Establishment and management of oil palm nurseries

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HIGH YIELDING
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Costa Rica
OIL PALM SEEDS AND CLONES

Contents

I. INTRODUCTION

A successful oil palm plantation must start with the selection of the best planting materials available on the market and excellent management of the plants during the initial stages (pre-nursery and nursery). The palm grower should make sure to purchase high quality seeds from reputable and well-established companies, which back up the genetic purity and health of the material with official certificates.

Only the best plants from a nursery should be planted in the field. Any savings in nursery costs can have negative consequences that will be reflected in the long productive life of the plantation.

The main advantages of establishing a nursery with strict quality standards are the shortening of the period between transplanting to the field and the first harvest (precociousness) and the increase in the initial yield of fresh fruit bunches, which are essential for improving cash flow and reducing initial field maintenance costs, particularly weed, pest and disease management.

The main activities in an oil palm nursery are described in the following sections.

II. GENERAL ASPECTS

1. Seed and nursery area requirements

The amount of seed required depends on the size of the project, but it also must take into account the losses that may occur due to failure to emerge and the discarding of abnormal plants. Usually, the total plants discarded is expected to be between 15 and 20%; however, this could be as high as 25% or more when the agronomic management of the nursery is deficient.

To estimate the nursery area required, the spacing between plants must be taken into account, which depends on the time the plants will remain in the nursery and the particular variety to be planted. In addition, another area for facilities and infrastructure such as storage, roads, drainage and irrigation system (approximately 15% of the total area) should be considered, as shown in Annex 1.

In general, plants remain in the prenursery for 2 to 3 months and in the main nursery for 9 to 10 months. It is not recommended to plant very young palms in the field (particularly those younger than 7 months), since several genetic abnormalities only become apparent during the final stages in the nursery. On the other hand, palms with little development are exposed to severe damage from eventual attacks by pests such as rats, leaf-cutting ants, beetles and others. In addition, weed control is more difficult and costly, and small palms suffer more from weed competition.

Nor should very developed plants (15 months or more) be taken to the field, as they normally suffer severe stress during transplanting, which can be aggravated by inadequate practices such as excessive pruning of leaves to facilitate their transport to the planting site in the field, which causes a significant delay in the subsequent development of the palms.

2. Site selection for the nursery and pre-nursery

The sites to select to establish the pre-nursery and the nursery must meet at least the following requirements:

- Topography preferably flat or slightly undulating.
- Soil with a surface layer rich in organic matter, with loam or sandy loam texture and strong structure.
- Sufficient area to accommodate the number of plants required for the project and the associated infrastructure, such as a warehouse, roads, buildings, drainage and an irrigation system.
- Availability of sufficient water throughout the year for plant irrigation.
- Easy access all year round.
- Strategic location with respect to planting areas (particularly the main nursery).

The following aspects are key to the success of a nursery:

- Timely preparation of the soil (in the dry season, at least two months before the germinated seeds arrive).
- The time of arrival of the seeds should be at the beginning of the rainy season, so that the transplanting of the nursery plants to the field coincides with the beginning of the next rainy season.
- Appropriate calculation of the needs for infrastructure, materials, equipment, transportation and other miscellaneous aspects.

Plans should consider 3% additional nursery plants to replace those that fail to establish in the field, either due to severe pest and disease damage, poor (abnormal) development, or any other cause. It is important that the bags in which the additional plants are grown are larger and spaced further apart, as they will remain in the nursery longer.

It is not advisable to keep a nursery in the same place for many years in a row, as some diseases, such as anthracnose, can become critical.

III. THE PRE-NURSERY

Germinated seeds are initially sown in small bags with a suitable substrate in a pre-nursery, and after two to three months (when they have 3 to 4 leaves); they are transplanted to larger bags, in what is called the main nursery.

The main advantages of a pre-nursery are the following:

- A much smaller area is required.
- Irrigation is more efficient and cheaper.
- Weed, pest and disease control is facilitated.
- It allows making the first selection of the best plants to take to the main nursery.
- Fewer nursery bags and their filling with soil is required due to the elimination of abnormal plants at the end of the pre-nursery stage.

Figures 1 and 2 show the general layout of a pre-nursery structure (module) to accommodate approximately 6,000 bags.

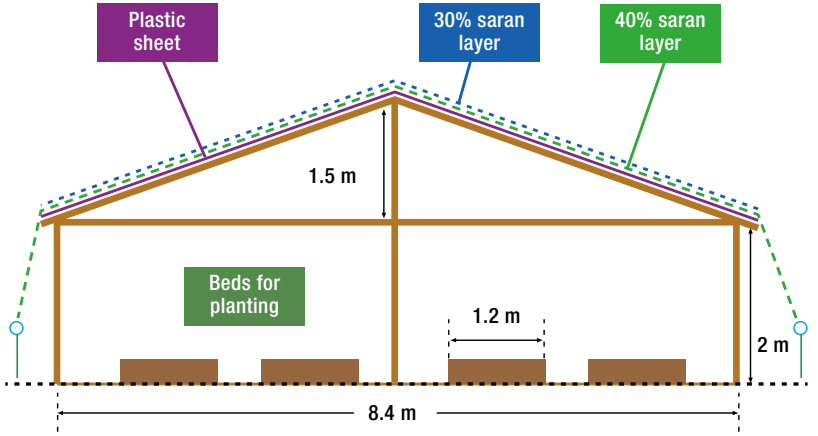

Figure 1. Diagram of the external pre-nursery structure.

This module is 16.6 x 8.4 meters, and houses four beds of 15 meters long x 1.2 meters wide, spaced at 0.8 m, where approximately 1,500 bags of 22 cm x 18 cm (10 bags across) are placed. The roof of these structures is gabled, with a maximum height of 3.5 meters and a minimum of 2 meters.

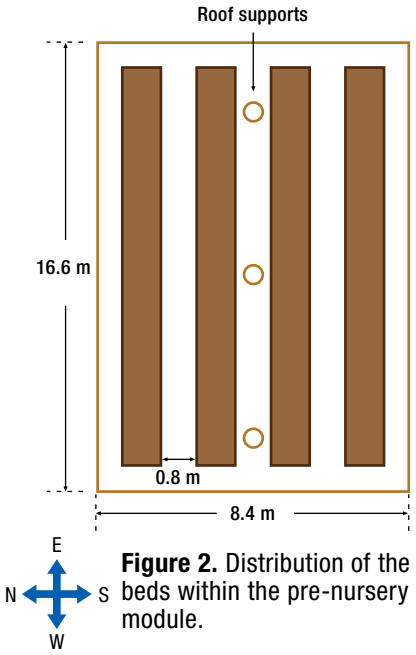

Figure 2. Distribution of the beds within the pre-nursery module.

These individual structures facilitate the distribution of personnel, the supervision of the different tasks, and they allow the separate management of groups of plants that differ in variety, age or any other characteristic. With respect to age, it allows uniform shade management for the whole group.

It is also possible to build larger modules, but it is difficult to supervise and manage shade, among other aspects, when plants of different ages are under the same structure. In places where there is a risk of damage by animals (domestic or wild) and other pests, it is advisable to fence the area.

III. THE PRE-NURSERY

Figure 3 shows several palm pre-nurseries, built using different materials, from the most rudimentary to modern and technified ones.

Figure 3. Pre-nurseries for palms built using different materials and designs.
A: Pre-nursery with a roof of palm leaves.
B: Pre-nursery of wood with a gabled roof.
C: Pre-nursery with saran roof.
D: Palm prenursery in a highly technical type of greenhouse.

III. THE PRE-NURSERY

1. Characteristics of the bag

In the pre-nursery stage, black plastic bags of either 25 x 20 x 0.01 cm or 22 x 18 x 0.01 cm (300 gauge) are used. The bags should be specifically requested from the supplier to have drainage holes in the bottom two-thirds (32 holes) and bottom (8 holes). Smaller bags are not recommended, as this makes seed sowing more difficult, greatly restricts root development, and transplanting to the nursery must be done prematurely as it increases the risk of plants suffering etiolation due to competition for sunlight.

2. Characteristics of the substrate, filling of the bags and their arrangement in beds.

The bags should be filled a few days before planting and placed as soon as possible inside the pre-nursery to protect the substrate from the direct impact of rain. The soil to be used should be of intermediate texture (sandy loam or coarse loam), so that it allows good drainage and has a suitable moisture retention capacity. In addition, the soil structure should be strong and the soil should be free of hard clods, stones, roots and sticks. The use of very heavy and plastic clay soils is associated with the appearance of a higher percentage of abnormal plants. On the contrary, the use of very sandy soils can cause water stress if the irrigation system fails. After filling the bags, it is advisable to water for a couple of days to allow the soil to settle.

It is of utmost importance that the soil to be used comes from an area with minimal or preferably no disturbance caused by agricultural activities, to avoid the presence of pathogenic fungi (*Pythium sp.*, *Phytophthora sp.*, *Fusarium sp*. and *Rhizoctonia sp.*), which can attack and cause damage and mortality to seedlings in early stages. If there are doubts about the biological quality of the substrate, it is suggested to add worm compost and inoculate it with beneficial microorganisms (*Trichoderma sp.*, *Bacillus sp*. and mycorrhizae), sometime before sowing the germinated seeds.

