

# The Bhola Method: A novel approach to the mass production of propagules of *Theobroma cacao L.*

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An optimised, highly efficient method of side-grafting on very young cacao (*Theobroma cacao L.*) seedlings (2-5 weeks old) is presented here. A series of evaluations was done in an attempt to solve a very serious dieback problem on such grafts, then to optimise the technique on even younger cacao seedlings. The proposed method was used in a series of evaluations, the first set of which are reported in this paper. The method includes the use of a special chamber (*Cover 10*) for the incubation of multiple grafts. The method is rapid, simple, and safe. It minimises problems with the usual challenge of slimy mucilage and improves the survival of grafts on otherwise difficult-to-propagate accessions. Preliminary results indicate that the method is reproducible, highly efficient and guarantees very favourable success rates. The method presents solutions to some other problems (specifically dieback issues) and provides a foundation for further investigations, developments and other propagation modifications.

Keywords: cocoa, propagation, grafting, dieback, side-grafting

The cocoa/chocolate agro-industry is projected to expand several-fold over the next decade. Market research reports have indicated an expected growth from \$83.2 billion in 2010 to \$98.3 billion in 2016 in the global chocolate market with estimated compound annual growth rate quoted at 2.7% (Markets and Markets 2011-2016). This increase in demand for chocolate requires that production volumes be increased considerably, which in turn means that more planting material will be required. Propagation of large quantities of suitable varieties will therefore be mandatory. Among the cocoa growing regions of the world, several different grafting techniques (top-grafting, side grafting, budding, air-layering etc.) are used for purposes of rehabilitation, research and for the establishment of new fields (Wood and Lass 2001). The literature shows that over the years, several modified methods and techniques have been introduced to help solve some of the major problems faced by researchers, propagators and farmers (Soderholm and Shaw 1965; Ramadasan and Mohd 1984). However, despite these advances, at least three major

challenges persist:

1. In fields where there is inadequate tree management, rootstock growth surpasses that of the scion and if untreated, eventually leads to the establishment of the rootstock and death of the scion. This leaves a tree of different genetic identity, thereby leading to mislabelling problems that carry considerable consequences for germplasm conservation and research efforts (Motilal et al. 2011), as well as for the farmer and his overall cocoa production and quality.
2. The success/dieback problem is a global issue and is more prevalent in difficult-to-propagate-clones (Kennedy 1981-1983b; Mooleedhar 1995).
3. There is generally much difficulty of binding the scion to the rootstock due to the slimy mucilage - a common problem particularly in some grafting techniques using very young seedlings (Ramadasan and Mohd, 1984). There are also contamination issues that arise when fingers, accidentally or otherwise, come into contact with cut parts of either scion or rootstock.

One of the institutions heavily involved with cocoa propagation is the Cocoa Research Centre (CRC) in Trinidad and Tobago. Its specialisations also include genomics, morphological characterisation, phytopathology, agronomy and cocoa/ chocolate flavour quality evaluations. One of the primary responsibilities of the CRC is the management of the International Cocoa Genebank (ICG,T) and provision of germplasm to other producer countries upon request. All of the research efforts of the CRC are therefore acutely dependent on the existence of the ICG,T and the accessions maintained therein. Efficient and rapid propagation of plant material is therefore vital to the CRC's role in the global cocoa producing community. As research and conservation demands for propagated material have increased both in number and frequency, the use of very young seedlings as rootstock for propagating clonal material has become critical. Previously, a top-grafting method on very young seedlings (Sreenivasan 1994) was adopted, but unfortunately the desired results of high long-term survival rates were rarely achieved (unpublished data). Initial survival rates for this method were high, however dieback rates were also very high (unpublished data), thereby reducing the suitability of the method.

Currently at the CRC (once rootstock and scion material are available), minimum propagation requirements are approximately 1200 plants per year for research, as well as for field replacements. In the past, due to considerable plant losses, twice the number of plants (2400) would be grafted to help offset these losses and to avoid compromising experimental designs. Coupled to this grafting effort, has been the increasing number of requests from other regional countries for the large-scale multiplication of selected grafted plants for their own field establishments. It becomes evident therefore; that there is a growing demand for large numbers of rapidly produced plants, with the highest achievable

success rate. A high success rate allows for more efficient use of funds, and better rationalisation of increasingly scarce resources since plant propagation and maintenance in the greenhouses are quite expensive. Development of a more reliable and rapid grafting method became an absolute necessity for the CRC. This work was therefore done in an effort to fulfil this need, and it documents a series of preliminary evaluations and observations that currently offer considerable encouragement for the future of cocoa propagation both locally and internationally.

## Material and Methods

Four key exercises were conducted to allow evaluation of the performances of different clones using a modified side-grafting technique, hereafter referred to as the Bhola Method.

