

## ADVANCES IN THE PROPAGATION OF RAMBUTAN TREE<sup>1</sup>

RENATA APARECIDA DE ANDRADE<sup>2</sup>, LÍVIA FELÍCIO BARRETO<sup>3</sup>,  
GUILHERME NACATA<sup>4</sup>, VÍCTOR GALÁN SAUCO<sup>5</sup>

**ABSTRACT** - The reality of Brazilian fruit farming is demonstrating increasing demand for sustainable information about native and exotic fruit, which can diversify and elevate the efficiency of fruit exploitation. Research on propagation of fruits tree is very important so that it can provide a protocol for suitable multiplication of this fruitful. Due to the great genetic diversity of rambutan plants, it is recommended the use of vegetative propagated plants. This research aimed to evaluate the propagation of rambutan by cuttings, layering and grafting, as well as seed germination and viability without storage. The results of this research indicate that this species can be successfully propagated by layering, grafting and seeds. We also observed that the germination percentage of seeds kept inside the fruits for six days were not influenced by the different substrates used in this experiment.

**Index terms:** *Nephelium lappaceum* L, grafting, layering, cuttings.

## AVANÇOS NA PROPAGAÇÃO DA RAMBUTEIRA

**RESUMO** - A realidade da fruticultura brasileira tem demonstrando crescente demanda de informações sustentáveis sobre frutíferas nativas e exóticas, as quais possam diversificar e elevar a eficácia da exploração de frutas. Pesquisas em propagação em frutíferas tem grande importância para que se possa fornecer um protocolo para adequada multiplicação dessa frutífera. Devido a grande diversidade genética das plantas de rambutan, para estabelecimento de pomares comerciais da cultura, recomenda-se o uso de plantas propagadas vegetativamente. Este trabalho teve como objetivo avaliar a propagação de rambuteira por estaquia, alporquia, enxertia, bem como a germinação por sementes e a viabilidade no armazenamento. Pelos resultados dos trabalhos nota-se que a frutífera pode ser propagada por alporquia, enxertia e por sementes, e se existir a necessidade de armazenamento de sementes que não ultrapasse um período de seis dias e sejam mantidas dentro dos frutos, não houve diferenças consideráveis na germinação nos substratos testados neste experimento.

**Termos para indexação:** *Nephelium lappaceum* L, enxertia, alporquia, estaquia.

## INTRODUCTION

Fruit production is very important so new options for fruit crops could serve and expand the market, such as exotic fruits, which were restricted to local populations in geographically limited areas and became common food in countries far from the center source (VINCI et al., 1995). According to Andrade et al. (2008), there is a search by producers and consumers for these new options, among which rambutan presents high market potential.

The rambutan (*Nephelium lappaceum* L.), belonging to the Sapindaceae family, is native

to Malaysia and Indonesia (TINDALL, 1994). According to Sacramento and Andrade (2014), it was introduced in Brazil in the mid-1970s, in the state of Pará, and only in 2000 it arrived in the state of São Paulo, with the introduction of the R-162 Malaysian clone, with grafted seedlings from Hawaii.

Data obtained until July 2016 from CEAGESP (2016) show that 22.4 t of fresh rambutan fruits were marketed, practically twice the annual quantity of 2015 (11.7 t). The state of Bahia is responsible for almost all of this supply, mainly from March to October, with a small participation of the states of Pará and São Paulo, and the last one provides

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<sup>2</sup>Agricultural Engineer, Assistance Professor, Dr., Department of Plant Production, UNESP/ FCAV, Jaboticabal Campus. Via de acesso Prof. Dr. Paulo Donato Castellane, s/n, CEP 14884-900, Jaboticabal-SP. e-mail: reandrad@fcav.unesp.br

<sup>3</sup>Agricultural Engineer Msc., PhD student at FCAV/UNESP Câmpus de Jaboticabal, Plant Production Program, e-mail: liviafbarreto@hotmail.com

<sup>4</sup>Agricultural Engineer, PhD student at ESALQ/USP, e-mail: guilherme\_nacata@hotmail.com

<sup>5</sup>Agricultural Engineer, Ph.D: Research Professor (retired) Instituto Canario de Investigaciones Agrarias, Canary islands Spain. Actually Consultant in Tropical Fruits. e-mail: vgalan46@gmail.com

the product in a time of small supply by Bahia (November to February), which highlights the great potential of São Paulo for production and marketing.

The methods of propagation for the rambutan crop are: seed, grafting and layering. The seed propagation is relatively easy, but it is not recommended for crop production, as the resulting seedlings are very variable and about 50% or more may be exclusively male-flowered plants (TINDALL, 1994), however, the sowing to obtain rootstocks should be used.

Some factors affect the germination, among them the temperature, which according to Carvalho and Nakagawa (2012) is the most important factor, since it exerts influence on the metabolic reactions, also affecting the growth of the seedlings. According to the species, the minimum, optimal and maximum temperatures are quite variable, and the optimum temperature for most seeds varies from 25 to 30 °C.

According to Hartmann et al. (2011), the seed storage is influenced by several factors related to initial seed quality (seedling vigor, climatic conditions during seed maturation, degree of maturation at harvest, pest and disease attack, degree of mechanical injury) and environmental characteristics (relative air humidity or seed water content, air temperature, action of storage fungi and insects, packaging).

The vegetative propagation has several advantages, among them, the maintenance of the genetic characteristics of the matrices plants, the uniformity of the orchard, the reduced size and precocity of flowering and production (HARTMANN et al., 2011), and, among asexual methods, grafting is one of the most widely used in fruit growing. The rambutan may be grafted by T-budding, in plate, modified Forket or by approach grafting (TINDALL, 1994). For the success of the procedure, there is a need to juxtapose the exchange tissue of both parties involved and to adequately protect the grafted region and the results of the process may vary for different reasons, such as: season of the year, origin and ages of the materials used, types of grafting, branch protection materials, types of rootstocks.

