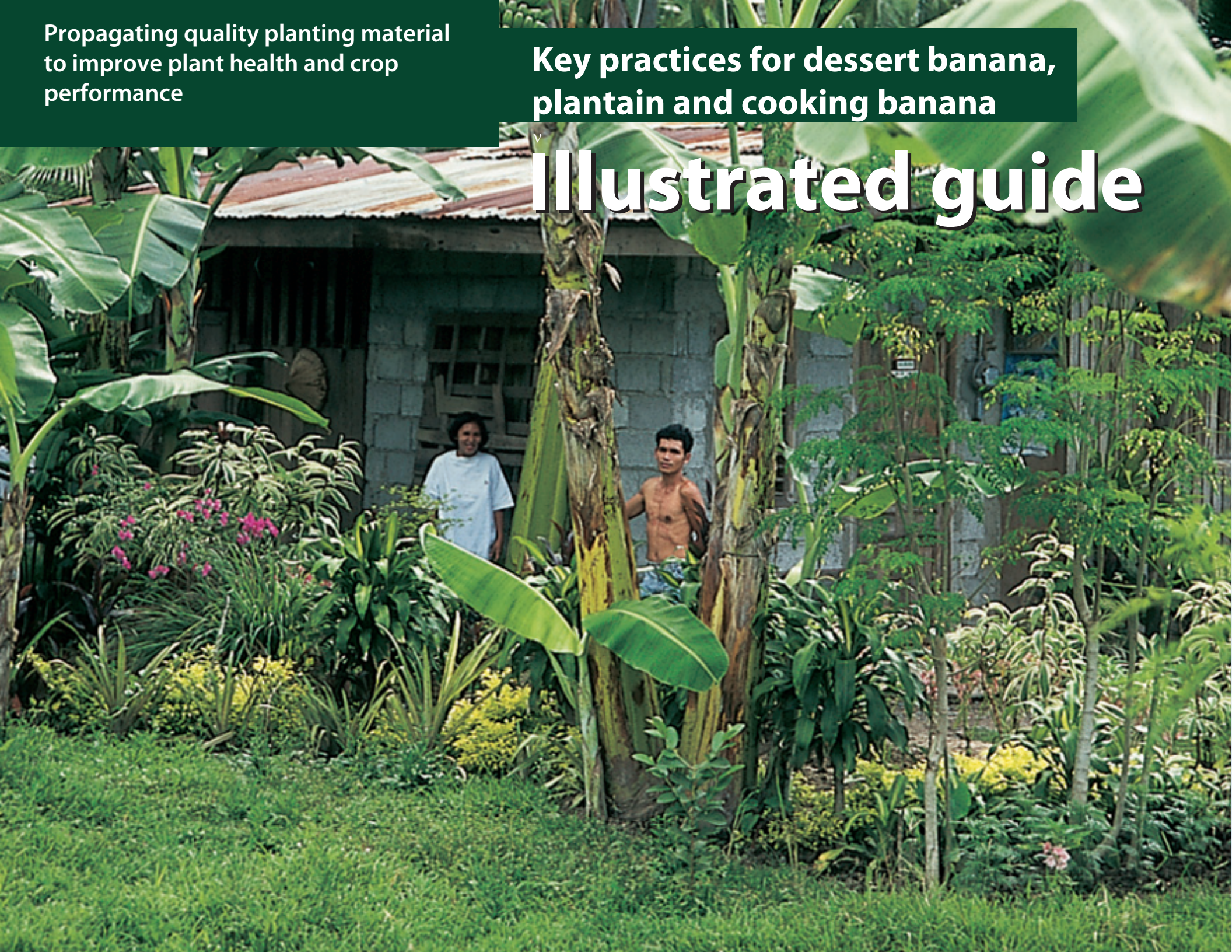
Propagating quality planting material to improve plant health and crop performance

Key practices for dessert banana, plantain and cooking banana

Illustrated guide



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Contents

CHAPTER 1: Is the quality of planting material important for banana productivity?

This illustrated guide summarizes the key practices for producing clean planting material of banana with a high yield potential for smallholders, depending on the pests and diseases which are present.

The guide is also designed to contribute to better planning of the propagation of planting material for rural development and disaster relief projects. A simpler version of this manual is available as grower fact sheets well-illustrated with photographs. The legends and explanations for the appropriate methods can be translated into local languages.

Dessert bananas, plantains and cooking bananas[1] are an important smallholder crop in the tropics and subtropics, providing food security, dietary diversity and income to millions of rural households. Every year rural households plant or replant fields of bananas, using more than 20-30 billion suckers or some other form of vegetative planting material.

A simplified version of this manual is available for producers in the form of well illustrated field sheets with photographs. Descriptions and explanations of the different methods may be translatedin local languages or dialects if necessary.

1 Hereafter the wide diversity of types and varieties of the genus *Musa* will be referred to as bananas, except when the difference in types is important. When one group is of particular importance, we will mention the group, e.g. AAA banana, AAB plantain, ABB banana, etc.

Minimize pest and disease transmission

Each sucker is an opportunity to improve the yield and the quality of smallholder production, but each sucker can also contribute to an unproductive plant. As with all vegetatively propagated crops, poorly selected planting material can transmit insect pests, fungal and bacterial diseases and viruses. Planting material infected with pests and diseases can result in yield losses in the first harvest of 20-100% depending on the problem and can reduce the number of harvests by half or more.

Obtaining sufficient clean planting material is a big challenge to smallholders, because each year they may need not just five or ten suckers, but hundreds to thousands. If only 10-20% of the planting material is infected, pests and diseases readily pass to healthy plants, reducing both bunch size and the number of harvests. Some diseases, such as banana bunchy top virus and Fusarium wilt, are lethal and new plantings with infected suckers will produce nothing.

For smallholders with a diverse backyard garden, suckers free of pests and diseases are very important, although they may prefer a diversity of cultivars that produce a few bunches each month for home consumption (GO).

Smallholders producing for the market and for home consumption concentrate on one or two cultivars and are interested in long lived plantations producing several harvests. They should use planting material without pests and diseases. Through careful selection of mother plants they can also improve the yield potential of their plantation at each new planting or replanting (CS).

