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Review Article

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Vegetative Methods of Plant Propagation: II- Grafting Cutting Layering and Budding in Mango

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ABSTRACT

Mango plants are propagated by sexual and asexual methods. The asexually propagated mango plants produce true-to-type (clones) of the parent plant, in addition to uniform yield, fruit size and quality. The fruit size and quality of asexually propagated mango is superior to those of seedlings. These mango trees have short juvenile period and have less vigorous growth habit compared to the seedling trees, making treatment and harvesting easier.

The asexual methods of mango propagation are of four types, namely, Grafting, Cutting, Layering and Budding; the grafting techniques being the most suitable method of vegetative propagation of mango. The veneer grafting technique is being used with high success rate in Madhya Pradesh, Andhra Pradesh, Uttar Pradesh and Bihar while the stone or epicotyl grafting is suitable for the Konkan region of Maharashtra and the coastal regions.

Presently the softwood grafting is being used commercially for the mango propagation in several parts of South India. The wedge grafting is the easiest grafting method of mango propagation to perform with a 90-100% success rate. This technique is adopted mainly for rejuvenation of the old orchards by top working the trees. Veneer grafting and soft-wood grafting techniques can be used for large scale multiplication of mango in north India. In this communication we present a detailed review on different grafting methods of mango propagation.

Key words: *Asexual/Vegetative plant propagation, propagation of fruit plants, cutting, layering, budding*

INTRODUCTION

Mango is native to India, where it has been under cultivation for more than 4000-6000 years[1]. It bears the botanical name *Mangifera indica* L. and is the most important species of the genus *Mangifera*, which includes the most delicious fruit tree-the mango[2]. Owing to its economic and nutritional values, numerous health benefits, fruit elegance, exotic and flavor appeal, mango is one of the most widely cultivated tropical fruits in the world, ranking amongst the top six fruits in volume production[3].

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To meet the increasing demand of mango, its orchards must be planted with vigorous and productive cultivars which require sound methods of propagation and advanced grafting plant management. The mango is propagated by two methods, (i) sexual method - propagation by seeds and (ii) asexual or vegetative method - propagation by cutting, layering, budding and grafting.

The mango seeds are either mono-embryonic or poly-embryonic depending on the cultivars. A seedling grown from a single sexual embryo from a mono-embryonic cultivar does not ensure a true- to- type mango tree. However, the poly-embryonic seeds produce true-to-type (clones) of the parent. Hence, the propagation by the seeds is recommended for the poly-embryonic mango cultivars only. Poly-embryonic seeds produce a number of shoots, one of which originates from fertilization. The other seedlings are clones of the mother tree. The fertilized seedling is often weak and stunted and should be discarded. The sexual method of propagation was extensively used before vegetative methods of propagation were known[4].

Contrary to the sexual method the asexual or vegetative methods of propagation always produce true-to-type or clone of the original plant. Moreover, the grafted trees also produce uniform yield, fruit size and quality. Any seed can be used to grow seedlings for grafting. The seedling plants can be used as the rootstock for the grafting purpose. The technique of grafting in mango was practiced in India since ancient times. Now various methods of grafting, cutting, air layering and budding are being practiced with varying degree of success in different regions of India for the vegetative propagation of mango.

1. Sexual (Seed) Method

Mango propagation by seeds is known as the sexual (seed) method of propagation. Plants grown by seeds are called seedling plants. Mango propagation by this method needs healthy mango seeds for growing seedlings. The seedling mango trees grow vigorously and attain large size.

2.1. Seeds

Mango seed (Fig.-2.1a) is one of the biggest seeds amongst the fruit seeds. The mango seed is a single flat oblong seed. It is fibrous or hairy on the surface. Inside the seed coat there is a 1- 2 mm thick lining covering a single embryo, 4 – 7 cm long, 3 – 4 cm wide, and 1 cm thick. The seed consists of a tenacious coat enclosing the kernel (Fig.-2.1b). It consists of nutrients, vitamins, and minerals, phytochemicals etc. There are two seed types amongst mango cultivars. Mango having the seeds with a single embryo is called monoembryonic (Fig.-2.1c). The single embryo is the result of cross-pollination, a sexual process, and combines the traits of the male and female parents. Seedlings of monoembryonic mango differ from the parent tree.

