Watering of a tree nursery in Yangambi - DRC

Photo credit: Axel Fassio/CIFOR

CHAPTER 13

Commodity tree crop planting material infrastructures in Africa

Alice Muchugi, Antoine Kalinganire, Joyce Chege, Isaac Nyoka

Highlights

- Commodity tree crops planting material infrastructure varies with tree species, the level of tree species improvement and the different stakeholders involved in the species production.
- In Africa, smallholder farmers access superior planting material through organised systems such as the cooperatives, unions or out-grower schemes, but a significant number still access material through private nurseries where quality is not assured.
- National research centres play a big role in acquisition of improved commodity tree germplasm by farmers; however, large scale farmers and corporate enterprises may have their own tree germplasm supply systems
- Vegetative propagation is a common method for most commodity tree crops to produce genetically uniform planting material faster.
- The main challenges to access quality planting material by smallholder farmers are financial and distribution networks.

1. Introduction

There are several commodity tree crops cultivated across Africa; this chapter focuses on cashew, coffee, cocoa, oil palm, rubber, tea and shea as major commodity tree crops in Africa. Some of these commodity crops (cashew, cocoa, rubber and tea) were introduced during the colonial era to supply high-quality raw materials for the western world. Planting material of these crops was introduced from other regions to establish large scale plantations (Jain and Priyadarshan 2009). The colonialists also pioneered the selection and improvement of native tree commodities such as coffee and oil palm. Agricultural reforms that came in after independence led to a significant number of African farmers growing these tree crops on a small and medium scale.

Muchugi A, Kalinganire A, Chege J, Nyoka I. 2021. Commodity tree crop planting material infrastructures in Africa. In: Minang PA, Duguma LA, van Noordwijk M, eds. 2021. Tree commodities and resilient green economies in Africa. Nairobi, Kenya: World Agroforestry (ICRAF).

Currently, production can be categorised into large estates, medium-scale and smallholder operated private companies, individuals, cooperatives and out-grower schemes. The latter arrangement has mainly been promoted as a way of integrating smallholders into global value chains. Contrary to common beliefs, smallholder farms are increasingly competitive with increasing land scarcity, and industrial estates have no inherent advantage in growing these crops considering long-term sustainability horizons (Byerlee 2014).

Presently, access to planting material of the different tree crops is quite varied and is controlled by different players as mandated by national institutions or private companies. Breeding and improvement of these commodity tree crops are mainly carried out by government-owned research institutions, which then avail the improved planting material to farmers via farmer cooperatives or other established local authorities (Figure 13.1). In some countries, some private individuals also undertake the multiplication of the improved planting material (Mbowa et al 2014). Large estates/plantations have invested in systems to procure their planting material, whereas smallholder growers may rely on cooperatives and out-grower schemes or informal markets (Asare et al 2018) for supply.

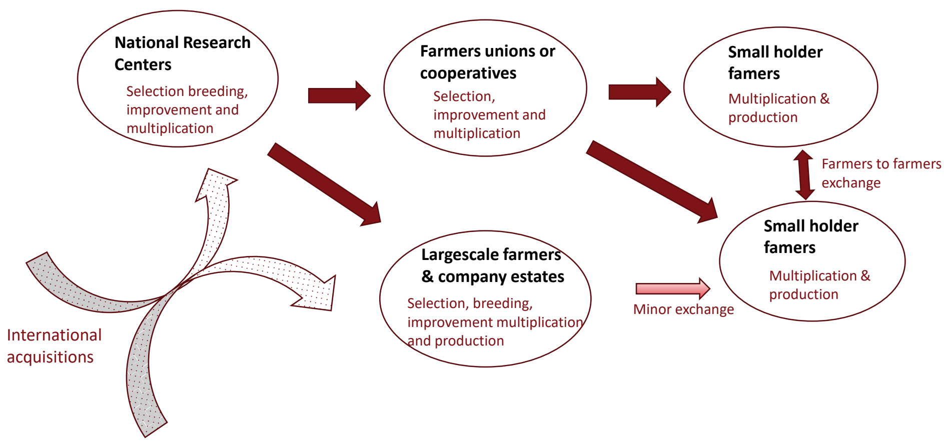

Figure 13.1: *A schematic presentation of tree commodities planting material pathways*

Although access to quality tree germplasm is key in sustaining smallholder farmers in the production value chain, this has been a challenge. Nyoka et al (2014) document that up to 73% of smallholder farmers generally source the bulk of their seeds and seedlings through informal channels. In some instances, smallholder farmers source their tree planting materials from local nurseries which are not registered or under any regulatory control. Therefore, the quality of planting material may be questionable as these nurseries raise seedlings from easily accessible seed sources and wildings. Since good quality germplasm remains a limiting factor to increased productivity on farms, continued tree improvement is therefore required to sustain yields and to satisfy various consumer preferences. However, tree crop breeding for improved cultivars is limited by the lack of diversity in the founder germplasm (Jain and Priyadarshan 2009). Fortunately, global germplasm exchange for some tree commodities is possible among specific crop research networks such as the World Coffee Research and World Cocoa Foundation, but varieties developed from these networks often do not trickle down to smallholder farmers.