Two other methods of vegetative propagation are cuttings and layering. The degree of success in obtaining seedlings in each of these propagation methods is influenced, among others, by species, season, physiological conditions of the matrix plant, variations in climatic conditions, position of the propagule in the matrix plant, size, type and time of collection, rooting medium, growth substances (HARTMANN et al., 2011).

For the establishment of rambutan commercial

orchards, it is especially recommended to use vegetative propagated plants, since the distinction between female and male plants is only perceived at the moment of flowering, in addition to obtaining uniformity and precocity of production. Due to the lack of studies in the literature related to the best method of propagation for the crop, a number of studies were carried out to verify the possibility of obtaining seedlings of rambutan by asexual ways (grafting, layering and cuttings), besides studying aspects related to seed germination (influence of temperature, substrate and storage), aiming to obtain rootstocks.

## MATERIAL AND METHODS

### Vegetative Propagation Methods

#### Grafting

The study was carried out with plants established in an orchard located in the municipality of Taquaritinga-SP, with coordinates 21°26'45.5" South latitude and 48°37'57.4" West longitude, with an altitude of 493m. Through the Köppen International System, the climate of the region is Aw, characterized as rainy tropical with dry winter.

The orchard originated from the introduction of seedlings propagated by seeds from commercial orchards in the state of Bahia, which resulted in great variability. The plants are 12 years old and the beginning of production was at five years. The orchard is drip irrigated whenever the dry season exceeds 30 days, receives fertilization from N:P:K - 19:10:19 (1 kg plant<sup>-1</sup>) in the months of February and October, and the plants are distributed in the spacing of 7 x 4 m.

The rootstocks were formed with seedlings produced by seeds, with 16 years and 24 months old (experiments 1 and 2 respectively), kept in 2.4L bags filled with Multiplant® substrate, fertilized every 60 days with the N:P:K-10:10:10 formula (1 gram per bag). The maintenance environment was covered with 50% light interception screen and irrigated whenever it was necessary.

The matrices suppliers of the branches were selected, for a total of 288 plants, based on their productivity historic, susceptibility to cold and the presence of reddish fruit peel, which are of more interest to the consumer, these plants being labeled by the producer as B10 and B11, according to arrangement in the orchard. Immediately after picking the branches, their leaves were removed and these were kept with approximately 10-12 cm (2 to 3 viable buds).

At the time of grafting, the rootstocks were

decapitated at an average height of 58 cm from the plant's neck, because at this time the tissues were in a development stage visibly similar to that of the branches in both experiments. The average diameter in the grafting region was 0.72cm.

The experiments were carried out at two times of the year: 1 - fall/winter (March to June) and 2 - spring/summer (November to February). The treatments in both experiments were: 4 types of grafts (whip graft-WhG; cleft graft -CG; wedge graft-WG; and inverted wedge graft-IWG, the last two being made with the aid of grafting pliers); 2 types of branch protection materials (plastic ribbon commonly used by nurseries covered with polyethylene bags (4x23cm) and biodegradable ribbon (BUDDY TAPE®) and 2 types of rootstocks (leafless and presence of 2 to 3 leaves below the grafting region).

The experimental design was completely randomized, with four replicates. Each experimental unit was composed of 10 plants, analyzed in 4x2x2 factorial (4 types of grafting, 2 types of protection materials and 2 types of rootstock), with 640 grafts per experiment and 1280 in total. The first evaluation was performed when the first sprouts were observed (17 and 19 days after grafting) and after that, 14-day interval evaluations were performed with 7 and 8 evaluations for the 1<sup>st</sup> and 2<sup>nd</sup> experiment, respectively, until the growth was constant. The variables analyzed were: setting percentage, number and length of the sprouts (cm).

The data, for analysis purposes, were transformed into  $\text{Log}(x + 5)$  to meet the assumptions of the statistical analysis and submitted to the analysis of variance by the F test, and the averages compared by the Tukey test at the 5% level ( $p < 0.05$ ) of probability, using the ASSISTAT 7.6 beta software (SILVA, 2012).

### Layering

The experiments were carried out on adult rambutan plants, evaluating the possibility of vegetative propagation by layering, as well as the response due to the season of the year in which the layering was made. The layering was made at different times of the year (spring, summer, fall and winter). Branches were selected from the median portion of the plant crown in full production and, at about 50 cm from the tip; the girdling was performed in these branches, which was wrapped with moist sphagnum and clear plastic. For each season of the year, 12 layering were made in 5 plants (each plant functioning as a repetition), totaling 60 layering. The evaluations, carried out 110 days after

the layering, were as follows: percentage of rooted layering, callus presence, and their survival while in the matrix plant. After the weaning, the layerings were kept under screened nursery conditions.

The experimental design was a randomized complete block design. The data were transformed into a sine root ( $x/100$ ), submitted to analysis of variance and average comparison by Tukey test ( $\alpha = 0.05$ ) by the SIGMAPLOT program (2008).

### Cutting

The experiments were made at different seasons of the year (spring, summer, fall and winter). The cuttings were collected from adult rambutan plants, early in the morning, avoiding dehydration, cut in an average length of 8 to 10 cm, with their bases in bessel, a pair of leaves and being kept in an open nursery, under intermittent misting and medium texture vermiculite, as substrate, in the rooting bed. In addition to the control treatment (without growth regulator), the cuttings received 1000 mg.L<sup>-1</sup>, 3000 mg.L<sup>-1</sup> and 5000 mg.L<sup>-1</sup> of indolbutyric acid (IBA) doses, characterizing rapid immersion, where the bases of the cuttings remained in the solution with the regulator for a time of 5 to 10 seconds. Four replicates were made with 10 cuttings for each treatment (40 cuttings), in a total of 160 cuttings at each season of the year.