Mango having seeds with multiple embryos are called polyembryonic (Fig.-2.1d). One embryo is of sexual origin, while the other embryos come from the maternal tissue and are identical to the mother tree. Polyembryonic cultivars have been grown traditionally from seed in many countries.

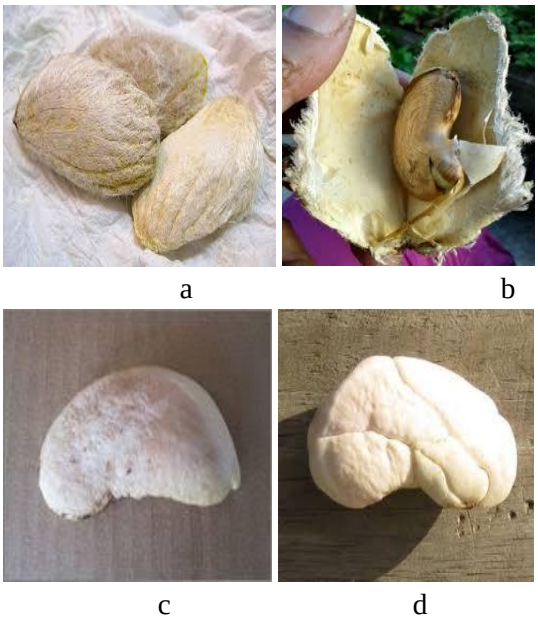


Fig. 2.1: Mango seeds

Irrespective of the seed type, a seedling tree takes longer time to produce fruit and usually is more difficult to manage, compared to a grafted tree. Hence, it is generally not recommended to grow mango trees from seed,

unless one desires to produce hybrids for the purpose of cultivar improvement. Mango seeds lose viability very rapidly. It is essential to clean the seed as soon as possible after its removal from the fruit. It then needs to be dried in the shade for a day or two. The outer husk must be removed before planting (Fig.-2.1b).

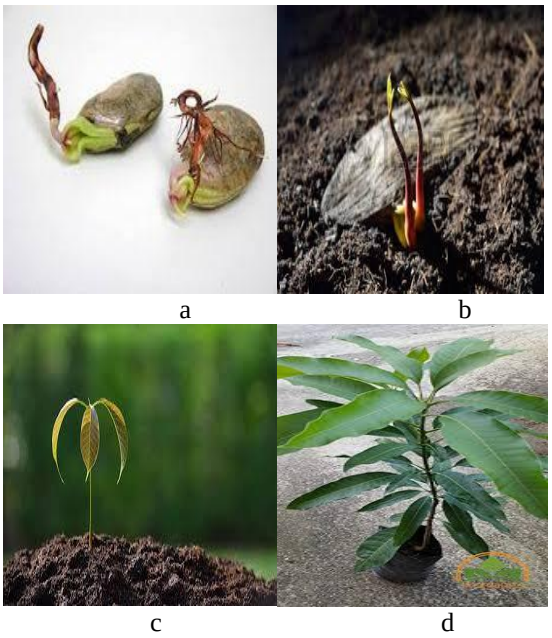
2.2. Propagation by seeds

Almost all the mango cultivars are monoembryonic, except a few which are polyembryonic and can give true-to-type seedlings from nucellar embryos. However, polyembryonic varieties have not been used on large scale to raise the plants. Generally mango stones are collected from local trees, market places etc. irrespective of the cultivar during the mango season. The fresh collected stones are sown in raised nursery beds of 1x5 m^2 size in July. The beds are prepared in semi-shade area. The stones are placed without leaving any space amongst them and plumule point is kept upwards so that straight tap root and stem is produced. After placing the stones, the moist leaf mould is placed over them. The seeds germinate within 20 days after sowing (Fig.-2.2a, Fig.-2.2b). When the colour of seedling leaves changes from coppery red (Fig.-2.2c) to green (Fig.-2.2d), the seedlings are shifted to permanent nursery beds.