The bags are normally arranged in blocks or beds raised about 5-10 cm above ground level, covered with gravel on the surface to facilitate drainage (Figure 4). The beds should be no more than 1.2 meters wide to facilitate planting and other subsequent tasks. The length can be variable but is usually set between 10 and 15 meters.

In the distribution of the module, a distance of at least 0.8 m should be left between beds to allow the passage of workers, and even to be able to move around with a wheelbarrow loaded with soil or with bags filled with soil. In these aisles, mulch (gravel, palm husks, rice husks) can be placed to prevent waterlogging of the soil and weed growth.

After the bags are placed in the beds, the substrate level in them can drop considerably when they become wet, so they must be refilled before planting (Figure 4).

Occasionally some time may elapse between filling the bags with soil and sowing the seeds. During this time, compaction and

Figure 4. A: Arrangement of bags in the planting beds. B: Filling the bags with soil prior to planting.

hardening of the substrate inside the bag may occur (as well as sinking of the surface and weed growth), so it is necessary to proceed as follows:

- Fold the top one-centimeter edge of the bag outward and downward.
- Remove weeds and break up the hardened surface of the soil with the help of a small metal spatula (of the type used to scrape paint from walls).
- Level the soil surface in the bags, leaving one centimeter of height between the soil and the edge of the bag so that a mulch can be placed after plant emergence.

3. Shade and its management

Shade during the early stages of seedling growth avoids damage caused by direct solar radiation and very high temperatures, and this helps maintain a favorable relative humidity in the prenursery environment. The use of shade does not necessarily increase the percentage of seeds that emerge (which depends on other factors), but it can certainly make a difference in obtaining better quality plants, particularly in places with high solar radiation.

Normally, the structure that supports the shade is more than two meters high and can be made of wood, bamboo or metal. Management within the prenursery is greatly facilitated and better plants are obtained when a gable roof is constructed with a transparent plastic sheet under the saran mesh (Figure 1). The plastic insulates the nursery from rain, which allows better control of substrate humidity in the bags and in the area inside the prenursery (avoiding puddles and exposure of the seeds to raindrops). The height of the roof (3.5 meters) and the placement of a wire mesh on the roof prevents the formation of water pockets on the plastic that could cause it to collapse (Figure 5)

Figure 5. Wire mesh placed on the roof to support the plastic sheeting and prevent the formation of water pockets.

A single layer of saran is placed laterally around the structure, particularly when there are birds or animals that may cause damage to the plants and to make irrigation more efficient. The outer layer of saran (which filters 30% of the sunlight) should be removed one month after planting; the remaining saran sheet (which filters 40% of the sunlight) is removed two weeks later.

Shade removal should be completed by the sixth week after planting and should be done gradually. When palm fronds or similar material is used to provide shade, an alternate frond can be removed each day, so that the plants gradually receive more solar radiation. Wind conditions, solar radiation and temperature should be considered in order to avoid burns or stress to the plants if the shade is removed prematurely.

4. Planting

Planting is a simple but delicate procedure that requires extreme care on the part of the workers. Damage caused to the seedlings exposes the tissue to attack by fungi and bacteria that reduce emergence and cause rickets (abnormalities) of the seedlings. It is important that qualified personnel are used for this work and that they are closely supervised. Because it is a delicate task, it is common to hire female labor for this work.

III. THE PRE-NURSERY

The main activities of the planting process are the following:

- Carefully check the documents accompanying the shipment, particularly the distribution of seeds per box according to radicle size and variety. This will indicate the chronological order in which the seeds should be sown; those with greater radicle development should be sown first. This and other information on product characteristics and handling recommendations are included by ASD in box No. 1 of each shipment.
- Before sowing, keep the seeds in their original packaging in a cool, shaded place protected from sun or rain, preferably in an air-conditioned room at a temperature between 20 and 22°C (68 and 72°F).
- Open the containers one by one once the sowing order has been established. Then distribute them in the prenursery directly from the plastic container that holds them. The boxes should be opened according to the rhythm of sowing, so that the seeds do not remain outside the original packaging for a long time or exposed to desiccation (Figure 6).
- During planting, the plumule should be positioned upwards and the radicle downwards (Figure 7). This is vital, as planting upside down will either prevent emergence or produce an abnormal plant.
- With the fingers, make a hole in the center of the bag of a depth according to the size of the radicle. Place the seed in the hole without releasing it, so that the plumule is 0.5 to 1.0 cm below the soil surface. If the tip of the plumule is exposed or too deep, plant development will be adversely affected.
- Holding the seed with one hand, fill the volume around the seed with soil. Release the seed after filling about two thirds, finish filling and then gently compact the surface with the fingers, trying not to press too hard and thus damage the plumule.

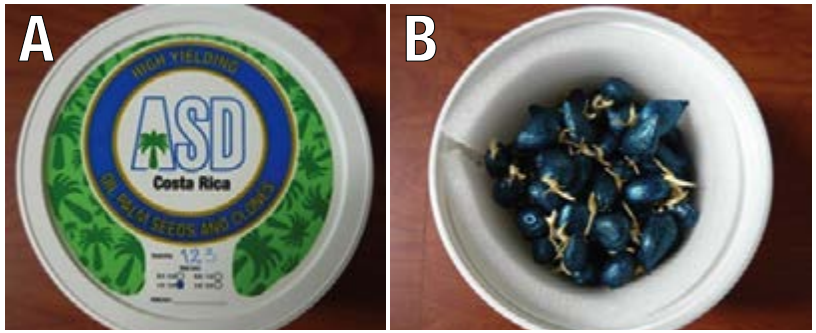

Figure 6. A: Container holding the palm seeds. B: Palm seeds packed in the container.

Figure 7. A: Correct seed placement, plumule upward and radicle downward. B: Introduction of the finger to make the hole in the center of the bag. C: Gentle compaction of the soil surface over the seed.

Good supervision during and after planting is important to avoid leaving uncovered plumules. The most common errors observed are the following:

- Inverted sowing (plumule downward).
- Deep planting or shallow planting.
- Breakage of the plumule or radicle.
- Detachment of the seedling from the seed.
- Seedlings that have deteriorated due to improper handling or that have dried out due to prolonged exposure to the sun.

Figure 8. Planting of oil palm seeds in bags in the pre-nursery.

If for some reason planting cannot be completed in a single day, it is advisable to identify each group with the date it was planted. This will help to identify differences in growth due to age.

5. Post-planting care

Rain or irrigation causes soil erosion in the bags and can uncover the planted seeds (Figure 9). This problem occurs when planting is shallow, and it is particularly common when palm fronds are used as shading material. Exposed seeds should be covered with soil immediately.

Figure 9. Seeds uncovered by soil erosion caused by rain.

To control weed growth, prevent erosion and sealing of the soil surface caused by irrigation or rain and maintain a good water infiltration capacity in the bag, we suggest to add a layer of mulch approximately one centimeter thick on the substrate surface after plant emergence. For this purpose, materials such as broken palm husks or rice husks can be used.

1. Weed control and phytosanitary care

Weeds growing in the soil of the bag should be removed manually. As a rule, herbicides should not be used inside the prenursery. When the management of the prenursery is adequate (particularly in terms of substrate quality, shade and water supply), no or minimal phytosanitary problems are expected. However, since the plants are in close proximity to each other, pests and diseases may eventually appear. This does not imply that agrochemicals should be used indiscriminately in the prenursery; they should only be applied in the presence of a specific problem, particularly a pest, for which the site should be checked in detail on a regular basis.

7. Fertilization

In the initial stages of seedling development (first two months), their nutritional needs are supplied mainly by seed reserves (endosperm). Even so, some chlorosis (yellowing) may occur on certain occasions, especially after the shade has been removed. In such a case, a solution prepared from a compound fertilizer such as 17-4-17-4 or similar (25 g/l) can be applied to the soil as a drench, adding 20 ml/plant. A backpack pump or a small, calibrated container can be used for this purpose. These applications can be started in the month of planting and repeated every 15 days. Additionally, every week it is advisable to spray the foliage of the plants with a solution of cane molasses (20 ml/l).

The indicated fertilizer can also be used directly (undiluted) applying 1 gram per plant 30-40 days after emergence. Solid fertilizer applications should be made with great care, avoiding that workers touch the foliage of the plants with their hands and that fertilizer grains remain in contact with the leaves. An easily built device (made of plastic tubing and the top neck of a plastic bottle) can be useful for this purpose (Figure 10). Solid fertilizers should be placed away from the base of the plants to avoid burning them.

Figure 10. Apparatus used to apply solid fertilizer in the pre-nursery.

8. Irrigation

An accurate water supply in the prenursery stage is essential, so no pre-nursery should be established if this requirement has not been met. In general, irrigation with micro-sprinklers (0.8 l/h discharge) is recommended, to reduce the risk of creating a lot of soil splash and uncovering newly sown seeds. In case of extreme need, manual irrigation could be used, but this system causes strong erosion and it is not possible to provide uniform irrigation to all plants.

9. Discarding of abnormal plants

The discarding of abnormal (off-type) seedlings is a fundamental task to guarantee the success of the future plantation. The selection of the best plants should be a strict task, since an abnormal plant taken to the field is an error that will last 25 years or more. The discard rate at the end of the nursery stage varies between 5 and 10%, although this depends in part on the genetic material and agronomic practices used. In general, the following management factors can increase the percentage of abnormal plants:

- Not using shade or removing it prematurely (Figure 11).
- Using very heavy (clayey) or compacted soils in the bag (Figure 11).
- Inadequate water supply: excessive or deficient.
- Use of agrochemicals with high phytotoxicity.
- Prolongation of the pre-nursery period, which causes etiolation (Figure 11).
- Neglect of pest or disease control, etc.