Improve yield potential

Each sucker which is planted has the potential to produce a bunch, the size and characteristics of which depend on the mother plant. Over thousands of years, farmers have selected individuals with special characteristics to plant and replant, thereby generating the world's banana diversity. East African farmers have over 200 cultivars of their AAA Highland banana type. Today the challenge for each household is to plant suckers with a slightly higher yield potential at each new planting, by selecting suckers from the best mother plants and eliminating the least productive plants.

Plan timing of harvest

In addition to disease and pest transmission and yield potential, the quality of the planting material also contributes to the timing of the harvest. Suckers of many different sizes planted in the same field will produce their first bunches during a much longer period than suckers or other planting materials which are highly uniform. For home consumption, production spread over a long period is useful, but in producing for markets more bunches in a shorter time period may be a more profitable strategy. Highly uniform planting material can be used to target production to specific periods of the year.

High input, high density annual plantings can be used to concentrate harvests in a short period of time when prices are high. Such systems demand clean planting material of very uniform size with high yield potential (LP).

CHAPTER 2: What are the primary pests and diseases transmitted in vegetative planting material?

Many different insect pests and diseases are found in suckers or other planting material and these may be moved from the old field where they originate to the new field where the material is planted. These different pests and diseases can be grouped into three categories according to how easy they are to manage by farmers and by other production services agencies.

1) **Nematodes and banana weevils**: these pests which occur quite frequently can be easily managed by growers with little risk.

2) **Bacterial and fungal wilts and banana streak virus in plantains (AAB):** this set of problems requires special management on-farm, although some risk must be faced.

3) **Banana bunchy top virus, banana streak virus in AAA dessert bananas, and other viruses: these** disease problems can only resolved by specialized off-farm propagation techniques.

Note: Bunchy top virus, bract mosaic virus, Fusarium wilt Tropical race 4 and bacterial wilts (*Xanthomonas* and *Ralstonia*) are only found in certain regions. International and national quarantine aims to reduce the spread of these diseases to new uninfected areas. Consult your local authorities to learn whether the diseases are present in your country or area.

Widely occurring pest problems easily managed on farm

Several plant-parasitic nematodes and the banana weevil are transmitted through infected planting material, but simple on-farm practices can produce relatively clean planting material.

Burrowing and root lesion nematodes cause reddish-brown lesions to healthy roots which are normally white. Roots turn black with more severe damage (CS).

Root gall nematodes produce roots which are deformed (IPB).

Nematodes are small worm-like animals living in plant roots and the soil. They are not visible to humans, but the damage they cause warns the farmer that they are present. They weaken roots and plants frequently fall over when the bunch is still very small. When the attack is severe, plants without bunches may also topple (PC).

The larvae of banana weevils feed on banana corms and pseudostems, forming a network of tunnels lined with black dead tissue. This feeding weakens the corm and plants often snap off at the corm (PC).

Banana weevils are present in banana fields in three life stages. The adults live among banana residues and move into tunnels formed by the larvae. They lay eggs on the corm which hatch into larvae which feed on the corm and pseudostem.

(PC)

(PC)

(PC)

Key practices for pest problems easily managed on farm:

1) select planting material from plantations free of the problem or with low infection rates, such as young, vigorous plantations in their first production cycle;
2) pare and/or boil suckers to minimize nematodes or weevils present on the suckers. Discard suckers with excessive brown or black corm material;
3) apply sucker sanitation practices (paring and/or boiling) close to where suckers were extracted. This avoids contamination of the field to be planted with infested roots or discarded corm parts;
4) store sanitized suckers distant from any banana plantation;
5) ensure clean substrate in nursery bags (free of plant parasitic nematodes) if macropropagation techniques are used.

Pest and disease problems requiring special management on farm

Good multiplication practices should be used to reduce nematode and weevil transmission in all banana planting material. Additional practices are needed on farm or in local nurseries to reduce the risks of transmission of bacterial and fungal diseases in planting material.

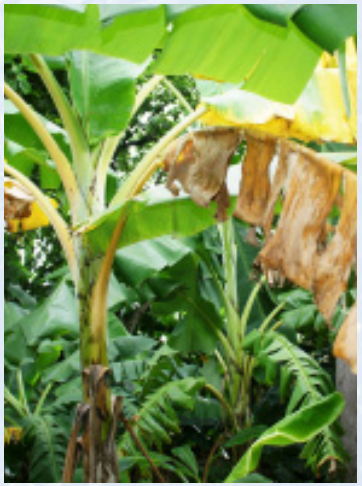
Fusarium Tropical Race 4 is a particularly lethal fungal strain appearing throughout Asia, since it attacks a wide group of bananas.

Banana streak virus (BSV) is found commonly in the B genome of plantains (AAB) and a few hybrids having the B genome where it makes up part of the gene sequence. These sequences are usually silent, resulting in normal production in plantain (AAB) plantations originating from suckers. Abiotic stress such as cool temperatures or drought, as well as tissue culture multiplication procedures, can activate the BSV sequence and result in plants with symptoms and reduced production. Practices on-farm, primarily the elimination of plants with symptoms, offer the best option for reducing the impact of BSV. Molecular tools are available to detect if plantain material has dormant viral sequences, but these are not commonly employed commercially. BSV in other cultivars (principally AAA) is described in the section on "Pest and disease problems requiring specialized off-farm propagation techniques".

Bacterial wilt causes yellowing and wilting of the older leaves, leading to plant death. Suckers should never be taken from plants with these symptoms or any neighbouring plants, since the bacteria are also carried in water or insects. Fields with bacterial wilt infections generally should not be used as a source of suckers (OB).

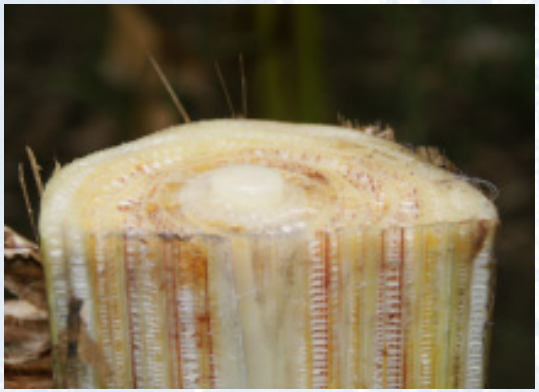
Plants with Fusarium, a fungus, show progressive leaf yellowing, starting with the oldest leaves, followed by a wilt and collapse of leaves (PC).