In nursery bed seedlings are planted in August at a separation of 45 cm from row to row and 25 cm from seedling to seedling. The seedlings are irrigated immediately after planting and are nourished in nursery till February and then shifted to another nursery bed to check the root growth. Regular irrigation and weeding is practiced in nursery. To get faster growth and healthy seedlings $(NH_4)_2SO_4$ or NH_4NO_3 is applied @110 kg/Ha. Bolder stones give seedlings with more vigour irrespective of whether these were collected from grafted or seedling trees. The fresh stones collected from canning unit give high germination while stones embedded in peels or in sun for long period or dried stones are poor in germination. Stones sown within one month of extraction germinate ~ 80 %. By proper storage and chemical treatment of stones viability is preserved for 100 days to one year. Before sowing, the stones should be washed pulp free and treated with 1% organomercurial compound to check the incidence of fungus *Sclerotium* causing collar rot and thus reducing mortality of seedling and grafts.

3. Asexual Method

There is a large variation in mango seedlings, raised even from a single tree due to highly cross-pollinated nature of mango.



a b c d

Fig. 2.2: Seed germination and small plants

Fully grown up seedling mango trees are large (Fig.-3a) as compared to the grafted trees (Fig.3b). Although seedling trees produce heavy crop, the fruit size and quality is inferior and do not fetch good return in market. The seedling trees have long juvenile period and have more vigorous growth habit,

a - Seedling Tree

b - Grafted Tree

Fig. 3: Mango Trees

which creates difficulty in taking plant protection measures and harvesting of fruits. The fruits of seedling trees do not mature in one stroke and hence, affect the marketing. Keeping these disadvantages of seedling trees in mind and to obtain uniformity in plant performance, a monoembryonic cultivar should be propagated through asexual methods of propagation. The vegetative methods of mango propagation in India are being practiced since ancient times as mentioned in Sanskrit Literature. The European missionaries in Goa first introduced the technique of inarching in India. The asexual methods of mango propagation can be divided in four groups as, (i) Cutting, (ii) Layering, (iii) Budding and (iv) Grafting. In an earlier communication[5] we reviewed in details the first three methods of vegetative or asexual propagation of plants, namely, cutting, layering and budding. In this review we present different methods of the plant grafting in details, with a brief discussion on the vegetative propagation of mango by cutting, layering and budding.

3.1. Grafting

There are a number of grafting techniques[6-12] . In the following we discuss the commonly employed grafting methods for the propagation of mango trees.

3.1.1. Approach/Inarch Grafting

The method of inarching or approach grafting is quite cumbersome and time consuming, but it is still the leading method for commercial propagation of mango plants. The method consists of uniting the selected shoot (scion) of a desired parent/mother plant with the potted or transplanted seedling/rootstock by approach grafting. For this purpose, about one-year-old seedlings are most suitable when these attain a height of 30-45 cm and thickness 0.75-1.5 cm. These seedlings are either grown in pots or under the mother plant from which the grafts are to be prepared. Generally, one-year-old twigs of the scion tree of ~ 60 cm in length and nearly of the same thickness as that of the stock is chosen for grafting. Young and non-bearing trees should not be selected as mother plants. A thin slice of bark and wood, ~ 5 cm in length, 7.5 mm width and 2 mm deep, is removed by means of a sharp grafting knife from the stem of the stock as well as from the scion branch. The cuts made should be absolutely flat, clean, boat shaped, even and smooth. The ends of these cuts should be round and not angular. The cut surfaces of both, the stock and scion are made to coincide facing each other so that there remains no hollow space between the two. Polythene/alkathene strips of ~ 1.5 cm width are tied around the union. After about one month of operation, the scion below the graft union and stock above the graft union should be given light V shape cuts at weekly interval in such a way that the grafts can finally be detached while giving the fourth cut. In the last stage, the top of the stock above graft union should also be removed completely. Inarching should be done during the active growth period. The end of the monsoon in heavy rainfall areas and early monsoons in the light rainfall areas is the best period for inarching.

