Original article

Effect of juvenility on cutting propagation of red pitaya

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Abstract — Introduction. Pitaya (*Hylocereus undatus*) is an exotic fruit species little known in Brazil and which needs basic studies about plant nutrition, propagation and physiology. Emphasizing the co-existence of juvenile and adult stages in the pitaya canopy, the plant is generally propagated by cuttings. **Materials and methods**. A completely randomized design with four treatments and five replications was adopted. Each treatment was represented by the part of the canopy from which the cutting was taken (upper, middle and lower cutting and cuttings from young plants). The following variables were registered: % cuttings with roots, % of live cuttings, root density, root diameter, root area, root length and root dry mass. Results were submitted to variance analyses, Tukey's test at 0.01 probability error and simple correlation analysis. **Results and discussion**. The results indicated that the position from which the cutting is taken had a quantitative effect on rooting formation of pitaya cuttings. Juvenile cuttings presented 35% more cuttings with roots than adult cuttings. Root density, root area, root length and root dry mass depended on juvenility, the highest results being registered for juvenile cuttings, independently of the variable. **Conclusion**. Juvenile and adult stages co-exist in the pitaya canopy. Juvenility is an important rooting factor for red pitaya cuttings.

Brazil / *Hylocereus undatus* / vegetative propagation / propagation by cuttings / plant developmental stages / juvenility of plants / rooting

Effet de la juvénilité sur le bouturage de portions de pitaya rouge.

Résumé — Introduction. Le pitaya (*Hylocereus undatus*) est une espèce fruitière exotique peu connue au Brésil et qui nécessite des études de base sur la nutrition, le bouturage et la physiologie de la plante. Du fait de la coexistence de stades juvéniles et adultes sur un même plant de pitaya, cette plante est généralement propagée par boutures. **Matériel et méthodes**. Un dispositif expérimental entièrement randomisé avec quatre traitements et cinq réplications a été adopté. Chaque traitement a été identifié par la partie de la plante sur laquelle la bouture a été prélevée (boutures de base, intermédiaires et d'extrémité, et boutures de jeunes plantes). Ont été considérés les pourcentages de boutures avec racines, les pourcentages de boutures vivantes, la densité des racines, leur diamètre, leur section, leur longueur et leur poids sec. Les résultats ont été soumis à des analyses de variance, au test de Tukey (seuil de 1 %) et à l'analyse de corrélations simples. **Résultats et discussion**. La position, sur le plant, du fragment prélevé a eu un effet quantitatif sur l'enracinement de la bouture de pitaya. Les boutures prélevées sur portions juvéniles ont présenté 35 % de boutures avec racines en plus que les boutures prélevées sur portions adultes. La densité des racines, leur section, leur longueur et leur poids sec ont été conditionnés par l'état juvénile des boutures ; quelle que soit la variable, les meilleurs résultats ont été obtenus à partir de boutures issues de tissus juvéniles. **Conclusion**. Les stades juvéniles et adultes coexistent sur un même plant de pitaya. La juvénilité est un facteur favorisant l'enracinement des boutures de pitaya rouge.

Brésil / *Hylocereus undatus* / multiplication végétative / bouturage / stade de développement végétal / stade juvénile des plantes / enracinement

1. Introduction

Pitaya (*Hylocereus undatus*) is a climbing fruitful cactus native to the tropical forest regions of Mexico and Central and South America [1, 2]; it is considered to be a promising new fruit species [3] for Brazil, although, in the exotic fruit market of Europe [4] and the United States [5], pitaya occupies a growing niche.

In Brazil, pitaya is still little known; the interest shown in this species is recent and, consequently, more detailed knowledge about this plant is required in relation to basic information such as genetics, plant nutrition, propagation and physiology, including juvenility studies emphasizing the co-existence of juvenile and adult stages in the pitaya canopy.

Propagation of pitaya by cuttings is the most common, simplest and preferable method, as it allows reliable reproduction of the cultivar and as the fruiting stage is reached more rapidly (less than one year) [2]. In Brazil, Silva [6], Bastos *et al.* [7], and Andrade *et al.* [8] studied cutting propagation of red pitaya. In addition, pitaya can also be grown by seeds, as seed viability is very high and germination occurs quickly, but new seedlings present a longer juvenility period and much seedling variation, affecting fruit quality and yield; micropropagation is also used, as proposed by Mohamed-Yasseen [9] and Drew and Azimi [10].