Figure 11. Abnormalities in pre-nursery plants due to poor agronomic management. A: Plants with burns due to premature exposure to the sun. B: Plants with little development, due to the use of heavy and plastic or compacted soils. C: Strong etiolation by keeping plants tightly grouped together competing for light.

The most common types of abnormal plants at the end of the pre-nursery stage are:

- Grass-like plants (very narrow leaves).
- Rolled, twisted or corrugated leaves (Figure 12).
- With deficient pigmentation (albinos and chimeras) (Figure 12).
- Underdeveloped plants (Figure 12).

Figure 12. Common abnormalities in palm plants in the final pre-nursery stage A: Normal plant next to a plant with curled and twisted leaves. B: Underdeveloped plant amid normal plants. C: Plant with deficient pigmentation or albino.

10. Multiple seedlings

Occasionally seeds have several embryos, so that two or more seedlings can develop from a single seed. The best decision in these cases is to leave only one seedling and eliminate the others, which should be done at the time of sowing the seeds, keeping only the seedling with the best vigor and appearance. In eventual cases where multiple seedlings have not been removed at the time of planting, they can be separated at the time of transplanting to the main nursery. For this purpose, we suggest to let the substrate in the bag lose a little moisture to make it more friable, and then loosen it a little by pressing the bag on both sides. Then hold firmly with one hand the plant to be preserved and with the other hand, by the base, the plant to be removed. Finally, with a forward and backward movement, the plant is detached from the seed and removed slowly and carefully from the bag, trying to cause as little damage as possible to the roots (Figure 13).

Figure 13. A: Plants developed from the same seed. B: Separation of double plants.

The plant removed from the bag should be replanted immediately, kept in the shade, and well-watered for a while until it recovers from transplant shock. To reduce the stress caused to the separated plants, a solution of molasses (20 grams per liter) plus a growth stimulant such as Kilol (1 ml/l) can be applied.

11. Use of other containers and substrates in the pre-nursery

In a traditional nursery, plastic bags filled with soil are used and placed on beds of sand or fine gravel. Other alternatives are the use of Jiffy bags, tubettes or plastic trays with containers with organic substrates, on beds raised approximately 10-20 cm above the ground. On these beds a wire mesh or thin metal rod is placed,

over which the trays containing the bags, tubes or trays with containers are placed to plant the germinated oil palm seeds (Figure 14).

These systems have been associated with good seedling emergence, good seedling health and good efficiency in most of the work, maintenance and transplanting to the main nursery (less transplanting stress and efficiency can be doubled). The selection of abnormal plants is facilitated and there is an economy in weed management and structures, since a module like the one in Figure 1 can hold up to 16,128 bags originating from Jiffy pellets, compared to 6,000 normal prenursery bags.

A limitation of these systems is that due to the small volume of substrate they hold and the proximity of the plants, transplanting to the nursery must be done earlier, to avoid the plants suffering from early etiolation and the roots growing out of the bag, tubette or plastic container in the tray. Before using Jiffy bags or tubettes and trays with containers with fine peat moss it is very important to have the bags already filled with soil and lined up in the main nursery. Plants in these containers with fine organic substrates should go to the main nursery no later than seven weeks after planting.

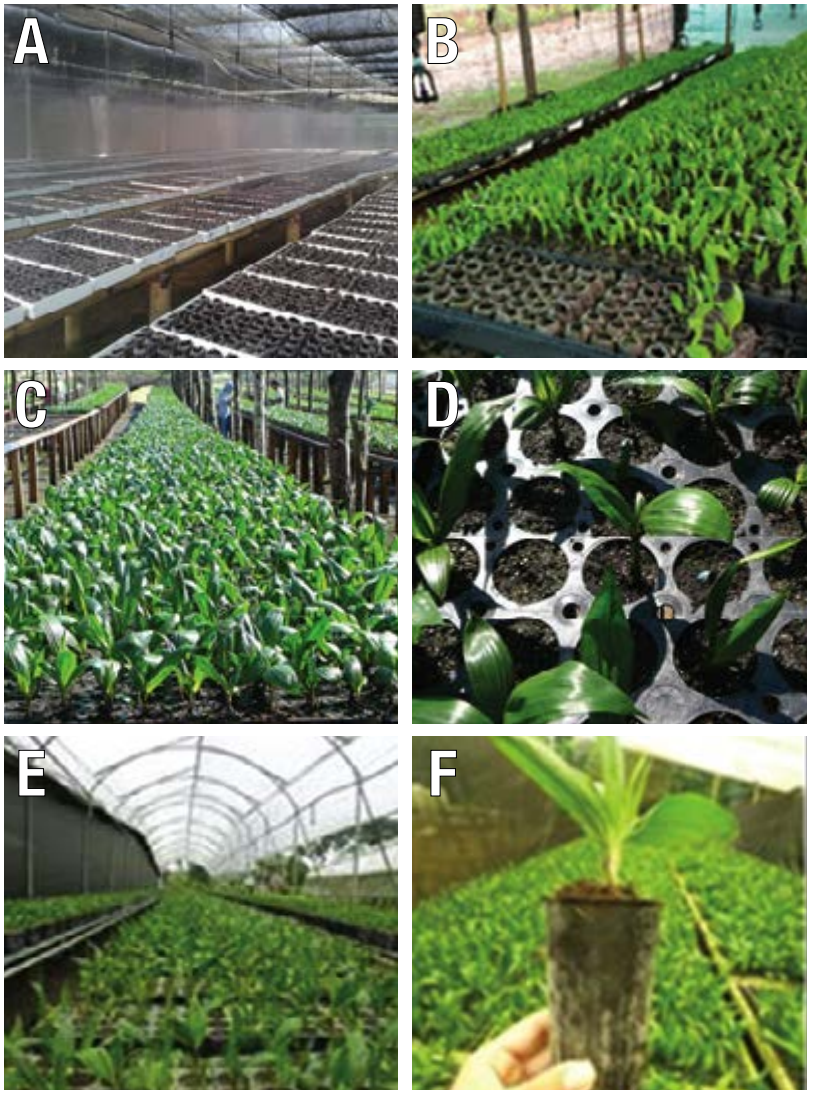

Figure 14. Use of other containers with organic substrates in palm pre-nurseries. A, B: Trays with Jiffy bags with peat substrate. C, D and E: Palm seedlings in tubettes and trays with plastic containers with fine organic substrates. F: Detail of a palm seedling in a tube with organic substrate (peat).

Figure 15 shows a useful tool to facilitate planting in the Jiffy bags. This tool is used to penetrate and break up the substrate by making a rotating and cutting movement until it reaches near the bottom. This is essential to facilitate planting and prevent the radicle from being damaged during the process.

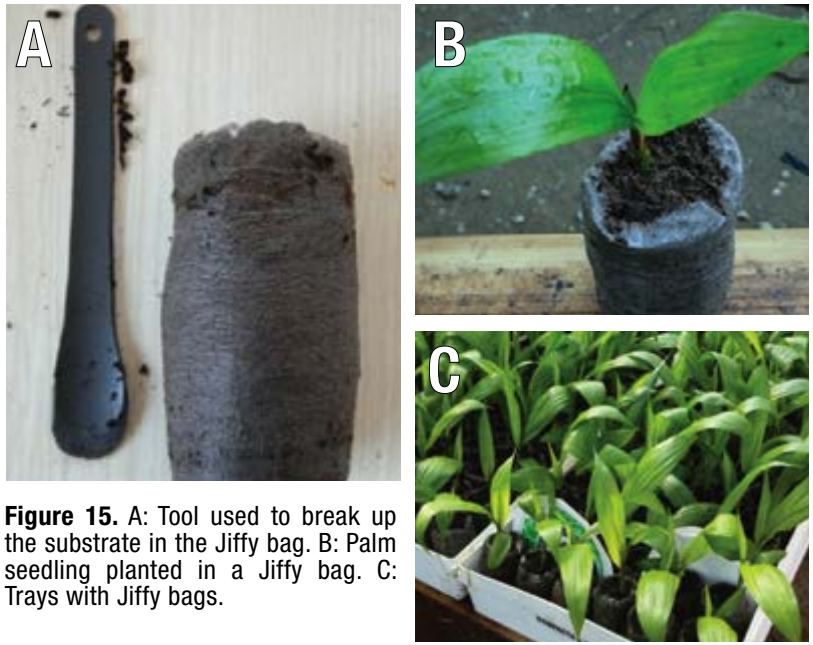

Figure 15. A: Tool used to break up the substrate in the Jiffy bag. B: Palm seedling planted in a Jiffy bag. C: Trays with Jiffy bags.

12. Transplanting to the main nursery

Plants from the pre-nursery are normally taken to the main nursery when they are 2.5-3 months old and have produced approximately 3-4 leaves (Figure 16).