Fig. 3.1.1: Approach/Inarch Grafting

For inarching, first the seedlings are to be raised. Seeds are sown in beds immediately after extracting them from the ripe fruits. A spacing of 22 cm from seed to seed in the row and about 45 cm from row to row is normally maintained. After about one year, the seedlings become ready for inarching. Seedlings should be carefully watched for vegetative malformation in the nursery bed and these must be culled in the beginning. These seedlings can be transferred either to pots or taken out (with ball of earth around the roots tied with grass all round to check the evaporation of water and to keep the roots intact) for inarching operation. These should be taken to the tree from which the scion part is to be selected and kept or tied up conveniently to facilitate the process of inarching. Sometimes the scion parent is headed back to produce a large number of conveniently available branches for grafting at ground level. The scion plant is about 2-3 years old. It is kept prostrate in the bed during rainy season so that a few branches arise from the exposed side of the plant. The seedlings are ultimately taken out from the nursery bed and planted just near this parent scion plant.

The actual process of inarching consists of removal of 6-8 cm long strip of bark, with a small layer of wood attached to it, from the potted seedling at a height of 20 cm from the soil surface. A similar strip is then removed from the scion shoot selected for inarching. The scion shoot should be healthy with well-developed foliage. Care is taken to ensure that the two exposed surfaces on the seedling and the scion shoots fit together securely, leaving no gap when the two treated shoots are held together by hand with the exposed parts in contact with each other. In this position they are tied firmly with raffia or banana fibre. The complete operation should be done at the commencement of rains for successful raising of the plants. The inarching is done in October when the rains are over. Mango leaf and ordinary *sutli* are used for wrapping and tying the cut portions. Though raising of mango stock seedlings is very scientific for the root distribution and the small ball of earth required while taking out the plant from the nursery, the method of raising scion material is unscientific because the scion wood is taken without the knowledge about the performance of the parent material.

3.1.1.1. Disadvantages of Inarch Grafting

The rootstock seedlings are brought near the mother plant, so it is more cumbersome. Moreover, it is laborious and time consuming. The inarched plants are irrigated regularly and care is required for 2-3 months at the place of mother plant. Only one plant is obtained from a long scion shoot so it is uneconomical. Usually one-year-old rootstock seedlings are planted / potted which causes high percentage of mortality during inarching.

3.1.2. Whip / Splice/Tongue Grafting

Whip / splice / tongue grafting is one of the oldest methods of asexual mango propagation[8]. The whip and tongue graft is used to make a very secure graft with a lot of surface area contact between the scion and rootstock. It is used to connect thin pieces of stock and scion, usually roughly pencil-thick, but it probably requires the highest fine skill of all the graft methods. Whip and tongue graft has a total of eight faces , which means a greater chance for the graft union healing to occur. Compared to a splice graft, the whip and tongue is stronger, because the interlocking tongues are held under compression by the natural springiness (elasticity) of the wood of both the stock and scion. This naturally generates the pressure needed for the graft union formation.

The additional length of the vascular cambium exposed along the cut surfaces of a whip and tongue graft (original diagonal cut plus tongue cut) is much greater than the length of cambium exposed by only the diagonal cut without the tongue, in the case of a splice graft.

Splice Tongue/Whip

Fig. 3.1.2: Whip Grafting

This results in greater cambial contact between stock and scion of a whip and tongue than of a splice graft. Natural pressure is generated by the interlocking tongues of the whip and tongue graft, compared to the splice graft, which is essentially the same graft without the interlocking tongues.