Erwinia, a bacterium, can be detected by the presence of soft, water soaked tissue which is quickly invaded by other organisms causing tissue rot (PC).



Bacterial and fungal diseases can sometimes be detected in the stem cross section. A healthy stem cross section should be white with no discolouration.

When bacterial wilts are present, brownish liquid or ooze appears on the stem cross section often associated with discolouration in the pseudostem (PC).



The fungus invades the roots and vascular system of the plant and brown threads (fungal mycelia) can be seen extending along the pseudostem (PC).

Outer leaves of the stem look water soaked, with off-colour brown tissue, as the problem spreads inward (PC).

(TL)

(TL)

(SD)

BSV in plantain (AAB) is evidenced by narrow, thick, distorted leaves with chlorotic streaks or blotches which later become necrotic. Stem splitting is common. The presence of BSV also produces breakdown of the leaf whorl at bunch emergence and distorted bunch formation.

Key practices for pest and disease problems easily managed on farm:

For bacterial and fungal wilts:

1) do not extract suckers from contaminated fields;
2) if no wilt-free fields are available, extract suckers only from plants distant and upslope from sick plants;
3) extract suckers from plants close to harvest, when symptoms may be more clearly expressed. Avoid plants with suspicious symptoms and their neighbouring plants;
4) to prevent dissemination of bacterial wilts, debud all flowering stems as soon after bunch formation as possible; Do not extract suckers from plants with suspicious symptoms and their immediate neighbours;
5) to prevent the spread of bacterial wilts from sucker to sucker through tools, disinfect machete/knife and other tools after each new sucker has been extracted and/or pared. Disinfection is not as useful or effective for fungal wilts;
6) discard any suckers with suspicious discoloration in the stem cross section;
7) pare and select suckers close to the field where they were extracted. This avoids contamination with damaged roots and corm parings of the new field to be planted.

For BSV in plantain (AAB):

1) avoid extracting suckers from plants with BSV;
2) extract suckers from plants close to harvest, when symptoms may be more clearly expressed;
3) rigorously rogue off-types and plants with BSV symptoms at each stage of multiplication and plantation establishment;
4) replant in areas close to the original plantation to avoid spreading BSV to new, clean areas.

Pest and disease problems requiring specialized off-farm propagation techniques

Certain types of viruses have a very severe impact on yield. If these viruses are commonly present in planting material in a region, farmers cannot use planting materials obtained from their own or neighbours' plantations. Virus-free tissue-cultured plants or vitroplants must be multiplied in specialized laboratories with virus testing and cleaning protocols.

Banana streak viruses (BSV) in bananas AAA are of several types with common symptoms: chlorotic streaks evolving into necrotic blotches. BSV symptoms described here look very similar to those described earlier for plantain AAB (JCR).

Plants with BSV often demonstrate stem splitting (P-YT).

In plants with banana bunchy top virus (BBTV), emerging leaves grow upright and have a stunted, bunched appearance. Each new leaf emerges smaller and narrower with brittle, yellow edges. An important diagnostic characteristic is dark green streaks found on the central midrib, secondary veins and the pseudostem. Dwarfism in banana plant is also significant (CS).

Banana bunchy top disease can appear in the suckers, although the adult plant does not present symptoms. The virus is present before the typical symptoms of leaf narrowing and yellowing occur (CS).

Banana bract mosaic virus (BBrMV) cannot be visually detected in suckers. BBrMV produces mosaics on the leaves which can disappear within 48 hours and a yellow or white-red mosaic may appear on the pseudostem. Reddish brown streaks or discolouration on the male bracts help to identify the presence of this virus (CS).

Other known viruses include cucumber mosaic virus (CMV) and banana mild mosaic virus (BMMV). When occurring alone, these viruses generally cause minimal damage. However, they can cause more serious yield losses if infecting a plant at the same time. CMV may also be more severe if other infected host plants such as watermelon, cucumber and squash have been intercropped.

Key management practices for pest and disease problems requiring specialized off-farm propagation techniques:

1) in regions with BSV in bananas (except AAB plantain) and BBTV, use vitroplants only from tissue culture laboratories with complete virus-screening facilities;
2) when obtaining vitroplants from regions with BBrMV (primarily in Asia), accept vitroplants only from tissue culture laboratories with complete virus-screening facilities. Risk can also be reduced by obtaining vitroplants only from laboratories located in countries free of BBTV;
3) when buying vitroplants, ensure that other viruses such as CMV and BMMV have been cleaned from shoot tips before multiplication;
4) if vitroplants are being used as planting material for macropropagation, use multiple isolation techniques to prevent infection of plants with viruses or bacterial diseases;
5) if using vitroplants for plantain (AAB), rigorously rogue off-types and plants with BSV symptoms at each stage of plant multiplication and plantation establishment.

CHAPTER 3: How uniform does the planting material need to be?

Many different types of planting material can be extracted from an established banana plantation. Almost any shape or type of sucker or the main corm can be used, either intact or cut into pieces, to plant a new plantation.

Uprooted maiden corm (PC).

While many different types of planting material are useful for producing a bunch, some planting materials have a shorter time period from field planting to harvest. **A large maiden corm has the shortest interval from field planting to harvest** followed by larger and then smaller sword suckers. Peepers, water suckers and new sprouts from buds on the mother corm have a longer interval from field planting to harvest.

Large sword sucker (PC).

Small sword sucker (CS).

A mat which has already produced a first harvest may have suckers of different sizes. Even water suckers and quite small suckers known as peepers can be extracted and grown into viable plants in a nursery. Large pseudostems can also be uprooted before flowering or after the bunch has been harvested (PC).

