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Chapter 7

Propagation techniques

Joseph G. Marattukalam and V.C. Mercykutty

1. INTRODUCTION

Propagation of *Hevea brasiliensis* is carried out using seeds or vegetative parts. During the early years of the rubber plantation industry, propagation of the crop was through seeds only. Later, vegetative propagation using buds became common. At present, seeds are utilized mainly for the production of root stocks. Special types of seeds known as polyclonal seeds are used directly for propagation.

2. METHODS OF PROPAGATION

2.1 Seeds

There are different kinds of rubber seeds such as legitimate, illegitimate, ordinary, monoclonal and polyclonal seeds. Among these, monoclonal and polyclonal seeds are produced in specially raised plantations. The other types of seeds are collected from commercially established plantations. Monoclonal seeds, especially those of clone Tjir 1, were once commonly used for propagtion. For this, plantations consisting of this clone alone were established. Special care was taken not to have any tree of any other clone in the garden to prevent contamination of pollen grains. This ensured that all the seeds produced were selfed seeds of Tjir 1. However, monoclonal seeds are not recommended now for raising plantations due to their inferiority compared to the modern clones.

2.1.1 Polyclonal seed generation

Polyclonal (polycross) seeds, which are hybrid seeds, are produced in plantations called polyclonal seed gardens. In these gardens, several clones are planted intermixed so as to maximize cross-pollination. Clones planted in these gardens should possess desirable characters like high yield, disease resistance, vigour, ability to produce good seedling families and profuse production of seeds. All the clones should flower simultaneously. Genetic factors like genetic divergence and inbreeding depression also have to be taken into account while selecting clones (Mydin, 1990). Some of the clones usually planted in polyclonal seed gardens are RRIM 600, RRIM 605, RRIM 623, PB 5/51, PB 28/59, Tjir 1 and PR 107. Other clones having the required desirable attributes mentioned above could also be included. The number of clones in the seed gardens usually varies from three to seven (Simmonds, 1986). To maximize cross-pollination, special designs are adopted while planting. Selection of at least four clones enables better randomization so that trees of the same clone are not planted adjacent to each other.

A design adopted for a garden with four clones A, B, C and D is furnished below :

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A  B  C  D  A
C  D  A  B  C   Repeat
A  B  C  D  A
   Repeat
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Each letter represents one clone, either as one tree in ideal cases, or a group of trees in less desirable cases. A simpler method would be to plant different rows in such a way that each row consists of one clone only and successive rows do not have the same clone. However, due to a higher possibility to self-pollination, this method is inferior to the former.

If nine clones are used, an ideal design in which each clone is surrounded by the remaining eight clones is as follows :

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A  B  C  D  E  F  G  H  I  A
G  H  I  A  B  C  D  E  F  G   Repeat
D  E  F  G  H  I  A  B  C  D
A  B  C  D  E  F  G  H  I  A
      Repeat
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The same objectives can be achieved adopting a triangular method of planting. A model design for a seven clone garden is shown below :

A B C D E F G A
F G A B C D E F
C D E F G A B C Repeat
A B C D E F G A
Repeat

A wider spacing is adopted in seed gardens for proper development of the crown, essential for profuse flowering and fruit set. A spacing of 9.1 x 3.0 m (358 trees/ha) is considered suitable for this purpose. The stand is reduced to 247 by the sixth year by progressive thinning out.

Pollinating insects may carry pollen from other nearby rubber trees. Such contamination of pollen grains can result in production of undesirable seeds with different genetic constitutions and their mixing up with the desirable ones. To prevent this, an isolation belt, about 100 m wide, is provided around the garden. This isolation belt is planted with a non-rubber crop. If rubber has to be planted, one of the clones included in the garden has to be used. Production of seeds in a garden depends to a great extent on clones, climate and diseases. On an average, a tree produces 150 seeds in well-maintained gardens. The RRII has established several polyclonal seed gardens in Kanyakumari district, the main seed production centre in India, in collaboration with different estates (Nair and Koshy, 1966) and in the Regional Research Station, Kolasib, Mizoram (RRII, 1991).

2.1.2 Collection

Fruits, when mature and dry, dehisce and seeds are popped off. The seeds lose viability very rapidly if left in the field. Seed viability is completely lost if exposed to sunlight for more than three days. Seeds, therefore, are collected daily. Deformed, discoloured, shrunken and light seeds are discarded.

Seeds should be sown for germination soon after collection. Germination is the most reliable method for testing the viability. Discolouration of the endosperm indicates poor quality of seeds. Viability can be prolonged through different methods which check loss of moisture and rate of respiration.

2.1.3 Germination

Germination of seed indicates the commencement of the active growth of embryo and emergence of the young plant. Seeds germinate within six to seven days after sowing. The mode of germination is hypogeal *i.e.* the cotyledons remain within the seed coat. Vivipary (germination of the seed still on the parent plant) is observed when climate is not favourable for pod dehiscence. On germination, the radicle pushes open the circular cap which closes the germpore (micropyle) and emerges as a small white stump with a flat end (Dijkman, 1951). As it lengthens, the tip becomes conical and a number of minute points develop on its surface. The conical point develops into the tap root and the marginal points emerge as laterals. The two cotyledons remain within the seed. Then the epicotyl

elongates and comes out of the seed forming a hump which subsequently straightens, bringing out the plumule. Fresh and heavy seeds show early germination (Saraswathyamma and Nair, 1976). About 75 per cent germination is considered good.

2.2 Vegetative methods

Propagation through asexual (vegetative) parts such as buds, leaves and stem cuttings is termed as vegetative propagation. Vegetative propagation of rubber is carried out mainly by budgrafting (budding). Propagation through rooted cuttings is possible in rubber but is not generally practised due to unsatisfactory development of the root system, especially tap root.

2.2.1 Budding

The principle involved in budding is the replacement of the shoot system of a plant with that of another more desirable plant. The method of budding adopted is a modified form of Forket method of patch budding (San, 1972). In this process, a patch of the bark of the seedling plant (stock) is replaced by a patch of bark with a dormant bud (bud patch) taken from the clone to be multiplied (scion). The bud patch gets attached to the stock permanently and becomes a part of it. The stock is then cut off above the budded portion and the grafted bud develops into the shoot (scion) exhibiting the characters of the plant from which it was taken. The new tree thus formed is a two-part tree, comprising a root system belonging to the stock plant and a shoot system contributed by the donor of the bud.