### Propagation

#### a. *Scion preparation*

Scions were collected on the morning of the designated grafting day using 70% alcohol-sanitised secateurs. Semi-hard scions were preferred (i.e. one side brown, the other side green. Chupon material was not used because of its larger diameter). A portion of a shoot with at least 7 leaves was cut from the parent plant. All the leaf blades except the two at the terminal end were removed, and the latter were pruned to about 1/8 of their area. The remaining petioles of this shoot were trimmed to about a quarter of their original length. The diameters of the scion and rootstock were about the same where the graft union was to be created. A trimmed petiole on the scion was chosen for inclusion in the graft union. The scion wedge was created by making two diagonal cuts (~2.5cm) from above the level of the petiole downwards,

ensuring that the petiole was retained on one side (Plate 1a). All cuts were made using the same blade which was sanitised after every cut by wiping on a 70% alcohol-soaked paper towel. Repeated sanitising of hands and apparatus was done as necessary.

b. *Rootstock preparation (Two Trinidad Selected Hybrid (TSH) Varieties were available)*

Seeds of THS 1076 and 919 were set to germinate in Phoneix®- filled 180 ml polystyrene cups, with holes in the bottom for water up take. When the seedlings were four weeks old the terminal bud was removed and a diagonal cut, about the length of the scion wedge (2.5 cm), was made on the hypocotyl, from the surface inwards. Wrapping tape (1.5 cm strips) made from very thin transparent plastic bags, was tied loosely at the base of the hypocotyl (Plate 1b).

c. *Grafting*

The wedge of the scion was inserted into the diagonal cut made on the rootstock (Plate 1c). One hand held the scion in place while the other raised the tape over the scion's petiole and the ends of the tape were pulled to secure the graft union within the first layer of wrapping tape. The union was then fully wrapped and firmly tied (Plate 1d). These steps were done in quick succession.

d. *Cultural conditions (for evaluations 1-3 documented below)*

1. Each grafted seedling and the top half of the polystyrene cup were enclosed in a transparent plastic bag, secured with a rubber band and placed in a 28 x 54 cm tray filled with 1.5 cm of water.

Sealing each plant separately took about 15 s. These seedlings were then left for 2 weeks in a (60%) shaded area of the greenhouse. Tray water levels were checked and topped up weekly.

2. The plastic bags were then removed after 2 weeks or with the appearance of new shoots (bud-take) on the scion (before or after 2 weeks). The grafts were kept in these trays of water and gradually moved from the shaded area to the preferred 50% sunlight as the leaves of the scion hardened.
3. Transplanting of the seedlings was done as soon as the first flush leaves were mature. The wrapping tape was removed on the hardening of the second flush.
4. The rootstock (above the union) was maintained on a weekly basis by removing its axillary buds. It was eventually cut off upon the hardening of the scion's third flush.

Clonal evaluations

The opportunity was used to collect survival information from grafted plants that were prepared for research use and re-supplying in the field. Three preliminary evaluations were done in an effort to assess the reliability of the Bhola Method across different accessions:

1. With 9 accessions

Scions from 9 cocoa accessions were side-grafted onto 170 TSH rootstocks. Grafts were done based on the availability of the scion and the rootstock materials. Survival rates were checked after 2 weeks and 3.5 months. The first five accessions were grafted in May and the last four were grafted in August 2008 (due to rootstock availability). Dieback usually occurs soon after bud-take, and before the hardening of the scion's first flush. Dieback after this stage is highly unlikely. The dieback

percentages were calculated as follows:

$$\frac{\text{Survival after 2 weeks} - \text{survival after 3.5 months}}{\text{Survival after 2 weeks}} \times 100$$

2. With 184 clones from 30 accessions. Table 2. Ten side-grafts were done per clone.
3. In comparison with a top-grafting technique

Using UF 11 as the scion source, a preliminary experiment was set up to compare the dieback results of a top-grafting method for young seedlings (Sreenivasan 1994) with the Bhola Method. UF 11 was chosen because the necessary amount of scion material, at the right physiological stage, was readily available. Ninety-five plants were grafted per method on four-week old TSH rootstock (Table 3). The dieback percentage was calculated as follows:

$$\frac{\# \text{ dead after cover removal (after bud-take)}}{\# \text{ alive at cover removal}} \times 100$$

### Mass propagation

A large-scale assessment of the method's success rate was also done. This time a decision was made to use a single cover for plant batches in an effort to replace the small plastic bags and rubber bands used for individual plants. It was reasoned that if a single cover could be devised for the entire lot grafted per accession, time and some resources could be economized. A simple structure (*Cover 10*) was therefore developed.

- a) a base (either a tray with holes but lined with plastic on the inside, or a tray without

holes) filled with approximately 1.5 cm of water,

- b) a 1.27 cm diameter polyvinyl chloride (PVC) tubing frame was constructed. The frame's length and width were calculated such that the legs of the frame would fit into the inside corners of the tray base and
- c) a frame cover (made from a 50 x 75 cm size transparent plastic bag, Plates 2 a-d).

Ten potted grafts were initially placed within the frame, hence the name *Cover 10*. However it can be referred to as a *Cover 10* chamber for a collection having more than ten grafts (Figure 1) or multiple chambers within (Figure 2).

### Results

1. With selected accessions

An overall average survival level of 78% was achieved for the side-grafts of the 9 accessions (Table 1). The first sign of dieback was seen in ICS 35. Although the success rate of ICS 17 was less than 50%, what was noteworthy was that there was no dieback of its remaining grafts. Seven of the 9 accessions had a survival percentage of  $\geq 80\%$ .