There are various approaches used in the propagation of commodity crops; some are species-specific. In general, raising tree crops from seeds is cheap and easy. However, most trees are outcrossing; hence seeds will exhibit genetic variability, whereas uniformity in quality is desired. Using vegetative propagation methods ensures the production of genetically identical plants with particularly favourable combinations of traits. It also solves the problems related to poor seeding or recalcitrant seed, the ability to propagate individuals of known seedling sex- in the case of dioecious trees and reduces the time between planting and first fruiting (Table 13.1). There are several vegetative propagation methods available and researchers have optimised vegetative propagation methods for these commodity tree crops, as summarised in Section 2 below. Among the selected tree crops, coffee, cocoa and oil palm are also propagated using certified seeds. However, the seeds are semi-recalcitrant and cannot be stored for long and this may affect the seed distribution network.

Table 13.1: *Possible reductions in time to first fruiting through vegetative propagation for seven important indigenous African tree species. (Adopted from Tchoundjeu et al 2012)*

Species	Planting to first fruiting, from seed (period in years)	Planting to first fruiting, vegetative propagation (period in years)
Allanblackia spp	12	5
Baobab (*Adansonia digitata*)	> 10	4
Ber (*Ziziphus mauritiana)*	2	0.5
Bush mango (*Irvingia gabonensis* and *I. wombolu*)	7	3
Safou (*Dacryodes edulis*)	5	2
Shea tree (*Vitellaria paradoxa*)	20	<5
Wild loquat (*Uapaca kirkiana*)	12	4

Tree crops require proper husbandry to ensure a fast growth rate and optimised production. Some of the tree crops such as coffee and cocoa have been found to perform better under shading, and suitable shade trees have been identified to develop the tree crop agroforestry. However, it is important to review the choice of shade tree species as some species may be highly competitive for water or nutrients and/or provide too dense shade, leading to a decrease in yields. In addition, certain shade tree species can suppress certain pests and diseases while others can increase their incidence and severity.

2. Technical aspects on propagation and improvement of commodity tree planting material

The genetic quality of planting material of tree crops determines productivity, including the quality of end-products. The adoption of improved varieties by farmers is a key contributor to productivity improvement on small farms and ought to be strategically supported. Small farms need special assistance, including support on agricultural inputs, to become successful and profitable (Lillesø et al 2018).

Appropriate propagation methods of key tree crops are briefly discussed under respective crops. Such approaches include grafting, stem and leaf cuttings (macro-propagation), and *in-vitro* tissue-culture techniques such as meristem proliferation (micro-propagation), organogenesis and somatic embryogenesis. The most common vegetative propagation methods in Africa for smallholders are grafting and cuttings, and these vegetative propagation methods are easily adopted by farmers and rural tree nurseries to produce genetically uniform stock for planting faster. The propagation method has been called the Rural Resource Centers (RRCs) approach (Figure 13.2) is used to mass-produce and distribute selected genotypes of key tree species under domestication (Takoutsing et al 2014). RRCs are community-managed centres that offer farmers access to resources, knowledge, interactive learning, and linkage to networks that include training in group dynamics, entrepreneurship, nursery development, seed and seedling production, tree propagation, post-harvest processing, storage and marketing. The model has been used to transfer tree improvement technologies and to distribute elite planting material of several other tree species such as *Dacryodes edulis*, *Allanblackia* spp., *Tamarindus indica*, *Vitellaria paradoxa* and *Ziziphus mauritiana.* In Cameroon, the model initiative won the prestigious UNDP Equator prize in 2010. In research and commercial enterprises, techniques such as tissue culture and micropropagation are also used to produce clean, uniform planting material. Box 13.1 presents an example of the use of mass propagation to avail clean cocoa planting material.