Depending on the colour and age of the buds as well as the age of the stock plants used, three types of buddings are mainly recognized. These are brown (conventional) budding, green budding and young budding. In the first method, older buds having brown colour are used while in the other two, tender green buds are utilized (Marattukalam and Saraswathyamma, 1992).

Depending on the part of the stock where budding is carried out, buddings are classified into four types. These are, base budding, crown budding, over budding and high budding. Base budding is carried out at the base of the stock plant and includes brown budding, green budding and young budding.

2.2.1.1 Brown budding

The technique of brown budding in rubber was developed in 1916 in Indonesia by a horticulturist named van Helten in collaboration with two planters Bodde and Tass. The first handbook on this subject was published by Bodde in 1918 (Dijkman, 1951). Brown budding is generally carried out by grafting brown-coloured buds taken from budwood of about one year's growth, onto stock plants of 10 months or more growth. Vigorously growing healthy stocks having a girth of 7.5 cm at the collar region are ideal for budding. Stocks should be budded when the bark peels off very easily. Peeling is usually good when the top whorl of leaves are well developed, but before further extension-growth commences. Test peeling of a small patch of bark 15 cm above the base is the surest method of assessing the peeling quality of the bark. Since all stock plants may not attain this stage at the same time, more than one round of budding may be necessary to cover all the stocks.

Brown buds are usually obtained from brown budwood produced by budded plants raised in budwood nurseries. Buds found in the axils of fallen leaves are generally utilized for budding. Budwood should be collected when the top whorl of leaves have fully expanded but not hardened to ensure proper peeling of the bark and high budding success. Test peeling may be carried out before harvesting the budwood. Collection of budwood should be done with sufficient care so as to avoid bruising. Budwood should, as far as possible, be collected in the morning or evening, and should preferably be utilized for budding as soon as collected. If budding is delayed, special measures should be adopted for preventing moisture loss. Budwood is harvested as per the requirement and cut into pieces of convenient length, usually 1 m. While handling budwood of different clones, proper labelling has to be done for identification.

Budding is usually carried out with a specially-designed knife with two blades, called budding knife. However, an ordinary sharp penknife with a blade of 7 to 8 cm length could also be used (Plate 10. a). The first step in the preparation of the stock plant for budding is thorough cleaning of the basal 15 cm portion to remove dirt, soil, *etc.* Cleaning can be done with cotton waste or rags. Then two parallel vertical cuts starting from about 2.5 cm above the collar are made (Plate 10. b). The cuts should be a little more than 5 cm in length and 1.5 cm apart. Then a horizontal cut, joining the bottom ends of the vertical cuts, is also made. All the three cuts should be made deep enough to reach the wood. After making these cuts, the latex is allowed to completely ooze out for a few minutes through the cuts. During this time the budder can mark a few more stocks in a similar manner. After the flow of latex ceases, it is wiped off from the surface. The flap of bark separated by the three cuts is then gently lifted with the aid of the knife and peeled upwards. Alternatively, the upper ends of the vertical cuts may be connected by the horizontal cut and the flap peeled downwards. The practice of removing the flap completely is also adopted. The exposed region is called the budding panel.

The bud patch used for brown budding has a length of about 5 cm and a width of about 1.5 cm. For preparing the bud patch, two parallel vertical cuts having a length of 5 cm are made on the two sides of a bud, 1.5 cm apart. Then two horizontal cuts are made connecting the lower and upper ends of these cuts (Plate 10. c). A little time is allowed for the latex to ooze out. During this time, incisions are made around neighbouring buds of the same budwood. When the oozing of latex stops, it is wiped off and the bud patch marked out by the four cuts is stripped off by gently pushing to one side.

After removing the bud patch from the budwood, the inner side is examined carefully for the presence of the core of the bud, which appears as a slight projection. If it is not present, the bud patch should be discarded. The bud patch should be handled with utmost care so as to avoid any damage to the cambium. It should always be held by the edges only without touching the cambium. Foreign matter like water, sand and sweat should not be allowed to fall on the cambium. Similarly, exposing the cambium to strong sun or dry wind can result in its drying. All these can cause damage to the cambium. Damage to the cambium of the budding panel also should be avoided.

The four edges of the bud patch are then slightly trimmed. The bud patch prepared in the above manner is then gently placed in the budding panel after lifting

the flap (Plate 10. d). It should be placed in such a way that the bud is above the leaf scar and its inner side is in contact with the budding panel. It should also not rub against or slip over the stock wood as this may damage the cambium. Any damage caused to the cambium of the bud patch or budding panel can adversely affect the success of budding. Exposure of too much area of the budding panel around the bud patch is another unfavourable factor affecting budding success. After placing the bud patch in the budding panel, the flap, if retained, is placed back over it and is then bandaged using polythene strips of about 45 cm length, 2.5 cm width and 250 gauge (62.5 µm) thickness. Bandaging should commence at the bottom and move upwards in a close spiral. During the first few turnings of the bandage, the lower end of the flap should be kept pressed over the bud patch gently to prevent it from slipping. Bandaging should be tight enough to keep the cambium tissues of the budding panel and bud patch in intimate contact with each other. The end is finally kept intact with a knot. In the field and along the borders of seedling nurseries, it may be necessary to shade the bud patch against strong sunlight. This can conveniently be done by tying rubber leaves over the bud patch. Carrying the various tools such as budding knife, cleaning materials and polythene strips in a box is convenient (Marattukalam, 1975).

If the budding is successful, the cambium of the stock plant and that of the bud patch unite and the bud patch establishes itself as a part of the stock. This process requires around 15 to 20 days and the plants are left undisturbed for 20 days after which the bandage is removed. The flap, if it had been retained, is cut at a little above the upper end of the bud patch and carefully separated from the stock. If the opening has been delayed, a thin white callus layer may be found completely covering the bud patch, which also should be removed carefully while opening up, to expose the bud patch. Initial budding success can be ascertained by a gentle scratch of the bud patch above or below the bud. Presence of green colour indicates initial success of budgrafting. The final budding success is ascertained in a similar manner after another 10 days.