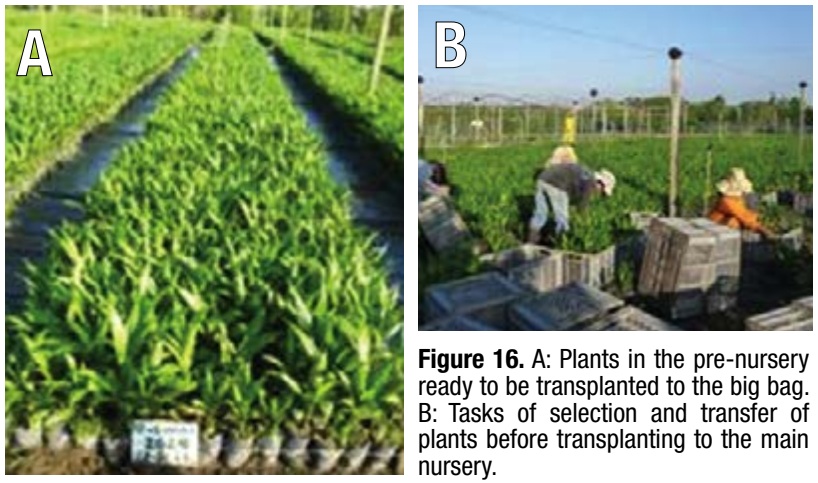

Figure 16. A: Plants in the pre-nursery ready to be transplanted to the big bag. B: Tasks of selection and transfer of plants before transplanting to the main nursery.

Because the plants are very close together and the bags are small, etiolation (abnormal leaf elongation due to competition for light) can occur if the prenursery period is extended. In this case, the plants will have stunted growth, they will be greatly delayed in the nursery stage and there will be a significant reduction in production during the first few years. This is an effect that must always be taken into account, since the idea of a commercial oil palm plantation is to obtain maximum fruit and oil yields as early as possible.

Annex 2 shows a table with the normal yields for the different tasks in a prenursery with oil palm plants.

IV. MAIN NURSERY

The main nursery is the phase following the pre-nursery, where larger and more widely spaced bags are used, placed in a triangular arrangement. The idea is to allow the plants to develop in an environment with a larger volume of soil and to receive as much sunlight as possible. At the end of the nursery period, only the best plants should be taken to the field. In this phase, as in the previous pre-nursery phase, there is no justification for false savings, as the decision to take a plant of questionable quality to the field will be a mistake that will have to be endured for the entire life of the plantation.

1. Land preparation and soil selection

In general, the soil used to fill the bags is topsoil, of medium texture and strong structure and rich in organic matter, coming from the same site where the nursery will be established. If the soil of the selected site does not meet these characteristics, then it is necessary to bring in soil of the required quality from another site.

The land in the nursery area should be prepared 2-3 months before placing the bags with soil. In soils infested with grasses or very aggressive weeds (e.g. Cyperus rotundus), special strategies are required to combat them. Once the weeds and their propagules have been eliminated, the soil is prepared to fill the bags.

If the soil structure is strong (which facilitates drainage) and its texture is adequate (sandy loam or coarse loam), it is suggested to make mounds with the surface soil (generally the first 15 cm) with a bulldozer, which are placed in strategic locations where they will be filled and from where the bags will be distributed. These mounds of soil should be covered with plastic or some other material to avoid wetting and loss due to erosion. It is important to disturb the soil as little as possible to preserve its natural physical properties. In some cases, it can be moderately broken up to remove stones and plant debris, but without pulverizing it, as this destroys the natural structure.

If soil fertility is low, 200 grams of biochar or leonardite can be added per bag (20 kg) as well as vermicompost (100 g/bag). Mixing soil with sand in equal amounts is also possible when the soil texture at the nursery site is clayey. In such a case, it is always desirable to add biochar or leonardite and vermicompost.

2. Infrastructure

In large nurseries, a network of roads is required, where the main road is generally located in the center or laterally along the length of the nursery. Secondary roads should run perpendicular to the main road, with a spacing between them of 40-80 meters (Figure 17).

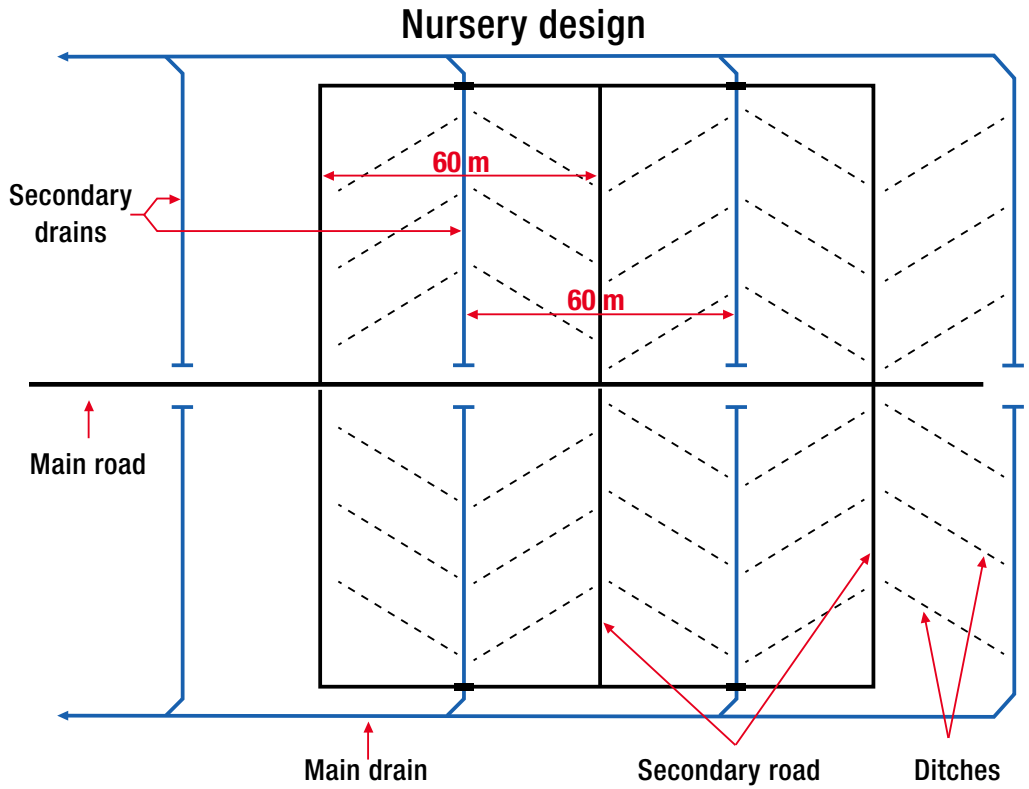

Figure 17. Layout of roads and drainage channels in a large palm nursery.

The main drain or drains are usually constructed on both sides along the length of the nursery. Secondary drains should be located between the secondary roads parallel to them. Small internal ditches may be dug every 15 to 30 meters, depending on the drainage condition and topography. These minor drains may run along the interlines at an oblique position with respect to the secondary drains. Detailed maps of the nursery, showing infrastructure and blocks with different characteristics or with different planting materials or materials of different age, are very useful for planning work and data recording.

3. Characteristics of the bag

The recommended type of bag is black high-density polyethylene, without recycled material, with protection against ultraviolet radiation (Tinuvin 622 at 2%) and with a gusset. The suggested minimum size is 45 x 50 x 0.015 cm, with approximately 120 circular perforations (side and bottom) (0.5 cm diameter, leaving the top 20 cm without holes) to allow for adequate drainage (Figure 18). This type of bag can be filled with about 20 kg of soil with adequate moisture.

It is essential that the bags remain in good condition for the nine months or more that they will remain in the nursery, since their premature deterioration causes serious problems for plant growth and increases costs (Figure 18). An additional 2% of slightly larger bags (45 x 55 x 0.015 cm) can be purchased to replace those that eventually deteriorate, but this is unnecessary if good quality bags are used from the start.

Figure 18. A and B: Nursery bags without holes with drainage problems. C: Premature deterioration of nursery bags.

4. Filling and distribution of the bags

Before adding the soil, it is advisable to place at the bottom of the bag a three-centimeter-thick layer of broken palm hulls or some other similar inert material, in order to promote more efficient drainage and isolate the bag from the nursery floor. The bag is then filled with soil, leaving at least four centimeters between the soil surface and the top edge of the bag; two centimeters will be used to make a hem and two centimeters to hold the cover or mulch. However, after filling the bags, the upper level of the substrate may drop a little due to the effect of watering or rain. Consequently, it is advisable to apply abundant water a couple of times and then refill with substrate until the desired level is reached (Figure 19).

