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MANGO PROPAGATION

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Abstract -This Chapter has the objectives to search, through the review of the available literature, important informations on the evolution of mango propagation regarding theoretical and practical aspects from cellular base of sexual propagation, nursery structures and organizations, substrate compositions and uses, importance of rootstock and scion selections, also it will be described the preparation and transport of the grafts (stem and bud) as well as the main asexual propagation methods their uses and practices. Finally, pattern and quality of graft mangos and their commercialization aspects will be discussed in this Chapter.
Index terms: cloning, propagation, propagation methods, graft mangos.

PROPAGAÇÃO DA MANGUEIRA

Resumo-Este Capítulo tem como objetivos buscar, por meio da revisão da literatura disponível, importantes informações sobre a evolução da propagação da mangueira na teoria e na prática desde sua base celular da propagação sexuada, as estruturas e a organização dos viveiros de mudas, a composição e o uso dos substratos, a importância e a seleção do porta-enxerto e da copa, bem como relatar a preparação e o transporte dos enxertos (garfo e borbulha) e os principais métodos de propagação vegetativa, uso e aspectos práticos dos mesmos. Finalmente, os padrões e a qualidade de uma muda de mangueira enxertada e os aspectos relativos à comercialização serão também discutidos neste Capítulo.
Termos de indexação: clonagem, propagação, métodos de propagação, mudas de manga.

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Introduction

Mango's economic and nutritional value, fruit elegance, exotic and flavor appeal, make it one of the most widely cultivated tropical fruits in the world, ranking among the top five fruits in volume production of 43,3 x 10^6 tons in 2013 (FAO 2013). To meet this demand, mango crops must be settled on vigorous and productive cultivars which require sound methods of propagation and advanced grafting plant management.

Mango trees can be propagated both by sexual and asexual means. Sexual reproduction involves the union of male and female sex cells during flowering stage. In angiosperm plants like mango trees the seed and fruit formations initiate during the flowering process when pollen is transferred from the anther of a male plant to the stigma of a mother plant (pollination) where it germinates. Subsequently, the pollen tube descends through the style into the ovary until it reaches the embryo sac within the ovule; two male gametes from the pollen tube are then discharged into the embryo sac, one uniting with the female gamete to form the diploid zygote (fertilization), while the other merges with the two polar nuclei to form the triploid endosperm; both the zygote and the endosperm enclosed within the nucellus of the ovule (HARTMAN et al., 1990). The resulting seedling population might have similar or differing genotypes since meiosis (chromosome reduction) is the main cell division characteristic of this type of reproduction.

A seedling grown from a single sexual embryo from a mono-embryonic cultivar does not ensure a true-to-type mango tree, although this type of propagation was extensively used before vegetative methods of propagation were known (RAM; LITZ, 2009). Asexual or vegetative propagation results instead from the mitosis type of nuclear cell division, which accomplishes chromosome replication with an identical individual or clone obtained.

Objectives for this chapter are to present the cellular basis for mango tree propagation, and also to describe the structures and media for growing grafted mangoes, nursery organization, sexual and vegetative methods, their uses and practical aspects of the propagation process. In addition, quality and commercialization of grafted plants will be also discussed in a summarized way.

NURSERY STRUCTURE AND ORGANIZATION

Tropical fruit nurseries are the places where seedlings and grafted fruit trees are established from sowing the seeds, growing and then grafting the seedlings with the objectives to plant or sell them for family use or for commercial orchards.

Nurseries for mango propagation had three different possibilities (types) in terms of structure, seedling establishment and propagation, such as: a) all establishment and organization from sowing to grafting is carried out directly in the field without using any close structure (at seedling-beds) using old irrigation system or without any irrigation; b) all establishment and organization made at seedling-beds covered partially with narrow and long stripe of wood (laths) or with coconut leaves thus receiving less sunlight incidence, but using old irrigation system; c) nursery with all seedling establishment, from sowing to grafting of plant, made in soil substrate in the polyethylene bags under modern protected environment and irrigation system. Nursery improvement from the first to the third type was due to the increasing demand for mango fruits mainly in the external markets thus requiring new plantings of graft mangos with better fruit quality which is found in the arid tropical exporting countries (e.g. Brazil). Economic conditions may have influenced this improvement since richer were mango graft producers more modern were their nurseries.

In general, all nurseries in the early 80's were of the first type and they produced grafted mangos with low technology and quality. Even actually, in most of the Asian countries mango nurseries are still established in the field with any protection of climate problems probably to reduce the cost of production of grafted mangos. A great problem of this type of nursery is the occurrence of high losses of plants (> 20%) during the transplanting since the poor root system of mango rootstock did not respond very well when transported straight to the field with no protection. Some growers used to spray or to immerse roots of graft mangoes (rootstock roots) into an anti-transpirant solution before planting in order to diminish transpiration and plant losses.

Around 90' there was a nursery improvement since seed-beds were still used, but they were protected by a covering made with narrow and long stripe of wood (laths) or with coconut leaves. In this type of structure, irrigation was made by hand with a watering can or by other improved way. Nurseryman sometime used micro sprinkler whose irrigation tube was tied to the wood stripe or to the coconut leaves by a flexible wire in the up position of the nursery. However, with intense and continuous use micro sprinkler may bring some problems, such as decomposition of wood then dispersion of anthracnose inoculum from coconut leaves, thus promoting seedling disease. The two types of nurseries described above used complete establishment from sowing to graft plant in seedling-beds. Therefore, it should be advisable to any new mango nurseryman to select sandy soil to establish and manage mango seedlings, since they allow easy pulling out of grafted plants from the soil with no injury at the root system. Sometimes, nurserymen make a selection of the best seedlings from seedling-beds and transplanted them to polyethylene bags where they grow and then are grafted when reach the adequate height and diameter of stem.

