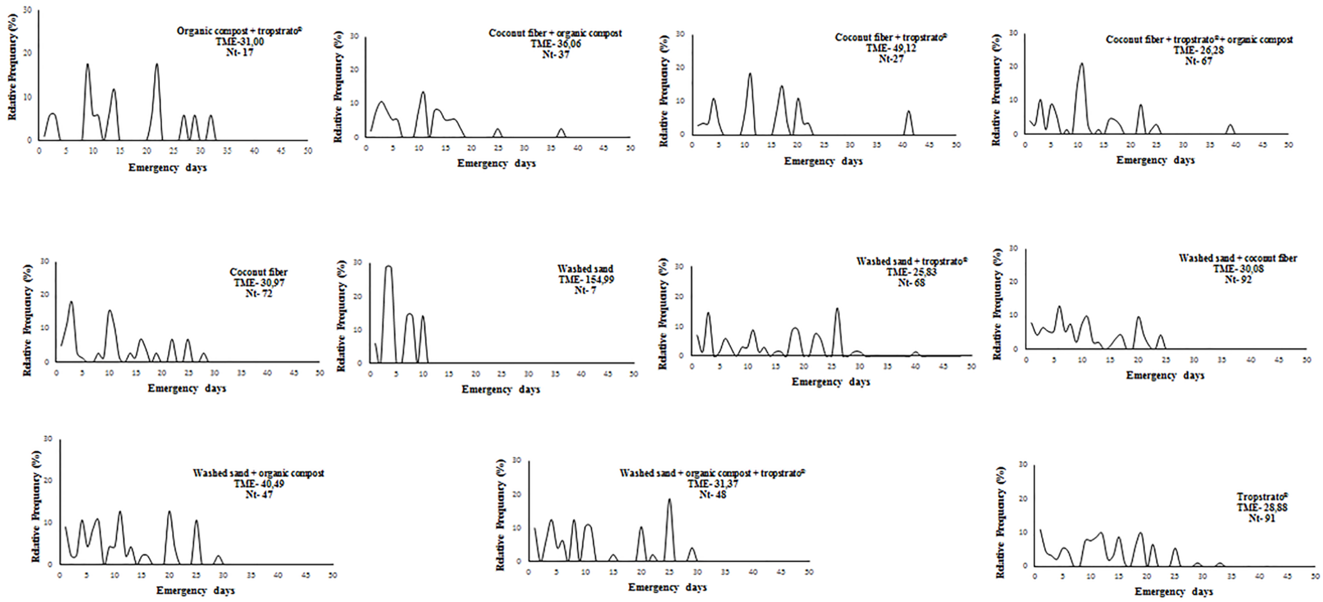

Figure 1. Relative emergence frequency of dragon fruit seeds (*H. costaricensis*) cultivated in different substrates. Mossoró/RN - Brazil, 2017.

Matheus & Lopes (2009) explain that the nonuniformity of the relative emergence frequency is due to the specie's occupation strategy, which causes seedlings emergence in different periods and reduces seedlings' competition for differentiated environmental conditions and herbivorism.

Dorneles et al. (2013) and Moraes et al. (2016) obtained similar results for morphophysiological nonuniformity of *Anadenanthera colubrina* seeds, leading to germination asynchrony. Alves et al. (2011) tested different temperatures and substrates for dragon fruit seed germination. The authors reported that the germination percentage in germination paper in gearboxes was higher at 25 °C, differing from the other treatments. However, when the researchers increased temperature to 30 °C, the germination pattern was maintained for three of the four substrates tested, showing an irregularity in the germination percentage due to high temperature. This fact may have caused the ununiform emergence in the present study since the semiarid region has temperatures higher than 30 °C during the day.

Growth variables

Coconut fiber + organic compost provided the best means for shoot length, with 3.03 cm, statistically differing from the other treatments analyzed by Scott-Knott's test, at a 5% probability level (Table 3).

Table 3. Shoot length (SL), stem diameter (SD), root length (RL), shoot dry matter (SDM), and root dry matter (RDM) of dragon fruit (*H. costaricensis*) cultivated in different substrates. Mossoró/RN - Brazil, 2017.