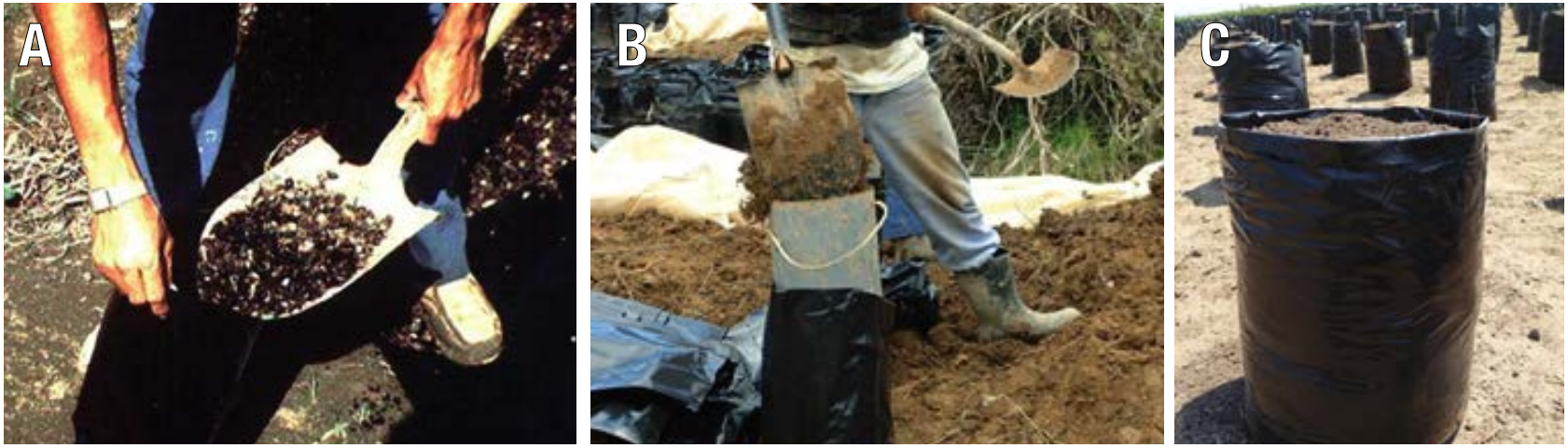

Figure 19. A: Placing a layer of palm husk at the bottom of the nursery bag before filling it with soil. B: Filling the nursery bag with soil using a calibrated plastic tube to facilitate the work. C: Nursery bag filled and placed correctly.

If gusseted bags are used, the bottom ends or points should be folded inward before filling. This allows the base of the bags to widen and prevents tipping or tilting of the bags.

In the main nursery, the bags are placed at the corners of equilateral triangles, which allows an optimal use of space and better utilization of solar radiation by the plants. Preferably, the rows of bags should be oriented in a north-south direction.

Wire chains with marks placed according to the spacing to be used are used to mark the points where the bags are to be placed (Figure 20). The distance at which the bags should be placed varies according to the time the plants will be kept in the nursery, although it should never be less than 1 x 1 m.

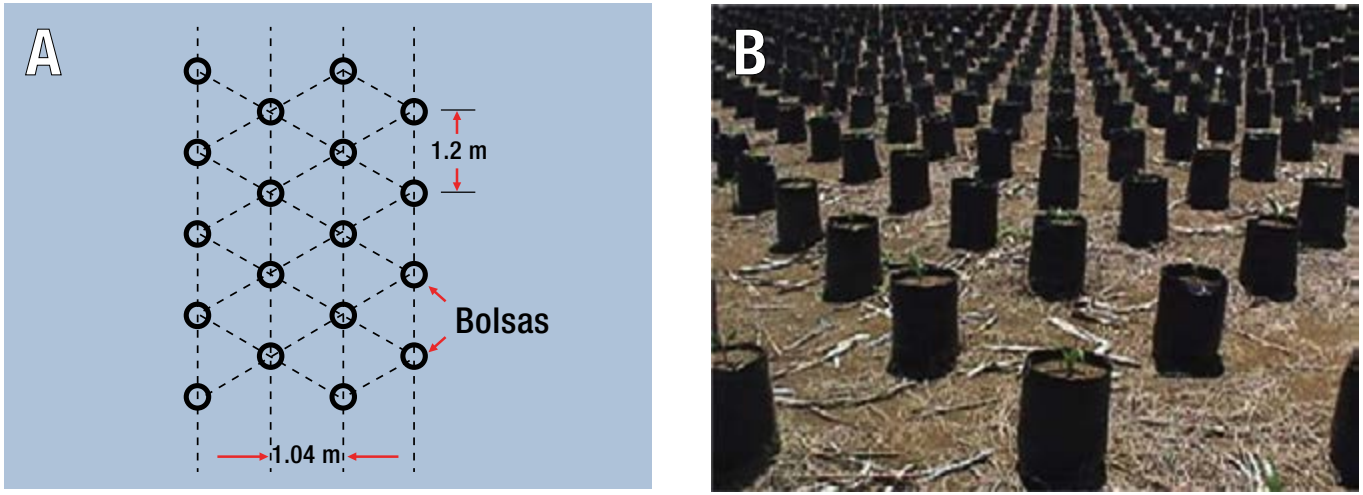

Figure 20. A: Distribution of nursery bags in an equilateral triangle. B: Nursery bags aligned.

5. Preparation and transport of pre-nursery plants

This delicate operation requires great care to preserve the quality of the plants produced in the pre-nursery. When the distance between the pre-nursery and the nursery is long, the transfer should be carried out in the early morning hours or in the afternoon, avoiding the hottest hours. Another important practice is to water the plants before removing them from the nursery. Transporting the palms to the nursery is greatly facilitated if they are placed in plastic baskets similar to those used to transport soft drinks (Figure 21).

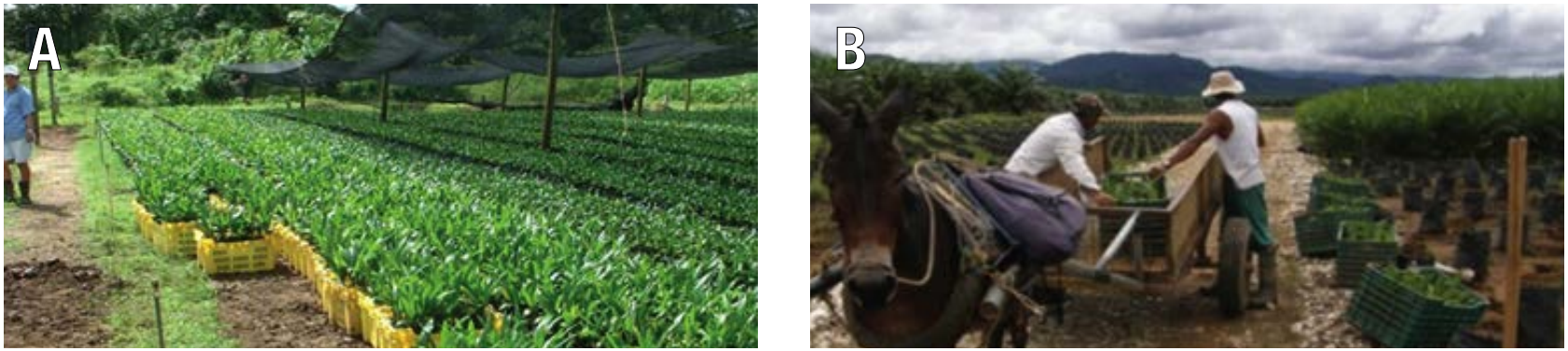

Figure 21. A: Selection of pre-nursery plants and preparation for their transfer. B: Transport of plants to the nursery site.

6. Transplanting

The tasks to be carried out during the transplanting of the palms to the nursery bag are described below (Figure 22):

- A cylindrical hole is made with a shovel, dredge shovel or metal cylinder in the center of the nursery bag filled with soil. This hole should have a slightly larger volume than the bag containing the pre-nursery seedling. When the pre-nursery is made in Jiffy bags, the planting hole should be smaller, thus increasing the efficiency of transplanting. In this case, a smaller dredge shovel should be used.
- The plastic pre-nursery bag is carefully removed, keeping the soil block intact and without causing damage to the roots.
- The plant is placed in the hole, taking care not to disturb the substrate block and finally the empty spaces around the substrate block are filled with soil and gently compacted.

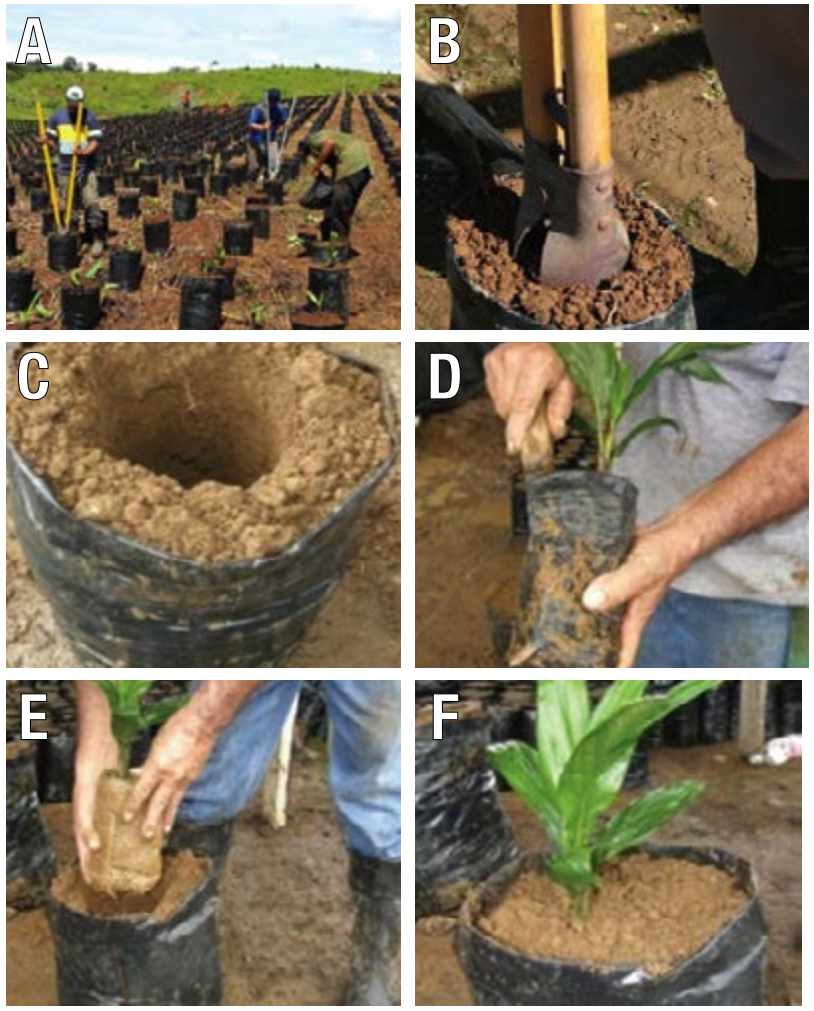

Figure 22. Work to be carried out during transplanting to the nursery bag. A and B: Use of a post hole digger to make the hole in the center of the bag. C: Hole with adequate space to place the pre-nursery plant. D: Removal of the pre-nursery plastic bag. E: Placement of the substrate block inside the hole. F: Palm transplanted to the nursery bag.