To plant a new field, farmers may need from a few hundred to thousands of suckers or other planting material. **The more uniform the planting material is in terms of size and age, the more concentrated will be the harvest** over a period of 2-5 months or more. If planting material consists of many different sizes or the field is planted over one to three months, then the harvest will also be spread out.

Water sucker (CS).

In addition to the size and age of planting material, there may also be some variability in the Musa type and cultivar. Depending on their objectives, farm households may prefer a diverse plantation for home consumption or a highly uniform plantation to harvest large quantities of a single type in a short period of time.

Peepers (PC).

CHAPTER 4: Can we improve the potential yield through the selection of mother plants?

The world currently has hundreds of cultivars of dessert bananas, plantains and cooking bananas. For thousands of years farmers in Asia, Africa and the Pacific have been observing their fields and fallows and have been selecting plants with special characteristics.

Each of our current cultivars has certain features which make it distinguishable from other cultivars – bunch and finger size and shape; taste, texture and fragrance of fruits; and leaf and stem colour and form. However, each cultivar is also characterized by variability in some of the same features mentioned above. This variability provides an interesting opportunity for small farmers to improve the productivity of their banana fields. Simply stated, planting material should only be taken from plants which have above average performance for important traits such as number of fingers, size of fingers, plant stature, bunching interval and rooting sturdiness. This has a two-way multiplication effect – reduction in plants with inferior traits and increase of plants with superior traits.

Examples of selection of superior mother plants

The export banana companies identify a few elite plants with preferred characteristics in their many plantations. After testing, these are multiplied in tissue culture labs to generate monoclonal lines with many, many plants having very uniform growth and bunch characteristics. This not only increases the yield potential, but also allows planting at a higher density, since all plants have a similar size and fewer plants are shaded by their taller neighbour plants.

The Taiwan Banana Research Institute has used mass selection to identify plants with a greater tolerance to Fusarium wilt. Each year Taiwanese banana growers replant their banana fields with tissue culture plants, a strategy initially designed to avoid crop losses to typhoons. Since the appearance of Fusarium wilt, scientists and farmers have been selecting plants which continue to grow even though all the neighbouring plants have been affected by Fusarium. Through this strategy new lines of dessert banana (AAA Cavendish) have been identified with tolerance to Fusarium Subtropical Race 4, even though it is generally considered that this group is susceptible to this disease.

Principles for the selection of superior mother plants

- identify important characteristics to be targeted in the selection process;
- determine minimum or maximum for the characteristics subject to selection;
- throughout the year, mark plants at harvest which have the desired characteristics;
- select only from plants which are located under normal soil conditions.
- avoid plants which are on the field borders or other locations which favour exceptional growth;
- avoid plants which have abnormal plant characteristics or show symptoms of prevailing pests and diseases.

Suckers selected in this way can be planted or multiplied using diverse techniques.

CHAPTER 5: What are the most common methods for propagating plants?

Five methods are commonly used to obtain planting material for the establishment of new banana plantings. Each method has specific requirements in terms of facilities and equipment, generates planting material at a characteristic rate and has particular risks of pest and disease contamination. The methods range from a few suckers extracted from backyard gardens, to small seedbeds of a few hundred seedlings distributed at the local level to the production of several million vitroplants per year for international export.

The simpler techniques are described and illustrated below. In later sections the good practices for different stages of plant multiplication are described.

1) Suckers extracted from banana fields in production

A banana plant produces suckers which arise from buds on the mother plant. These suckers can be extracted and replanted to establish a new field (CS).

Suckers must be extracted from a mother plant with appropriate techniques to avoid weakening its supporting root system (PC).

2) Suckers reproduced in sucker multiplication plot

When plants initiate flower formation well before flower emergence, plants are decapitated to stop further flower or bunch development and stimulate sprouting of abundant suckers. False decapitation or bending of the pseudostem can also be used, which impedes flowering, but maintains the mother plant, while also stimulating the sprouting of suckers (PC).

The sucker multiplication plot is established with good quality, pest and disease free suckers planted at a high density on quality soils, rich in organic matter (JC).

Decapitation stimulates the emergence of 10-20 suckers per stem (PC).

These suckers can then be extracted for planting into a commercial plantation with adequate practices to minimize pest and disease transmission (JC).

3) Microcorms

Small cone-shaped suckers of 200-300 g are extracted from a field in production or a sucker multiplication plot (PC).

Suckers are pared, treated with surface disinfectant and then planted into small nursery bags filled with clean substrate (CS).

By the end of 6-8 weeks, plants reach an appropriate size for transplanting into the field. Plants can be grouped by height and number of leaves to ensure more uniform growth and time to harvest (CS).

Since all plants are healthy and vigorous in their growth, the new plantation suffers few gaps in the population (PC).

4) Propagation from axillary buds

Leaf sheaths from medium sized sword suckers (200 – 500 g) are stripped away individually to expose axillary buds found at the base of each leaf sheath. The primary sprout is destroyed with a X cut across the top of the sucker (TL).

Suckers are covered in a bed of wet sawdust for several weeks inside a high humidity chamber made of plastic sheeting (TL).

Sprouts are carefully cut free from the sucker which is placed back in the chamber for the growth of another set of sprouts. These sprouts are also removed. A single sucker can produce 15-60 shoots during 4-5 months (TL).

Sprouts are planted in nursery bags filled with clean substrate to be grown out for 1-2 months in preparation for transplanting into the field (TL).

5) Plants from tissue culture

Suckers should preferably be extracted from a region free of diseases, subject to quarantine, tested for disease presence and then cleaned, if necessary. The resulting shoot tips are disinfected before being introduced into the sterile lab (YM).

Meristems are individually excised and transferred to a growth and rooting medium. Each meristem gives rise to 3-20 new meristems which are again cultured to multiply at the same rate. No more than 10 subcultures should be done from an initial meristem (about 1000-2000 vitroplants) to minimize the risk of off-type plants (YM).

5) Plants from tissue culture

(TL)

(YM)

The tiny plants are then sized and transplanted into trays or small individual pots and set out in a hardening nursery with high humidity and limited light, during a period of about 4-7 weeks. During this period the small, tender plants gain size and leaf area.