In vegetative propagation (*e.g.*, cutting), ontogenetic aging (juvenile or adult) is important because buds and cuttings, when removed from the mother plant, perpetuate their ontogenetic age in the progeny plant [11]. Accordingly, Davis *et al.* [12] reported that the juvenile and mature forms can be maintained as separate plants through use of cutting propagation or they can co-exist on the same plant, which demonstrates the relevance of studies aiming to identify ontogenetic aging and its influence on vegetative propagation, especially for exotic species, such as pitaya in Brazil.

Apparently, pitaya is a homoblastic species, *i.e.*, there is a very little obvious change in the plant's appearance as it grows from a seedling to its mature condition [11].

Hence, the objective of our work was to identify the co-existence of juvenile and adult stages and their effect on cutting propagation of red pitaya.

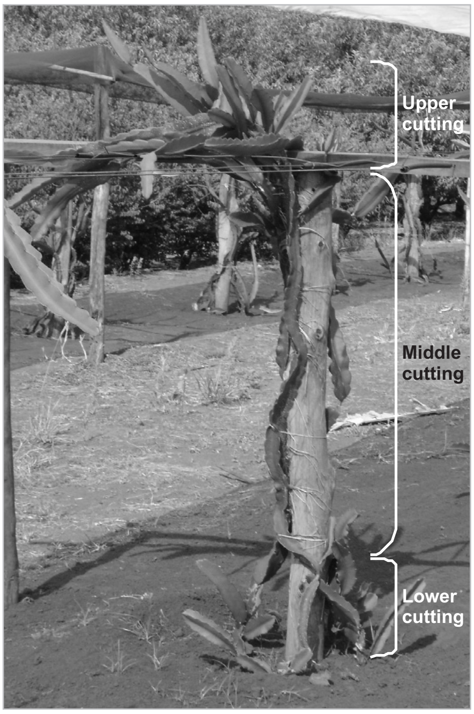

Figure 1.
Part of the canopy of *Hylocereus undatus* from which cuttings were taken for evaluating juvenility for pitaya propagation.

2. Materials and methods

2.1. Growth conditions and plant material

The study was conducted from May 2007 to July 2007 with red pitaya (*Hylocereus undatus*) cuttings collected from plants of the Active Germplasm Bank of the Faculty of Agricultural and Veterinarian Sciences, São Paulo State University, Jaboticabal, Brazil. The 1.5-year-old mother plants were formed by cutting propagation, spaced 3 m between lines and 2 m between plants, trained vertically and grown under 50% luminosity.

The local climate is classified as Cwa with average precipitation of 1400 mm·year^{-1} and temperature between (18.5 and 25) °C.

Pitaya cuttings (approximately 25 cm length) immediately after being collected had the base dipped in a solution with Captan® fungicide; then they were planted in polyethylene pots (15 cm in diameter × 20 cm in height) filled with a soil mixture commonly used for seedling formation under [soil (red oxisol): sieved sand: bovine manure] in the proportion [3:3:1], placed in a 50%-shade-house, and irrigated daily (once a day) with good quality water. Approximately 15 cm of the cutting was exposed to the atmosphere. No treatment with exogenous auxin (IBA) was realized, according to a previous study of Andrade *et al*. [8].

2.2. Treatments and experimental design

A completely randomized design was adopted and four treatments were performed, with five repetitions of ten cuttings each, reaching 200 cuttings. Each treatment was represented by the part of the canopy from which the cutting was taken (*figure 1*), and identified as: upper, middle and lower cutting; cuttings from young (one-year-old and also propagated by cuttings) plants were also studied as a treatment.

2.3. Variables registered and statistical analyses

Cuttings were removed from the substrate 6 weeks after planting and adventitious roots (on average) were analyzed through the following variables: (i) % cuttings with roots; (ii) % of live cuttings; (iii) root density in mm·mL^{-1} of soil mixture; (iv) root diameter; (v) root area; vi) root length, and (vii) root dry mass. For determination of variables (iii) to (vii), adventitious roots were taken to the biology laboratory, washed with tap water and 1 g of root was taken and scanned using a “Delta-T Scan” root measurer.

Statistical analyses included analysis of variance (ANOVA), mean separation of cutting types using Tukey’s test and correlation analysis between dependent variables [13]. All the calculations were performed using the SAS Statistical Program [14] and terms were considered significant at a 0.01 probability error.