Treatments	SL	RL	SD	SDM	RDM
	---------cm---------		mm	---------g seedling--------	
Organic compost + Tropstrato®	2.04 d	2.98 c	6.2 c	0.11 e	0.05 d
Coconut fiber + organic compost	3.03 a	3.55 c	7.33 b	0.34 c	0.15 c
Coconut fiber + Tropstrato®	0.29 f	4.05 b	3.18 e	0.03 f	0.04 d
Coconut fiber + Tropstrato® + organic compost	2.46 b	3.93 b	8.28 a	0.60 a	0.32 a
Coconut fiber	0.33 f	4.20 b	3.03 e	0.10 e	0.08 d
Washed sand	0.53 e	3.07 c	2.83 e	0.01 f	0.02 d
Washed sand + Tropstrato®	0.40 f	4.85 a	3.10 e	0.09 e	0.13 c
Washed sand + coconut fiber	0.34 f	3.30 c	2.83 e	0.12 e	0.06 d
Washed sand + organic compost	2.59 b	3.73 c	6.10 c	0.41 b	0.31 a
Washed sand + organic compost + Tropstrato®	2.31 c	3.48 c	5.83 c	0.37 c	0.26 b
Tropstrato®	0.48 e	4.45 a	4.73 d	0.11 d	0.13 c
CV (%)	8.05	11.54	11.41	11.93	21.45

Means followed by the same lowercase letter in the column do not differ from each other by the Scott-Knott's test, at 5% probability level.

Lower means for shoot length were observed when using the substrates coconut fiber + Tropstrato®, coconut fiber, washed sand + Tropstrato®, and washed sand + coconut fiber, which did not statistically differ from each other. Nogueira et al. (2012) studied different substrates in seedling production of *Solanum lycopersicum* and reported similar results to those of the present study. According to the authors, seedlings obtained the highest growth due to the physicochemical quality of the organic compost. This substrate supplies essential nutrients, such as nitrogen (N), phosphorus (P), potassium (K), besides being a source of organic matter, leading to a high-water retention capacity, increased porosity, and lower density. Coconut fiber has similar properties and high resistance to decomposition caused by water and bacteria, ensuring adequate plant growth (Leal et al. 2016).

For the stem diameter, coconut fiber + Tropstrato® + organic compost provided the best result, with 8.28 mm, statistically differing from the other substrates by the Scott-Knott's test, at a 5% probability level (Table 3). According to Zietemann & Roberto (2007), the substrate organic compost has several biological, physical, and chemical characteristics that guarantee an environment with good water retention capacity and nutrients' availability to the plant, promoting adequate root development. Their mixture allows satisfactory results, directly influencing the stem diameter.

Root length (Table 3) had the best means when cultivated in the substrate washed sand + Tropstrato® and Tropstrato®, with 4.85 and 4.45 cm, respectively, and did not statistically differ by the Scott-Knott's test, at 5% probability level. Both substrates resulted in optimum root growth. This behavior occurred due to the porosity and sterility of the washed sand, promoting the movement of water and air in the soil and better breathing of the root system. The treatment Tropstrato® provided the best emergence percentage and emergence speed at 50 days of evaluation. Therefore, these substrates provided a satisfactory environment to the plant, enabling the seedlings to express their full vigor, causing rapid, uniform emergence and proper development in the field.

Similar results were reported by Silva et al. (2017) when evaluating the germination and vigor of *Parkia platycephala* Benth seedlings. Based on their results, the root length was favored by the commercial substrate Tropstrato® for presenting nutrient contents and moisture retention suitable for the full seedling development.

The substrate coconut fiber + Tropstrato® + organic compost provided the best result for shoot's dry matter, statistically differing from the other treatments by Scott-Knott's test, at 5% probability (Table 3). For root dry matter, the substrates coconut fiber + Tropstrato® + organic compost and washed sand + coconut fiber had the best mean and did not statistically differ by the Scott-Knott's test, at 5% probability (Table 3).

The results verified at the end of the evaluation were satisfactory due to the favorable conditions provided by the substrate, considering the adequate nutrients content, hydrogen potential (pH), and cation exchange capacity (CEC) for the whole seedlings' development. However, washed sand had the lowest means for the shoot's and root's dry matter. Generally, a substrate does not have all the necessary characteristics for the plants' complete development. Therefore, the mixture of different substrates is a strategy promoting the balance of the different elements and obtaining an ideal substrate for seedlings production. Moura et al. (2016) analyzed the emergence and initial development of *Theobroma grandiflorum* seedlings cultivated in different substrates and verified that washed sand had the least satisfactory means, as also observed in the present work. This result is due to the inappropriate characteristics for a better seedling development since washed sand does not retain proper moisture content, making the substrate quickly dry.

Conclusions

The substrates containing washed sand + coconut fiber and Tropstrato are the most suitable for the germination and emergence of pitaya seedlings.

The mixture of coconut fiber, organic compost, and Tropstratum substrates provided the best characteristics for the initial seedlings' growth, such as shoot length, root system growth, stem diameter, and shoots' and roots' dry matter.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.