(YM)

Plants are transplanted into larger bags filled with sterile medium and moved into a weaning nursery. Little by little they adapt to higher sunlight and lower humidity found under field conditions. In 4-7 weeks plants are ready for transplanting.

(TL)

CHAPTER 6: How does the presence of pests and diseases affect the propagation method to be used?

In earlier sections three categories of pests and diseases were described – easily managed on farm, requiring special management on-farm and requiring specialized off-farm techniques.

In the table below the risk of transmission of eight important pests and diseases is estimated for the most common multiplication methods. This estimate of risk is valid only if certain key practices are employed with skill and care for each method. The key practices for each method are described in Section 7 in the following pages. Please pay close attention to the key practices as you plan the preparation or purchase of planting material. Of course, if any of these pests and diseases are not present in your areas, for example BBTV in Latin America, the risk is reduced, unless you are bringing planting material from another continent or a another zone with the pest or disease present.

Risk of transmission of pests and diseases for each multiplication method assuming 100% use of good multiplication practices

Pest/disease	Suckers selected from field in production	Suckers grown in a multiplication plot	Micro-corms	Propagation from axillary buds	Tissue culture
	green = low risk of transmission; yellow = moderate risk; red = high risk				
Nematodes					
Weevils					
Bacterial diseases*					
Foc*					
BSV in AAB					
BBTV*					
BSV in AAA and ABB*					
Other viruses					

(*) If pest or disease is not present in region or country, then risk declines substantially.

CHAPTER 7: What are the key multiplication practices from each method to guarantee quality?

Farmers are keen to use low cost techniques whenever possible in their crop production. However, using poor quality planting material contaminated with pests and diseases may have a negative impact on both yields and on profits. Plantlets from specialized laboratories are often sold as both clean and of high genetic quality. However, this so-called modern technology does not reduce the risk of producing non-compliant variants nor the risk of contamination by viral and bacterial diseases, if certain procedures are not followed. Growers need to know the key practices for alternative multiplication methods to make good choices in their production planning. Here we do not describe all the details for multiplying plant material. We identify the key or most important practices that influence the quality of planting material.

Key practices for selecting healthy superior mother plants:

1) extract suckers only from fields free of symptoms of BBTV, BBrMV, BSV and CMV ;
2) extract suckers only from fields free of bacterial and fungal wilts;
3) extract suckers only from fields with a minimal presence of nematodes and weevils;
4) throughout the year, mark plants with big bunches as a source of suckers when the bunch is harvested. Once the harvest is past, it may be difficult to recognize these superior productive plants;
5) throughout the year, mark plants with healthy, abundant leaves, firm rooting, stout trunk and below average height as a source of suckers;
6) if selecting suckers for multiplication in a tissue culture laboratory and even through propagation of axillary buds, carefully select mother plants with best the characteristics and no faults. If these elite mother plants are not well chosen, then the materials multiplied will not offer the full advantage of the high multiplication rate;
7) materials taken from mother plants for tissue culture multiplication should be quarantined and tested for the presence of viruses and bacterial wilts.

Select suckers from plants which have been marked previously for their vigour, below average height, firm root system, stout trunk and large bunch. Extract suckers from younger fields with fewer nematodes and weevils (PC).

DO NOT extract suckers from old fields or from fields in which superior plants have not been identified (CS).

DO NOTS in the selection of mother plants:

1. DO NOT extract suckers from old fields or unproductive fields;
2. DO NOT select suckers from plants without observing the bunch;
3. DO NOT select suckers from fields with bacterial or fungal wilts, BBTV, BBrMV, CMV or BSV.

Key practices for extracting and preparing suckers for direct planting:

1) Use practices described in the section on selecting healthy superior mother plants;
2) select cone-shaped sword suckers that reach 1 metre in height before broad leaves are produced, although peepers and corm pieces from harvested corms or maiden corms can also be used.

Preferred planting material (PC).

Acceptable planting material (PC)

Acceptable planting material (DC)

3) Use paring or boiling water treatment to sanitize planting material.

For paring:

- pare suckers in the field where they were extracted until only white flesh is showing;
- discard any sucker for which much of the corm has been cut away, for which the corm has brown-black discoloration, or for which off-coloured spots or ooze are found in the stem section;
- immediately move pared suckers to a new location distant from banana plantations to avoid recontamination from weevils which are attracted by the odour of freshly cut banana tissue.

Well pared sucker (PC).

Incomplete paring
NOT acceptable (PC).

Weevil galleries remaining
NOT acceptable (PC).

Small corm
NOT acceptable (PC).

Off-coloured stem section
NOT acceptable (PC).

Off-coloured ooze
NOT acceptable (SM).

For treating suckers in boiling water:

- select suckers with healthy white corm material, rejecting all suckers with very small corms, off-coloured stem section or ooze, or much of the corm damaged by galleries. However, complete and thorough paring is not necessary;
- immerse suckers in boiling water for 30 seconds;
- immediately move boiled suckers to new location distant from banana plantations to avoid recontamination from weevils.

Suckers ready for immersion in boiling water (DC).

Boiling water treatment (DC).

Suckers after boiling water treatment (PC).

DO NOTS in extraction and preparation of suckers for direct planting

1. DO NOT plant diseased or not well pared suckers

DO NOT plant suckers with weevil or nematode infestation (PC).

DO NOT plant suckers with off-coloured stem section or ooze (SM).

DO NOT plant suckers root shaved or only partially pared, since nematodes and weevils may still be present (PC).

Key practices for sucker multiplication plots:

1) use practices described in the section on selecting healthy superior mother plants;
2) use practices described in the section on extracting and preparing suckers for direct planting, including paring or boiling;
3) select field for planting which has not been planted to bananas for at least one year and which is distant from established banana fields;
4) rogue any off-type plants or plants with suspicious symptoms and do not use the field as a source of planting material if plants with symptoms of BBTV, BSV, BBrMV, bacterial wilts or Fusarium wilt are found;
5) eliminate flower before emergence (decapitation, 'false decapitation').

DO NOT in sucker multiplication plots:

1. DO NOT fail to eliminate flowering stem.

Decapitation serves to eliminate the growing point before flower emergence and stimulate sucker formation (JC).