The first cut is a long sloping diagonal as much as one to two inches long. The second cut begins about 1/3 of the way down from the top of the first cut. It begins vertically and then gradually becomes nearly parallel to the first cut surface, to create the tongue. Identical complementary cuts are made in both the stock and scion. Preferably, the scion should be of the same diameter as the stock, but if it is smaller, it is important that the scion be placed over to one side of the stock, rather than centered, so that the vascular cambia line up. The stock and scion should fit together.

Smooth and clean part of the branch is selected. A sharp narrow blade knife is used and the stub is split through the middle 2-4 cm deep. This makes the tongue of the stock. As in cleft grafting a scion bearing a number of buds, 10-25 cm long is taken. The scion is cut in a sloping shape and is inserted on the stock into the center so that the inner back lies against the inner most back of the split stub. With the scion in place, the union is covered with waxed string or plastic sheet. All the cut surfaces are washed thoroughly and the scion is allowed to grow.

3.1.3. Veneer/ Detached Grafting

The method of veneer or detached grafting is a suitable technique for the mass scale commercial propagation of mango[7,8]. This is the best method of propagation for mango. It is easier and more economical and gives a high percentage of success and is ideal for establishing *in situ* orchards. The seedling rootstocks 8 months to 2 years old and 5 cm diameter are suitable for this method. The scion is also selected of similar thickness having age of 3- 4 months, preferably a terminal non-flowering shoot. The selected scions are defoliated on the mother plant 7-10 days prior to detaching, keeping a part of petiole intact on the selected terminal shoot. This helps in forcing the buds to swell and increasing the percentage of success in grafting.

For conducting this grafting operation, a downward and inward 3-4 cm long cut is made in the smooth area of the stock at a height of about 20 cm. At the base of cut, a small shorter cut is given to intersect the first so as to remove the piece of wood and bark. The scion stick is given a long slanting cut on one side and a small short cut on the other so as to match the cuts of the stock. The scion is inserted in the stock so that the cambium layers come on the longer side. The graft union is then tied with polythene strip as recommended for inarching. After the scion remains green for more than 10 days, the rootstock should be clipped in stages. The scion wood to be used for veneer grafting requires proper preparation. The desired shoots should be defoliated at least one week prior to grafting so that the dormant buds in the axel of leaves become swollen.

Fig. 3.1.3: Veneer/ Detached Grafting

This method can be adopted during March-September, preferably from July to September. When scion shoot starts growing and produces the vigorous sprout, the rootstock just above the graft union is cut back. Then care and maintenance of graft is done in nursery. The success is about 96 % when done in June - July.

3.1.3.1. Veneer Grafting *in situ*

The saplings raised from different methods when grown in the nursery for 20 months differ in their growth capacity. Some researchers have found that amongst the plants

propagated by various methods; those grown by veneer-graft *in situ* exhibited the highest growth. Establishment of a grafted mango orchard of uniform trees is somewhat difficult when done by inarched plants. Veneer-grafting *in situ* is the right answer for this problem. Freshly extracted mango seed-stones are placed at appropriate distance in the field, and thus the seedlings are raised *in situ*. These vigorous seedlings when 2-year old are veneer-grafted with scion sticks of the variety one desires to plant. Such plants grow very fast and attain a stature in a few years, which the inarched plants would have taken many more years to attain. The advantages of the Veneer grafting *in situ* are: early economic yield, better growth, no mortality, less expenses, and an orchard of uniform trees.

3.1.4. Side / Side-Veneer Grafting

It is also known as Nakamura method and is popular in Japan, normally practiced in coastal regions. The side grafting method is an effective grafting method of mango propagation but this requires more experience. It is used when the rootstock is much larger than the scion material. It is exactly similar to that of veneer grafting except that in veneer grafting the vertical flap of the root stock bark is completely removed whereas in side grafting this flap is retained and tied over scion. Another difference between the two methods is that only one side of the scion is sliced away in sloping manner in the veneer grafting, whereas in the side grafting the scion is sliced on both the sides of the lower portion in the form of wedge.