2.2.1.2 Green budding

Green budding is a comparatively new method of vegetative propagation developed in Indonesia in 1960 by H.R. Hurov. Both the stock plant and budwood used for green budding are very young. Seedlings which are two to eight-month-old, are used as stock. Buds are collected from six to eight-week-old budwood, also known as bud shoots or bud sticks. Buds found above the scale leaves of the shoots alone are used for budding. These buds are green in colour and hence the name green budding.

Young, vigorous seedlings raised in nursery or in polythene bags are used as stock plants for green budding. Plants having a girth of about 2.5 cm at the base, with brown bark up to a height of about 15 cm, can be used for this purpose. The stock plants require about four to five months to attain this size. By proper care, this period could further be reduced.

Green budwood is obtained from budwood plants (source bushes) grown in nurseries for this purpose. They are collected when six to eight-week-old. At this stage they will have a length of 30 to 60 cm with a whorl of leaves at the top. The bud shoots are harvested

by cutting at the base with a sharp knife. For proper peeling of the bud patch, harvesting should be done when the leaves are copper brown to dark green. After harvesting, the leafy portion of the shoot is cut off (RRIM, 1964a). The non-leafy portion shows two to five scale leaves with axillary buds which are utilized for budding.

After cleaning the basal portion of the stock, two vertical incisions, a little more than 5 cm long and 1 cm apart, are made starting from a point about 2.5 cm above the collar region. The lower ends of these cuts are joined by a horizontal cut and a few minutes allowed for the cessation of latex flow. The flap of bark thus separated out is then gently lifted upwards exposing the budding panel. The flap is then cut off leaving a short 'tongue' of about 1.5 cm at the top. The stock is now ready to receive the bud patch.

The bud patch can be stripped from the bud shoot in the same way as in the case of brown budding (Plate 11. a). However, other methods can also be employed for this purpose. In one such method, a 6 cm long bud patch shaped like a tower is marked out. Then the top 1 cm is separated from the bud shoot and holding on to this portion (by touching the inner and outer sides), the whole bud patch is gently stripped off. The top 1 cm of the bud patch with damaged cambium is pruned off. In a third method the bud patch along with a thin slice of wood is first taken from the bud shoot (Plate 11. b). This is the bud slip. The two sides of the bud slip are trimmed to the required width. Then the bud patch is gently separated from the wood by pulling them apart. While doing so care should be taken to see that the bud patch does not bend. Only the slice of wood is bent (Plate 11. c). After separation, the lower and upper ends of the bud patch are also trimmed. When finally prepared, the bud patch should have a length of approximately 5 cm and a width of 1 cm, so that it fits snugly into the budding panel (Hurov, 1960).

The upper end of the bud patch prepared in the above manner is gently inserted under the 'tongue' (Plate 11. d) and placed in the budding panel (Tinley, 1962). Then the bud patch is secured firmly by bandaging with a transparent polythene strip (Plate 12. a) as in the case of brown budding. This strip should be about 25 cm long and 2 cm wide. Transparent tape is insisted upon as it allows light to fall on the green bud patch which in turn enhances budding success. For the same reason no shading is given. Buds are examined three weeks after budding by observing through the bandage or after removing the bandage. Retention of the green colour is the indication of budding success. Final observation on budding success is done after ten more days. If the observations are made through the bandage, after the second observation, the bandage is removed. The plant is now ready for cut back.

Budding can be carried out at any time of the year. However, too dry or very wet weather is unsuitable (de Silva, 1957). Generally more success is obtained during rainy season than in summer. Experiments have shown that in India the period from May to December is generally suitable for brown budding. Green budding gives good success during the summer months (January-March) also. However, days with heavy rainfall are not suitable for budding (Marattukalam and Premakumari, 1982). For best results, budding should be carried out either in the early morning hours or in the evenings.

It is always advisable to use stock plants and budwood of more or less the same girth. Too much difference in the size of the stock and budwood causes bending or stretching of the bud patch, resulting in damage to the tissues which may adversely affect budding success.

Both brown budding and green budding have certain advantages and disadvantages. Advantages of green budding over brown budding are : (1) it utilizes the growth of the stock more efficiently, *i.e.* when green budded plants are cut back, only a small amount of stock growth is lost (RRIM, 1963); (2) green budding is simpler and faster than brown budding and hence more number of plants can be budded reducing the labour cost per budding; (3) it is more adaptable for production of advanced planting materials; (4) it gives higher percentage of success during summer than brown budding; (5) opening of the budding and cutting back can be done simultaneously, thus saving labour cost; (6) yield of green buds from a unit area of nursery is two to three times that of brown buds; (7) since the polythene strip used for green budding is smaller, cost incurred for this material is reduced; (8) after cutting back, green buds develop earlier than brown buds; and (9) green budding is more suitable for crown budding. The major defects of the green budding technique are : (1) green bud shoots cannot be retained in the nursery for long after they become mature enough for harvesting (RRIM, 1964b); (2) after harvesting, green sticks cannot be kept for long periods, unlike in the case of brown budwood; and (3) scion of green budding is less vigorous than that of brown budding and hence it requires very careful attention during the early period of growth especially in the field.

2.2.1.3 Young budding

This is a kind of green budding carried out on very young plants less than two months old (Ooi *et al.*, 1976). Stocks are raised in small bags of lay flat size 33 x 15 cm. The plants are given intensive nursing such as foliar application of fertilizers and fungicides twice weekly (Leong *et al.*, 1986) and soil application of NPKMg mixture weekly. When seven to eight-week-old, they are green budded. Four weeks after budding, plants are cut back leaving a snag of 20 to 25 cm length. Buds on the snag are nicked or the shoots coming from them pruned off promptly (Yoon, *et al.*, 1987). When the scion develops two or three whorls of leaves, they are transplanted in the field just like other bag plants. This technique has got several advantages over the normal green budding technique. By adopting this technique, bag plants could be produced within seven months after the planting of germinated seeds in the bags, which is usually done in August/September. In India, the time required for this is around nine months in the case of normal green budding. Since small bags are used for the production of plants, transportation is easier. The cost of production is also slightly less compared to the normal method (Ng *et al.*, 1991). Since the stock plants required for young budding are raised by sowing seeds directly in the bag, these plants have better-developed root systems than the bag plants raised from green-budded stumps. A well-developed root system prevents breaking of soil core and ensures faster and easier establishment of plants after transfer to the field (Seneviratne, 1995). However, under the climatic conditions existing in our country, this method does not have much practical application because by the time the bag plants produced from young buddings are ready (March - April), the climate becomes unfavourable for field planting.