False decapitation also serves to stimulate sucker formation by inhibiting flower emergence (OB).

Suckers should be harvested as soon as they reach the minimum useful size to allow space for remaining suckers (JC).

Key practices for growing out microcorms:

1) use practices described in the section on selecting healthy superior mother plants;
2) use practices described in the section on extracting suckers for direct planting;
3) pare suckers to a size ranging from 200-500 g and sort by size;
4) follow key practices for weaning nurseries.

DO NOTS in growing out microcorms:

1. DO NOT use unpared suckers;
2. DO NOT crowd plants without sorting, especially after two weeks.

Small suckers are first pared (PC).

Pared suckers are planted into nursery bags with clean substrate (PC).

Sprouting plants are sorted and spaced into uniform batches. Off-types, diseased plants and plants lacking vigour are eliminated (CS).

Shade should gradually be reduced to zero before transplanting into the field (LP).

Key practices for propagating plants from axillary buds:

1) use practices described in the section on selecting healthy superior mother plants;
2) use practices described in the section on extracting for direct planting;
3) pare suckers to a size ranging from 200-500 g to expose only white tissue;
4) strip leaves one by one to expose axillary buds at the base of leaves and cut deep X over main growing point at the centre of the stem section;
5) prepare deep bed of well moistened sawdust within humidity chamber which is partially shaded;
6) eliminate any main shoots which sprout, since these will inhibit the sprouting of axillary buds;
7) carefully remove sprouts with roots, maintaining the bulb at the base of stem intact;
8) return suckers to well moistened sawdust for additional sprouting;
9) follow key practices for weaning nursery.

Suckers are first pared and then leaves are stripped one by one to expose axillary buds (TL).

Suckers are placed into a bed of moistened sawdust within a high humidity chamber. The chamber should be shaded to about 50% natural sunlight (TL).

Sprouts of the main shoot should be eliminated as soon as they appear, since they will inhibit the sprouting of the axillary shoots (TL).

The bed of sawdust should be moistened frequently. If droplets of water do not condense on the inside walls of the humidity chamber, the sawdust is too dry (GB).

Suckers can be returned to the humidity chamber to stimulate additional sprouts which can also be removed (TL).

Shoots originating from axillary buds should be carefully cut away for transplant into bags in a weaning nursery (OB).

DO NOTS in the propagation of plants from axillary buds:

1. DO NOT allow the main sprout to grow undisturbed;
2. DO NOT damage axillary buds when leaf sheaths are being removed;
3. DO NOT leave excess leaf sheath covering axillary buds;
4. DO NOT allow the temperature in the humidity chamber to elevate excessively or allow the chamber to dry out.

Poorly prepared suckers will produce few sprouts from axillary buds **NOT** acceptable CS).

The growth of the main sprout will suppress growth of axillary buds **NOT** acceptable (CS).

Key practices for purchasing vitroplants:

1) request certification that superior mother plants of the desired cultivar for the climatic conditions of the production zone were used;
2) request certification of mother plants from zone free of bacterial (*Ralstonia and Xanthomonas*), viral (BBTV and BBrMV) and fungal (Fusarium TR4) wilts;
3) request certification of virus testing of mother plants for BBTV, BSV, BBrMV, CMV and other viruses. For BSV in plantain AAB, IC-PCR indexing should be used;
4) request certification of vitroplants free of bacterial (especially *Ralstonia* and *Xanthomonas*) and fungal (especially Fusarium Tropical Race 4) infections;
5) request certification that a maximum of 1000 plants are generated from a single shoot tip;
6) request guarantee that off-types will not be greater than 5%. If the percentage is greater than 5%, replacement plants should be provided at no extra charge.

DO NOT for purchasing vitroplants:

1. DO NOT purchase vitroplants without certification of quality of mother plants, of virus testing procedures and of lack of contamination of bacteria and fungi.

Vitroplants may perform poorly in the nursery and the field due to contamination by bacteria or fungi in the laboratory (TL).

Viruses can be introduced through vitroplants if virus testing is not rigorous (MLC).

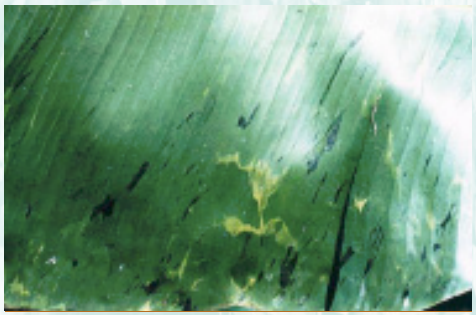
Key practices for growing out microcorms, plants from axillary buds and vitroplants in weaning nurseries:

1) select a well drained site with easy access to clean uncontaminated water for irrigation;
2) to reduce the risk of infection of plants from nearby banana plantations, especially by insects, including ants, screening should be used and the surrounding area of 10 meters width should be kept free of any vegetation;
3) plan for a maximum shade of 50% which can be gradually reduced and then eliminated just prior to transplant;
4) prepare a clean substrate rich in organic matter and adequate nutrients for initial vigorous plant growth and free of nematodes and possible contamination with bacteria and fungi;
5) at regular intervals, eliminate off-types, plants lacking vigour and plants with disease;
6) increase the space between nursery bags as plants grow larger and leaves begin to overlap.

The nursery site should be well drained with good air circulation and easy access to water (IVDB).

The substrate should be free of contaminating pests and diseases, but also rich in organic matter and nutrients (LP).

All off-type, unhealthy or slow-growing plants should be eliminated (QDPI).



Tips on growing out plants in weaning nurseries:

1. DO NOT use soil contaminated with plant parasitic nematodes;
2. DO NOT use excess or uneven shade;
3. Isolate the structure from possible contamination from outside (by insects and irrigation water);
4. DO NOT forget to rogue unhealthy, off-type or slow-growing plants;
5. DO NOT maintain plants too crowded as this restricts access to light and good air drainage;
6. DO NOT forget to sort plants by size and number of leaves;
7. DO NOT maintain plants too long in the nursery.