Provision of shade during and after grafting was found to have beneficial effect on success of mango grafting (KUMAR; MITRA, 1994) and the rate of photosynthetic activity varies with the level of shade. On the other hand, light is essential for triggering photosynthetic activity and thereby better nourishments of grafts. This was mainly attributed to optimum temperature and relative humidity, but very little research has been done to develop technology to produce grafts throughout the year. The demand for planting materials of mango is huge in different mango producing countries. It is necessary to produce mango grafts throughout the year to meet the demand of quality planting materials. This would be possible only by creating optimum temperature and relative humidity in propagation structures.

Nowadays, mango grafts are usually developed under different conditions in several countries, although modern structures, such as polyhouse or green house with controlled environment, shade net, net house (25-50% shade) and mist propagation unit all will be described in the following paragraphs.

Polyhouse (Force Ventilation with Evaporative Cooling System)

The humidity in polyhouses should be maintained between 80 – 90 per cent by frequent misting of water in order that the environment may become congenial for higher percentage of survivability of grafts. This type of structure is successful because the atmospheric humidity is low in most times of the year. Modern polyhouses are automated for temperature and humidity control. Mango rootstocks are raised in polyethylene bags or in ground or benches. Irrigation and fertigation system **are** automated in order to provide measured quantity of water and nutrients to plants. In this type of structure, mango grafting is possible round-the-year.

Shade Net

Shade net provides necessary microclimate for acclimatization and hardening of grafted/ budded plants and often protection from direct sunlight, heavy rainfall and heat waves/dry winds. Shade house will also facilitate the raising of seedlings in bags directly where necessary (Figure 1). Considering the envisaged capacity of the nursery, a shade net area of 500 square meters is considered adequate to house 10,000 grafted plants. Construction of shade net varies widely and its size depends on the propagation needs since the transpiration and soil evaporation are appreciably reduced due to low temperature and light intensity and less watering is required (MAITY, 2004).

Figure 1 - Shade Net structure used in modern commercial mango propagation nurseries.

Net House

Under tropical conditions, where artificial heating is not necessary, and cooling is very difficult and expensive, a greenhouse covered fully with glass is of little utility for any commercial purpose. Under such conditions net house is an excellent alternative and very useful for many purposes, such as for the raising of mango seedlings and cuttings and other propagation methods. The roof of the net house may be covered with glass or glass substitutes like plastic film and the sides should be covered with wire net. This system provides sufficient ventilation and keeps the internal temperatures sufficiently warm during winter and cool during the summer months. Sometimes the roof glass is covered with burlap (gunny cloth), or with live creeper, to cut off the solar radiation energy and thereby to keep the Net House cool. The Net House may be of different sizes and may have beds of different dimensions to meet the requirements of the propagation.

Mist Propagation Unit

Mist propagation beds are useful propagating units for the rooting of cuttings, especially those which are difficult-to-root like mango. Mist beds are constructed usually within the greenhouses. A fine mist is sprayed over the cuttings intermittently usually during the day; during night is not necessary. The mist is controlled by a time-clock, operating a magnetic solenoid valve that is set to turn the mist on for 3 - 5 seconds to wet the leaves, and is then turned off. When the leaves begin to dry, the mist is again turned on. There must be continuous supply of water for misting. Installation of a pressure tank and pump ensures consistent pressure for misting. The water for misting should be clean, not salty and uncontaminated. The optimum pH of the water for misting is 5.5 to 6.5 (DHUA; MITRA, 1988).

Misting may sometimes lower the temperature of the rooting medium below safer levels for propagation, especially when cuttings are made in winter. Under such circumstances application of warmth to the base of the cuttings will promote root development quickly and adequately in difficult–to-root mango. The bottom heat can be provided by means of soil warming cables. These can be laid suitably about 5 cm below the surface of the rooting medium in the propagation benches to warm the rooting medium uniformly. Thermostats are used to control and maintain the adequate temperature automatically.

Substrate quality has marked influence on seedling growth of rootstock/ propagated by cuttings. A good substrate has both the chemical and physical properties that promote healthy and rapid plant growth since these properties work together. A good substrate should have adequate nutrients but should not be heavy to block water and air movement. Similarly, a substrate that has adequate drainage, but is deficient of plant food, is also not desirable. The physical properties of the substrate include: a) Amount of water it can hold; b) How much air space it contains; c) Texture of the substrate; d) The weight of container or bag with substrate. The chemical properties of the substrate include: a) The nutrients quantity; b) How easily they are available to the plants and; c) Rate of release of the nutrients to the plants.

A good nursery substrate should have the following characteristics: a) Light in weight to facilitate transport but hold the plants firmly in place; b) It retains water but also allows drainage and aeration; c) It should have necessary nutrients for proper growth and development of plants; d) It should be free from weed seeds, toxic chemicals, and soil borne fungus, bacteria and pests; e) Sterilization should not change the characters of the substrate.

Sanitation is one of the most important factors for the success of high quality graft mango. Therefore, it is necessary to use clean growing medium, sterile containers, a sanitized bench, and pathogen free plant materials. However, soil pathogen may contaminate the soil mixture even when all precautions are taken; small outbreak of diseases can be controlled by using appropriate fungicides.

Propagating media can be easily pasteurized by heat (electric or steam) or by chemicals. Expensive equipments and training of personnel are necessary for pasteurization (partially sterilized) or sterilization of propagating media. A temperature of about 70° C for 30 minutes is considered sufficient to kill almost all disease producing organisms (SADHU, 2005).

