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An Evaluation of Factors Influencing Successful Grafting of Breadfruit on Chataigne Rootstock.

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ABSTRACT.
The potential for expanding the availability of breadfruit (*Artocarpus altilis*) as a food source in the Caribbean by establishment of commercial orchards is limited by its being vegetatively propagated. One of the disadvantages of this propagation method is a shallow rooting system, which results in limited distribution of the tree mainly to wetter regions, susceptibility to root-inhabiting diseases and proneness to hurricane damage. Chataigne (*A. camansi*), a close seed producing relative, produces a tap root and exhibits these disadvantages to a lesser extent. Therefore, grafting breadfruit on chataigne can potentially benefit commercial establishment. Poor success in grafting these species has been reported. This experiment aimed to evaluate the effect of grafting techniques, scion cultivars and ages of rootstock on grafting success. Grafting techniques were top wedge, side, and whip and tongue; the scions were the ‘Yellow’ and ‘White’ breadfruit cultivars and chataigne and ages of chataigne rootstocks were 47, 67 and 130 days old. A three-factor, factorial arrangement in a complete random design was used with 10 plants per treatment. Data were collected on the condition and length of survival of grafted scions and analysed using ANOVA, General Linear Model. Variety was the only factor with significant (p < 0.001) effect on success of grafting. Six weeks after grafting, there was 71% survival of grafts of chataigne scion grafted on chataigne rootstock, compared with 28% of ‘Local Yellow’ scion and 18% of ‘Local White’ breadfruit. The results suggest a genetic influence and a possible physiological effect on the success of grafting.

KEYWORDS: *Artocarpus altilis, Artocarpus camansi*, rootstock age, grafting technique, variety

INTRODUCTION
For commercial establishment of seedless breadfruit focus has to be placed on a propagation method for successfully producing a large number of plants. Ragone (1991) reported that the seedless types are sterile because of triploidy and that fruit development is due to parthenocarpy, therefore, the seedless breadfruit can only be propagated vegetatively. There are several reports on vegetative propagation of the seedless breadfruit (Galang and Elayda 1924; Padolina 1931; Narasinga 1957; Rowe-Dutton 1976; Roberts-Nkrumah 1993; Rouse-Miller and Duncan 1999; Nandwani and Kuniyuki 2005; Murch et al 2007). Propagation methods include stem cuttings, root cuttings with suckers, excised adventitious shoots cuttings, grafting, air layering and most recently micropropagation.

Propagation by root cuttings with or without suckers present major disadvantages with respect to large scale commercial production of planting material due to limited
availability of root pieces. Additionally, frequent removal of roots damage trees and the exposed cut surfaces create entry points for pathogens (Narasinga 1957; Rowe-Dutton 1976; Roberts-Nkrumah 1993). There has been very limited successful propagation of stem cuttings (Hamilton et al, 1983). In the Bahamas, Russell (1953) reported that attempts to propagate breadfruit on a large scale by air layering, using a covering of air-wrap, did not prove very successful. Additionally, in India Narasinga (1957) reported that air layering of aerial shoots has not been successful, even with the aid of root-inducing hormones and plastic films. Padolina (1931) reported that there is greater difficulty in rooting branches of old breadfruit trees than young seedlings. Apparently, due to the upright growth habit of the breadfruit tree it would be difficult to find many branches suitable for air-layering. However, early reports from India indicated that air-layering root suckers have been used quite successfully on a commercial scale (Rowe – Dutton 1976).

Grafting is one vegetative method of propagation that minimises the problem of damage to parent trees. Galang and Elayda (1924) reported successfully approach grafted breadfruit onto jackfruit, *A. heterophyllus*, *A. elastica* and chataigne, but gave no details. Similarly, Padolina (1931) briefly stated that breadfruit was inarched successfully on chataigne. Thomas (1969) reported young shoots of breadfruit being grafted on wild jackfruit, also gave no further details. Medagoda and Chandrarathna (2007) grafted breadfruit onto chataigne rootstock with 83% success. They however, did not highlight some factors that may influence the outcome of a successful graft union. These include varieties used, type of scion wood and the location on the parent plant which they were collected.

Grafting of the seedless breadfruit has a limitation with respect to choice of rootstock. Because the production of root stock from these breadfruit types relies on vegetative propagation, the methods discussed previously that are not suitable for large scale production. The seeded breadfruit types produce seeds that are short-lived and very highly variable due to cross fertilization but the seedlings grow quickly (Narasinga 1957; Ragone 1997). These types are not available in the Caribbean, and would not be considered as rootstock at present with respect to commercial establishment.