DO NOT maintain excess shade. As plants grow larger, they can tolerate and use effectively more light (PC).

DO NOT mix small plants with taller plants (PC).

DO NOT crowd plants. As they grow taller and develop more leaves, they need more space per plant (CS).

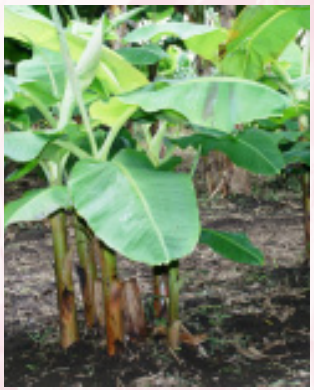
CHAPTER 8: How to decide which method to use – the production of large quantities of high quality, clean planting material takes a long time

The major challenge for the production of clean, high quality seed is choosing the appropriate technique for the local pest and disease problems and then planning the multiplication process to have the plants available for timely planting. This is especially important in rain-fed plantations when planting is completed only during a few months of the year.

Below are several multiplication programmes combining different techniques which have been described earlier in this section. These provide a general guideline on the time period needed and the multiplication efficiencies. Depending on the service infrastructure and land and labour costs, options may be more viable and cost-effective in some localities than in others.

Corms (PC).

Microcorms (PC).



Corm multiplication in plots (PC).

Axillary buds (TL).

Vitroplants (YM).

Combination of several methods (PC).

Alternative programmes to produce 50,000 plants when serious diseases requiring off-farm propagation are present

The use of locally-produced suckers for direct planting, sucker multiplication plots, microcorms or plants from axillary buds represents a very high risk of multiplication of certain diseases which may be present. The only options available depend on *in vitro* multiplication with clean shoot tips thoroughly indexed free of virus. The initial emphasis in these multiplication programmes should be on disease-free material, but over a period of 5-10 years, the selection process should also include the identification of superior clones with a high and uniform production potential.

Option 1 (see table 1 next page) is more applicable where vitroplants are inexpensive and the re-infection rate is high. This approach is used in Taiwan under threat from Fusarium wilt, and in the Philippines where BBTV pressure is very high. Under such conditions the use of sucker multiplication plots represents a high risk of re-infection before plants from axillary buds can be implemented.

Option 2 (see table 1 next page) is demanding in terms of the protective measures during several stages, but may be applicable where the risk of re-infection is lower, where tissue culture plants are more expensive or lab facilities are limited and when the cultivar is primarily of local interest.

Table 1. Options for planting material multiplication where quarantine diseases are present

Option 1: Vitroplants			**Option 2:** Vitroplants, sucker multiplication plot, plants from axillary buds		
Steps	Time (months)	Factors in multiplication	Steps	Time (months)	Factors in multiplication
Selection, indexing, cleaning of 55 virus and disease-free shoot tips of desired cultivar	6 to 12	Small losses due to shoot tip survival and multiplication	Selection, indexing, cleaning of 2 virus and disease-free shoot tips of desired cultivar	6 to 12	Small losses due to shoot tip survival and multiplication
Production of 55,000 vitroplants	6 to12	1 shoot tip yields 1000 vitroplants	Production of 210 vitroplants	8 to 10	1 shoot tip yields 1000 vitroplants
Hardening and weaning nurseries to produce 50,000 plants in insect proof conditions. Indexation (virus + bacteria) for between 1/100 and 1/1000 plants at the end	2 to 3	8-10% loss due to off type plants, damaged containers, plants not surviving transplant	Hardening and weaning nurseries to produce 205 plants	2 to 3	Loss of 8-10% due to off types, damaged containers
			High humidity chamber with 2000 suckers	6	1 sucker yields 25 plants from axillary buds
			Weaning nursery with 50,000 plants	2 to 3	Small loss due to damaged containers and plants not surviving transplant
Total	14 to 27			32 to 44	

Alternative programmes when serious diseases requiring off-farm methods are absent

In regions where diseases often subject to quarantine are absent, there are numerous options to produce clean planting material. The primary challenge is to reduce nematodes in planting material as well as other diseases mentioned earlier. The major challenge in such regions is developing superior clones with a high and uniform production potential. The use of *in vitro* multiplication is not illustrated among the options below, but may be very effective once superior clones have been identified.

Options 3 and 4 are most applicable when there are already abundant areas of the desired cultivar (Table 2). When the source of mother plants is more limited, then a longer time period is required as shown in Options 5 and 6 (Table 3). When very few suckers are available to multiplication, an even longer time period is required to reach the target of 50,000 plants as shown in Options 7 and 8 (Table 4).

Table 2. Planting material multiplication from fields in production (quarantine diseases absent)

Option 3: Suckers from plantation for direct planting			**Option 4:** Microcorms from plantation into weaning nursery		
Steps	Time (months)	Factors in multiplication	Steps	Time (months)	Factors in multiplication
15-20 hectare field (1000 plants/ha) planted for production from which suckers extracted	10	1 plant yields 2 to 5 suckers	15-20 hectare field planted for production from which microcorms extracted	8	1 plant yields 2 to 5 suckers
50,000 suckers pared and treated for planting	0.5	Small losses due to suckers not sprouting	microcorms pared, treated and grown out in nursery	2	Very small losses of plants not surviving transplanting
Total	10 to 11			10	

Table 3. Planting material multiplication from sucker multiplication plots (quarantine diseases absent)

Option 5: Sucker multiplication plot			**Option 6:** Microcorm multiplication plot, microcorm nursery		
Steps	Time (months)	Factors in multiplication	Steps	Time (months)	Factors in multiplication
2 hectare field planted for production from which suckers extracted	10	1 plant yields 2 to 5 suckers	2 hectare field planted for production from which suckers extracted	8	1 plant yields 2 to 5 suckers
1 hectare sucker multiplication plot (50,000 plants/ha) from suckers pared and treated	10	1 plant yields 10 suckers	Microcorms pared, treated and grown out in nursery	2	Very small losses of plants not surviving transplanting
			1 hectare microcorm multiplication plot (50,000 plants/ha) from suckers pared and treated	8	1 plant yields 10 microcorms
			Microcorms pared, treated and grown out in nursery	2	Very small losses of plants not surviving transplanting
Total	20			20	