2. With 184 clones from 30 selected accessions

One hundred and eighty four clones (1840 plants) were grafted with an average survival rate of 68%. Table 2 provides the accession groups and their respective survival rates. The best survival rates ( $\geq 80\%$ ) were found in 10 accession groups (GU, AMAZ, GCT, GS, EET, TRD, SLA, AMEL, LCT, SLC). The lowest survival rates ( $< 50\%$ ) were found in 3 accession groups (BH, CLM, LV).

Table 1: Survival rates and dieback percentages of side-grafts using nine selected cocoa accessions

| Month  | Accession    | Number Grafted | Survival      |                 |     | *Dieback % |
|--------|--------------|----------------|---------------|-----------------|-----|------------|
|        |              |                | After 2 weeks | After 3½ months | Δ % |            |
| May    | LCT 162/1010 | 20             | 17            | 17              | 85  | 0          |
|        | GCT 998/59   | 15             | 13            | 13              | 87  | 0          |
|        | GCT 998/96   | 20             | 16            | 16              | 80  | 0          |
|        | GCT 998/38   | 20             | 17            | 17              | 85  | 0          |
|        | GCT 998/60   | 15             | 13            | 13              | 87  | 0          |
| August | ICS 15       | 20             | 16            | 16              | 80  | 0          |
|        | ICS 23       | 20             | 18            | 18              | 90  | 0          |
|        | ICS 35       | 20             | 14            | 13              | 65  | 7          |
|        | ICS 17       | 20             | 9             | 9               | 45  | 0          |
| Total  |              | 170            | 133           | 132             |     |            |

Δ based on total number of plants grafted

\*  $\frac{\text{Survival after 2 weeks} - \text{survival after 3½ months}}{\text{Survival after 2 weeks}} \times 100$

Table 2: Accessions grafted using the Bhola Method in 2009/10 for research purposes

|    | Accession Group Name | Number of clones used | Number of plants grafted | Number of survivors | Survivor % |
|----|----------------------|-----------------------|--------------------------|---------------------|------------|
| 1  | GU                   | 10                    | 100                      | 86                  | 86         |
| 2  | AMAZ                 | 2                     | 20                       | 17                  | 85         |
| 3  | GCT                  | 4                     | 40                       | 34                  | 85         |
| 4  | GS                   | 2                     | 20                       | 17                  | 85         |
| 5  | EET                  | 3                     | 30                       | 25                  | 83         |
| 6  | TRD                  | 10                    | 100                      | 83                  | 83         |
| 7  | SLA                  | 5                     | 50                       | 41                  | 82         |
| 8  | AMEL                 | 1                     | 10                       | 8                   | 80         |
| 9  | LCT                  | 1                     | 10                       | 8                   | 80         |
| 10 | SLC                  | 2                     | 20                       | 16                  | 80         |
| 11 | MOQ                  | 7                     | 70                       | 55                  | 79         |
| 12 | B                    | 27                    | 270                      | 211                 | 79         |
| 13 | AX                   | 2                     | 20                       | 14                  | 70         |
| 14 | BLZ                  | 1                     | 10                       | 7                   | 70         |
| 15 | NA                   | 4                     | 40                       | 28                  | 70         |
| 16 | SCA                  | 1                     | 10                       | 7                   | 70         |
| 17 | IMC                  | 7                     | 70                       | 47                  | 67         |
| 18 | RIM                  | 2                     | 20                       | 13                  | 65         |
| 19 | CL                   | 20                    | 200                      | 120                 | 65         |
| 20 | ICS                  | 5                     | 50                       | 32                  | 64         |

Table 2 continued

|    | Accession Group Name | Number of clones used | Number of plants grafted | Number of survivors | Survivor % |
|----|----------------------|-----------------------|--------------------------|---------------------|------------|
| 21 | AM                   | 27                    | 270                      | 165                 | 61         |
| 22 | JA                   | 10                    | 100                      | 61                  | 61         |
| 23 | CLEM                 | 1                     | 10                       | 6                   | 60         |
| 24 | UF                   | 3                     | 30                       | 18                  | 60         |
| 25 | SJ                   | 12                    | 120                      | 71                  | 59         |
| 26 | LP                   | 4                     | 40                       | 21                  | 53         |
| 27 | MXC                  | 1                     | 10                       | 5                   | 50         |
| 28 | BH                   | 1                     | 10                       | 4                   | 40         |
| 29 | CLM                  | 7                     | 70                       | 28                  | 40         |
| 30 | LV                   | 2                     | 20                       | 3                   | 15         |
|    | <b>Total</b>         | <b>184</b>            | <b>1840</b>              | <b>1251</b>         | <b>68</b>  |

3. In comparison with a top-grafting technique

The results (Table 3) show the dieback figures for both the top-grafts and the side-grafts. At the beginning, the success rates were favourable for each technique. However, the main difference between the two techniques can be observed as early as the subsequent

month; the dieback percentage for the top-grafts observed after this month was 41.1% while the dieback percentage for the same period of the side-grafts was approximately 3%. Top-graft percentage dieback levelled off at 50% after almost two months, while side-graft percentage dieback levelled off at 6% after only two weeks.