However, chataigne or breadnut which is seeded is a parent of the breadfruit (Zerega et al 2004) and may have greater potential as a rootstock for breadfruit, than both seeded and seedless breadfruit. The authors have observed that fresh mature chataigne seeds germinate quickly and have high germination rates. Due to its taproot system, chataigne is better adapted to drier regions than breadfruit, which because of vegetative propagation, has a shallow rooting system.

The factors associated with successful grafting of breadfruit require evaluation. The objective of this study was to evaluate the effect of age of rootstock, grafting technique and breadfruit variety of the scion on successful grafting of breadfruit on chataigne rootstock.

**MATERIALS AND METHODS**

The study was conducted at the University Field Station (UFS) of the University of the West Indies St. Augustine Campus, Trinidad from August 13 2005 to February 23, 2006. The experiment consisted of three factors - age of rootstock, grafting technique and
scion variety, each with three levels, arranged in a completely random design. There were 10 plants for each of the treatment combinations.

The methods used to generate scion material included manipulation of lower branches, propagation of stem cuttings, heavy pruning of donor plants and shoots of young seedling plants.

(i) Manipulation of branches - Six weeks prior to grafting, the distal end of lower branches of approximately three trees each of ‘Yellow’ and ‘White’ breadfruit cultivars and chataigne from the UFS Artocarpus germplasm collection were manipulated by bending to approximately 30 - 60 cm from the ground level with the use of stakes and twine. Horizontal cuts 15 cm apart were placed along the upper part of these branches from the proximal to the distal end.

(ii) Stem cuttings approximately 30 – 38 cm long, and 3 – 6 cm in diameter were cut from chataigne branches, dipped in Benlate solution (2.5g/L), and then placed to a depth of 1½ - 2 cm in propagation bins containing sharp sand. (iii) Terminal shoot cuttings of young chataigne seedling plants were taken from seedlings that were not required for use as rootstocks.

(ii) Epicormic shoots that emerged after pruning trees in the Crop Museum of the UFS consisting only of ‘Yellow’ breadfruit were used as scion material for the 9 week old rootstock.

Because suitable scion material for breadfruit cultivars was inadequate, ‘Yellow’ scion was grafted only on 7 and 9 week old rootstock, and ‘White’ scion only on 7 and 18 week old rootstock.

Two days prior to the grafting the leaf blades of the potential scion shoots were cut in half. Scion materials ranged from 9 - 12 cm in length and were matched as closely as possible to the diameters of respective rootstocks. Chataigne seeds with approximately 0.5 cm of the embryo emerging were selected from freshly harvested ripe fruits and soaked in Mankocide solution (7g/L) for 5 to 7 minutes. The seeds had an average weight, length and width of 7.7g, 3 cm and 2 cm, respectively. One seed per potting bag (10 cm L x 15 cm W x 25 cm D) was planted to a depth of 2.5 cm into a 3:2:1 mixture of soil, decomposed cow manure and sharp sand, respectively. On August 13, 2005 chataigne seeds for the 13 wk old rootstocks were planted. The seeds for the 7 wk and 9 wk old rootstocks were planted on November 3, 2005. The grafting of the 7 wk and 9 wk old rootstocks was done on December 20, 2005 and January 10, 2006, respectively while the 13 wk old rootstocks were grafted on December 21, 2005. The average diameters of the 7 wk, 9 wk and 13 wk old chataigne rootstocks at time of grafting were 0.72 cm, 0.89 cm and 1.45 cm respectively.

Three grafting techniques were used at approximately 30 cm from the base of the rootstock stem. (i) Whip and tongue - the length of the cut ranged from 2.5 to 4 cm due to the variability in diameter of the rootstocks. The cut end of the scion was cut to match with the cut on the rootstock. (ii) Side graft - a straight, downward cut was made at 30 ° angle on the rootstock. (iii) The top wedge graft - the top of the chataigne rootstock was cut off at an internode using a grafting knife a horizontal cut. Then a vertical cut 2.5 to 4.5 cm long was made downwards at the top cut. The base of the scion was cut to a wedge-shape using an angled cut on the two opposite sides. This ensured that the cambium of the scion would line up with the cambial surface of the rootstock. All grafts were tied with plastic strips and the entire plant covered with a plastic bag. The plants
grafted on the 9 wk old rootstock were observed for six weeks and those on the 7 wk and 18 wk old rootstock, were observed for 10 weeks. The condition of all graft unions was scored subjectively over a six and ten week period. The score ranged from 0 – 5 representing - death (0), >90% necrosis (1), 70 - 90% necrosis (2), 40-69% necrosis (3), < 40% necrosis (4) and healthy (5) respectively. Length of survival in weeks of the grafted scions was recorded and statistically analysed using ANOVA, general linear model. The statistical program, Minitab 15 was used to analyse this data.