Fumigation is most useful for destroying harmful bacteria, fungi and nematodes in a relatively small quantity of soil that is used for propagation of plants. The most widely used soil fumigant is methyl bromide, a colorless, odorless and potently toxic gas, which is usually mixed with chloropicrin. Methyl bromide may be used at 14.6 kg/m2 soil surface. The treatment is usually done 24-28 hours. After treatment, the soil should be covered with gas proof cover (SADHU, 2005). However, the use of methyl bromide has been largely restricted in Brazil because there is a suspicion that it contributes to break the ozone layer thus contributing to the enlargement of the “black hole” in the atmosphere thus affecting the environment equilibrium. Therefore, solarization has been indicated as a cleaner and more economic technique to substitute methyl bromide application. According to Ghini (1997), solarization is a physical method of soil disinfestation through which microorganisms, nematodes, weeds and fungi are controlled efficiently. This method consists of covering the pre-sowing or pre-planting substrate with a transparent polyethylene for a long solar exposition (60 to 90 days) in which substrate reach around 50°C of temperature, although it depends on the substrate layer (better one is 25 cm height), climate and time of substrate exposition.

Drenching the medium with certain fungicides such as Captan or Fytolan (1g/litre water) is also useful

in eliminating pathogens from the medium. Drenching with fungicides is inexpensive and can be easily done, even when the plant is growing on that particular medium.

Besides a clean and sterile medium, disinfection of pots, flats, greenhouse benches, watering cans and other garden tools, general cleanliness are also necessary to avoid recontamination of the medium. It is useless to put clean sterile soil in contaminated pots. Garden tools can be sterilized with 2 per cent formaldehyde, chlorinated water, and alcohol or even with boiling water. Pots, flats and propagating benches can be sterilized with steam, boiling water or 2 per cent formaldehyde.

The watering and water quality must be well controlled since regular supply of clean water is essential to plant growth. When grown in polyethylene bags, nursery plants have only a limited volume of substrate which may dry up very quickly. The amount of water required depends on seedling age, soil type and amount of sunlight that the plant is receiving. Irrigation water quality is a critical factor in the production of container grown nursery plants. Poor quality water applied with overhead sprinkler irrigation can damage foliage, change substrate pH, or create unsightly foliar residues. Poor quality water also can clog micro-irrigation emitters and cause non-uniform applications of water. Saline water which has high concentrations of dissolved minerals including possible toxic elements from natural deposits that contain oil, or pesticides from local agriculture should be avoided.

Many commercial nurseries capture and recycle irrigation water runoff to irrigate container plants. The recycle water could be a source of pathogenic fungal species such as *Pythium* and *Phythopthora* and other diseases. Recycled water, if used should be disinfected to remove algae, iron bacteria, fungus and other organisms. Liquid and/or gas chlorination system or bromination should be followed to disinfect the recycled water. More recently, chlorine dioxide has been used for water disinfection (NQWENYA et.al., 2013)

It is advisable to check regularly the water status (turgidity) of the leaves to determine when to irrigate. Irrigation should be done in the early or late hours of the day, when temperature is cooler. When plants are watered in the hot sun, they lose more water by evaporation or transpiration than they gain from watering. Water drops on the leaves can also magnify the sunlight effect causing the leaves to burn. Irrigation of seedlings (rootstock) or graft mango should be done on the substrate not on the leaves and irrigate slowly and check that the water penetrates to the bottom of the containers, watering is better to be done with a spray nozzle. Drip irrigation has been used for this purpose since it can save water and keep seedlings free of diseases, although cost of installation is too expensive. It is now very common method of irrigation in many good nurseries in India and other countries.

A reduction of the amount of water four weeks before the seedlings grafted plants are planted out should be done. At this stage it is advisable to allow the soil to completely dry out and the plants to wilt for a day. This process should be repeated several times to hardening the plants. It is advisable to irrigate the plants very well before they are taken from nursery since this will reduce water stress during transport to the planting site.

SEXUAL PROPAGATION

Importance and Reasons for its Use

Monoembryonic mango cultivars, such as Kent, Keitt and Tommy Atkins, are originated from sexual embryo and due to its heterozygotic character they should not be propagated directly from seeds since they will not develop uniform plants. This is the reason why mango crops established from monoembryonic mango varieties are limited to those from family orchard with no commercial purpose. On the other hand, polyembryonic cultivars, such as Carabao, Manila and Ataulfo develop homogeneous and identical progenies (true-to-type) to the mother plant due to the presence of nucellar embryos and, therefore, they are theoretically recommended to be propagated by seeds in order to establish mango rootstock. The nucellar embryos from polyembryonic seeds preserves the identical characteristics of the mother plant then giving a possibility to obtain homogeneous rootstock to receive the scion of a superior mono or polyembrionic cultivar thus executing an asexual propagation by grafting, for instance. However, the guaranty of homogeneity is not total, because of the presence of a viable sexual embryo that should be eliminated to avoid the development of a seedling coming from open pollination distinct from mother plant. In general, growers select the vigorous seedling to be grafted taking on account that it is a nucellar seedling, however, it is not easy to differentiate and eliminate seedlings by their vigor.

The great advantage of asexual propagation is the shortening of the plant juvenile phase allowing mangoes to enter much earlier in the productive stage which is one of the objectives of mango growers.