The quality of the planting should be carefully supervised so that the plants are not damaged and the integrity of the root system is preserved (the substrate block does not crumble). In addition, planting should be neither too deep nor too shallow, as this slows the growth of the small palms (Figure 23).

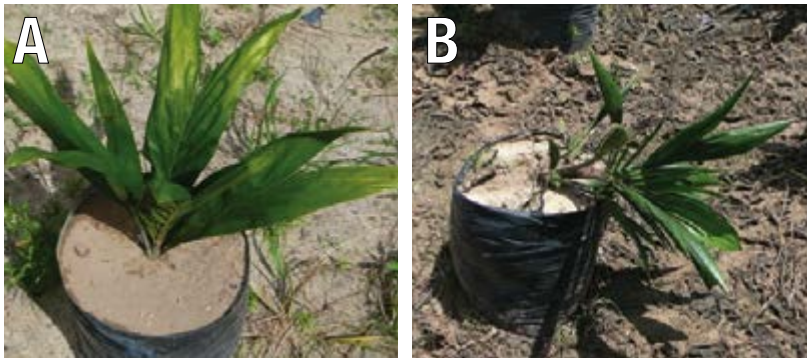

Figure 23. Problems caused by poor quality planting. A: Very deep planting. B: Shallow planting that led to the overturning of the plant.

7. Irrigation

Nursery plants require a daily water supply, especially during the first stages after transplanting and when the substrate has a low moisture retention capacity. Therefore, it is essential that the irrigation system be ready before receiving the germinated seeds, even if that moment

coincides with the beginning of the rainy season, as dry periods can occur, even for a few days, which could have a disastrous effect on the young plants.

Sprinkler irrigation is the type most widely used in oil palm nurseries because it is very efficient, easy to control, allows good water distribution and requires little labor to operate. Although there is a diversity of options regarding the type and quality of equipment and materials, the system consists of a pumping unit, water distribution piping for the sprinklers, couplers, flow and pressure valves, towers and sprinklers (Figure 24). The design of the system, including its pumping capacity, pipe size and strength, and other related aspects, may vary in different situations.

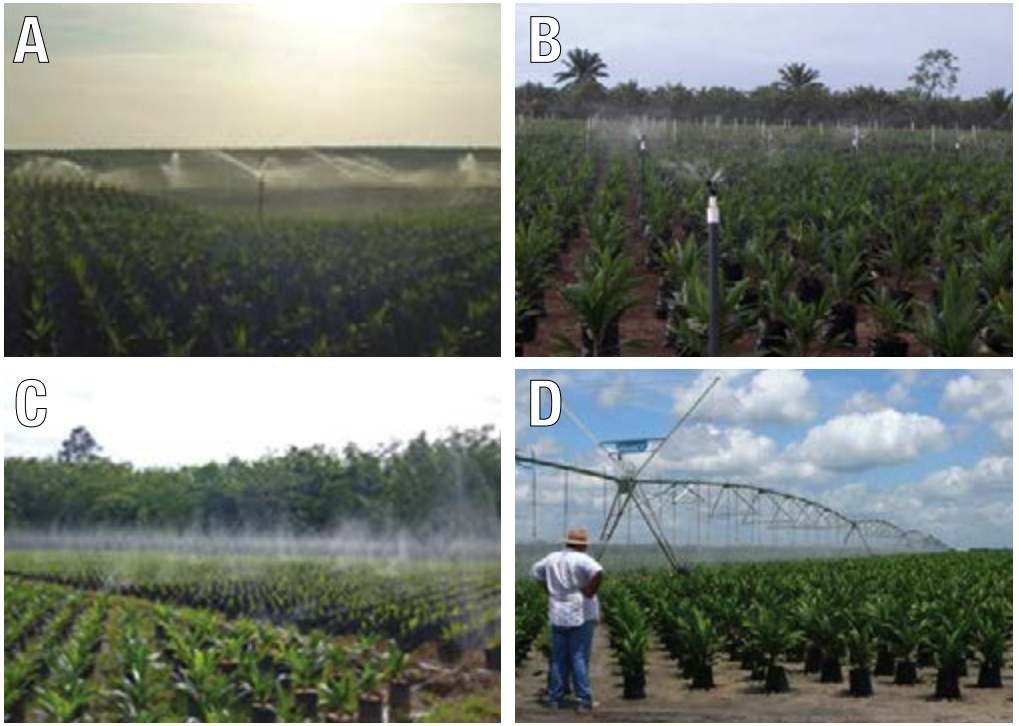

Figure 24. Different irrigation systems used in palm nurseries. A and B: Sprinkler irrigation. C: System with Sumisansui porous hoses. D: Central pivot irrigation system.

Depending on the age of the plants, the soil and the climate, the need for irrigation in the nursery normally varies between 5 and 10 millimeters per day. It is important to check the pressure in the sprinklers and place plastic rain gauges at different strategic points in the nursery to verify that the amount of irrigation water applied is correct (Figure 25).

Initially, the root system explores the soil inside the bag, but eventually roots bore through the bottom and grow into the soil beneath the bag. A normal nursery bag (40 x 50 cm) contains a soil volume of about 22 liters, so the available water capacity (AWC), which is the soil moisture that can be maintained between field capacity and the permanent wilting point, is very limited (2.7-5 liters) and water can be depleted quickly. Therefore, it is suggested to always keep soil moisture within a capacity range where it is readily available, which is between one-half and two-thirds of the total AWC. Tensiometers and moisture meters based on electrical conductivity are very useful in determining when the desired upper and lower moisture limits are reached in the bag substrate.

Figure 25. Plastic rain gauge used to verify the amount of water applied.

If for unforeseen reasons the sprinkler irrigation system is not ready in time, there is no other option but to resort to manual irrigation. Water can be applied with plastic containers or hoses, which are less costly; however, water distribution is usually very uneven and causes erosion of the soil in the bag, which leads to the uncovering of seeds and roots and heterogeneous plant development (Figure 26). Failure of the irrigation system for a few days can have disastrous consequences for the plants.

Figure 26. Erosion caused by manual irrigation in bags with poor quality substrate.

V. FERTILIZATION

Fertilization in oil palm nurseries normally includes nitrogen, phosphorus, potassium, magnesium and boron. Eventually, under particular conditions, the addition of other elements such as copper, zinc, sulfur, etc., may be required.

The total amount of fertilizer to apply per plant during the entire nursery period is about half a kilogram. However, the best development is achieved with an optimal ratio of the different nutrients and an adequate application frequency (every 15 days). The fertilizer should be carefully placed on a wide band around the plant (about 3 cm from the base), up to the edge of the bag, avoiding its direct contact with the foliage to avoid burning it (Figure 27).

Figure 27. Total foliage burn of a plant caused by incorrect fertilizer application.

To avoid burning plants, workers should not touch their foliage (particularly if it is wet) with their hands during fertilization, nor should they wipe their hands on the clothing they wear.

Since the amounts of fertilizer applied per palm are small, they must be carefully weighed. Therefore, a scale with an accuracy of ±0.5 grams is needed. Plastic containers and various devices can be used to apply the recommended doses (Figure 28).

Figure 28. Different ways of applying solid mineral fertilizer in palm nurseries. A: Addition of fertilizer by hand. B: With a kind of long-handled spoon. C: With a funnel attached to a plastic tube. D: With a soda bottle top used as a fertilizer container.

V. FERTILIZATION

The type and amount of fertilizer to use depends on the type of substrate used to fill the bag and the amount absorbed by the plants at an early age, although the frequency with which it is applied is also very important. Applications every two weeks are recommended for optimum plant growth in the nursery stage.

A popular recommendation used in nurseries in Malaysia is shown below in Table 1.

Table 1. Fertilization program used in Malaysian nurseries.

Age of the plants (months)	Numbers of applications per month	Grams of formula per plant	
		14-13-9-2.5	12-12-17-2
4	2	14	-
5	2	-	28
6	2	28	-
7	2	-	42
8	2	42	-
9	2	-	56
10	2	56	-
11	1	-	70
12	1	70	-
13	1	-	84
14	1	84	-
TOTAL		294	280

In Costa Rica, where oil palm is grown mainly on alluvial soils, with a loam to silty-clay loam texture, slightly acidic and with very high calcium content, the nursery fertilization indicated in Table 2 has given good results.