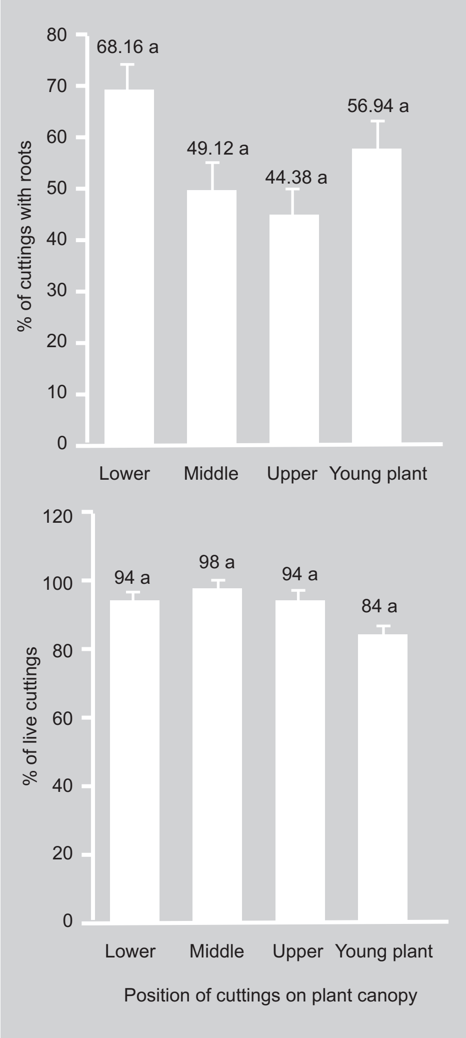

Figure 2.
Percentage of cuttings with roots (SMD = 69.58) and percentage of live cuttings (SMD = 15.95) of pitaya as a function of the part of the canopy from which the cutting was taken. Averages followed by the same letter do not differ by Tukey’s test at 0.01 probability error.
SMD = Significant Minimum Difference. Symbols represent the standard error.

3. Results and discussion

Despite the lack of significant statistical effects, the percentage of cuttings with roots presented a large range from (44.38 to 68.16)% (*figure 2*). The higher result was registered for juvenile cuttings while the lower one was for adult cuttings; the difference of nearly 35% is representative of successful cutting propagation. From these results it can be inferred that the ability to form adventitious roots from cuttings is

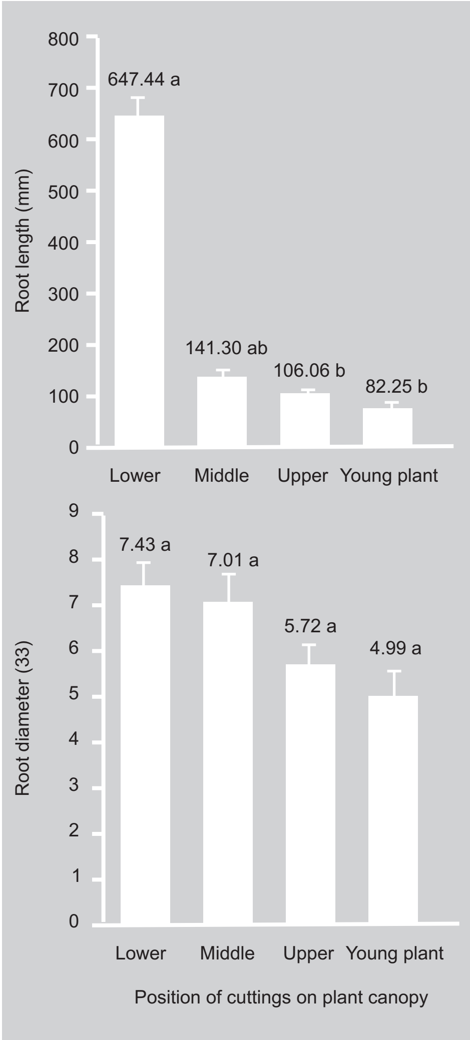

Figure 3.
Root length (SMD = 508.54) and root diameter (SMD = 4.15) of pitaya cuttings as a function of the part of the canopy from which the cutting was taken. Averages followed by the same letter do not differ by Tukey's test at 0.01 probability error.
SMD = Significant Minimum Difference. Symbols represent the standard error.

reduced once pitaya becomes mature; this is in agreement with Ansari *et al.* [15] who reported that adventitious rooting in *Dalbergia sissoo* cuttings was found to vary with position within a single tree and to be correlated with the existence of a juvenility gradient within the plant canopy. On the other hand, Kibbler *et al.* [16], in a similar study with *Backhousia citriodora*, observed no difference in rooting between cuttings taken from the base of the mature plants propagated from cuttings and those taken from the apex.