Growth of Mango Fruit and Seed

During the mango growth phases of fruit and seed, the tree needs an excellent mineral nutrition and irrigation support in order to respond to an acceptable fruit production. Kennard (1955) studies described that mango fruit as well as seed embryo has a sigmoid growth patterns. Also, it is important to remind that during the fruit set and at the beginning of the fruit growth an adequate temperature, never below of 15ºC, is necessary for the development of viable embryos (GALÁN SAÚCO, 2008).

Seed Selection and Preparation

The process of mango seed selection and preparation are clearly described in some literatures (GALÁN SAÚCO, 2008; CASTRO NETO et al., 2002; RAM; LITZ, 2009), but some points should be emphasized in this work.

Mango fruits must be collected from healthy polyembrionic selected trees and seeds must be free of pest and disease. Under any suspicion of mango seed weevil *Sternochetus* (*Cryptorhynchus*) *mangiferae* attack, this seed must be eliminated immediately.

Fruits should have complete maturation avoiding those over mature and/or rotten fruits due to a delay on their collections. Fruits and seeds should as much be larger as possible according with the selected cultivar since germination and vigor are positively related both to seed weight (GIRI; CHAUDHRI, 1966) and to the size of the cotyledons (SIMÃO, 1960).

Seeds with endocarp must be washed and pulp removed immediately after the extraction and then dried in the shade under good aeration environment for 1-2 days. The endocarp should be removed after drying by use of a pruning scissor or a sharpened knife avoiding injury or wound the cotyledons. The removal of the endocarp promotes a quick seed germination and also favors the emergence of a larger number of right (erect) seedlings which improves the graft quality. The thin tissue covering the cotyledons might also be removed, but no influence has been noticed on the germination success (Alberto C. de Q. Pinto, Personal Communication, 2016). To facilitate pulling out the cotyledons on an easier and faster way without causing any injury to them, a tool named Endocarp Remover has been developed (Figure 2). The nurseryman should make a small cut in the endocarp of about 15 mm by using a sharpened knife and insert the final thin part of the tool (it looks like a duck peak) then force it as if he were using a scissor. A skilled nurseryman may remove 26 endocarps in 10 minutes with a sharpened knife, but with the possibility of wounding many cotyledons, while using an Endocarp Remover he may pulled out 35 cotyledons in the same time with no injuries (PINTO; GENÚ, 1996).

Due to the short viability of mango seeds which decrease rapidly after 15 days of the fruit harvest, sowing must be executed immediately after pulling out the cotyledons from the endocarp. Mango cotyledons are kidney-shaped and the sowing should be executed in such a way that the concavity portion(ventral part) of the cotyledon should be buried into the soil substrate then covering slightly the convex portion of about 1 cm height (above the dorsal part) with the same soil substrate. It is advisable an immediate irrigation over the soil substrate mixed with a solution of soil fungicide.

Establishment and Management of Mango Seedlings

In the majority of the Asian countries and even in some other tropical regions, the sowing of mango seeds is made directly in the soil (at seedling-beds) where growers also graft them. As indicated before, it is advisable to select sandy soil to establish and manage mango seedlings, which allows an easy pulling out of grafted plants from the soil without injury to the root system. Another possible problem is the need to analyze the presence of soil pests and diseases (e.g. nematodes) which may promote heavy losses of mango seedlings. With these precautions, growers may minimize losses during the transplanting process and then having adequate growth with healthy and more vigorous grafted mangos which are highly desirable for modern mango plantings. However, to avoid these problems, modern mango growers make the sowing directly into porous organic matter and well drained substrate inside vases or polyethylene bags under protected conditions where the seedlings are later grafted. It is important to indicate that the soil substrate inside the bags must have a Full Air Porosity (FAP) between 15% and 20% in order to allow a better growth of the root system (MCKENZIE, 1994).

The depth of the seedling-bed to sow mango seeds should be 25 cm of soil substrate and seeds should be sown at 15 cm of depth. The size and certainly the depth of the polyethylene bags are extremely important since due to the fast development of the mango root system, the roots may touch the bottom of the bag and then resulting on a twisted and bad root development. A reasonable decision of some mango graft producers has been the use of open bottom bags keeping a type of railing structure. This technique allows an adequate soil substrate aeration and also the pruning of the tap root with use of a prune scissor which may improve a better growth of the secondary and tertiary roots and a more vigorous mango rootstock. Chemical application of cupric compost into the plastic bags is another technique to prune the apex of young roots then improving growth of the secondary and tertiary roots (MCKENZIE, 1994).

One of the most common preparation of soil substrate for mango rootstock (seedlings) development in Brazil has the following composition for each cubic meter of substrate: 3 parts will be of local subsoil land and one part of matured cow manure mixed with 3 kg of simple superphosphate and 1 kg of potassium chloride. The size of the bag depends on the time they will be maintained in the nursery before planting and/or selling. A bag with a maximum of 300-350 mm length x 200-222 mm of diameter and 0,15-0,20 mm thick dimensions which contains about 12-14 kg of the above mixture (CASTRO NETO et al., 2002) has been commonly used. Under subtropical conditions the grafted plants may stay in the nursery a longer period due to climate reasons

and, in this case, it is advisable that the polyethylene bags have a minimum diameter of 250 mm, a length of 400 mm and the same thickness above (0,15-0,20 mm). Since germination occurs 2-3 weeks after sowing, when sowing is made in seedling-beds, the transplanting of the seedlings should be executed soon after the germination which is about 1 month after sowing. Seedlings should be transplanted at longer spacing in the seedling-beds or transplanted carefully into the plastic bags to avoid injuries to the root system at least a minimum of 1 month before graft operation.