Hence planting has to be delayed till the onset of the monsoon (June). Bag plants produced from green buddings also become ready by this time.

2.2.1.4 Crown budding

Replacing the undesirable crown of a high yielding clone with a desirable crown is of practical significance. In many of the modern clones, though the trunk possesses a capacity for high yield, the crown shows many undesirable characters such as susceptibility to diseases and wind. An undesirable crown can be replaced by a desirable one through crown budding. Crown budding was first adopted in Indonesia (Java) in 1928. It was widely adopted in South America in the 1930s to prevent the damage caused by South American leaf blight. The tree produced by crown budding is a three-part tree comprising the root system of the stock plant, trunk of one clone and the crown of another clone. Thus the desirable characters of the trunk of one clone and crown of another clone are combined (Yoon, 1973).

Crown budding is ideally carried out when the scion of the budded plant has attained a height of 2.4 to 3.0 m. One to two years are usually required for the plants to attain such a growth. The height of the plant is more important than the age. Crown budding may be commenced when 50 to 60 per cent of the plants in the field are buddable. Budding is carried out at a height of 2.1 to 2.4 m on the inter-whorl region below the top whorl of leaves. Budding should be done only when the top flush of leaves is fully expanded and hardened. Stem tissue should be green or dark green at the time of budding. This ensures maximum budding success. Too tender or too mature stem tissues adversely affect budding success. If the topmost flush of leaves is not mature enough, budding could be done below the second whorl of leaves provided all other conditions are satisfied. Plants having a height up to 4.5 m can also be used for crown budding. In the case of such overgrown plants having the green tissue at a height higher than the prescribed, the height of budding has to be raised correspondingly so as to carry it out below the top whorl. For crown budding, the green budding technique is followed. Since the budding has to be done at a higher level, a self-supporting ladder should be used. On no account should the plant be bent for budding or any other operation. If the budding is a failure, rebudding is done on the opposite side of the stem, 5 cm above or below the first budding. Successfully budded plants are cut back leaving a snag of about 5 cm. Treating the cut ends of the stem with some wound dressing compound is desirable. After cutting back, usually many trunk shoots arise. All of them should be pruned regularly at fortnightly intervals with a knife having a long handle. This should be continued until the crown bud sprouts and the crown shoot grows to a length of about 2.5 cm. After that, two or three trunk shoots arising about 15 to 45 cm below the crown shoot are allowed to grow. These shoots should be spaced apart and be on different sides of the stem as far as possible. They should never be allowed to become more dominant than the crown shoot, as this may suppress the growth of the latter. For this, if necessary, the top portion of the trunk shoots may be pruned. About nine months after cutting back, when the crown-trunk union is firmly established, the trunk shoots are pruned. Necessary precautionary measures have to be taken for the protection of the crown shoot especially from wind damage and perching of birds. The crown shoot later on fully establishes itself and in due course develops

to be the crown of the three-part tree. If the crown shoot is lost for some reason before the pruning of the trunk shoots, the most vigorous among them is again crown budded, if possible, or allowed to develop as the crown (Yoon, 1973).

2.2.1.5 Over budding

Budwood plants are sometimes budded at higher levels for converting an existing budwood nursery of a clone to another clone without replanting. This is termed as over budding. The method adopted is to carry out budding at the basal portion of the brown budwood (Plate 12. b) before harvesting it. Since the budding is carried out on a well-established plant, the scion grows vigorously producing more budwood compared to a newly established nursery. Thus it is a quick and economic method for converting budwood nursery of one clone to that of another.

2.2.1.6 High budding

This is a type of crown budding where seedlings are budded at a level of about 90 cm from the ground. The aim of this technique is to combine the desirable characters of both seedlings and budded plants *i.e.* vigour of seedlings along with high yield and uniformity of buddings. High budding can be carried out on plants raised in the field or nursery. In the case of field plants, after budding they are cut back above the bud and the high bud is allowed to develop. When nursery plants are high-budded, they are subsequently cut back and raised in polybags until one or two whorls of hardened leaves are produced. Transferring to the field is carried out at this stage. Improved varieties of seedlings such as polyclonal seedlings are used for this kind of budding. The technique of budding is similar to normal crown budding *i.e.* carrying out green budding below the top whorl of leaves of the stock plant. Budding success is around 80 per cent and field establishment about 99 per cent. Tapping is commenced at 76 cm above ground level. Studies conducted in Malaysia have proved that high budding with clones like PB 235 and PB 260 increases the girth, yield and bark thickness of PBIG seedlings. However, the extent of enhancement varies depending on the clone used for high budding. Certain clones like GT 1 and RRIM 712 are observed to exert negative influence and retard the performance of the high-budded seedlings. High-budded seedlings in general exhibit reduced variability compared to unbudded seedlings (Yoon *et al.*, 1991). The technique, however, is not adopted on a wide-scale.

2.2.1.7 Bench grafting

Bench grafting is budding carried out on a work bench indoors, as against nursery or field grafting carried out on stock seedlings established on the ground outdoors (Mahlstede and Haber, 1966; Macdonald, 1986). It is usually adopted when outdoor grafting is very difficult due to adverse climatic conditions like rain. For this type of budding, stock plants are pulled out and their stems and roots pruned as in the case of budded stumps. Then they are taken indoors and budded. Budded plants are immediately planted in polybags. After 20 days, the polythene bandage covering the bud is removed. However, removing the bandage 40 days after budding ensures better budding success and establishment (Marattukalam and Varghese, 1998). Stock shoots are also pruned off. Subsequently the bud develops and grows into the scion. Preliminary studies conducted at the RRII for

comparing this technique with nursery grafting have shown that even though success of budding and establishment are less, growth is better (Marattukalam and Varghese, 1993).