Table 3: Observation and comparison of the dieback rates (UF11 as scion material), of a top-grafted method (Sreenivasan 1994) and the Bhola Method over a 2 month period (22<sup>nd</sup> February to 19<sup>th</sup> April, 2014)

|                      | Number of plants grafted | Initial Inventory at bud-take | Weekly inventory |       |       |       |       |       |       |       |       |
|----------------------|--------------------------|-------------------------------|------------------|-------|-------|-------|-------|-------|-------|-------|-------|
|                      |                          |                               | 22/01            | 22/02 | 01/03 | 08/03 | 15/03 | 22/03 | 29/03 | 05/04 | 12/04 |
| Top-grafted (alive)  | 95                       | 90                            | 53               | 50    | 48    | 47    | 46    | 46    | 45    | 45    | 45    |
| Top-grafted (dead)   | -                        | 5                             | 42               | 45    | 47    | 48    | 49    | 49    | 50    | 50    | 50    |
| Percentage dieback   | -                        | -                             | 41               | 44    | 47    | 48    | 49    | 49    | 50    | 50    | 50    |
| Side-grafted (alive) | 95                       | 72                            | 70               | 70    | 68    | 68    | 68    | 68    | 68    | 68    | 68    |
| Side-grafted (dead)  | -                        | 23                            | 25               | 25    | 27    | 27    | 27    | 27    | 27    | 27    | 27    |
| Percentage dieback   | -                        | -                             | 3                | 3     | 6     | 6     | 6     | 6     | 6     | 6     | 6     |

Mass propagation (*Cover 10*)

from 60 to 100%. A total of 11 accessions (150 plants) were grafted with an overall average survival of 77%.

Except for LCT 46 and LCT 411, the results of this evaluation showed success rates ranging

Table 4: Results of 11 accessions (three batches) grafted at three different time periods using separate *Cover10* chambers for each accession.

| Graft date: 16 <sup>th</sup> May, 2013 (first trial)     |                |                        |                            |             |           |
|--|----------------|------------------------|----------------------------|-------------|-----------|
| Accession  | Number Grafted | Survival after 2 weeks | Survival after 6 .5 months | Survival %  | Dieback % |
| EBC 148/S301   | 10             | 9                      | 9                          | 90          | 0         |
| JA 5/35  | 10             | 10                     | 9                          | 90          | 10        |
| JA 5/36  | 10             | 10                     | 10                         | 100         | 0         |
| JA 5/5   | 10             | 8                      | 8                          | 80          | 0         |
| LCT 46   | 10             | 2                      | 2                          | 20          | 0         |
| Total:   | 50             | 39                     | 38                         |             |           |
| Graft date: 10 <sup>th</sup> August, 2013 (second trial) |                |                        |                            |             |           |
| Accession  | Number Grafted | Survival after 2 weeks | Survival After 4 months    | Survival %  | Dieback % |
| LCT 411  | 10             | 5                      | 3                          | 20          | 40        |
| POUND 37/C   | 10             | 7                      | 7                          | 70          | 0         |
| POUND 21/B   | 10             | 8                      | 8                          | 80          | 0         |
| POUND 31/A   | 10             | 6                      | 6                          | 60          | 0         |
| POUND 26/C   | 10             | 9                      | 9                          | 90          | 0         |
| Total:   | 50             | 35                     | 33                         |             |           |
| Graft date: 11 <sup>th</sup> January, 2014 (third trial) |                |                        |                            |             |           |
| Accession  | Number Grafted | Survival after 2 weeks | Survival after 2 months    | Survivors % | Dieback % |
| SLA 93   | 50             | 45                     | 45                         | 90          | 0         |

## Discussion

This paper aimed to present a) the modified side-graft method (Bhola Method) and b) the results of preliminary evaluations of the method using different accession groups. These evaluations also included a comparison of the Bhola Method with a conventional top-graft method (Sreenivasan 1994). The results thus far proved to be extremely encouraging for the accession groups evaluated. The

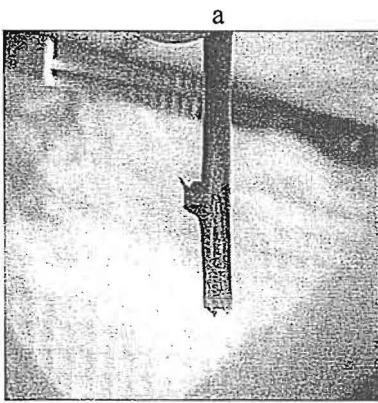
percentage of successful long-term survivors is well above 70% in more than half of the accessions used for the first two evaluations. Meanwhile, in the mass propagation exercise, approximately 82% of the accessions evaluated showed survival rates ranging from 60-100%. These overall results therefore strongly suggest that the method is in fact quite successful and requires further testing to confirm the reliability of its performance across all the accessions of the ICG, T.

The Bhola Method: a novel approach to mass production of *Theobroma cacao* L; J. Bhola

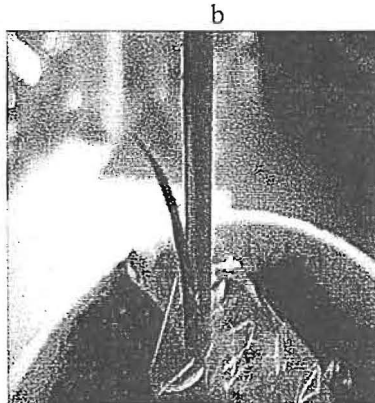
There are a number of key aspects of this technique that may have contributed to the positive outcome. These include, but may not be limited to four points: a) the wrapping stage,

b) the rapidity of execution, c) the maintenance of the rootstock above the graft union during the early phase, and d) the inclusion of the scion's petiole at the graft union.