3.1.5. Epicotyl/Stone Grafting

Stone or Epicotyl grafting is a one of the successful methods of mango propagation and is used when rootstocks are 7-15 days old and scions are 1-2 months old.

Fig. 3.1.4: Side / Side-Veneer Grafting

The scions are prepared by prior defoliation of shoots of comparative thickness. Splice and wedge methods are used for grafting. For splice grafting the epicotyl is cut slantingly for 2-3 cm length and the lower portion of scion is also cut to match it. The cut surfaces of both the stock and scion are tied together with alkathene so that the cambium of each other comes in close contact.

Fig. 3.1.5: Epicotyl/Stone Grafting

In wedge grafting, a 4-6 cm long vertical cut is given into the beheaded epicotyl, to receive the wedge-shaped scion. This is then tied with alkathene film. The grafts prepared by these methods are planted immediately in pots and watered. Grafting is done in rainy season when there is high humidity in the atmosphere. The scion sprouts within a month of operation. The percentage of success in splice and wedge methods is 50 % and ~ 33 % respectively. These techniques enable preparation of more grafts during rainy season.

3.1.6. Cleft / Wedge/ Top Grafting

Cleft grafting is also called wedge or top grafting. The wedge grafting is the easiest grafting method of mango propagation to perform with a 90-100% success rate[8]. This technique is adopted mainly for rejuvenation of old orchards by top working the trees. The rootstock due to more thickness which is not fit for other grafting technique is used in this method for grafting. The scion selection is similar and procured similarly. The stock is beheaded from any desired height and cut is made at right angle to the main axis of the branch. A vertical split 5.0 - 7.5 cm down the centre of the cut stub is made with the help of

a sharp knife. The lower end of scion shoot is given two 5.0 - 7.5 cm long slanting smooth cuts on either side. The scion is inserted into split of rootstock, and tied with polyethylene strip.

3.1.7. Soft-Wood Grafting

The method of softwood grafting is similar to that of the cleft or wedge grafting. In the past softwood grafting method was in use *in situ* orchard establishment under adverse soil and climatic conditions. The soft-wood grafting is a very successful method of mango propagation[6,13] and is used when rootstock and scion are 3-12 months old. Seedlings, on new growth when the leaves turn bronze, are suitable for soft-wood grafting. Shoots of 3-4 months, which have prominent apical bud, are taken as the scion material. Leaf lamina from such shoots is removed about a week before detaching them from the parent tree. At the time of removal of these shoots, the apical bud should remain intact. The top of the new growth of the stock is cut and the scion is fitted by wedge grafting. The union is tied with 1.5 cm wide 200 gauge polythene tape.

Fig. 3.1.6: Cleft / Wedge/ Top Grafting

Fig. 3.1.7: Softwood Grafting

If the selection of rootstock and scion is proper, success is 100% when the grafting is done during July-August under the north Indian conditions. This method is utilized for establishing *in situ* mango orchard in gravelly soils. This method can be used for large scale propagation of mango in north India.

3.1.8. Saddle Grafting

Saddle grafting is similar to the cleft grafting except that the wedge is made on the rootstock and the cleft is made at the base of the scion. The rootstock and scion should be of the same size. Using two opposing upward strokes of the grafting knife, the top from the rootstock is severed. The resulting cut should resemble an inverted V, with the surface of the cuts ranging from 1.2 to 2.5 cm long. The technique is now reversed to prepare the base of the scion. These cuts on the rootstock and scion must be of the same length and have the same slope so that maximum amount of cambial tissue make contact when the two halves are joined. The V-notched scion should be placed onto the saddle of the rootstock. If rootstock and scion are of the same diameter, cambial alignment is easier; otherwise adjustment may be needed. The graft is wrapped with a grafting twine, tape, or strip, and sealed with the grafting wax or grafting paint. It is used for the propagation of grape and rhododendron cultivars.

3.1.9. Bark Grafting (Rind Grafting)

Bark or rind grafting is very simple method of propagation, because it can be done without splitting the stub, which prevents the entry of pathogens. It can be done in branches, which

are 25-30 cm long. It should be done in the spring season when the bark of the root-stock slips easily.