2.2.2 Other methods

Apart from budgrafting, several other methods are also adopted for the vegetative propagation of *Hevea*. Important among them are rooting of cuttings, approach grafting, cleft grafting, root grafting, layering and tissue culture. At present these methods have very little practical use due to their cumbersome nature, high cost of production, problems of root anchorage, *etc.*

2.2.2.1 Rooting of cuttings

For rooting, terminal cuttings with one whorl of mature leaves are used. Rooting is done in a mist-propagation chamber, in raised beds made of rooting media under artificial mist generating systems. Proper shade and coverage are provided to protect the cuttings from intense sunlight as well as to prevent mist drift (RRIM, 1959). Shoots of about 30 cm length are planted in the beds and mist applied continuously during day time. After five to nine weeks, the cuttings produce roots. Subsequently, they are transferred to polybags and kept in hardening beds (RRIM, 1962). In these beds after giving continuous mist for one week, its duration is gradually reduced. Shade also is progressively removed. Within three to six weeks the process of hardening is over and the plants are ready for field planting.

2.2.2.2 Approach grafting

Approach grafting involves grafting of branches of the scion still attached to the parent plant to the stocks raised in containers. Young stock plants having a girth of about 2.5 cm at the base and green shoots with one whorl of leaves are used for this type of grafting. Containers with the stocks are placed near the branches in such a way that the portions of the stock plant and scion branch remain parallel to each other at the region where they are intended to be joined together. A strip of bark about 18 cm long along with a thin slice of wood is removed from the facing sides of both the stock and the scion. Exposed regions are pressed together and kept as such by bandaging with polythene strips. Within two months, union takes place. Then the scion is separated from the source plant by cutting below the grafted portion. Stock tissues above this portion are also cut and removed. Shock caused by these cuttings will be over within one or two months. Then they are transplanted in the field (Ooi *et al.*, 1976).

2.2.2.3 Cleft grafting

In this method of vegetative propagation, the apex of the scion shoot is grafted onto the decapitated stem of the stock plant (Webster, 1989). Two to three week old seedlings raised in bags usually serve as stock (San, 1972). Apices of young shoots 2.5 to 5.0 cm long are used as the scion. The size of the stock and scion should match each other perfectly. The stock is decapitated at a height of about 4 cm above the collar with two slanting cuts, making it V-shaped. Then the stock is split into two. The cut end of the scion shoot is shaped into a wedge with two sloping cuts, inserted into the split made on the stock and kept in position by bandaging with polythene tape. Grafted plants are kept in

mist for two weeks or in dense shade for four weeks. Subsequently they are hardened over a period of four weeks, after which they are ready for field planting.

2.2.2.4 Root grafting

Grafting of roots taken from seedlings or rooted cuttings to green scion shoots is referred to as root grafting. Severed green shoots with one whorl of fully expanded leaves and dormant terminal bud are used as the scion for this type of grafting. Shoots are severed from the source plant with a horizontal cut about 35 cm from the apex. Stocks are one week old seedlings having well-developed radicle and plumule. The grafting panel of size 2.5 x 0.5 cm is opened at or near the cut end of the shoot by stripping and tying up a flap of bark. Roots are collected by cutting the epicotyl at a distance of about 2 cm from the collar. The cut should be highly slanting so as to expose a large cut surface. The epicotyl is placed in the grafting panel in such way that its cut surface touches the exposed wood of the scion. Bandaging is done to keep the root in position. The grafted plant is placed in mist for three weeks and later planted in bags for further growth (Ooi *et al.*, 1976).

2.2.2.5 Layering

Development of roots on a stem while it is still attached to the parent plant is known as layering (Hartman and Kester, 1968). The type of layering adopted in the case of rubber is air layering. Young branches are used for this purpose (RRIM, 1960). The stem is first girdled by removing the bark around it to a width of about 2 to 5 cm. Cambium of the exposed wood is completely removed by scraping. Growth hormones are applied at this region to enhance rooting. Then this portion is completely covered with a ball of any moist rooting medium such as sphagnum moss, soil containing plenty of organic matter, coconut husk-soil mixture, *etc.* and finally covered with polythene sheet to prevent loss of moisture (Yoon and Ooi, 1976). Within a few weeks, roots develop from the upper edge of the girdle and grow into the rooting medium. When the roots are properly developed, the layer is separated from the plant by cutting the branch below the ball. The layer is then planted after removing the polythene cover without damaging the rooting medium. Studies conducted by the RRII have proved that sphagnum moss is far superior to the other rooting media (Sobhana *et al.*, 1995).

2.2.2.6 Tissue culture

Propagation of rubber is possible through tissue culture also. Tissue culture or micropropagation is the technique of producing plants from small (micro) pieces of plant tissues (Hartman and Kester, 1968; Macdonald, 1986). Studies on tissue culture of rubber plants were started in 1966 (Chua, 1966). Different parts of the plant such as embryo, anther, shoot tip and integument can be used for tissue culture (Chua 1966; Paranjothy and Gandhimathi, 1976; RRIM, 1984; Asokan *et al.*, 1988; 1992a,b; RRII, 1992). The RRII has developed a technique for the production of tissue culture plants (Plate 12. c) from shoot tips (Asokan *et al.*, 1988). Rubber plants were also developed through anther culture technique (Asokan *et al.*, 1992a) and a procedure has also been developed for the generation of plants through somatic embryogenesis from integumental tissue (Asokan *et al.*, 1992b). Attempts are being made for tissue culture other plant parts like leaf, floral buds and inflorescence.