In a study about the effect of juvenility on rooting of trifoliate orange cuttings, Bhusal *et al.* [17] verified that the rooting percentage of cuttings from juvenile plants was statistically higher than that from adult plants, a decrease of 76.7% being registered.

When compared with the rooting results of Bastos *et al.* [7] and Andrade *et al.* [8], who studied cutting propagation of red pitaya, it is observed that the averages of the present study are lower, independently of the treatment.

The decline in the percentage of cuttings with roots of cuttings from the mature part of the pitaya canopy may be associated with the presence of some rooting inhibitors such as cytokinin, abscisic acid and gibberellin, while promoters (auxin, ethylene and carbohydrate) are observed in juvenile cuttings. Studies have shown that root initiation potential might be related to ethylene synthesis or action. Raviv *et al.* [18] isolated and identified four rooting promoters with an acetylenic moiety (1,2,4-trihyroxy-n-heptadeca-16yn is most active) that accumulates faster in the bases of juvenile cuttings of avocado during the course of the rooting than in mature cuttings. Accordingly, Girouard [19] found that the anatomical process of root initiation is quite different in juvenile and mature cuttings.

For the percentage of live cuttings, the lowest percentage (84%) was registered for cuttings from young plants (*figure 2*) and no statistical difference was observed among the parts of the canopy from which the cuttings were taken, which demonstrates that plant juvenility had no effect on cutting survival. Accordingly, no correlation was observed between the percentage of cuttings with roots and the percentage of live cuttings, as Maldonado *et al.* [20] and Franco *et al.* [21] also observed. The high percentage of live cuttings evidences the adequate conditions in which the experiment was realized in relation to the mother plant, environment and techniques adopted, as also proposed by Hartmann *et al.* [11] in a general form.

Root length was remarkably and significantly influenced by the part of the plant from which the cutting was taken (*figure 3*). Juvenile cuttings promoted the longest roots, almost 87% above mature cuttings, thus evidencing the juvenile and mature phases on the same plant of pitaya, previously observed for other species by Hartmann *et al.* [11], naming this phenomenon the "cone of juvenility", *i.e.*, seedling plants undergo the juvenile, transitional and mature phases of development to various degrees in different parts of the plant in a gradient from base to top.

The root length was correlated positively with root dry mass ($r = 0.96$, significant at the 1% level); a correlation classified as high by Ferreira [13]. On the other hand, root diameter was not correlated with any variable, which confirms that root length was more affected by juvenility than root diameter.

As also observed for percentage of cuttings with roots, root diameter was not statistically influenced by plant juvenility, although a quantitative reduction of nearly 32.87% in root diameter was registered from young cuttings to juvenile cuttings (*figure 3*). In addition, Taiz and Zeiger [22] argue that cuttings from the base of the plant are juvenile and their growth is fast.

The results of root dry mass, root area and root density (*figure 4*) depended on the ontogenetic aging of the part from which they were collected. Following the same tendency of root length (*figure 3*) and root diameter (*figure 3*), cuttings from the base of the pitaya canopy presented significantly higher averages, an increase of nearly (93, 91 and 93)% being registered for root dry mass, root area and root density, respectively. These results evidence that juvenility affected both root initiation and root initial development and growth. Additionally, cuttings taken during the juvenile phase of most plants inherently have a higher root potential than those from the mature phase [17, 23].

Davis *et al.* [12] concluded that there is an ontogenetic loss of capacity to form adventitious roots, but the steepness of the gradient for ontogenetic loss of rooting capacity varies with species, which shows the importance of specific studies about each species, especially those little studied in Brazil, such as pitaya. Also significant is the fact that cuttings from young plants also propagated by cuttings presented the sec-