Fig. 3.1.7: Softwood Graftin

Fig. 3.1.8: Saddle Grafting

It is Important to note that the scion used in bark grafting should be dormant. The rootstock is first sawed off at a point, where bark is smooth. If the stock is thick many scions can be inserted. For each scion, bark is split downward, about 5 cm from the top of the stub. Scions of 10-12 cm length containing 2-3 buds are prepared by giving a slanting cut (5 cm) downward along one side of the base. On the other side, a small cut is made. The scion is then inserted in the centre of split between the bark and wood of the rootstock. The longer cut of the scion is placed against the wood. The scion is held firmly by using adhesive tape. Afterwards, all the exposed portions of the stub and scion should be tied with polyethylene strip tightly. The scions will start sprouting after 6-8 weeks in the case of successful grafts.

Fig. 3.1.9: Bark Grafting

3.1.10. Root Grafting Methods

In root grafting method, the seedling rootstock, rooted cuttings or layered plant is dug up and the roots are used as the rootstock for the graft. The entire root system may be used (whole-root graft) or the roots may be cut into small pieces and each piece is used as a rootstock (piece-root graft). As the roots used are relatively small (0.5-1.5 cm) in diameter, the whip and tongue graft is generally used. Root grating is usually bench grafted indoor during the late winter or early spring. In preparation of root-grafts, the root-pieces should be 7.5-15 cm long and the scions of about the same length containing 2-4 buds are used. After the grafts are made and tied properly, they are bundled together in groups of 50-100 and stored for callusing in damp sand, peat moss or other packing material.

Fig. 3.1.10.Root Grafting

3.1.11. Bridge Grafting Methods

A bridge graft is used to supply nutrients to the rootstock of a woody perennial when the bark, and therefore, the conductive tissues have been

removed from part of the trunk. This wound is often caused by rabbits or other rodents, stripping the bark away and girdling the tree. The inability of the plant to transport food manufactured in the leaves down to the root system, causes the root system to die and in the death cycle, the resulting lack of root system causes the upper portions of the plant to die. Where one-quarter or less of the trunk circumference has been girdled, it may not be necessary to use this technique. It is also difficult on small caliper tree trunks. A bridge graft uses scions to bridge the gap. Each scion is taper cut in order to accommodate the need for matching the cambium layers of the scion with those of the tree being repaired. Once in place the graft wounds must be completely sealed to prevent moving of tissues which would inhibit them from joining together and to prevent dissection of the site which would lead to the death of the scions.

Fig. 3.1.11.Bridge Grafting

3.1.12. Suitable Grafting for Mango

Nurserymen in many of the mango growing areas still use inarching, the traditional method of mango propagation. During past few decades, experimental results have shown that veneer grafting technique can be used with high success rate in Madhya Pradesh, Andhra Pradesh, Uttar Pradesh and Bihar. Stone (epicotyl) grafting is suitable for Konkan region of Maharashtra and Coastal regions.

Presently, softwood grafting is being used commercially for mango propagation in several parts of south India. The wedge grafting is the easiest grafting method of mango propagation to perform with a 90-100% success rate. Primarily this technique is adopted for rejuvenation of old orchards by top working the trees. Veneer grafting and soft-wood grafting techniques can be used for large scale multiplication of mango in north India. With the use of polyhouse and nethouse structures, period of propagation can be extended easily under north Indian conditions.

3.1.13. Selection of Grafts

Before actually embarking upon any plantation of mango, one should select the desirable grafts from the nursery. A good graft should be straight and established for a year in the nursery. The union should be clean and complete and should be at ~20 cm from the ground level. The scion should be green and healthy, not showing any sign of withering. It should indicate excellent growing condition and be free from diseases like galls and malformation. It should not be purchased from nurseries which do not maintain the high-yielding and healthy mother plants for propagation. It is better to select own mother plants and prepare grafts from them.