Important steps involved in tissue culturing of *Hevea* are collection of explant, its sterilization, placing in culture medium taken in test tubes, autoclaving, adding nutrients and growth hormones at the appropriate time in required quantities and keeping the culture tubes under optimum light and temperature conditions for the required period. Plants are formed in about three months. They are then transferred to polythene bags and kept in a green house until two or three whorls of leaves are developed and hardened. At this stage they are transplanted in the field after removing the bags. Requirement of various inputs such as nutrition, hormones, light and temperature is different for various clones. Even for the same clone, culture conditions vary with the physiological stage of the explant, season, part of the plant used, *etc.* Because of these variations separate protocols have to be developed for each clone, plant part, physiological stage, season, *etc.* This is a laborious and time consuming process. However, procedures have been perfected for the propagation of several important clones by optimizing these parameters. As in the case of most other tree crops, multiplication rate in *in vitro* culture is very low in rubber. Further, in the post-laboratory stages mortality is very high. However, after overcoming all these hurdles the RRII has successfully developed a large number of plants through various methods of tissue culture. These plants have been established in the field and are under various stages of evaluation. Test tapping carried out on some of these plants has shown a significant increase in yield in certain clones over their budgrafted controls. Due to the complexity of procedure and the high cost of production, tissue culture has not developed as a viable commercial method of propagation.

3. PREPARATION AND PACKING OF PROPAGATION MATERIALS

The propagation materials handled by rubber growers are fresh seeds, germinated seeds, seedling stumps, brown budwood, green bud shoot, brown-budded stumps, green-budded stumps, polybag plants, stumped buddings, three-part stumps (stumped three-part plants), core stumps and soil core plants and specific techniques are required for each. If not properly prepared, their quality could be reduced, which in turn adversely affect the establishment after planting. After preparation, these materials may require transportation from one place to another or storage for varying durations. During storage and transit, they are likely to get damaged by loss of moisture or by breaking, rubbing, bruising, crushing, *etc.* To avoid these and give ample protection to these materials, certain specific methods are adopted for packing and transporting.

3.1 Seeds

3.1.1 Fresh seeds

Fresh and healthy seeds collected from the field can be kept under shade without much loss of viability for about seven days. Storing fresh seeds in water at ambient temperature increases their water content which in turn prolongs the viability (Mercykutty *et al.*, 1996). By packing seeds loosely in well-aerated containers with powdered charcoal having 40 per cent moisture, 70 per cent viability could be retained up to 30 days (Eikema, 1941). Viability of seeds could be kept unimpaired for two months by mixing the seeds with an equal volume of sawdust (10% initial moisture content) in perforated polythene bags

(RRIM, 1966). Storage of seeds at 4°C in sealed polythene bags is also considered to be a reliable method (Wycherley, 1971) for retaining viability up to four months.

Immediately after collection, seeds are generally packed in powdered charcoal of 20 per cent moisture for transportation (Wycherley, 1971). Containers usually used are wooden boxes, double gunny bags, bags lined with polythene or polythene bags. For transporting over very long distances, seeds may be packed tightly in layers in aerated cases with damp sawdust-charcoal powder mixture, at least 2 cm thick between two layers of seeds.

3.1.2 Germinated seeds

Germinated seeds are collected from germination beds when the radicle just comes out of the seed. If the root is allowed to elongate it may get damaged while packing and transporting. To prevent this, germination beds are inspected every day and germinated seeds are picked up. For short distance transporting and immediate use, germinated seeds are carried in water taken in buckets or trays. Since they remain suspended in water, chances of rubbing against each other and damaging the growing tip of the root are minimum. For transporting over long distances and storing for up to three days, they are packed in boxes between 2.5 cm thick layers of aged sawdust, charcoal powder or damp coconut fibre. A layer of packing material of the same thickness should be provided around all sides of the box (Subramaniam, 1980). They should be laid in such a manner that the radicle points downwards. The top side of the box must always be kept up. Some space should be provided for the expansion of the contents of box due to elongation of the radicle.

3.2 Budwood

3.2.1 Brown budwood

After harvesting, the brown budwood is cut into pieces of 1 m length with a pruning saw for the convenience of handling. The immature top portion which may be green or partially brown is discarded. For use on the same day and transporting over short distances, brown budwood is kept wrapped in wet sacking. For longer storage and transport over distant places, their cut ends are sealed with molten wax and each piece covered with banana sheath, wet sacking, coconut fibre or grass leaves. They are then tied into bundles of convenient numbers. By this method, viability can be retained up to three days. For storing up to 14 days and carrying over very long distances, each piece is first wrapped with perforated polythene and then packed in boxes with wet sawdust or coconut fibre.

3.2.2 Green bud shoots

After collection of the shoots, the leaf bearing top portion is cut off. The leafless lower part having the scale leaves alone is used for taking buds. Since green bud shoots are tender it is better to use them for budding immediately after harvesting. Usually shoots harvested in the morning are used on the same day, preferably by noon. In the seedling nursery they are carried in trays or buckets containing water or kept rolled in wet sack or cloth without touching each other and always kept in shade. If packed with wet, aged sawdust in alternating layers after sealing the cut ends with wax, storage is possible up to six days (Subramaniam, 1980).

3.3 Stumps

3.3.1 Seedling stumps

Seedlings prepared to convenient size by pruning the stem and roots are called seedling stumps. Healthy and vigorous one year old seedlings are generally used. The seedlings should have a minimum girth of about 7.5 cm at the base and brown colour up to a height of 45 cm or more. For stumping, firstly, the seedlings are cut back at some point between 45 and 60 cm, where the brown colour ends. Pruning is always done with a slanting cut, preferably above a whorl of buds. While cutting back, green or partially brown stem should not be retained on the stump as transpiration can take place through such regions and the resulting loss of water may lead to the drying of the stumps after planting. The plants are left in the nursery for 7 to 10 days. During this period, a few buds below the cut end become activated and swell. At this stage the decapitated plants are pulled out without causing much damage to the roots and bark of the stem. If it is found very difficult to pull out the plants due to drying of soil or extensive development of the root system, the lateral roots can be loosened by digging the soil on one side of the tap root or all around the plant, to facilitate easy pulling out. After pulling out, the tap root is pruned to the maximum possible length, but not more than 60 cm and not less than 45 cm. The minimum of 45 cm is insisted on for the sake of better establishment, and the maximum of 60 cm is fixed for the convenience of handling. Lateral roots are pruned to a length of 10 to 15 cm. Plants infected by diseases or having defective roots are discarded. If more than one tap root is present, the most vigorous one alone should be retained by pruning all others at the base. After preparing the seedling stumps by proper pruning of roots and stem, the cut end of the stem is immediately sealed by dipping in molten paraffin wax. For storing overnight, they should be kept in fresh water. For transporting over short distances they are tied into bundles and then covered with a layer of grass or leaves. In this manner they can be stored up to three days. For transporting over long distances and storing up to 10 days, they are packed in boxes along with wet sawdust in alternate layers (RRIM, 1968).