Table 2. Fertilization program used in palm nurseries in Costa Rica

Age of the plants (months)	Grams of formula 14-12-20-6 per plant
3	12
4	20
5	24
6	30
7	33
8	36
9	40
10	45
11	50
12	60
TOTAL	350

VI. WEED MANAGEMENT

Bags should always be kept free of weeds, but management on the nursery floor requires some judgment, as not all weeds are necessarily harmful. The use of pre-emergent herbicides after soil preparation generally results in a subsequent decrease of the problems.

Weeds on the nursery floor should be kept at a height at which they do not compete with the palms and do not impede work in the nursery. To control ground weeds, periodic sprays with paraquat in combination with diuron, oxyfluorfen and pendimentalin give good results. However, the use of these herbicides after the plants are transplanted to the nursery is risky, as they may burn the foliage of the palms. Therefore, herbicides should be sprayed only on weeds, using special anti-drift nozzles and shields or screens to prevent the splashing and drift of fine droplets. Selective herbicides such as Fusilade (fluasifop-butyl) and Gallant (haloxyfop-methyl) are effective in eliminating grasses. Herbicides such as glufosinate-ammonium (Finale, Basta) are a good option, but should be applied with a wick or mop to avoid contact with palm foliage (Figure 29). Hormonal herbicides such as 2-4 D and other broad-spectrum systemic herbicides such as glyphosate should not be used in oil palm nurseries.

Figure 29. Different systems for controlling weeds. A: With a weed-trimmer. B: With herbicide and a shield to prevent drift. C: With a wick or mop touching only the weeds on the floor. D: Herbicide spraying, covering the plants with sacks to avoid burns due to herbicide drift. E: Coverage of the nursery floor with palm husk. F: Manual removal of weeds in the bag.

VI. WEED MANAGEMENT

The use of inert mulches such as rice husks or broken palm hulls can efficiently reduce weed growth on the nursery floor; however, they are expensive to implement and this material is not always available. Geotextile mulches are also appropriate but their cost is high.

The use of live cover crops such as forage peanut (*Arachis pintoi*) is becoming popular in some advanced nurseries (Figure 30). This is an excellent option because, due to its creeping habit and low growth, this plant does not hinder the movement of workers nor does it compete in any way with nursery plants. In addition, the improvement of the physical and chemical properties of the soil caused by living mulches over time benefits the nursery plants, whose root system develops in the nursery soil largely after 6-7 months. The opposite is true for herbicides, which accumulate over time in the nursery soil and may eventually cause toxicity to roots and palm plants.

Figure 30. Nursery with a cover crop of the legume called forage peanut (*Arachis pintoi*). This cover is excellent for use in nurseries due to its creeping and low growth habit.

Initially, manual weed control in the bag can be done every three weeks. Subsequently, this work can be done less frequently, depending on weed regrowth. Placing broken palm hulls or similar materials such as mulch on the surface of the bag substrate greatly helps to reduce the emergence of weeds, avoids splashing and soil loss caused by irrigation and rain, helps to maintain better moisture in the substrate and helps reduce the spread of some diseases.

VII. PEST AND DISEASE MANAGEMENT

The most common diseases affecting plants in the nursery are mainly caused by fungi, which can attack the foliage and roots, so the use of fungicide products may eventually be required.

Figure 31. Fumigation of nursery plants with a motorized pump.

The products and doses mentioned in the following paragraphs are only a guide, so it is always recommended to read the label. Likewise, when any product is to be used for the first time, a test should first be carried out on a small group of plants, with the objective of observing if the product causes phytotoxicity.

The most common phytosanitary problems and suggested general management measures are as follows:

1. Anthracnose (*Colletotrichum gloeosporioides*) (Figure 32)

To prevent and control the development of this disease we recommend the following:

- Correct nutritional imbalances (particularly when there is high N and low K).
- Avoid excess or lack of water (particularly in substrates with low moisture retention capacity).
- Cut and remove foliage already heavily damaged by the disease outside the nursery area.
- Spray plants weekly with Mancozeb (2.5-4 g/l c.p.[1]) or flowable maneb (3.5 cc/l c.p.) mixed with Mertec (thiabendazole) at 0.1% a.i.[2] or benomyl (1-1.5 g/l c.p.), plus surfactants. Other products such as Busamart 30 AC (TCMTB) at 1-2 ml/l c.p., Cuproxat 35.2% FW (copper sulfate) at 3 ml/l c.p., and Phyton 27 (copper sulfate) at 1 ml/l c.p., but these may cause toxicity if not properly applied.

Figure 32. Anthracnose symptoms on the foliage of nursery palms.

[1] Commercial product
[2] Active ingredient

2. *Curvularia sp.*, *Helminthosporium sp.* and related fungi

- Correct nutritional imbalances (mainly when N is high and K is low).
- Avoid water deficiencies.
- Eliminate grassy weeds in and around the nursery area.
- Cut and remove disease-affected tissue outside the nursery at the onset of attack.
- Sprinkle the plants weekly with flowable maneb (3.5 cc/l c.p.) or Thiram (0.2% a.i.) with benomyl (1-1.5 g/l p.c.).

3. *Rhizoctonia sp.* (Attacks mainly in the prenursery)

- Use a cover or mulch of inert material to avoid soil splashing on leaves.
- Avoid excessive shading and watering.
- Eliminate the palms affected by the disease.
- Spray the plants with thiabendazole (0.1% a.i.) or benomyl (1g/l c.p.) mixed with mancozeb or maneb.
- Transplant as soon as possible to the main nursery.

4. *Phytophthora sp.* spot (blight)

- Avoid conditions of high humidity and excessive shading.
- Outside the nursery, cut and remove disease-affected tissue.
- Spray plants weekly with Metalaxyl (3.5 g/l c.p.) or Fosetyl-Al (6-8 g/l c.p.).

5. Chlorotic ring virus (Figure 33)

- Locate the nursery away from low-lying areas.
- Keep the nursery area and its surroundings free of grassy weeds.
- Eradicate affected plants immediately and remove them from the nursery.
- Spray plants with fast-acting insecticides.
- Place an aphid repellent mulch such as rice husk on the nursery floor and in the bag on the substrate surface.

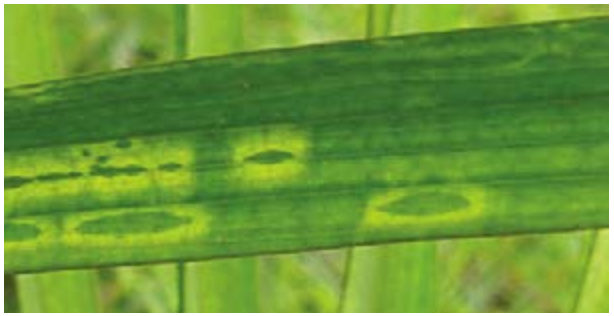

Figure 33. Symptoms of chlorotic ring virus on a young palm.

To combat other soil fungi that may attack the roots and base of the plants, sprays with Captan or Banrot (0.1 g/l) can be made. However, inoculations with antagonistic fungi such as

Trichoderma sp. and *Aspergillus sp*., mycorrhizal fungi and bacteria of the genera *Lactobacillus sp*. and *Bacillus sp*. are effective for the general suppression of pathogens in the substrate.

Several pests can attack oil palm plants in the nursery stage. However, pests do generally not attack well-nourished plants. Some of the most common pests in nurseries are the following:

1. Grasshoppers and similar defoliating insects

- Spray with Deltamethrin (0.1 g a.i./l), Fenitrothion (0.15g a.i./l) or Diazinon (0.6 g a.i./l), when pest emergence is observed.

2. Cutworms and similar pests

- Spray with Carbaryl (0.12 g a.i./l), Methomyl (0.1g a.i./l) or Cypermethrin (2 g a.i./l) when pest emergence is observed. Applications of Carbofuran and Aldicarb granules at 2-4 g/plant also give good results.

3. Mites

- Spray plants with micronized sulfur (0.5-0.8 g/l, Binapacryl (0.5-0.6 g a.i./l), Monocrotophos (0.4 g a.i./l) or Cyhexatin (Plictran), when pest emergence is observed. Borax applications and spray irrigation are useful for reducing mite populations.

Some products mentioned above may be phytotoxic if used at high doses. Likewise, sprays should be made on dry foliage, entirely covering both leaf surfaces. With a knapsack sprayer of 18-20 liters it is possible to spray 800-1,000 plants with 4 to 5 leaves, or 100-150 when the palms have 10 to 12 leaves.

4. Rodents

Although attacks by rats or other rodents in nurseries are not very common, precautions should be taken so that damage does not become serious. The best way to handle the problem is to take the following preventive measures:

- Maintain a strip no less than 25 meters wide around the nursery, free of weeds and accumulations of organic matter.
- Keep drainage channels clean (free of sediment and weeds).
- Keep the nursery area free of weeds, waste and puddles.
- Use poisoned baits (first generation anticoagulants such as warfarin) when the problem occurs.