### Sexual Propagation

#### Sowing and Substrate test

The experiment was carried out in the Wooden Slats of Fruit Farming of the Department of Production of the FCAV/UNESP, Jaboticabal Campus, using seeds of rambutan mature fruits and being divided into two phases:

**2.2.1.1 Test of seed germination in different substrates:** the seeds were extracted, washed for total removal of the pulp, placed to dry in room condition for 24 hours and the sowing carried out in trays containing the different types of substrates, composing the treatments: commercial pine-based substrate, medium texture vermiculite and coconut fiber. Four replicates were used with 20 seeds each, totaling 80 seeds per treatment. The evaluation was weekly, considering as germination the opening of the cotyledonary leaves (emerged seedlings). The experiment lasted 6 weeks, obtaining stabilization of the germination. At this stage, observations were also made as to the occurrence or not of multi-stems and polyembryony.

**Initial plant growth:** the seedlings from the germination test on the different substrates were used and transferred to polyethylene bags with a capacity

of 1.5 liters, containing as substrate a mixture of soil + sand + manure (3:1:1), evaluating the initial growth of the seedlings, as a function of the seed germination substrate. During the experiment, no fertilization was performed, in order to verify the extent to which the seedlings would develop without the need for nutrient supplementation. The height of the plants (cm) and the diameter of the stem (cm) were evaluated weekly. The evaluations were weekly until the fourteenth week, when there was stabilization in the development. After this period, the plants were evaluated monthly for 3 months, confirming the stabilization in growth. Thirty seedlings were used for each treatment.

The experimental design was completely randomized. The percentage data, for statistical analysis purposes, were transformed into  $\arcsin(x/100)^{1/2}$ , evaluated through analysis of variance and, when a significant difference between averages were observed, these were analyzed by the Tukey test at 5 % significance.

### **Sowing and Storage test**

This stage was carried out in two years, according to the quantity of fruits required for storage and for the extraction of the seeds, as follows:

**First year:** the seeds were extracted after collection of mature fruits and placed in paper bags, kept in an environment condition and in a low temperature condition (10°C), being sown after 3, 6, 9 and 12 days of storage, in different temperatures: 20, 25, 30, 35 and 40°C. A control treatment was also carried out, the seeds being placed to germinate at the same described temperatures, as soon as they were removed from the fruits (0 days). The seeds were placed in containers containing commercial pine-based substrate. Four replicates were used with 10 seeds each, totaling 1800 seeds per treatment.

The percentage and the time for emergence (in days) were evaluated, with the experiment lasting seven weeks, until the stabilization with germination safety. The experimental design was completely randomized, the data evaluated through analysis of variance and when significant difference was observed between the averages, these were analyzed by the Tukey test at 5% significance.

**Second year:** mature fruits were collected and kept in low temperature condition (10°C), to verify if there is difference in the germination and the possibility of seeds storage when they are kept in the fruit. The seeds were then extracted from the fruits in the days of sowing: 3, 6, 9 and 12 days after storage and they were placed to germinate in containers

containing commercial pine-based substrate at temperatures of 20, 25, 30, 35 and 40°C. As in the previous year, a control treatment was carried out, with seeds extracted from the fruits on the same day of harvest (0 days of storage). Four replicates were used with 10 seeds each, totaling 1800 seeds per treatment.

The percentage and the time for emergence (in days) were evaluated, with the experiment lasting eight weeks, until the stabilization with germination safety. The experimental design was completely randomized, the data evaluated through analysis of variance and when significant difference was observed between the averages, these were analyzed by the Tukey test at 5% significance.

## **RESULTS AND DISCUSSION**

### **Vegetative Propagation Methods**

#### **Grafting**

The treatments carried out with the aid of the grafting pliers did not have any viable results (Table 1), so it was decided not to use these data in the performed analyzes. In both experiments, the setting occurred on average up to 45 days after grafting (DAG).

#### **Experiment 1 – Fall/Winter**

For the setting variable, there was no significant interaction between the treatments. Regarding the method used, no statistical difference was observed between WhG and CG. The use of the biodegradable ribbon gave the best setting percentages, with approximately 12% higher than the plastic ribbon (Table 2), as well as results obtained by Brunner (2016), in studies with rambutan grafting with rootstocks directly in the field, in Puerto Rico, that obtained a setting of 42% using parafilm and 23% in greenhouse, using plastic bag. The same benefit of the parafilm was observed by Jacomino et al. (2000) in avocado, mango and macadamia, results confirmed by Mindêllo Neto et al. (2004) in avocado trees that obtained setting of 30.97% higher than the use of plastic.

The leaf maintenance in the rootstock was detrimental, providing a 3.75% setting compared to the leafless rootstock, which was 40.65%, indicating that by this time they should be removed (Tables 1 and 2), while Ojima et al. (1978) observed that the presence of leaves in the loquat tree rootstock was found to be of great importance, and their absence reduced the setting, and in studies by Almeida et al. (2008), with yellow mango rootstock, the maintenance of leaves below the point of grafting had a negative influence on the graft adhesion,

reducing the success of the grafting from 80.8% to 67.5%. Then proving that the results of grafting vary according to species.

For the number of growths per graft, there was a double interaction between graft and rootstock protection treatments (Table 3), and this number was higher when the plastic ribbon and leafless rootstock were used. For the length variable, there was a triple interaction between the treatments and, although the number of growths was higher with the use of plastic ribbon, their length was higher when the biodegradable ribbon was used (Table 4). This response can be explained, since when there is a greater number of buds, in a single stem, these because they use the same amount of translocated by the rootstock they will grow inversely proportional to the number of growths.