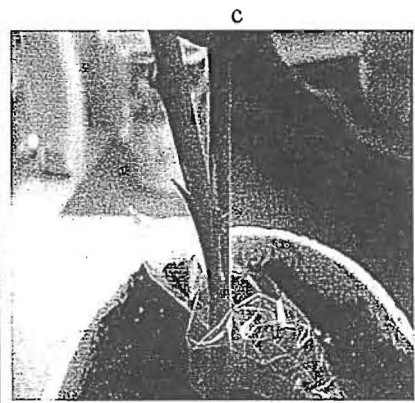
Plate 1



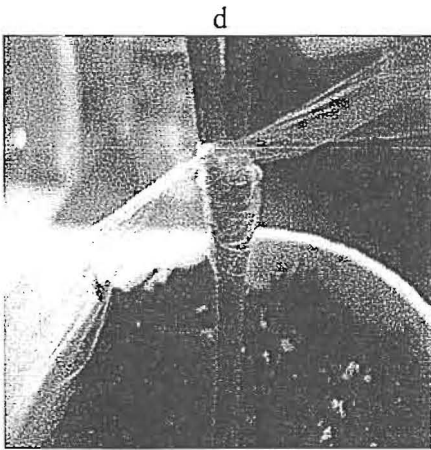
a  
Scion wedge, 2-3mm  
of petiole



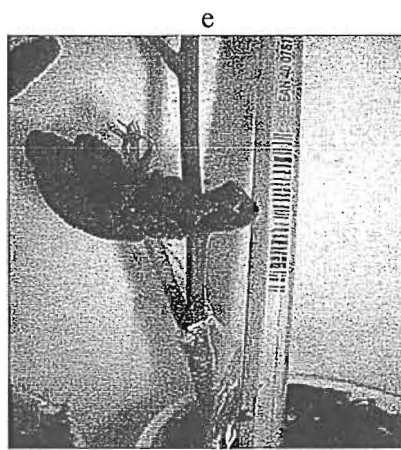
b  
Preparation of rootstock



c  
Insertion of scion  
Into rootstock



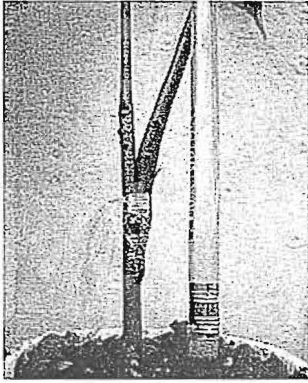
d  
Wrapped and tied



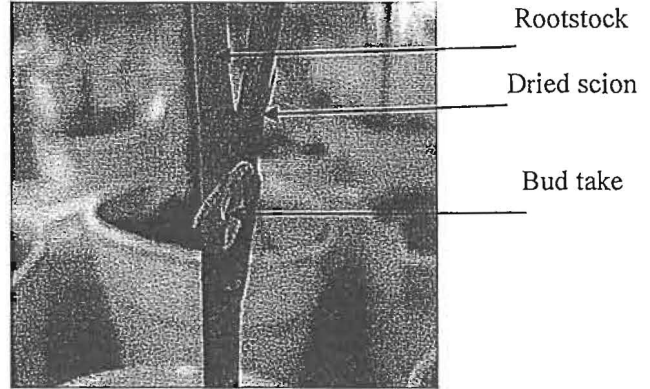
e  
Very young rootstock (delicate)  
and transparency of the tape

f

g



Stable union



Bud-take after the majority of the scion dries up

1 Wrapping.

Firstly, the order and technique of using the wrapping tape in the method eliminates problems with the slimy mucilage, (placing the scion into the rootstock and securing the union with the tape takes about 30 s). Secondly, the grafter is given a great degree of control over the procedure, making it easier to avoid contact between his or her hands and the exposed (cut) parts of the seedlings and scion during the procedure thus limiting chances of contamination. Thirdly, the wrapping tape properly secures the scion onto the rootstock with the scion's petiole serving as an anchor (refer to Plate 1e and f). The two-week old graft in Plate 1e appears to be unstable because of the size of the scion. However, during the incubation period the rootstock above the cotyledons grew significantly to stabilise the graft union. Finally, the transparency of the tape (refer to Plates 1e and f) helps the grafter to see and assess each union that has been wrapped.

Although the method was specifically designed for this very delicate grafting procedure, it can be applied to different grafting techniques on young cacao and other crops. It also allows the grafter to successfully graft scions that are slightly larger (in length and cross-sectional area)

than that of the rootstock. This allows for a wider selection of scion from the parent trees for use in grafting.

2 Quick execution.

Firstly, the method takes a minute and a half to complete (compared to about 3-5mins required for top-grafting). It can actually be faster depending on the experience of the grafter. This means that those cut parts forming the union are only exposed to the atmosphere for a short period of time. Secondly the incision made on the rootstock is merely a shave from the bark slightly into the cambium. Absolutely no fingers are in the way when this is done and therefore the method is relatively safe and this would encourage grafters to work faster.