RESULTS
Scion material production
Breadfruit and Chataigne trees were in the reproductive phase when the branches were manipulated, when stem cuttings were taken and when the trees were pruned. On the branches of the ‘Yellow’ and ‘White’ breadfruit cultivars that were tied downwards, approximately 5 to 8 epicormic buds /branch were released. These buds were used as scion materials for grafting 7 and 18 week old rootstock, with the exception of ‘Yellow,’ which produced many shoots at the proximal end of the branches with diameters that were too large for grafting (Plate 1). As a result, 18 week old rootstock was not grafted with scion from this variety. Pruned ‘Yellow’ trees produced in excess of 50 epicormic buds/tree which provided scion material for grafting 9 week old rootstocks. Chataigne branches that were tied downwards released only 2 to 4 epicormic buds/branch which was insufficient for use as scion in this experiment. Attempts to produce epicormic buds on chataigne stem cuttings failed since the cuttings either decayed or failed to produce new buds.

Plate 1: Epicormic shoot emergence on lower branches as a result of branches bending, (a) newly emerging shoots (b) shoot used as scion material. Note size difference.

Survival of grafted plants
Effect of variety:
Plants grafted with the chataigne scion appeared to maintain the best condition, up to Week 8 but declined thereafter. Those grafted with ‘Yellow’ scion were of intermediate condition and declined noticeably until week 4, after which, the condition score fell to 1 (Fig. 1). At the end of six weeks the survival rate of grafted chataigne scion
was 71% compared with 28% for ‘Yellow’ and 18% for ‘White’ breadfruit cultivar scions grafted on chataigne rootstock (Fig. 2). At six weeks after grafting, the variety of the scion significantly (p< 0.001) affected the length of survival of grafted scion. There was no significant interaction observed among factors. Although scions died, the rootstocks survived and showed regrowth.

**Effect of rootstock age:**

Plants grafted on 9 wk old rootstock appeared to maintain the best condition, followed by those on the 18 wk old rootstock over the first six weeks after grafting (Fig. 3). The condition of the plants declined over time regardless of rootstock age, but the rate of decline slowed from week 5 for those plants grafted on 7 and 18 wk old rootstocks. At the end of week 6, the survival rate of graft unions on the 9 and 18 wk old root stock was 48%, while it was 39% on the 7 week old rootstock. At the end of week ten, the survival rate on the 7 and 18 week old rootstock was 29% and 35% respectively, indicating a steady decline over the experimental period (Fig. 4). Age of rootstock, did not have any significant effect on survival of the grafted unions (Table 1).

**Effect of grafting technique:**
With respect to the effect of the grafting technique on the condition of the grafted scion, the plants with the side graft appeared to maintain a better condition than those grafted by other techniques (Fig. 5). The survival percentage of grafted scions showed a steady decline over the period with all grafting techniques (Fig. 6). Grafted scion with top wedge and whip and tongue grafting technique accounted for 31% and 35% respectively at six weeks. The grafting technique did not affect the survival of grafted scion at six weeks after grafting (Table 2).

Table 4: Effect of variety of the scion on the length of survival of grafted scions on rootstock of different ages.

<table>
<thead>
<tr>
<th>ROOTSTOCK AGE (WEEKS)</th>
<th>LENGTH OF SURVIVAL (WK)</th>
<th>ROOTSTOCK AGE (MEANS) (P = NS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Variety of scion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>‘Yellow’ breadfruit</td>
<td>‘White’ breadfruit</td>
</tr>
<tr>
<td></td>
<td>Chataigne</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>3.3</td>
<td>2.7</td>
</tr>
<tr>
<td></td>
<td>4.8</td>
<td>3.6</td>
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<tr>
<td>9</td>
<td>3.9</td>
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<td></td>
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<tr>
<td>18</td>
<td>-</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>5.2</td>
<td>3.9</td>
</tr>
<tr>
<td>Variety Mean</td>
<td>3.6b</td>
<td>2.65c</td>
</tr>
<tr>
<td>(p &lt; 0.001)</td>
<td></td>
<td>4.9a</td>
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</tbody>
</table>

Average LSD value for the variety of scions is = 0.92 NS: Not significant.

Table 5: Effect of grafting technique on the length of survival of grafted scions on rootstocks of different ages.