As the initial growth of the single-stem seedling is desired, and it has a good development, the ones that had larger growths will be selected, so the results with the biodegradable ribbon are more adequate. This same effect of grafting materials on graft development was cited by Oliveira et al. (2004) in citrus, when they observed the advantage of the use of biodegradable ribbon in relation to plastic ribbon, as well as Mindello Neto et al. (2004) in avocado.

#### **Experiment 2 – spring/summer**

At this season of the year, the results were much lower than those of the previous season, and only the data on the interaction between rootstock types and grafting methods were observed (Table 5), showing that the methods do not differ independently of the presence of leaves in the rootstock used. Only the CG method has inferior results when using leafy rootstocks in relation to the leafless with 7.5 and 15% of setting respectively.

The grafts carried out at this season obtained a much lower setting than expected, because tropical species have excellent survival rates in periods when the temperature is around 30°C, since it is when there is a greater exchange activity. However, in 2012, in November, the average temperature after grafting (11/14/2012 to 11/30/2012) was 24.5°C and in December, until the date of setting occurrence (12/30/2012), the average temperature was 25.3°C, temperatures below of the expected for this time, thus, being one of the factors responsible for the low success of the grafting, showing that the climatic conditions of several seasons of the year may influence the setting as observed by Islam et al. (2004) in mango crop.

Another factor that may have been aggravating is the age of the rootstocks and according to Santana et al. (2014) in studies with breadfruit (*Artocarpus*

*altilis*) observed that there is influence of the age of the rootstock on the efficiency of the grafting. The rootstocks used in the experiment were eight months older than those used in the first experiment when they were 16 months old.

Martins et al. (2002) evaluating two types of lychee rootstocks (ungrafted and layering), belonging to the same rambutan family, observed the best results using one-year-old rootstocks (27.2%), while when the graft made on rootstocks generated by layering, the setting was practically null (0.5%). These results show that the age of the tissue (juvenility) may influence the results.

In relation to the number of sprouts, there was a triple interaction between the treatments and the WhG method, when associated with the plastic ribbon, it was superior when the leafy rootstock was used, being this one, superior to the CG in the same conditions (Table 6).

For the length of the sprouts, there was a significant interaction only in relation to the method used and the type of rootstock (Table 7), showing that for the WhG it is necessary to use the leafy rootstock and the CG rootstock without leaves, agreeing with results from Ojima et al. (1978) in loquat, in which the WhG method associated with the leafy rootstock provided a higher development of growths compared to the leafless.

In Australia, the development of rambutan buds is reduced during the months in which the minimum temperature averages are below 22°C (TINDALL, 1994), a fact that probably can explain the lower development of the growths in the first experiment, since the average temperature, from the day of grafting to the last evaluation (100 DAG) was 20.89°C and in the second experiment (116 DAG) was 24.36°C.

#### **Layering**

There was no significant difference in percentage of rooting and callus formation, as presented in Table 8. However, the same did not occur for the survival percentage, noting higher rates for layering performed in spring, fall and winter, not differing from each other, but differing from the rate observed when the layering was performed in the summer. Pio et al. (2007) reported the contrary, when evaluating the influence of the season in the accomplishment of the layering in Japanese quince; the authors verified that there was only a significant difference in rooting percentage, with the highest rates observed in the month of July (winter).

Although there is no statistical difference, it is clear that the percentage of rooting was higher in

the spring, which was to be expected, since at this time there is high temperature and relative humidity, factors that favor cell division, photoassimilates production and rhizogenesis inducing hormones, which according to Fachinello et al. (2005), who report that the layering must be carry out in spring or late summer, corresponding to the stage of plants growth, occurring accumulation of carbohydrates and other important substances for the emission of roots, the same also being observed by Danner et al. (2006) in 'jaboticabeira'.

The process of root formation is influenced, according to Hartmann et al. (2011), by a large number of factors, which may act alone or in combination, among which the physiological conditions and age of the matrix plant, juvenility, and environmental factors, such as availability of water, luminosity and substrate, which may explain the lower rooting rates in summer when compared to spring, because there are too high temperatures, contributing to excess in plant transpiration, requiring a greater amount of water, not always available at this season of the year. The lowest rooting rates observed for fall and winter are also due to climatic factors associated with the physiological stage of the plant, which can be explained by the fact that there is competition between leaves and roots by carbohydrate (DAVISON, 1990).

The coefficient of variation obtained for the rooting percentage should be in function of the different stages of development of the branches, showing that, despite the attempt to homogenize them, each part of the plant has a distinct response depending on the physiology of the plant itself, according to what Simon (1998) had reported.

The difference of season in the cloning process of the rambutan by layering, with respect to the cellular division, can be verified when observing Figure 1, which records the volume of the roots developed in the branches. The larger the root volume of a seedling is the better will be its establishment in nursery. Thus, even if there is no statistical difference for this variable, the knowledge of the plant response allows distinguishing between the seasons which is the most appropriate for this crop.

As conclusion of the experiment with layering, under the conditions in which it was carried out, there is the possibility of rambutan seedlings production by layering, with the indication that it should be carried out in the spring. However, the seedlings were ready to go to the field only about one year after weaning, which is not interesting for a seedlings producer. Thus, new

research is suggested, in order to study alternative and environmental options and leaf area reduction of the layering after the weaning, in an attempt to avoid the need for this long time to have the seedlings ready.

### Cutting

The cuttings, in the rooting bed, were observed weekly and, for all seasons and doses of tested regulator, total loss of the leaves by the cuttings was noticed after a week or, in the maximum of 10 days. Around 30 days after the cutting, the cuttings, regardless of the treatment and season of the year, were already dead. Thus, there was no success in the cutting process, the way it was done. New research is suggested, because the process is highly desirable in the seedlings production, since it allows obtaining a greater quantity of clones of the same matrix, when compared to layering. Thus, other environments and doses of regulator should be studied, before discarding the possibility of this method of propagation for this species.