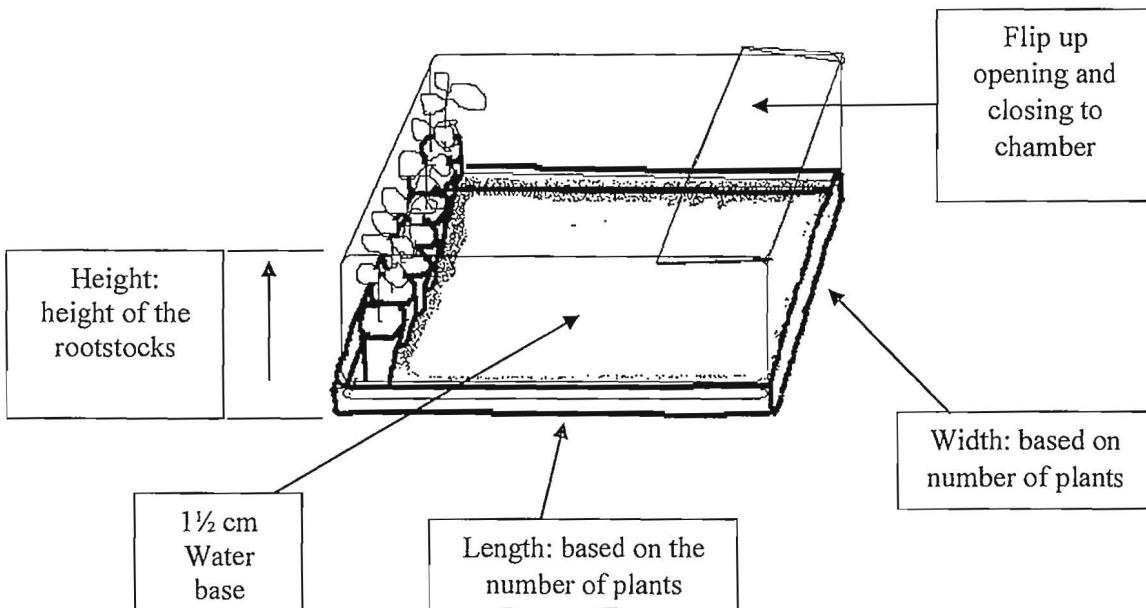
3 Rootstock maintenance above the union.

Through its leaves, the rootstock above the union continues to contribute to the energy requirements (economy) of the plant (Shepherd, Chong and Taylor 1981). It fosters the growth of the scion for as long as it is needed by providing nutrients and shade for the scion's survival until the shade becomes unnecessary. Rapid growth was observed, possibly because the maintained rootstock acts as a surrogate source of vital nutrients until the scion can

adequately establish itself. It was also observed that to ensure this rapid growth and long-term survival, the rootstock above the union should remain intact until at least the hardening of the scion's third flush. This is when the contribution of the rootstock's leaves could be considered negligible as the scion's leaves begin to flourish. It is important to note that growth of the rootstock above the union is prevented through cutbacks of the apical buds. Removal of the rootstock above the union is done by cutting between the union and the location of the cotyledon scars. This ensures that there is no re-growth of the rootstock (Wood and Lass 2001).

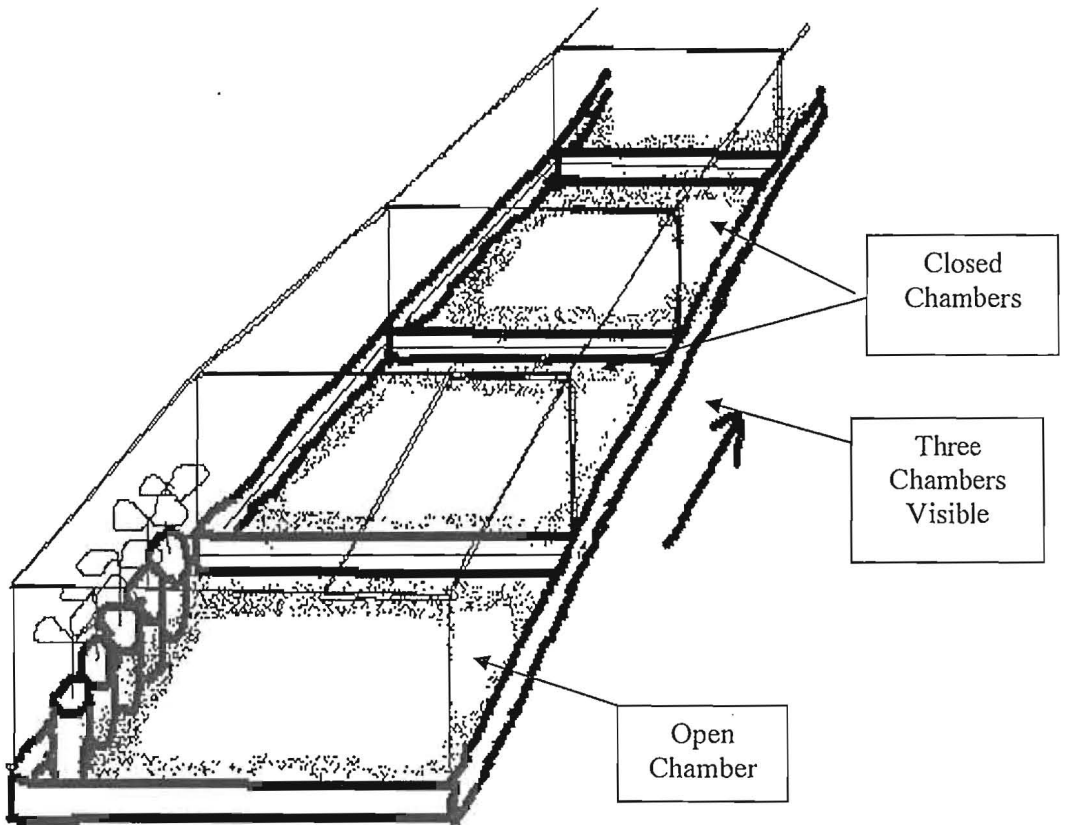
- 4 The use of the petiole at the union.  
There are three main reasons for this. One, when the union is wrapped, the tape is