<table>
<thead>
<tr>
<th>Rootstock Age</th>
<th>Length of survival (wk)</th>
<th>Rootstock Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grafting Technique</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Whip and Tongue</td>
<td>Side</td>
</tr>
<tr>
<td>7 wk</td>
<td>3.40</td>
<td>4.10</td>
</tr>
<tr>
<td>9 wk</td>
<td>4.05</td>
<td>4.25</td>
</tr>
<tr>
<td>18 wk</td>
<td>3.75</td>
<td>3.70</td>
</tr>
<tr>
<td>Grafting technique means (p = NS)</td>
<td>3.7</td>
<td>4.02</td>
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</tbody>
</table>
DISCUSSION

Scion material availability is a key consideration in the grafting of breadfruit and chataigne. Pruning the donor tree produced the most scion material due to the emergence of epicormic shoots because apical dominance was removed. However, bending the lower branches to disrupt the basipetal movement of auxins responsible for apical dominance generated the required quantities of scion material from breadfruit varieties but the materials were not of uniform size, especially, in ‘Yellow’. The dormant buds at the proximal end of the bent branches, emerged, grew and became woody faster due to less apical dominance exerted on these buds than on those at the distal end. This made selection of scion material difficult as the large, woody shoots produced closer to the proximal were unsuitable for grafting. Chataigne branches were less responsive to bending as a means of forcing emergence of epicormic shoots and there was no success with stem cuttings. This poor response may be a result of the trees being in a reproductive state between late August and early November. The overall result was that breadfruit scion materials of varying size and hardness from mature branches were grafted on to the chataigne rootstocks. After branch manipulation and stem cuttings failed to produce sufficient chataigne scion, the material for grafting on chataigne rootstock material was then sourced from seedlings and was very juvenile in comparison with the breadfruit scion material.

Variety significantly affected the survival of the grafted scions. Although breadfruit is closely related to chataigne (Zerega et al 2004), the ‘Yellow’ and ‘White’ breadfruit scion material did not do as well as the chataigne scion on chataigne rootstock. While this may be partly the result of differences in the genetic make up of both species, other factors may be responsible. Since scion materials were not uniform, the size of the scion and rootstock might not have been properly matched. The scion materials used for both breadfruit cultivars were mature, which might also have contributed to the poor success of their graft unions.

The chataigne scion materials grafted onto chataigne rootstock achieved the highest length of survival period among variety of scion material on chataigne rootstock. These chataigne scions were genetically more similar and closer in size and age to their respective rootstock. Additionally, these scions were of juvenile material with very active cambium. All these factors might have contributed to the high success rate reported for the chataigne scion on chataigne rootstock. Given these factors, an even higher percentage of success was expected than was obtained in this study and there may be a need to improve execution of the grafting procedures. Nandwani and Kuniyuki (2005) reported 80% success grafting various cultivars of breadfruit together. Since the species of the scion and rootstock were identical, there may be in fact a genetic influence on grafting success with breadfruit. Additionally, they reported that the scion materials used were juvenile, which suggests that juvenility of the scion might be required for successful grafting of breadfruit. However, Medagoda and Chandrarathna (2007) reported a 83% success rate when grafting mature breadfruit scion material onto chataigne rootstock. There was no significant effect of rootstock age on the length of survival of grafted scions in this study. Medagoda and Chandrarathna (2007) reported that 45 day old rootstocks performed better than younger and older rootstock and attributed the differences to the relative hardness of the rootstock stems. 30 day old rootstocks were too soft while, 60 day old rootstocks were too hard. Nandwani and Kuniyuki (2005) achieved
success on one year old plantlets that they used as rootstocks. These successes on varying rootstock age may suggest that rootstock age may not be a contributing factor to successful grafting.

Grafting technique did not have any significance with this experiment. Medagoda and Chandrarathna (2007) reported using only wedge grafting. On the other hand, Nandwani and Kuniyuki (2005) used approach grafting and side grafting and found that the former was much more successful (80%) than the latter (20%), which confirms earlier reports of successful grafting of breadfruit. Successful results were also obtained when breadfruit was inarched to chataigne (Padolina, 1931) an approach grafted to jackfruit, chataigne and A. elastica (Galang and Elayda 1924). This suggests that grafting of breadfruit may require that the scion remains attached to its parent as is the case in approach grafting and inarching.

CONCLUSIONS
The study emphasizes a critical need for a method of generating adequate scion material of uniform size to facilitate a commercial scale. Additionally, it emphasizes the need for generation of standardised and uniform scion material to match respective rootstock diameter and need for longer term evaluation of unions. While genetic compatibility may play a role in the success of the graft union between breadfruit and chataigne, other important factors may include the hardness of the scion wood and the physiological state of the parent plant. While age of the of the chataigne rootstock may not be critical for successful grafting of breadfruit, grafting technique needs to be evaluated further, especially methods in which the scion remains attached to a parent source, example, approach grafting.

REFERENCES