3.3.2 Brown-budded stumps

Brown-budded plants prepared for planting by pruning the stem and roots are known as brown-budded stumps. The ideal way to prepare a brown-budded stump is to cut the plant at a height of about 7.5 cm above the upper end of the bud patch. The cut should have a downward slant of around 45° from the side of the bud to the opposite side. The cutting back is done about 10 days before pulling out. During this period the bud gets activated, which in turn will speed up the establishment of the budded stump after planting. The plants are then pulled out and the tap root pruned to a length of 45 to 60 cm and the laterals to a length of 10 to 15 cm if used for field planting (Plate 12. d). While pulling out the plant, special care should be taken not to exert pressure on the bud patch, as otherwise, there are chances of the bud getting damaged. In case it is found difficult to pull out the plant after cutting back, the plant can be pulled out before cutting back and then pruned. If the budded stumps are intended for planting in polybags, the tap root should be pruned to a length about 15 cm less than the depth

of the soil core and laterals to around 5 cm length. Brown-budded stumps are hardy and hence a proper method of packing retains the viability for a longer time. The cut end of the stem is sealed with wax as in the case of seedling stumps. The bud patch is protected by covering with a small piece of banana sheath or folded rubber leaf, to be removed at the time of planting. For overnight storing, they are kept erect in water as in the case of seedling stumps. For retaining their viability up to three days and carrying over short distances they are tied into bundles and each bundle covered with banana sheath, grass or leaves (RRIM, 1976). Rolling the root portions alone in polythene sheet lined with paper and wet sawdust prevents desiccation for 20 to 30 days (RRIM, 1982). The viability of brown-budded stumps can be retained up to 30 days by packing them in boxes with wet sawdust. Fungicide treatment of the stumps, followed by covering each stump with polythene film and packing with jute hessian is also suitable for retaining the viability for four weeks (Premakumari and Nair, 1974). However, storing for more than 10 days is not advisable as callus appears on the roots. Sometimes the buds also may start sprouting.

3.3.3 Green-budded stumps

Green-budded stumps are prepared from green-budded plants in almost the same way as brown-budded stumps (Plate 12. e). The major difference is that if cutting back is done before pulling out, it should be done only seven days before pulling out as green buds require less time for activation. In both types of budded stumps, the budded plant should be pulled out without much delay after budding. If retained in the nursery for a long time, the dormancy of the buds will increase and consequently their sprouting after planting may be delayed. Rejection of defective plants, pruning of multiple tap roots, *etc.* are similar to those of seedling stumps. Green-budded stumps being comparatively tender and smaller with less reserve food, it is always preferable to plant them immediately after preparation. Packing methods adopted for green-budded stumps are basically the same as those adopted for brown-budded stumps. Protection to the bud patch can also be provided by retaining the polythene strip used for bandaging the bud patch at the time of budding. Keeping in water enables preservation overnight. Additional steps like bundling and covering the bundles with grass give protection for two days. If packed in boxes with wet sawdust these could be safely stored up to six days and transported over long distances.

3.4 Advanced planting materials

3.4.1 Polybag plants

Polybag plants are prepared by raising green-budded or brown-budded stumps or by *in situ* budding of stock plants. The polybag plants are field planted usually at two to three whorl stage. While transporting bag plants, utmost care should be given to prevent any damage to the soil core. If the soil core is damaged, roots may break and consequently the plant will be deprived of all the advantages of bag planting. Transporting over a short distance is done by carrying them on the head or shoulder. Vehicles like lorry, truck, tractor, *etc.* are used for transporting over long distances. While transporting by vehicles, the bags are stacked on the platform tightly to minimize swaying and shaking. Providing shade for protection from hot sun is also desirable. The bag should always be kept in a vertical position while loading, transporting and unloading. Carrying them

in an inclined or horizontal position may cause breaking of soil core. Care should also be taken to avoid tearing of the bags as it can cause breaking of the soil core.

3.4.2 Stumped buddings

Stumped buddings are mainly of two types, ministumps and maxistumps. To prepare ministumps, the scion is cut back when it develops brown colour up to a height of 60 cm from the bud union. Pruning is done at the point where brown colour ends, preferably below a whorl of buds. The cut end is treated with any wound dressing material to prevent dehydration. The stem is then whitewashed with hydrated lime to avoid sunscorch. Ten days are given for the activation of buds. Then the plants are pulled out and the roots pruned as in the case of budded stumps. If pulling out is found to be difficult due to the deep tap root, it can be made easy by removing the soil at one side of the tap root up to a depth of 45 to 60 cm. A crowbar is inserted through this opening and the tap root is severed at the desired depth. This is called tailing.

For preparing maxistumps, cutting back of the scion is carried out when brown colour is formed up to a height of 240 cm. The first step in the extraction of the plant is tailing which is done five weeks before pulling out. Early tailing reduces the transplanting shock and enhances the development of new roots from the cut end after transplanting. After tailing, the soil removed for this purpose is placed back. Pollarding of stem is done 10 days before pulling out at a height of 240 cm, where brown colour ends. As in the case of ministumps, pruning of stem is done below a whorl of buds. Wound dressing, whitewashing, pulling out and pruning of lateral roots are also done as for ministumps. Packing and transporting of ministumps are similar to that of seedling stumps. Maxistumps are not usually made into bundles due to their large size. They are packed head to tail on lorries or trailers, using grass or leaves as packing medium to prevent bruising and drying.

3.4.3 Three-part stumps

This type of planting materials are produced by the proper pruning of the stem and roots of crown-budded plants raised in the nursery. To produce a three-part stump, a budded plant in the nursery is first cut back above the bud patch as in the case of stumped buddings. When the scion grows to a height of 240 cm, crown budding is done below the top whorl of leaves. Then the scion (trunk shoot) is cut back at about 7.5 cm above the crown bud. The crown bud grows and produces the new crown shoot. When this shoot develops brown colour at least up to the second whorl of leaves it is stumped below this region. Other cultural operations such as tailing, whitewashing, treating of the cut end of the stem, pulling out, pruning of lateral roots, packing and transporting are similar to that of maxistumps.