3.2. Cutting and Layering in Mango

Cuttings and layering are methods of asexual plant propagation[5]. There is no commercial practice of propagating mango either through cuttings or layering. However, these methods have been tried experimentally with varying degree of success. Mango can be propagated through cuttings. However, a high humidity and, temperature controlled chamber is needed to root mango cuttings as these are difficult to root. Experiments at the IARI have shown that juvenility could be induced in a mature mango tree by beheading and successive disbudding. The cuttings taken from forced shoots root and establish better than those taken from unforced shoots. Rooting capacity of both the forced and unforced cuttings is further increased when both the types of shoots are subjected to etiolation treatment. However, rooted cuttings could not be established into plants in the field. The pre-treatment of the rootstock with cycocel and ethrel induced rooting on cuttings and air-layers of mango. Application of IBA to the cuttings and air-layers from pre-treated shoots improved the rooting, though pre-treatment with chlormequat was more effective than that with ethrel. Shoots of less than 2 years give higher percentage of rooting than the older ones. Rainy season is the optimum period for layering in mango.

Although the root initiation in such air-layers is fairly good, the establishment of such air-layered shoots is poor. This is due to initiation of thicker roots, which do not possess optimum absorbing power and consequently when the rooted shoots are transferred to pots the mortality is appreciable. As a precautionary measure, the potted plants are kept in the shade and regularly watered. Besides, about 20% of the leaves are pinched off to minimize transpiration. However, an advanced technique is required to ensure initiation of thinner roots in the air-layered shoots.

The air-layers of mango show appreciable varietal difference in their rooting capacity. It has been found that while in Langra the rooting was only 35% and survival of the rooted layers only 40%, in Gulabkhas these were 70% each. The varieties Bombai and Himsagar exhibited intermediate rooting. They also observed that in the air-layers ringed and treated with IBA, there was significant accumulation of carbohydrates, enhanced protein synthesis and greater accumulation of rooting co-factors. The shoots of less than 2 years, on old trees up to the age of 30 years, gave higher percentage of rooting than on the trees of more than 30 years. Out of the 7 different combinations of rooting media and wrapping materials tried, sphagnum moss plus vermiculite wrapped with polythene and then with gunny sack was found to be the best. Establishment of the layers was better in sand-garden soil-leaf mould mixture than in sand-and-garden soil alone.

3.3. Budding in Mango

Budding is a type of asexual reproduction in which a new organism develops from an outgrowth or bud due to cell division at one particular site. The small bulb like projection coming out from the yeast cell is called a bud. The new organism remains attached as it grows, separating from the parent organism only when it is mature, leaving behind scar tissue. Since the reproduction is asexual, the newly created organism is a clone and is genetically identical to the parent organism. These buds develop into tiny individuals and, when fully mature, detach from the parent body and become new independent individuals.

This is the most economical method but uniform good success has not been obtained in different types of agro-climatic regions. The budding technique is highly suitable to those areas where general atmospheric humidity remains high. The rootstock seedlings are raised in nursery. The best-suited time of budding in North India is February - June while in South India it is August - September. The bud wood/scion should be of last season growth and shoot should be round in shape having grey colour. The middle bud is considered best for good success. The most commonly employed methods of budding in mango are forkert, shield and patch budding[5].

Mango-budding was first tried by the growers as early as 1899, without success. However, with proper preparation of bud-wood, wise selection of closely-related rootstock on which buds are inserted and other precautions, budding can have a success rate of up to 85 %. Vigorous plants are obtained more quickly than if they are propagated by other means. In this method buds are taken from one-season-old mature shoots. A plump bud is selected and carefully cut out with the help of a sharp budding knife. Then the bud along with a patch of bark is inserted on a corresponding stem on the rootstock from which a piece of bark has been pulled down. The bark is then pulled up over the bud and the whole thing is tied with polythene tape. The barks of mango seedlings do not separate easily in young age. So the rootstock should be at least 2-3 years old[9].

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