According to Costa et al. (2015), some species have difficulties in obtaining seedlings by vegetative multiplication, in most cases it is associated with restrictions for rooting, even if they are in conditions for good development, some factors, such as the hormonal balance is responsible for the failure of the practice.

### Sowing and Substrate test

Table 9 shows that there was only influence of the substrate on germination during the first and second week after sowing, with lower germination percentages when coconut fiber was used as substrate. From the third week until the end of the experiment (sixth week after sowing) there was no significant difference between the substrates used, except that 100% germination was obtained in the fourth week when vermiculite was used, this percentage obtained only in the fifth week when the commercial pine-based substrate was used and in the sixth week when the coconut fiber was used, although without significant difference. This information is important for nursery owners, as the vermiculite allows obtaining the total germination earlier.

Regarding the initial growth of the seedlings, Figures 2 and 3 show that it was small, most probably influenced by the time of accomplishment, once the experiment started in July, due to the availability of the seedlings, and the rambutan is very sensitive to low temperatures (15-17°C already causes damage), typical of this time of the year. However, the highest growth rates were observed for seedlings from

germination in vermiculite, for seedling height and stem diameter. This may be a reflection of these seedlings being originated in a totally inert substrate without any nutrients and, when placed in the mixture of soil+sand+cattle manure (3:1:1) readily absorb and respond to organic matter present in this mixture, while the seedlings originated from seeds germinated in commercial pine-based and coconut fiber substrates, which ended up containing some traces of nutrients, had lower response in initial growth, with lower rates.

The stabilization in the initial growth occurred at the ninth evaluation week and the stem diameter stabilized at the tenth week, signaling that there are times when the plants deplete their reserves for growth and need a nutrient source; they indicate when the fertilization of the seedlings is necessary, so that they continue to grow and develop.

According to Wagner Junior et al. (2006) the substrate used for germination and seedling formation is a factor that has great influence, allowing the production of healthy and quality seedlings, which will originate plants with high production potential, contributing to the success of the crop.

In a study with barium germination in different substrates, Oliveira et al. (2014) and Costa et al. (2012) verified that in the treatments with greater amount of vermiculite there was a tendency to a greater emergence percentage. In this study, although there was no significant difference between the substrates tested for the germination percentage, the vermiculite also tended to better results for the germination, since it provided greater precocity in the germination process, which confers advantage to the producer. The vermiculite was also the substrate indicated as more appropriate, together with the sand by Guedes et al. (2010), in a study to verify the best substrate for the germination of *Amburana cearensis* seeds. Although the vermiculite is indicated as a good substrate, containing some highly desirable characteristics (MINAMI, 1995), for some species it is not the best option, for example in a study by Maker et al. (2010), studying the germination of '*mandacaru*' seeds in different substrates, observed lower values for germination, length and dry mass of the seedlings when using sand and also vermiculite.

Each species responds differently to the substrate used, either for germination of the seeds or for the initial formation of the seedlings, until they go to the field. In the literature, a large number of studies are testing the most diverse substrates for different species, for example, the best response to pitaya when using the paper roll (ALVES et al., 2011), the

use of soil, sand and cattle manure mixture in equal proportions for '*jaboticaba*' (DIAS et al., 2011), sand and coconut fiber for sunflower (SILVA et al., 2010), and vermiculite plus organic compound for papaya (COSTA et al., 2010).

Thus, tests should be carried out for each species with which it is intended to work, taking into consideration, in choosing the substrate, in addition to the traditional factors, such as water retention capacity, pathogen exemption, easiness of access, according to Silva et al. (2014), the possibility of using agro industrial residues, such as coconut fiber and sugarcane bagasse, being a sustainable and economic alternative, especially for small producers.

The study of biometry in the initial development of seedlings provides important information, regardless of the species, allowing obtaining relevant data of practical application, as verified by Espíndola et al. (2004) in a study on the most suitable diameter for spondias tuberosa grafting. Studies about the biometry of fruit trees are carried out a lot, such as in '*jaboticaba*' (DANNER et al., 2011), mango (RUFINI et al., 2011), caryocar brasiliense (RAMOS and SOUZA, 2011), rambutan (ANDRADE et al., 2009) and mamey (NASCIMENTO et al., 2008), emphasizing the importance of this type of study, allowing more information about the crops.

#### **Sowing and Storage test**

Observing the statistical analyzes of the two years of evaluation (Tables 10 and 11), the germination percentage due to the storage environment of the seeds, the temperature at which they were submitted and the storage time, for seeds extracted of the fruits as well as for those kept inside the fruits, the seeds stored in ambient condition had a better germination rate than those stored in a cold room. Better germination rates were also obtained for the seeds submitted to temperatures of 25 and 30°C, however, in the seeds germinated at 30°C the occurrence of a large number of abnormal seedlings with excess budding, which may be due to the fact that a more intense cell division occurs at higher temperatures. As for the storage time, for seeds extracted from the fruits, a better result is observed with the absence of storage, higher germination rates for the seeds that were used right after the fruit extraction. As for the seeds kept in the fruits, there is no significant difference between germination after extraction and storage for 3 days. In both cases, however, as the storage period increases, there is a decrease in the germination rate.

From the analysis of the factors interaction, better results are observed for temperatures of 25 and 30°C, regardless of whether they were removed or stored in the fruits, differing significantly from the other temperatures and storage conditions (cold room). Regarding the time of storage in function of the environment, higher germination rates up to 3 days of storage are observed in the environment condition when the seed is placed for storage after extraction from the fruit and, when it is kept inside the fruit for storage, similar rates of germination, up to 6 days of storage and, when the cold room is used, up to 3 days of storage.