3.4.4 Core stumps

Core stump or core-stumped budding is a kind of stumped budding which is transplanted in the field with a soil core and intact root system. To prepare this type of planting material, polybag plants are first produced in the usual way. When these plants produce two or three whorls of leaves and root mass enough for binding the soil core, they are taken from the polybag nursery. Then the base of the bags are cut and removed.

If any roots remain coiled at the bottom of the bag they are cut off carefully without damaging the soil core. The bag plants are then transplanted in the nursery, with the remaining portion of the bag, at a wider spacing of 90 x 90 cm or 120 x 120 cm. While planting, the top 10 cm of the bag should be kept above the soil as it is essential for the proper development of the roots. The plants are maintained in the nursery until they reach the maxistump stage (Leong and Yoon, 1988). Pollarding of the stem and its protection is done at this stage as in the case of maxistumps. The plants are retained in the nursery to any stage from bud break to two whorls of hardened leaves. They are then dug out after tailing the tap root and transplanted in the field after removing the bag completely like bag plants. Plants with damaged or improperly developed root system as well as broken soil core are discarded. Transporting of core stumps is similar to that of bag plants.

3.4.5 Soil core plants

Soil core plants are prepared by taking out budded plants growing in the nursery along with the root system and the supporting soil core. Plants with three whorls of mature leaves are ideal. For the success of this technique, firmness of the soil core is essential. Therefore, nurseries for core stumps are established in soil with fairly high clay content. Stock plants are raised at a spacing of 60 x 60 cm and green budded when five months old. Budded plants are then cut back and the buds allowed to grow. When two to five whorls of leaves are produced, the plants are extracted. If core plants are prepared after brown budding, seven to nine month old stocks are used. For extraction, a metal cylinder is first driven into the soil around the plant. The cylinder is then levered upwards with the aid of a crowbar, pulling the plant also simultaneously. After extraction, the tap root is pruned. The cylinder, along with the soil core and the plant is then placed on a piston. By pushing the cylinder downwards the soil core and the plant are pushed out of the cylinder. The soil core is then wrapped with polythene or paper. To reduce shock, the plants are kept in shade and irrigated for one or two days. Core stumps extracted as budded stumps are kept in shade for longer durations so that the scion develops a few whorls of leaves. Transporting and field planting of core plants are similar to those of bag plants.

3.5 Export of propagation materials

Propagation materials to be sent abroad should be packed in strong containers using enough packing medium to avoid damage during transit. Containers, packing medium and propagation materials should be free from pathogens and other pests. Methods like fumigation, dusting, spraying, dipping, *etc.*, with fungicides and other pesticides can be adopted for this, depending on the suitability and specific regulations for each country. A phytosanitary certificate issued by the competent authority of the despatching country should accompany each parcel of the propagation material. When carried by air, the materials should be kept in the warm pressurized compartments to avoid low temperature and low pressure.

4. INDUCING BUD SPROUTING

Soon after planting, buds begin to sprout. Green buds require about two weeks for bud break while three to four weeks are usually needed in the case of brown buds. If undue delay occurs, sprouting of buds could be induced by certain minor horticultural

manipulations. These manipulations are carried out usually above the bud, on the bud patch or above the bud patch on the stock stem. Methods adopted on the bud patch are pricking and notching. Pricking is done with the pointed end of a knife just above the bud without causing any damage to the bud. Notching is carried out about 5 mm above the bud, with a horizontal cut below and an oblique cut above so as to remove a thin slice of bark above the dormant bud. Ringing and arching are the methods applied above the bud patch. Ringing is done by making a circular wound all around the stock immediately above the bud patch with a sharp knife (Edgar 1958). Arching involves the making of a wound above and on the two sides of the bud patch in the shape of an arch or inverted U. In all the four methods, the wound should be deep up to the wood so as to cause a complete severing of the conducting vessels. The stimulus given by the wounding as well as the accumulation of nutrients below the wound causes the development of the bud. While making these wounds, special care should be taken not to disturb the plant which can cause damage to the newly developed roots. Since loss of latex and moisture from the tissues can occur to some extent by these methods it is advisable to carry out this operation under wet conditions only. Coating the bud patch with molten paraffin wax kept at a constant temperature of 85°C in a water bath using a brush enhances bud break and induces uniform sprouting (Ramanathan *et al.*, 1991). Spraying a two per cent solution of thiourea (Thiocarbamide - CH_4N_2S) on buds is reported to increase the percentage of bud sprouting (Seneviratne *et al.*, 1996).

5. ENHANCING ROOT DEVELOPMENT

Early and proper development of roots is essential for the establishment and growth of the plants. Development of roots could be accelerated by treating the roots with a formulation containing growth regulators like indolebutyric acid (Webster, 1989). Dipping roots in cowdung slurry before planting also enhances root development.

6. STOCK-SCION INTERACTION

A grafted plant, as stated earlier, comprises of the root system donated by the stock plant and the shoot system contributed by the scion plant. Since both these parts coexist in the same plant they exert mutual influence, which is termed as stock-scion interaction. The stock can influence the growth and yield of the scion to varying degrees. Vigorous and high yielding stocks increase the vigour and yield of the scion (Dijkman, 1951; Ooi *et al.*, 1980). Stocks raised from monoclonal seeds of clones like PB 5/51, are found to influence favourably the growth and yield of several scion clones, while some other stocks like RRIM 600 affect the performance of the scion negatively. As polyclonal seeds are generally more vigorous they impart better growth to the scions (Ng *et al.*, 1981). Stocks produced from vigorous clones like GT 1 also enhance growth of the scion, resulting in reduction of immaturity period (Combe and Gener, 1977). Similarly, vigorous scions induce more growth in the root system. (Dijkman, 1951). The high yield potential of a clone could be exploited to the maximum by using the most compatible stock material. Potential vigour of the stock is more important than its yield potential as far as influence on the yield of scion is concerned. However, of the two parts of a budded tree, *viz.* stock and scion, it is primarily the scion that determines the performance of the plant.

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