Table 4. Planting material multiplication with plants from axillary buds (quarantine diseases absent)

Option 7: Plants from axillary buds from suckers from a field in production			**Option 8:** Plants from axillary buds generated from a sucker multiplication plot		
Steps	Time (months)	Factors in multiplication	Steps	Time (months)	Factors in multiplication
1 hectare field planted for production from which suckers extracted	10	1 plant yields 2 to 5 suckers	100 plants planted for production from which suckers extracted	10	1 plant yields 2 to 5 suckers
2100 suckers into high humidity chamber	6	1 sucker yields 25 plants from axillary buds	250 suckers in multiplication plot from suckers pared and treated	8	1 plants yields 10 corms
Weaning nursery with 50,000 plants	4	Small loss due to damaged containers and plants not surviving transplanting	2100 suckers into high humidity chamber	6	1 sucker yields 25 plants from axillary buds
			Weaning nursery with 50,000 plants	4	Small loss due to damaged containers and plants not surviving transplanting
Total	20			28	

CHAPTER 9: Keys to improved farmer planting material - services, materials and information and who provides them

Choosing among the options described above, or putting together an alternative based on a unique combination of the different approaches, requires matching the threats and opportunities faced by banana growers with the requirements in terms of materials, services and information needed to implement the alternative. This can be a relatively simple task involving few changes or a complex challenge requiring infrastructure development and human and institutional capacity building in the medium term.

In developing an action plan for improving farmer planting material, the first questions to answer are what do we want to achieve and who needs to know what in order to achieve the improved situation?

In the case of countries or regions with no diseases requiring special off-farm services, two major areas deserve attention:

1) Quarantine services need to be strengthened to ensure that the country or region remains free of such diseases as BBTV, Moko (*Ralstonia*), BXW (*Xanthomonas*) and Fusarium Tropical Race 4;

2) Capacity building can focus on a relatively few technical staff who direct and execute plant quarantine procedures, with public awareness efforts directed at those who might represent higher risk by inadvertently introducing diseased materials.

There are also opportunities to strengthen farmer capacity to use planting material from superior mother plants and with lower risk of weevil and nematode infestation. Through improved teaching materials and field exercises for technical high schools, universities and extension training programmes, farmers would be more likely to receive technical assistance in quality planting material.

When a disease such as BBTV is present and spreading, the challenges are numerous simply to avoid catastrophic losses. BBTV is present is Australia, Philippines and the Democratic Republic of Congo, countries with widely varying infrastructure and human resources to implement solutions. Australia is currently trying to eradicate BBTV after many decades of limiting its impact and spread. Philippines is currently developing a clean, BBTV-free seed programme for important local market cultivars based on a highly efficient tissue culture sector which serves primarily the export banana farms. An earlier attempt to provide virus-free planting material through university tissue culture labs had limited impact, but universities are key players in training technical staff and farmers. In DR Congo BBTV has spread across the country into the remote fields of small farmers over several decades, during which time public and private sector services were collapsing due to civil strife. Australia and Philippines have different expected outcomes with different information delivery to different stakeholders. DR Congo is only beginning to mobilize public sector agencies to discuss the need for action.

To address improved planting materials for farmers, public and private sectors in Australia and Philippines have key services, materials and human resources such as virus testing laboratories, private tissue culture companies, virologists and field plant quarantine officers. DR Congo, on the other hand, faces two challenges: to determine the additional services, materials and human resources that are needed to provide BBTV-free planting material and then to implement a strategy beginning in zones with the lowest cost and highest likelihood of success.

This illustrated guide has drawn on decades of research and development on more efficient and effective planting materials. However, the implementation of effective programmes which facilitate farmer use of higher quality planting material still offers a considerable development challenge beyond the details and key practices of the different multiplication methods.

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Glossary

Abiotic stress
Factors which reduce banana plant growth rate and bunch size such as excess or lack of water, lack of macro- or micronutrients, excess of toxic elements, temperatures outside the optimum range for growth and yield and less than optimum levels of light.

Bract
Specialized leaf, which develops in its axil only one flower or inflorescence.

Decapitation
Destruction, prior to the emergence of the flower, of the source of new leaves and the flower at the center of the pseudostem to stimulate new sucker formation.

Exudate
Plant sap which is formed when tissue is cut or damaged.

False decapitation
Impedance of the emergence of the flowering bud by means other than destruction (see decapitation) which also stimulates new sucker formation in a sucker multiplication plan.

Hardening nursery
Initial nursery for the artificial acclimatization to *in vivo* conditions of plants grown *in vitro*. A high humidity environment with moderate temperatures is required. Temperature fluctuation and wind should also be avoided. This environment allows the plant to root and generate leaf area before transfer to a weaning nursery. Once plants are actively growing, they are transplanted to larger container and are described as *ex vitro* plants.

High density planting
Monoculture production system with annual cycles (or one cycle) that should be considered as a new production technological alternative whose base is high planting density which depends on several supporting and complementary activities. It can be described as a cumulative system where each eliminated component (density greater than 2500 plants/ha, uniform seeds, no suckers, no direct planting, water control, etc.) reduces the total expected production. (Source: Rosales FE et al. 2010. Practical guide for plantain production using high density planting).

Meristem
A localized region of rapidly dividing, undifferentiated cells from which new cells arise that differentiate into specialized tissues. Meristems are found in growth areas, e.g. shoot and root tips. In banana, the apical meristem is first vegetative and then reproductive (inflorescence). (Source: Lassoudière, 2007. Le bananier et sa culture).

Monoclonal lines
Intensive selections of highly productive individual plants with desirable characteristics multiplied through tissue culture resulting in highly uniform plantations based on limited genetic variability.

Weaning nursery
In a weaning nursery growing conditions for tender plants are gradually shifted from partial shade to full or almost full sun. This process is useful to allow planting material which is small with limited growth potential to generate additional roots and leaf area. The purpose of a weaning nursery is to prepare plants for transplant to field conditions with an increase in light and greater fluctuations in temperature, relative humidity and water.


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