pulled tightly over the petiole (Plate 1f). This secures the scion to the rootstock and prevents scion slippage as the mucilage accumulates in the bonding process. Secondly, if the major portion of the scion dies, or dries up (before or after removing the plastic enclosure), the bud at this petiole (once still alive) will now act as a potential bud graft at the union (Garner 1976), (Plate 1g). Bud-take in this regard was observed to be as early as 1 month and as late as 8 months. Hence the method serves as a two-in-one graft. For this reason, plants that are assumed dead should not be immediately discarded. Finally, the petiole protects the bud at the union from being too tightly wrapped, and appears to enhance the chances of bud survival after the rest of the scion above the union dries up.



Cover 10, single chamber designed to fit X number of grafted plants (50,100, etc.).

Figure 1: Cover 10 chamber for mass propagation of cocoa seedlings (2-4 weeks old)



Single Cover 10, multiple chambers for X number of varieties.

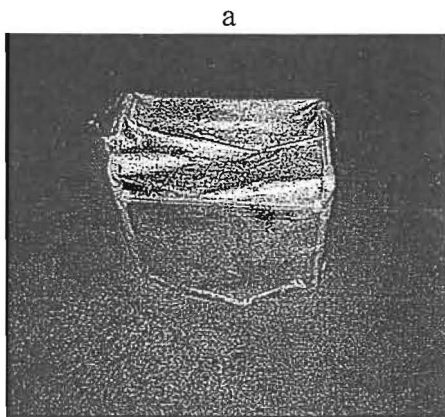
Figure 2: Cover 10 for mass propagation, different varieties

### Mass propagation

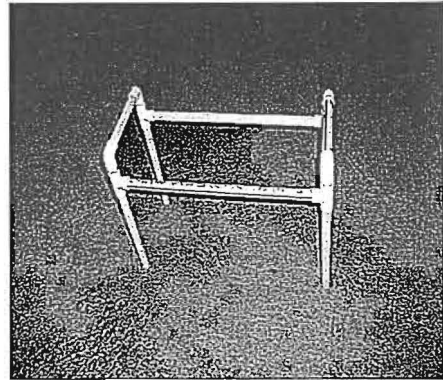
The *Cover 10* method (Figure 1) enables faster completion of the overall method. The name suggests exactly what it does, however *Cover 10* can be modified to accommodate more or fewer plants as in the third evaluation (SLA 93) shown in Table 3. Larger or smaller trays, chambers with doors and zippers are some design possibilities. The use of a single chamber enclosure immediately removes the

need for individual plastic bags and rubber bands per plant. It also eliminates the need for time to put them on/remove them. In a single movement of a single *Cover 10* an entire batch of plants can be enclosed or exposed. Usually mass propagation of cacao material involves a single covering (glasshouse), and a spray mist or some form of humidification (electrical or otherwise) required to prevent desiccation (Murray 1953). With *Cover 10*, misting is eliminated and humidification is automatic.

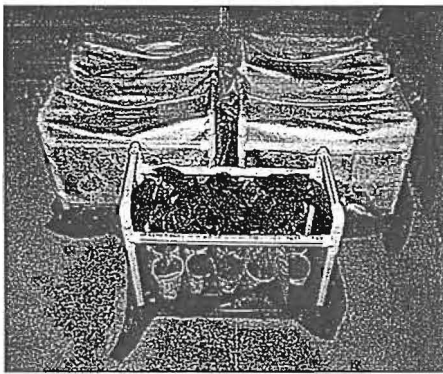
Plate 2



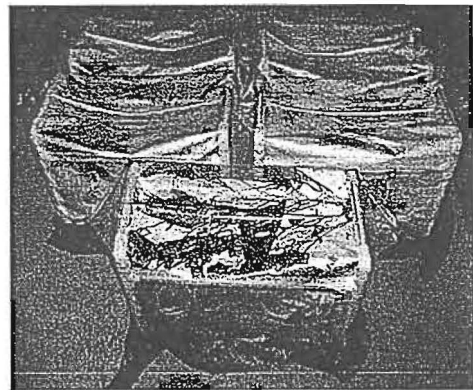
Cover 10



Cover 10 frame



Plants with frame only



Plants covered

The Cover 10 frame (Plate 2b) can be made from wire, wood, and or PVC pipe – or any other convenient, available and inexpensive material. Transparent sheets of plastic can be used for the covering (like those of the 50 x 75 cm transparent bag). The base of the covering is sealed as it enters the water in the tray (or stuck to the tray base in the case of multiple chambers), thereby creating the necessary humid environment. In this case it is important to provide an opening for access to the chamber (Figure 2). Regarding the volume of water required per chamber, it must be stated that no additional work was done on the exact volume needed for supplying a greater number of plants. It was assumed, based on the results of the three mass propagation evaluations, that the required volume for *Cover 10* should be the

volume needed for 1 graft, multiplied by the number of grafted plants placed within (refer to Plate 2). The covers should all have the same height; only the length and width should vary in order to accommodate more plants.