In polyembrionic seeds the competition among the various emerged seedlings may develop deformities in the area of the union of root and stem resulting in a bad seedling development. Therefore, it is advisable to select the best seedlings (erect and without deformity) then eliminating the other ones by cutting them at the stem base (bottom). When seedlings stay long time in the seedling-beds or in the polyethylene bags it is recommended to eliminate 2-3 pairs of leaves in order to avoid intense transpiration and seedling losses. Seedling selection must be made continuously to eliminate those showing yellow leaves, short internodes and compact shape, small and twisted leaves in the apex. Seedlings that eventually show flowers**,** due to any stress condition which influence negatively the seedling development**,** must be eliminated.

Fertilization is usually executed with use of solid fertilizers incorporated into the soil substrate of seedling-beds or polyethylene bags. In the modern nurseries, a complete mineral solution is applied through automatically irrigation system named fertigation or even using both methods, incorporation and fertigation. Granulate and slow releasing fertilizers should be used for seedling development since the sowing process was established. However, during hot climate the exclusive use of slow releasing fertilizer is not recommendable since high temperatures promote a faster release of nutrients which is not desirable for seedling development. Depending on the right management, seedling may be ready to be grafted between 8-12 months after sowing. The adequate size of seedlings ready for grafting is 400-500 mm height with a stem thickness of 8-12 mm at the middle of the height.

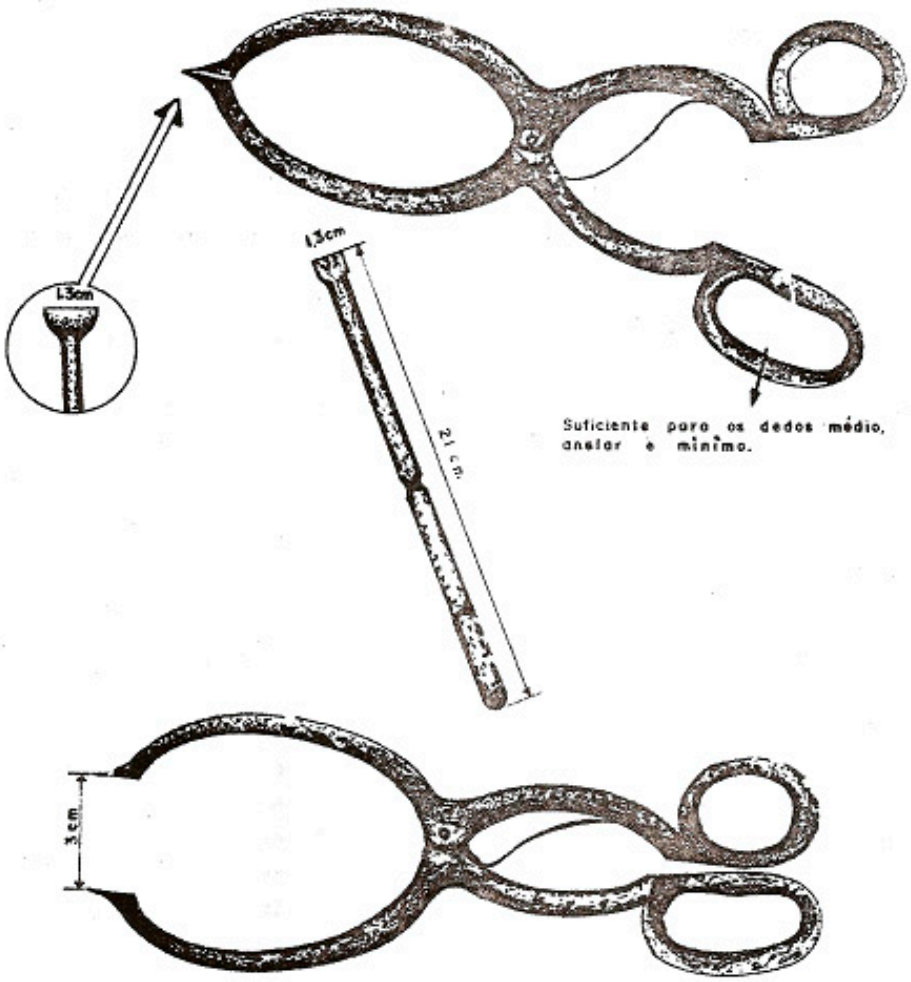

Figure 2 – Endocarp remover may help to pull out mango cotyledon free of injury from inside the endocarp.

The Importance of the Rootstock

The most important aspects for mango rootstocks are vigour, high yield potential, good compatibility with scion variety, environmental adaptability and resistance to pest and diseases (ROSSETTO et al., 1996). Despite the noticeable impact on the growth, yield, tolerance to salinity, nutrient absorption as well as fruit quality of mango cultivars, rootstock study and its relationship with the selected scion cultivars is important, perhaps the most important, field of research lacking on mango (GALÁN SAÚCO, 2008). This fact may partially explain why polyembryonic rootstocks long time introduced in the countries (Criollo type varieties) are generally used for mango propagation in the tropics since they are more adapted to the different regions where they are found. These seedlings are, for the mango growers, a source of selected homogeneous seedlings with a more regular bearing condition and they will continue to be the only option as rootstock until new specific studies be developed on each region.

VEGETATIVE PROPAGATION

Mono and polyembryony can both occur in mango seed and resulting seedlings may therefore be sexual or nucellar in the origin. Mango seeds can therefore be used to produce a true-to-type nucellar seedling of some superior clone or recommended rootstock. Nowadays, mango is mostly propagated by vegetative or asexual method since it enables farmers to establish uniform or homogeneous orchards of outstanding clone cultivars. Grafting on nucellar seedling of polyembryonic seeds preserves the genotype and phenotype of superior cultivars resulting in seedlings identical to the mother plant.