By the analysis of the interaction between storage time and germination temperature, when the seed was extracted from the fruit, better results are obtained for the temperatures of 25 and 30°C, and for the temperature of 25°C, there is good germination of the seeds when stored up to 6 days, while for the seeds submitted to the temperature of 30°C only for the storage up to 3 days. For the storage of the seeds kept in the fruits, better germination rates for 25 and 30°C were observed, but the seeds can be stored up to 6 days.

Thus, in general, we concluded that the temperature indicated for the germination of rambutan seeds is 25°C (since at 30°C there were many abnormal seedlings, as mentioned) and, if necessary to carry out the storage, it should be storage in a maximum of 6 days, in ambient condition, preferentially keeping the seeds inside the fruits.

According to Freitas et al. (2004), an important aspect to be considered, within the productive process of any crop, is the maintenance of seed quality during the storage period, being a determinant factor to obtain productivity. The storage, according to Azevedo et al. (2003) is fundamental for the control of the physiological quality of the seed, preserving the quality and maintaining the vigor at a reasonable level, in the period between harvesting and planting. In the germination process, according to Carvalho and Nakagawa (2012), temperature is the most influential environmental factor, being able to accelerate, reduce and even suppress the emission of the primary root, since it is directly related to the chemical reactions that occur right after the water absorption by the seeds.

In a study with '*araçá*', Tomaz et al. (2011) verified that the seeds stored in the refrigerator presented 90% of germination, differing from the one found in this study, since the low temperature storage for rambutan seeds led to a considerable drop in the germination rate. However, the sensitivity to

low temperature of storage was also reported by Nascimento et al. (2012), who verified, for '*cupui*' seeds, loss of viability when exposed to a temperature of 7°C for 8 hours.

For the germination temperature, a factor already described and reported as important and fundamental, the indication for rambutan is that it occurs at 25°C, in contrast with Nascimento et al. (2011) in a study with '*ingá*', where they verified similar germination for the alternating temperature of 20-30°C and for the temperature of 30°C.

Danner et al. (2011), studying the storage of '*jaboticaba*' seeds and their germination at different temperatures, verified that the storage, as reported in this study with rambutan, rapidly lost viability (5 days), denoting behavior of recalcitrant seeds, the ideal is medium temperatures for the germination of '*jaboticabeira*', since they found greater losses of the seeds viability under low temperatures (12°C and 6°C), in contrast to the one found by Picolotto et al. (2007), who verified, for in vitro cultivation of '*jaboticabeira*', reduction in the formation of phenolic compounds and stimulation to germination at 5°C. In a study with tamarind, Queiroz (2010) reported, based on the evaluation of the emergence and initial growth of the seedlings, that there is a possibility of seeds conservation up to 13 months in a refrigerated environment. However, similar to that found in this study with rambutan, Silva et al. (2013) concluded that the seeds of jackfruit present reduced germination power after storage, and the deleterious effect increases progressively during the storage, recommending the sowing after the seed remove from the fruit. The influence of temperature on the germination of the fruit seeds has been widely studied, and it is possible to know a little more about the characteristics of each species and the ability to grow or produce seedlings in certain places and seasons of the year. Experiments show and evidence the differentiated response according to the species, and Lamarca et al. (2011) observed a wide adaptation to the emergence of seeds of some species of *Eugenia* in the most diverse temperatures tested, with germination and development of normal seedlings in the temperature range of 20 to 30°C, being still indifferent to the temperature alternation (20/30 and 20/35°C) and also reported by Lima et al. (2007), who found higher rates for '*urucuzeiro*' seeds at temperatures of 25, 30°C and alternated between 20-30°C. Silva et al. (2006) observed better results for '*bacabinha*' seeds when submitted to a temperature of 30°C the same was verified by Oliveira et al. (2005) for false annona muricata and by Dias et al. (2011) for '*jaboticabeira*'.

**TABLE 1-** Setting average (%) of the treatments Whip graft (WhG), Clef graft (CG), Wedge graft (WG) and Inverted wedge graft (IWG), with graft protection materials: biodegradable and plastic ribbon in 2 types of rootstocks: leafless and leafy in grafts performed with rambutan in two experiments: 1 – fall/winter (100 DAG) and 2 – spring/summer (116 DAG) days after the grafting (DAG).

Graft method	Treatments		Setting (%) Experiment	
	Graft protection	Rootstock	1	2
WhG	Biodegradable	Leafless	57.5	12.5
WhG	Biodegradable	Leafy	2.5	10
WhG	Plastic	Leafless	32.5	7.5
WhG	Plastic	Leafy	0	12.5
CG	Biodegradable	Leafless	45	17.5
CG	Biodegradable	Leafy	7.5	12.5
CG	Plastic	Leafless	27	12.5
CG	Plastic	Leafy	5	2.5
WG	Biodegradable	Leafless	0	5
WG	Biodegradable	Leafy	0	2.5
WG	Plastic	Leafless	0	0
WG	Plastic	Leafy	0	0
IWG	Biodegradable	Leafless	5	2.5
IWG	Biodegradable	Leafy	0	0
IWG	Plastic	Leafless	0	0
IWG	Plastic	Leafy	0	0

\*Original data

**TABLE 2-** Comparison of setting averages (%) in grafting by whip graft and clef graft in rambutan with Biodegradable ribbon and Plastic ribbon as protective materials and, leafless and leafy rootstock, in experiment 1.

<b>Graft protection</b>	<b>Setting (%)</b>
<b>Biodegradable</b>	28.13a
<b>Plastic</b>	16.25 b
<b>Rootstock</b>	<b>Setting (%)</b>
<b>Leafless</b>	40.65a
<b>Leafy</b>	3.75 b
<b>CV (%)</b>	16.28

\*Averages followed by the same letter for graft or rootstock protection did not differ statistically by the Tukey test at 5% (p> 0.05) probability. Original data

**TABLE 3-** Interaction deployment of Graft protection (Biodegradable ribbon and Plastic ribbon) x Rootstock (Leafless and Leafy) for number of rambutan growths in experiment 1.