Concerning the accessions that performed poorly (<50% survivors), for the moment it is not yet clear what factors may have specifically negatively affected the graft union. There is always the possibility that sanitising of the scalpel blade may not have been as thorough as previously thought. There is also the likelihood that less-than-ideal cuts might have been made on both scion and rootstock leading to physical ‘misalignment’ and incompatibility at the graft union. There may also have been some undetected poor banding of the plastic tape at the graft union. Grafting

efforts in the near future will repeat the grafts of these poor-performing clones in an effort to determine the possible sources of error.

## Conclusion

These small-scale evaluations thus far suggest that the Bhola Method has the potential to be a very reliable side-grafting technique for use on very young cacao seedlings - especially for those accessions considered as difficult to propagate. Mass propagation can begin as early as two weeks from the sowing of the cocoa beans. With proper maintenance of the rootstock above the union, the survival and successful development of the scion is further assured. Additionally, with the inclusion of *Cover 10*, the method makes room for other propagation explorations and experimentations not only in cacao, but also for research on other perennial tree crops. The high success and rapid growth of the grafted plants can facilitate rapid replanting, rehabilitation or establishment of new cocoa fields. The method is also of value for shipment of plants abroad as bare-rooted grafted seedlings and therefore has tremendous economic potential in terms of resource utilisation and revenue generation.

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## References

- Garner, R.J. 1976. "Grafting — Five: Grafting established trees 148—166." In *The propagation of tropical fruit trees* by A.J. Garner, S .A. Chaudhri et al. Horticultural Review No.4. Commonwealth Agricultural Bureau, Slough, England.
- Kennedy, A.J. 1981-1983a. Summary of Projects: *Propagation 03312 Budding Problems of Particular Clones in Quarantine Stations*. Page 20 In: Annual Report 1981-1983. St. Augustine, Trinidad and Tobago: Cocoa Research Unit, the University of the West Indies.
- Kennedy, A.J. 1981-1983b. Summary of Projects: *Propagation 03321 Propagation of old estate trees*: Page 20 In: Annual Report 1981-1983. St. Augustine, Trinidad and Tobago: Cocoa Research Unit, the University of the West Indies.
- Markets and Markets. 2011. "Global Chocolate, Cocoa Beans, Lecithin, Sugar and Vanilla Market By Market Share, Trade, Prices, Geography Trend and Forecast (2011-2016)." Accessed on July 27, 2015. <http://www.marketsandmarkets.com/Market-Reports/global-chocolate-market-164.html>
- Motilal, L., D. Zhang P. Umaharan, S. Mischke, S. Pinney, L. Meinhardt. 2011. "Plant Genetic Resources: Characterization and Utilization (2011)." 1–9 doi:10.1017/S147926211100058X
- Murray, D.B. 1953. "A new technique in the vegetative propagation of cacao." Pages 53-55: A Report on Cacao Research 1953. The Imperial College of Tropical Agriculture: St Augustine, Trinidad, B.W.I.
- Mooleedhar, V. 1995. Conservation: *Cocoa Germplasm Movement and Quarantine*: Page 12 In: Annual Report 1995. St. Augustine, Trinidad and Tobago: Cocoa Research Unit, the University of the West Indies.
- Ramadasan, K., and Y.A. Mohd. 1986. "Recent Advances in Vegetative Propagation Techniques of *Theobroma cacao* L. Under Malaysian Conditions."

- International Conference on Cocoa and Coconuts: Progress and Outlook, Kuala Lumpur (Malaysia), 15-17 Oct 1984.* Incorporated Society of Planters.
- Shepherd, R., C.F. Chong, and J.G. Taylor. 1981. "Experience with Nursery Budgrafting on Cocoa Estates in Malaysia." *Cocoa Growers Bull.* 32, 28. Harrisons and Crosfield (Malayasia) Sdn. Berhad.
- Sreenivasan, T.N. 1994. "Grafting on very young cacao seedlings." Pages 45-48 In: *Annual Report 1994.* St. Augustine, Trinidad and Tobago: Cocoa Research Unit, the University of the West Indies.
- Soderholm P.K., and E.W. Shaw. 1965. "A Modified Side Graft Technique for use in a Cacao Virus Indexing Program." *Proceedings of the American Society for Horticultural Science Caribbean Region: XIII Annual Meeting, July 5-11 9, 25-29.* Kingston, Jamaica.
- Wood G.A.R., and R.A. Lass. 2001. *Cocoa.* 4th ed. Tropical Agriculture Series, Longman, London/New York, 621p