Several types of vegetative propagation have been used for long time, such as: approach grafting, also called inarching, which is an ancient Indian method; grafting (several types); budding; rooting; air layering; and micro-propagation. They all have advantages and disadvantages and what type becomes preferentially adopted in different countries and regions will depend on several factors, such as market characteristics and nurserymen skills, for instance. Inarching, rooting and air layering are propagation methods of low effectiveness and workability on mango tree, while micro-propagation usually lends unfavorable cost-benefit analyses.

Grafting, especially cleft and splice grafting, are the most effective and acceptable mango propagation methods and will be discussed in detail in the following sections. Basically, there are five steps for a successful graft: a) Selection of plants and seeds for the establishment of seedling for rootstock population; b) Selection of superior cultivars (mother-plant) as scion sources; c) Scion preparation in the mother-plant, packing and transport; d) Grafting technique; e) Maintenance of the grafted plant until planting.

Selection of Mango Seedlings for Rootstock Use

The mother-plant variety whose seeds are going to be used for seedling population (rootstock) must be selected based mainly on the following characteristics: a) Polyembryonic genetic material; b) Resistant to pest and diseases; c) Productive and vigorous plants adapted to soil and climate of the region; d) Dwarf or semi-dwarf variety; e) Sufficient number of mother plants in the region in order to have an adequate supply of seeds to establish seedlings or rootstocks.

Polyembryony is a genetic-physiologic phenomenon commonly occurring in mango in which one seedling may be sexual and two or more are nucellar seedlings. Therefore, polyembryonic mango seeds are used worldwide to produce a true-to-type nucellar seedling of some superior clone or a rootstock on which the desired clone is budded or grafted, although monoembryonic seedlings are still used as rootstocks in India (RAM; LITZ, 2009). There is an interesting fact that growth of several shoots from one seed does not indicate the presence of nucellar embryos, since some cultivars may develop shoots from below the ground, arising in the axils of the cotyledons of one embryo which may be or may not be of zygotic origin (HARTMANN et al., 1990). In the field, this phenomenon is called "polycaulism" and it may render unsuccessful grafting or budding propagation approaches.

Resistance to pests and disease is one of the most important characteristics for selection of mango rootstock. Polyembryonic seedlings from 'Carabao' (also called ´Manila´), 'Pico' and 'Manga Dágua' are considered resistant to *Ceratocystis fimbriata* (RIBEIRO et al, 1995). However, these polyembryonic seedlings, mainly seedlings of 'Carabao', are not commonly used by nurserymen because they have thin and unadequated stem at 50 cm height from ground which is the position for grafting (CASTRO NETO et al., 2002) and also mother plant to collect seeds may not be found easily in the region.

A dwarf rootstock was at some point a very important selection criterion to establish a high dense orchard, nevertheless, modern mango pruning techniques may also keep the small productive canopies required for these intense system of mango cultivation. Additionally, to have both dwarf and tall productive mother plants as sources of genetic variability might not be of great advantage since only few mother plants are available from each type**.** The highest advantage is to have available a large number of mother plants to establish seedling populations. The use of varieties for mango rootstocks differ among Brazilian Regions. In Northeast of Brazil seedlings of polyembryonic 'Espada' is the most used as rootstock, but in Central Region, both Espada and Common variety of Cerrados are preferred by nurserymen while in Southeast Region, the varieties Coquinho and

Rosinha are the most important. Cultivars are important not only because of their vigors and well adaptive behaviors to different soil and climate conditions, but also due to the ease to find them for seed collection everywhere in the region.

Sowing of seed and rootstock management were described in the previous section about Sexual Propagation.

Selection of Superior Cultivar (Mother-Plant) as Scion Source

Selection criteria for scion source cultivars must be based on the main economic and/or commercial traits such as high and regular production, fruit quality, as well as resistance to pests and disease. High productivity depends on the cultivar adaptation to pruning technique which is one of the requirements for high dense planting. In general, superior cultivars with yield of 200 commercial fruits per plant are selected as scions. However, fruit quality in terms of skin color, such as red, purple or pink blushed fruits are preferred. Nevertheless, the yellow skin fruits of some cultivars, such as Nam Doc Mai, Okrong and Ataulfo, sometimes sweeter than the red skinned mangos, have increased in the preference of the consumers since these cultivars might be used for a double purpose, fresh consumption and processing.

Vegetative and floral malformations are important mango diseases caused by fungus *Fusarium* spp. (PLOETZ, 1994; ANJOS et al. 1998). Since this pathogen is found in the tissues of mango grafts in the nursery and also in inflorescence of adult plant, the use of these infested grafts must be prohibited (SANTOS FILHO et al., 2002) to avoid abnormal and diseased grafting plants.

Incompatibility between mango rootstock and scion may bring serious problems on plant production and this phenomenon occurs mainly due to genetic differences on growth of these two materials (rootstock and scion). The first author, as mango nurseryman for about 28 years, has observed a strong incompatibility between mangos 'Coquinho' used as rootstock, with a weak growth, and 'Van Dyke' used as scion which has strong growth.

Scion Preparation at Mother-Plant, Packing and Transport.

An important physiological decision before executing the grafting method is to consider the scion age before its selection and preparation. Generally, the scion must have a diameter between 8 and 12 mm when is about 4-6 months old. The scion preparation is made when it is still attached to the mother plant in the field. This technique is vulgarly named "toalete" and it consists of cutting the petioles and removing leaves about a week before execution of the grafting. This technique has the objective to promote the swelling of the scion buds in order to improve the grafting success (CASTRO NETO et al., 2002).