VIII. PLANTING IN THE FIELD

Transplanting from the nursery to the field implies an important change of environment, which causes stress and therefore has a negative effect on the initial performance of the palms. To reduce transplant shock, it is advisable to use a shovel or chisel to prune half of the roots growing out of the bag two weeks before transplanting, and the remaining half just before taking them to the field. However, root pruning should be done considering wind direction and strength, as the plants may eventually tip over. One month before transplanting, the last dose of fertilizer is applied and the palms should receive a generous watering before being taken to the field.

Figure 34. Root system of a well-developed palm at the end of the nursery stage.

Much of the effort and investment made to obtain excellent nursery plants can be lost if special attention is not paid to the handling of the palms during transportation, planting and subsequent care in the field. Poor plant selection, careless and rough transport, and poor handling after planting, will undoubtedly have major negative consequences on the production potential of the plantation.

Figure 35. Nursery plants in optimal conditions, ready to be planted in the field.

Table 3 shows values of growth measurements for 10 and 12 month-old palms (including nursery and pre-nursery).

VIII. PLANTING IN THE FIELD

Table 3. Average growth measurements on 10- and 12-month-old plants (including nursery) of three of the ASD varieties.

Variety/ Age (months)	Number of leaves	Length of rachis (cm)	Leaft area (m^2)	PxS (cm^2)	Base of stem (cm)	Plant height (cm)
Themba (10)	10-11	65-73	0.21-0.30	0.70-0.80	4.5-5.0	115-130
Themba (12)	14-15	80-85	0.32-0.42	0.80-0.90	7.5-8.5	135-160
Spring (10)	12-13	75-85	0.30-0.42	0.75-0.85	5.0-5.5	125-145
Spring (12)	14-16	85-100	0.43-0.52	0.85-1.0	8.3-9.5	150-170
La Mé (10)	12-13	65-78	0.27-0.37	0.65-0.85		122-135
La Mé (12)	14-16	80-93	0.30-0.42	0.70-0.83		140-170

1. Plant selection and discarding

Culling abnormal (off-type) palms is a fundamental task to guarantee the success of the future plantation. The selection of the best plants should be a strict task, since an abnormal plant taken to the field will never repay the investment made in it. The percentage of discards at the end of the nursery stage depends partly on the genetic material, but also on the agronomic practices carried out.

Some of the management factors that can increase the percentage of abnormal plants in the nursery were discussed in the section on pre-nursery discard, excluding of course those referring to shade. The common level of discard at the nursery stage can be between 7 and 10%, so that the total culling percentage (nursery plus nursery) varies between 12 and 20%. However, in poorly managed nurseries the discard can reach 30-35%.

The final culling round is carried out before transplanting to the field. The common characteristics of the atypical plants found in this nursery stage (Figure 36) are the following:

- Underdeveloped plants.
- Leaves with short and closed leaflets.
- Leaves with narrow needle-like leaflets.
- Plants with short young leaves that give them a flat appearance at the top.
- Plants with an abnormal acute insertion angle, giving the plant a rigid and erect appearance.
- Leaves on which the leaflets remain united (juvenile leaves).

VIII. PLANTING IN THE FIELD

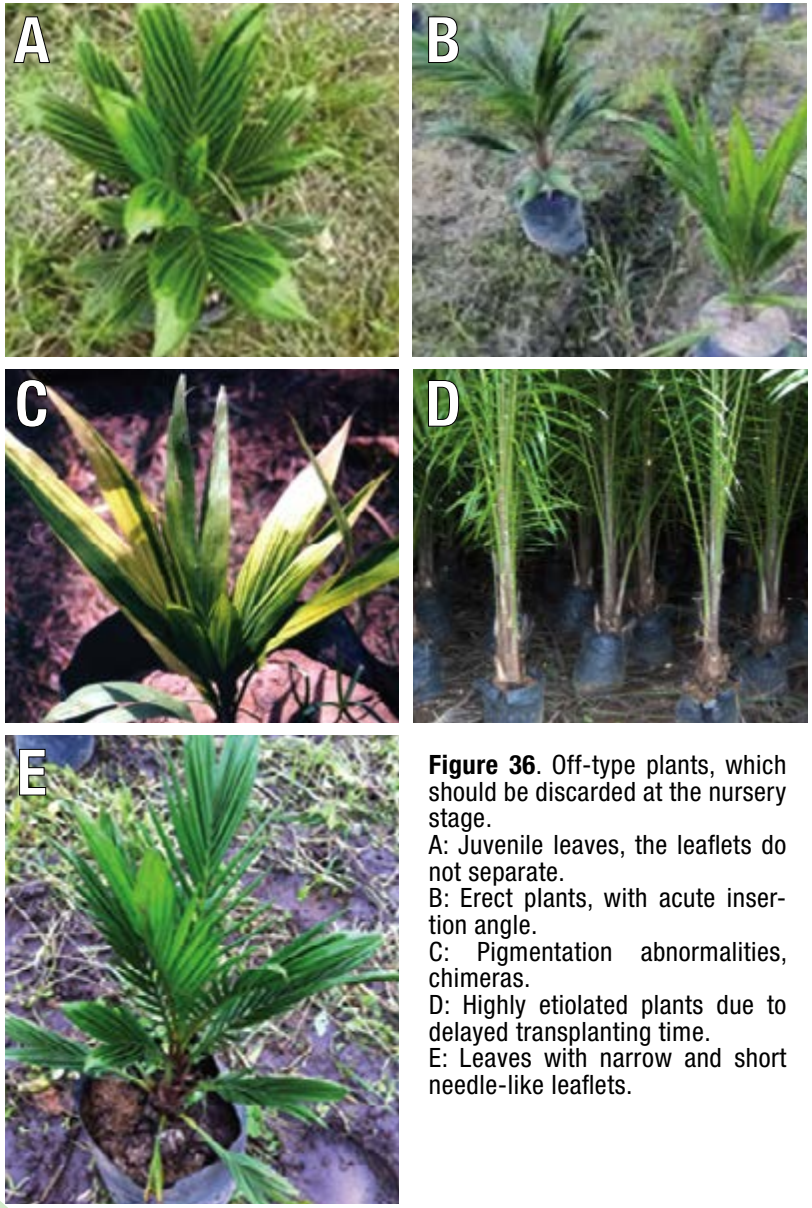

Figure 36. Off-type plants, which should be discarded at the nursery stage.
A: Juvenile leaves, the leaflets do not separate.
B: Erect plants, with acute insertion angle.
C: Pigmentation abnormalities, chimeras.
D: Highly etiolated plants due to delayed transplanting time.
E: Leaves with narrow and short needle-like leaflets.

Planting poor quality plants in the field can lead to the following:

- Reduction of 15 to 20% of production during the first two years, due to the planting of strongly etiolated plants.
- Reduction of 25% or more of production during the first two years, due to the planting of very young plants (less than 7 months old).
- Reduction in production of 1 to 3 ton/ha/year with the planting of 5% of abnormal plants.

The impact on field production of selecting nursery plants with various abnormalities is shown in Table 4.

Table 4. Impact of poor nursery selection on field production.

Type of abnormality	Reduction in the production of fresh fruit (percentage)
Flaccid appearance, fallen leaves	59.2
Erect habit (acute insertion angle)	29.9
Narrow leaflets	12.6
Juvenile seedlings	12.3
Short internodes	26.7

Annex 3 shows the yields for the normal tasks to be carried out in an oil palm seed nursery.

VIII. PLANTING IN THE FIELD

ANNEX 1

Seed and area (ha) required for an oil palm nursery, according to plant spacing and project area (discard 15%, replanting 2%).

Project size (ha)	Planting density (palms/ha)	Seed required	Area requiered for the nursery according to palm age (months) 12*	14**
50	143	8,500	0.87	1.06
100		17,200	1.74	2.12
500		85,800	8.7	10.6
1,000		171,600	17.4	21.2
50	160	9,200	0.94	1.15
100		18,400	1.88	2.3
500		92,000	9.4	11.5
1,000		184,000	18.8	23.0
50	170	9,800	1.0	1.22
100		19,600	2.0	2.44
500		98,000	10.0	12.2
1,000		196,000	20.0	24.4

*1 m spacing in triangular arrangement.
**1.2 m spacing in triangular arrangement.

In general, the area (m^2) required for the nursery is calculated using the following formula, including the desired spacing between bags:

$$N = \frac{10{,}000}{S^2 \times 0.866}$$

Where: N= number of plants/ha; S=spacing between bags

For example, if we use a spacing of 1.2 m, the resulting number of plants that we can place in a hectare is 8,019.

ANNEX 2

Expected work efficiency calculated for one day (8 hours), in a standard pre-nursery with plastic bags.

Activity	Quantity (units)
Filling of bags	600
Refilling of bags	8,000
Placement of bags in beds	5,000
Planting	1,350
Manual weeding in the bags	4,000
Foliar fertilization	40,000
Granular fertilization	8,000
Pesticide application	40,000
Discarding/Culling	25,000

ANNEX 3

Average efficiency in the work of a palm nursery, during an 8-hour workday.

Activity	Quantity (units)
Filling of bags	350
Refilling of bags	1,700
Alignment of bags	1,200
Distribution of prenursery bags	1,000
Making holes in the bags	1,250
Transplanting	1,250
Manual weeding (every two months)	2,500
Placement of cover on the bag	3,000
Pesticide application	10,000 - 8,000- 5,000 When the plants have 5, 8, and 11 leaves respectively.