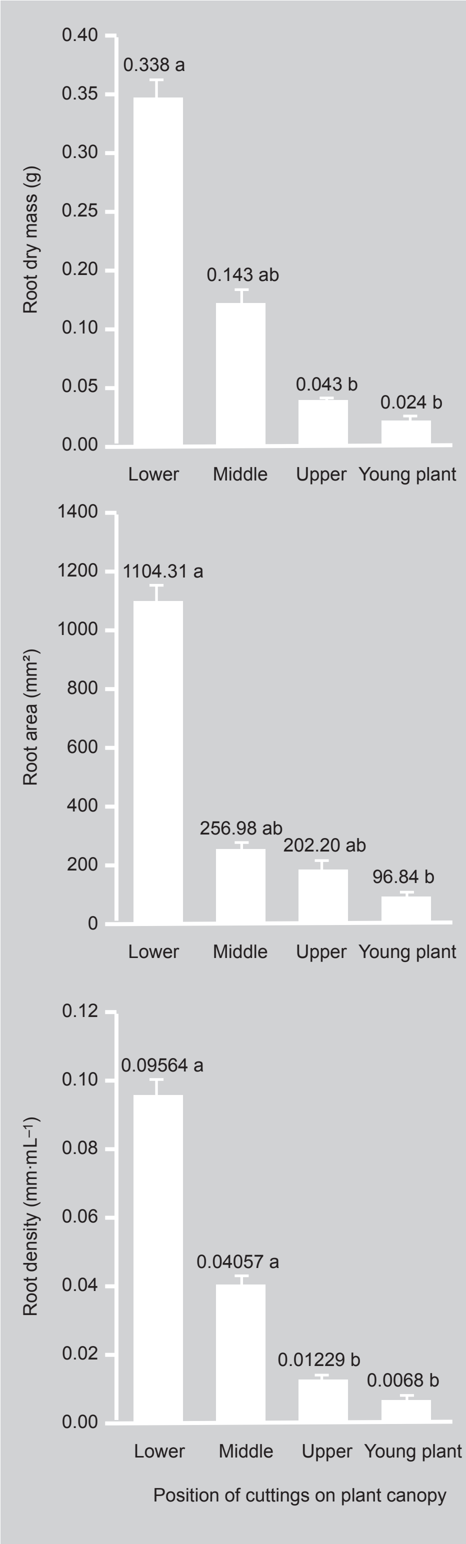

Figure 4.
Root dry mass (SMD = 0.28), root area (SMD = 914.27) and root density (SMD = 0.08) of pitaya cuttings as a function of the part of the canopy from which the cutting was taken. Averages followed by the same letter do not differ by Tukey's test at 0.01 probability error. SMD = Significant Minimum Difference. Symbols represent the standard error.

ond highest percentage of cuttings with roots, although this sequence was not observed for other variables, showing that there was a difference in plant effect related to root initiation and initial root growth and development.

4. Conclusions

In conclusion, our results showed that juvenile and adult stages co-exist in the pitaya canopy. Juvenility is an important rooting factor for red pitaya cuttings.

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Efecto de la juventud en la propagación por esquejes de porciones de la pitahaya roja.

Resumen — **Introducción**. La pitahaya (*Hylocereus undatus*) es una especie de fruta exótica poco conocida en Brasil y que necesita estudios de base sobre la nutrición, la propagación por esquejes así como sobre la fisiología de la planta. A causa de la coexistencia de los estados juveniles y adultos en una misma planta de pitahaya, ésta última se propaga mediante esquejes. **Material y métodos**. Se adoptó un dispositivo experimental completamente randomizado con cuatro tratamientos y cinco replicaciones. Se identificó cada tratamiento por la parte de la planta sobre la que se extrajo el esqueje (esquejes de base, intermediarios y de extremidad, y esquejes de plantas jóvenes). Se consideraron los porcentajes de esquejes con raíces, los porcentajes de esquejes vivos, la densidad de las raíces, su diámetro, su sección, su longitud y su peso seco. Los resultados se sometieron a análisis de la varianza, al estadístico de Tukey (límite del 1 %) y al análisis de correlaciones simples. **Resultados y discusión**. La posición, en la planta, del fragmento extraído tuvo un efecto cuantitativo en el arraigamiento del esqueje de la pitahaya. Los esquejes extraídos sobre las porciones juveniles presentaron un 35 % de esquejes con raíces más que los esquejes extraídos en porciones adultas. La densidad de las raíces, su sección, su longitud y su peso seco se condicionaron por el estado juvenil de los esquejes. Los mejores resultados se obtuvieron a partir del estado juvenil de los esquejes, independientemente de la variable. **Conclusión**. Los estados juveniles y adultos coexisten en una misma planta de pitahaya. La juventud es un factor que favorece el arraigamiento de los esquejes de la pitahaya roja.

Brasil / *Hylocereus undatus* / propagación vegetativa / esquejado / etapas de desarrollo de la planta / estado juvenil de las plantas / enraizamiento