After removing the scion, two asexual propagation techniques may be adopted: budding or grafting. The nurseryman may execute one of these methods by grafting the selected scions immediately. On the other hand, if the grower intends to transport the scions and graft them in a place far from the site where the mother plant is being cultivated, there is **a** need of a special technique to scion transport which comprehends three steps: a) After the cutting and removal from the mother plant, about 5 cm of the cut portion of the scions (25 cm long) should be rapidly immersed into a paraffin liquid solution about 51º C; b) Join and tie the scions making a scion bundle and wrap it up with toilet paper then spray with tap water; c) wrap them up again with plastic and put inside a Styrofoam box in order to preserve turgor and keep it cool; in this wrapping process should be used an adherent ('celofilm' or similar), but not sticky tape. Even after one week of scion transport this technique may enable a grafting superior to 80% of success.

The job to import or export mango germplasm (e.g. grafting materials) for commercial purpose or for scientific research takes long time. This problem is not only due to the distance to be covered until its final use, but also a host of difficulties from legal and bureaucratic national rules to be accomplished and succeeded. After the advent of Biodiversity Convention developed in Rio de Janeiro1972, several international and national laws were established in order to discipline the exchange of genetic resources, or propagation material of plant species mainly the laws and rules which consider the bio-security to prevent the entry of new pests in the country. One of the decisions taken after this Convention was the requirement for a document named Material Transfer Agreement (MTA) which allows the exchanging of genetic material. Therefore, to import or export mango propagation materials, either seeds or cuttings (grafts), the donor and recipient for mango propagulum must sign the MTA document where the rules to use this exchanging material are exposed.

The propagation material of mango must be attached to a Phytosanitary Certificate (PhC) issued by the donor country according to the requirements of the recipient country. Moreover, after the arrival of this propagulum material, it must go through a mandatory and strict quarantine system at laboratories to determine mites, insects, fungi, bacteria, nematodes, viruses and/or weeds presence. Only after this step, this material will receive a Certification through which it can be released for the intended use. If it is detected any quarantine pest, which cannot be eradicated, this material is summarily incinerated in conformity to the law of the Department of Plant Protection of the Ministry of Agriculture Livestock and Supply (FERREIRA; SILVA NETO, 2015). Besides the technical aspects, there are various laws, rules and

regulations related to importation of any material, which obviously prolong the process of sending and receiving the propagulum material to its destination. In Brazil, although these materials have no commercial value which run into taxes, they have to meet the requirements of federal, state and/or district revenues as well as airport administration staff, post offices and others.

Grafting Technique

Although budding, inarching and air-layering are also important mango propagation methods, grafting is the most common and commercially used.

There are three types of grafting methods, such as soft wood, splice (whip) and side grafting (RAM; LITZ, 2009). Soft wood and splice (whip) grafting are the preferred methods by the majority of the mango growers and they will be described in details. The following steps must be taken in order to obtain success in the execution of the softwood grafting method: a) Cut the scion in two sides like a fork (Figure 3A) with 30-40 mm long; b) Make a transversal cut in the rootstock with distance about 150-300 mm from its base and keep two leaves below this cut; c) Make a longitudinal cut in the rootstock as long as the two scion cuts (3-4 cm) and insert it into the longitudinal cut of the rootstock (CASTRO NETO et al., 2002 – Figure 3B); d) Wrap and unite these two parts (scion and rootstock) with a plastic band about 250 mm long, 20 mm wide and 0,01 mm thick, starting below this union then going up above it then again coming down below it, where it is tied to avoid water goes into this union (Figure 3C); e) Cover the grafted scion with a plastic bag about 200 mm long, 40 mm wide and 0,01 mm thick to promote a kind of humid chamber (Figure 3D); f) About two months later one can remove the plastic band and see that the union is totally scarred (Figure 4A) which allows the development of a high quality commercial graft mango (Figure 4B)**.**

Maintenance of Grafted Mango

To maintain grafted plant with acceptable growth and development in the nursery some cultural practices, such as fertilization, irrigation, and weed and disease controls are needed. The amount and quality of fertilizers – macro and micro-elements – usually do not deserve much consideration by nurserymen and vary greatly among different countries and regions. Nowadays, both fertilization and irrigation are most of the times accomplished simultaneously through the fertigation approach which saves money and time. Nevertheless, selection of the irrigation method and the amount of water to apply during the growth of the grafted mango are important nursery concerns. The amount of water to irrigate the substrate of the bags varies according to the local climate. In Northeast of Brazil, for instance, where drought is a very common phenomenon, grafted mango must be irrigated a minimum of one liter of water per bag/day. Besides the organic matter in the substrate, some nurserymen use only micro-elements (trace elements) through fertigation technique or even by aerial spray on the mango leaves every 10 days. Anthracnose control is made by spraying specific fungicides every ten days on the leaves while weeds are controlled by removing them from the bag substrate.

The Techniques

Many other techniques are mentioned in the literature, such as interstock or double grafting, micro-propagation, and the recovery of canopy by using the pruning and then grafting technique on the new sprouts, although this last technique is the only been applied commercially with good results.

Interstock technique was tested to reduce the height of commercial mango trees (PINTO et al., 1994). Veloso et al. (1998) evaluated interstock technique by using a well-known dwarf variety (cv Mallika) between the varieties Fiapo, as rootstock, and Tommy Atkins, as scion, with the objective to reduce the height of this scion cultivar. These authors did not find significant differences in height when compared with the normal grafted plants.