Graft protection	Rootstock	
	Leafless	Leafy
<b>Biodegradable</b>	1.90 bA	0.88 aA
<b>Plastic</b>	3.55 aA	0.56 aB
<b>CV (%)**</b>	9,44	

\*Averages followed by the same letter in line do not differ from each other by Tukey test at 5% probability. Original data

**TABLE 4** - Interaction deployment of Grafting method (Whip graft – WhG and Clef graft – CG) x Rootstock protection (Biodegradable ribbon and Plastic ribbon) x rootstock (Leafless and Leafy), in the length of the sprouts (cm) in rambutan plants in experiment 1.

Graft method	Graft protection x Rootstock			
	Biodegradable x Leafless	Biodegradable x Leafy	Plastic x Leafless	Plastic x Leafy
WhG	10.11 aA	3.52 aB	4.05 aAB	0.00aB
CG	9.02 aA	3.11 aAB	3.53aAB	0.54aB
CV (%)	15.06			

\*Averages followed by the same letter in line do not differ from each other by Tukey test at 5% probability. Original data.

**TABLE 5** - Interaction deployment of Grafting method (Whip graft – WhG and Clef graft – CG) x Rootstock (Leafless and Leafy), in the setting (%) in rambutan plants in experiment 2.

Graft method	Rootstock	
	Leafless	Leafy
WhG	10.00 aA	11.25 aA
CG	15.00 aA	7.50 aB
CV (%)	23.59	

\*Averages followed by the same letter in column do not differ from each other by Tukey test at 5% probability. Original data

**TABLE 6**- Interaction deployment of Grafting method (Whip graft – WhG and Clef graft – CG) x Graft protection (Biodegradable ribbon and Plastic ribbon) x Rootstock (Leafless and Leafy), for the number of sprouts in experiment 2.

Graft method	Graft protection x Rootstock			
	Biodegradable x Leafless	Biodegradable x Leafy	Plastic x Leafless	Plastic x Leafy
WhG	1.00 aAB	1.00 aAB	0.25 aB	3.00 aA
CG	1.55 aA	1.33 aA	1.38 aA	0.50 bA
CV (%)	8.44			

\*Averages followed by the same letter in column do not differ from each other by Tukey test at 5% probability. Original data

**TABLE 7**- Interaction deployment of Grafting method (Whip graft – WhG and Clef graft – CG) x Rootstock (Leafless and Leafy), in the average length in grafts performed with rambutan plants, in experiment 2. Taquaritinga, SP, 2013.

Graft method	Rootstock	
	Leafless	Leafy
WhG	6.67bB	17.18aA
CG	16.83aA	9.76aB
CV (%)	23.21	

\*Averages followed by the same letter in column do not differ from each other by Tukey test at 5% probability. Original data.

**TABLE 8** - Result of the statistical analysis for percentage of survival, rooting and callousing in rambutan layering. Jaboticabal, 2012.

Time of the year (TY)	Survival (%)	Rooting (%)	Presence of calluses (%)
Spring	90.00 a	63.00	22.82
Summer	42.60 B	36.77	37.54
Fall	90.00 A	39.71	42.99
Winter	83.29 A	26.18	59.01
<b>F test</b>			
TY	11.540 **	1.499 NS	1.763 NS
CV (%)	19.62	68.44	62.00

<sup>1</sup>In each column, for each factor, averages followed by the same capital letter do not differ from each other by the “Tukey test”, at 5% probability. NS: not significant (p>0.05); \*: significant (p>0.05) and \*\*: significant (p>0.01). CV %: coefficient of variation.



FIGURE 1- Appearance of rambutan layering roots in spring (a), summer (b), autumn (c) and winter (d). Jaboticabal, 2012.

TABLE 9-Evolution of germination percentage of rambutan seeds, in function of the substrate, during six weeks.

Substrate	% Germination					
	1	2	3	4	5	6
Vermiculite	0.00 a	42.50 a	97.50 a	100.00 a	100.00 a	100.00 a
Pinus	0.00 a	28.75 a	95.00 a	98.75 a	100.00 a	100.00 a
Coconut fiber	0.00 a	7.50 b	67.50 b	95.00 a	96.25 a	100.00 a
CV		28.9220	14.3909	4.4222	4.3849	
DMS		14.9885	24.6232	8.5487	8.5487	

\*Averages followed by the same letter in column do not differ from each other Turkey test, 5% probability.

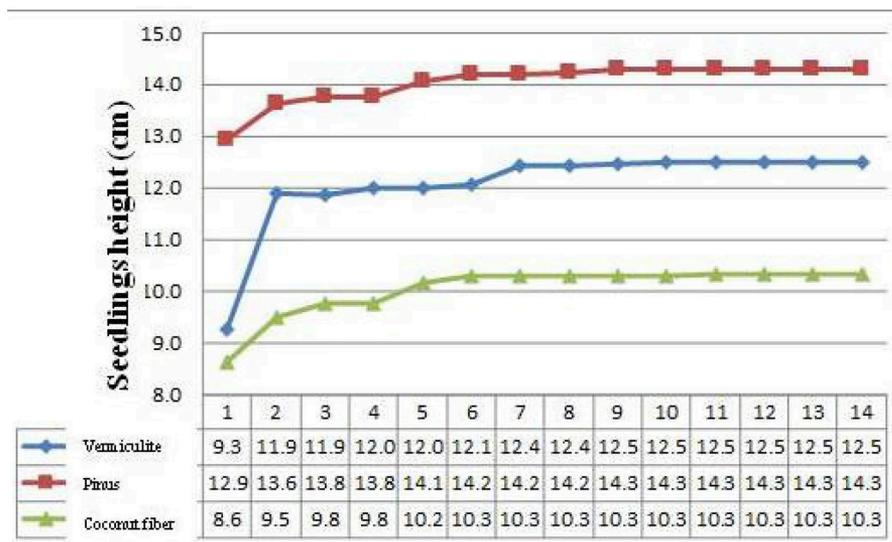


FIGURE 2-Initial growth of rambutan seedlings, height in cm for 14 weeks.