There are some literatures describing propagation methods by mango cuttings whose results are shown 100% of success (RAM, 1997; REUVENI; CASTORIANO, 1997). Micro-propagation is an important technique which is applied on several fruit crops, such as banana and strawberry and several techniques have been tested (LITZ; LAVI, 1997; REUVENI; OLUBOWICZ, 1997). In mango crops the scientific results obtained till now appear to be too imprecise or precocious to enable commercial application. Although somatic embryos were induced from cultured nucellus of monoembrionic mango cultivars and protocols for large-scale production were optimized by DeWald et al. (1989), the rate of multiplication is low to achieve commercial purpose and, in addition, performance of plants in the field has not been tested (RAM; LITZ, 2009).

The recovery of canopy by using top working and double grafting, through which canopy pruning and then the grafting techniques on new scions are made, has demonstrated good commercial results (Figure 5). This practice has been used particularly to substitute Haden cultivar, which is not well adapted to high temperature (above 30º C) of Northeast Brazil, by Tommy Atkins cultivar. A new tree or a new cultivar with its renewed canopy will be producing very well three years later.

MARKET QUALITY OF GRAFT MANGO

Previous to discuss about quality of graft plant we must define the concept or definition of a quality product. Business Dictionary (2016) says that a "quality product is the one that was brought about by strict and consistent commitment to certain standards that achieve uniformity in order to satisfy the customer or user requirements". Rouphael et al. (2010) give an important overview of the recent literature on the effects of grafting on the fruit quality including physical aspects, flavor and related compounds. Graft mango standards should be related to technical conditions from mother-plants (seed and scion) as well as the graft mango, its commercialization and quality inspection of the graft mango (CASTRO NETO et al., 2002).

Some graft mango standards were described by Castro Neto et al. (2002) in order to comply with the request of quality and commercialization and they are summarized as follow: a) The graft mango must be grown and commercialized in appropriate substrate maintained in plastic bags of 20 cm of diameter, 35 cm of height and 0,15 mm thick having perforation in the base to facilitate the drainage and excess of water from irrigation; b) It should have 55-80 cm height with an only stem and age of about 13 months, free of pests and diseases; c) A firm and strong union between rootstock and scion and no difference between diameter of these two structures which indicates an excellent compatibility between this two parts; d) Each graft mango should have a label indicating the name of the nursery, names of scion and rootstock cultivars and date of grafting in order to indicate its age.

Figure 3- A Cutting the scion in two sides like a fork; B – Insertion of the scion into a longitudinal rootstock cut; C – Wrapping the scion and rootstock with a plastic band; D: Covering the grafting union to avoid water entrance.

Figure 4-A – Mango graft showing agood cicatrization of the union; 4B – A high quality commercial graft mango.

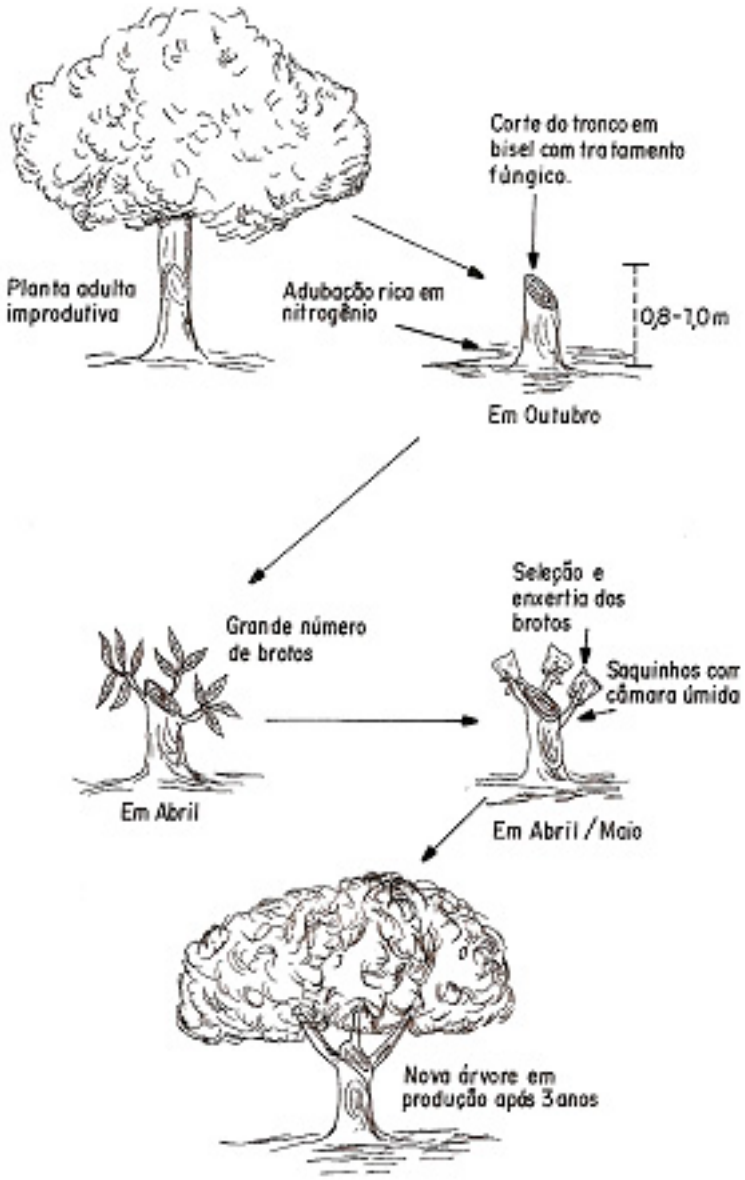

Figure 5 – The recovery of mango tree is a recommended technique in commercial mango orchard at Northeast Brazil.

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