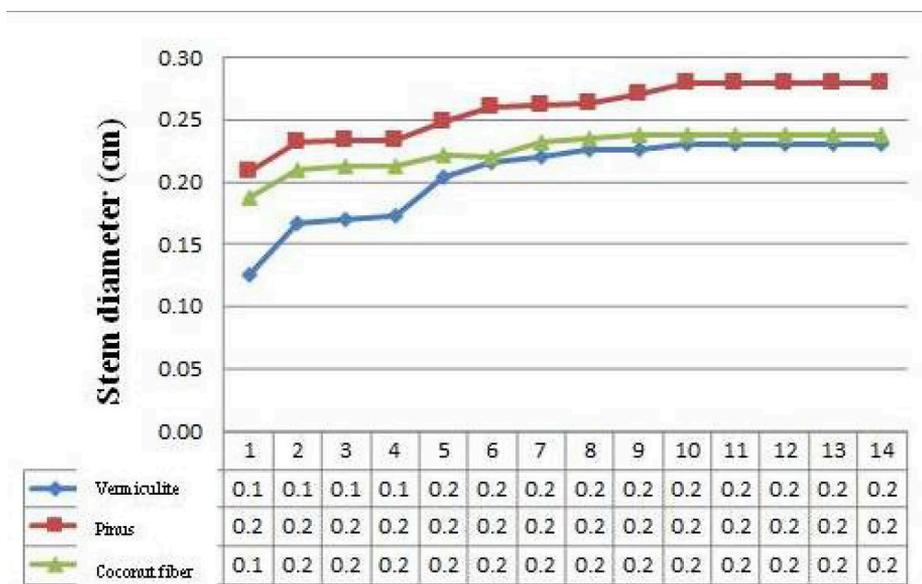


FIGURE 3- Initial growth of rambutan seedlings, stem diameter in cm for 14 weeks.

TABLE 10-Results of the statistical analysis for germination percentage of rambutan seeds submitted to different temperatures, periods and storage conditions.

Environment (E)	Germination (%)
Normal	38.30 A
Cold room	30.89 B
Temperature (T)	
20°C	37.82 B
25°C	51.29 A
30°C	46.83 A
35°C	36.96 B
40°C	0,0 C
Days of Storage (DS)	
0	63.88 A
3	52.02 B
6	37.71 C
9	18.88 D
12	0.46 E
F test	
E	25.31 **
T	151.31 **
DS	238.05 **
E x T	3.24 *
E x DS	5.45 **
T x DS	18.71 **
E x T x DS	1.71 NS
CV (%)	<b>30.97</b>

<sup>1</sup>In each column, for each factor, averages followed by the same capital letter do not differ from each other by the "Tukey test", at 5% probability. NS: not significant ( $p>0.05$ ); \*: significant ( $p>0.05$ ) and \*\*: significant ( $p>0.01$ ). CV %: coefficient of variation.

**TABLE 11-** Results of the statistical analysis for germination percentage of rambutan seeds submitted to different temperatures, periods and storage conditions.

Environment (E)	Temperature (T)				
	20°C	25°C	30°C	35°C	40°C
Normal	40.09 A b	54.63 A a	54.66 A a	42.09 A b	0.00 A c
Cold room	35.65 B b	47.96 B a	39.00 B ab	31.82 B b	0.00 A c

Averages followed by the same capital letters in columns and lower case in line do not differ from each other by Tukey test at 5% probability.

Environment (E)	Days of Storage (DS)				
	0	3	6	9	12
Normal	63.88 A a	56.98 A a	46.24 A b	24.39 A c	0.00 A d
Cold room	63.88 A a	47.07 B b	29.19 B c	13.38 B d	0.92 A e

Averages followed by the same capital letters in columns and lower case in line do not differ from each other by Tukey test at 5% probability.

Temperature (T)	Days of Storage (DS)				
	0	3	6	9	12
20°C	90.00 A a	57.83 B b	34.61 B c	6.91 BC d	0.00 A d
25°C	85.39 A a	75.88 A ab	62.78 A b	32.42 A c	0.00 A d
30°C	81.70 A a	67.23 AB b	48.62 AB c	34.32 A c	2.30 A d
35°C	62.30 B a	59.17 B a	42.56 B b	20.76 AB c	0.00 A d
40°C	0.00 C a	0.00 C a	0.00 C a	0.00 C a	0.00 A a

\*Averages followed by the same capital letters in columns and lower case in line do not differ from each other by Tukey test at 5% probability.

## CONCLUSION

For grafting performed in the fall/winter period, both the whip graft as well as the clef graft with biodegradable fiber and the leafless rootstock can be used for the propagation of rambutan, but whip graft provided more satisfactory results. For spring/summer, the whip graft associated with plastic ribbon and leafy rootstocks, and the clef graft associated with biodegradable ribbon and leafless rootstocks provided the best results.

There is the possibility of production of rambutan seedlings by layering, with indication that it is carried out in the spring, but with a high time for acclimatization of the seedlings.

The cutting was not efficient to obtain seedlings of this species.

As for the germination, the best temperature for rambutan seeds is 25°C. If storage is required, it should be a maximum of six days and the seeds should be kept inside the fruits until the moment of sowing. There is no influence of the substrate on the germination percentage of rambutan seeds, but the vermiculite presents a higher precocity and a higher growth rate of the seedlings.

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