Despite the improvement in propagation techniques for the commodity tree crops, access to superior germplasm remains a challenge (Mbowa et al 2014). Thus, there is a need to establish efficient seed and seedling supply and distribution systems, ensuring that smallholder farmers' planting materials demand is met and supplied satisfactorily. A better strategy for access and use of quality germplasm by smallholder farmers would indeed consider existing selected/adapted

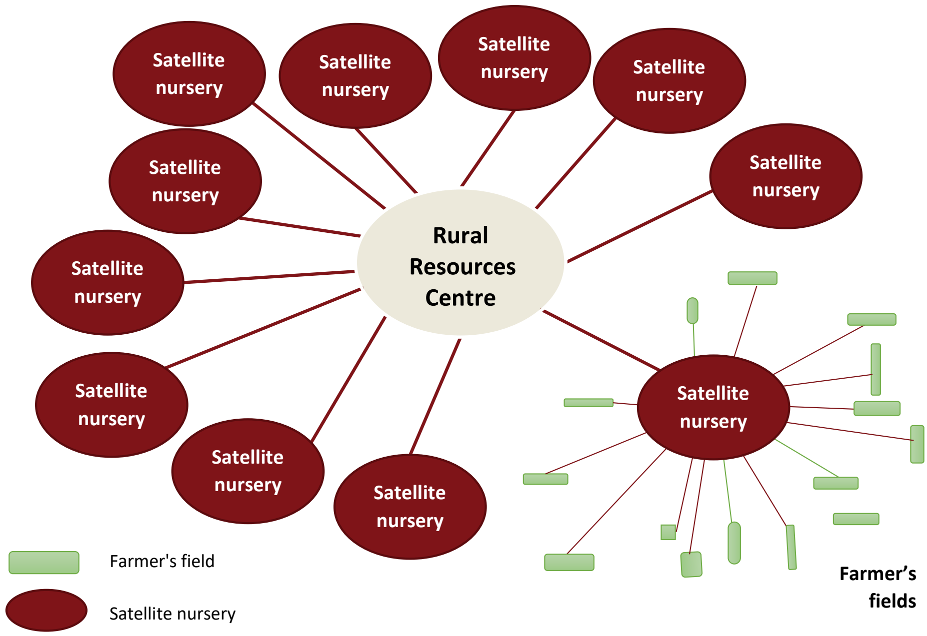

Figure 13.2: *Rural Resources Centre model used in distribution of tree germplasm. One Rural Resources Centre serves 10-30 satellite nurseries, and one satellite nursery serves 20-50 farmers*

tree crop varieties responding to their needs, local seed and seedling networks, including the establishment of suitable germplasm sources for respective tree crops. In some instances, farmers may employ *in situ* grafting technique to improve the qualities of their established trees. In this technique, scions are collected from trees with desired characteristics and are grafted onto an already established tree in the farmer's field. The technique is commonly used in coffee and shea tree improvement.

Since most tree commodity crops are cultivated outside their native ranges, they provide an excellent example of how international transfer of plant genetic resources (both for breeding purposes and simply for planting by farmers) has been and will continue to be important for supporting smallholders' livelihoods (Dawson et al 2014). In most cases, transfer of germplasm involves few individuals, as is the case of botanic gardens and arboreta, hence low genetic variation, thus resulting in poor field performance. For example, cashew plantations in West Africa were originally based on seedlings transferred from Latin America, as is the case for rubber (Priyadarshan et al 2009). Therefore, with the importance of the production of these commodities for smallholders, further investments in genetic improvement, in the delivery of improved cultivars, and in better farm management have wide benefits (Jain and Priyadarshan 2009).

The adaptability to smallholders' marginal production conditions, including poor soils, limited use of inputs and poor management practices, and the quality of end-products are essential in the improvement of commodity trees. The main steps involve identification and genetic selection of superior populations and desired phenotypes in such populations (e.g. shea tree), followed by recurrent rounds of testing and selection. Other important phases include the screening and mobilisation phases, where populations and individuals with desired phenotypic traits are identified, selected and evaluated under smallholder farmers' conditions and requirements. The breeding phase is where superior genotypes are crossed, and progenies from these crosses are tested in farmers' fields, new selections are made, crossed and evaluated over successive generations. The breeding program of tree crops would thus involve several successive cycles of crossing and genetic selection. A proposed shea breeding program is given in Figure 13.4, and other examples include breeding models for cashew (de Paiva et al 2009), cocoa (Monteiro et al 2009) and rubber (Priyadarshan et al 2009).

Tree commodity crops native to Africa such as shea, oil palm and coffee are under threat due to deforestation and habitat loss following agricultural expansion for food and other tree crops production (Dawson et al 2014). As the forests of sub-Saharan Africa keep dwindling and protected areas become difficult to manage and control, agriculture-based approaches for

Box 13.1

Mass propagation of elite germplasm under the Vision for Change Project in Cote d'Ivoire

The Vision for Change project is a collaborative initiative with several partners among them World Agroforestry and the Mars Inc that was being implemented in Cote d'Ivoire (CDI). The project aimed to increase access to improved clean planting material, strengthen farmer capacity and demonstrate improved cocoa farming rehabilitation technologies. This was in response to major production challenges being experienced in CDI namely aging cocoa orchards, depleted soils, insufficient improved planting material and emerging pests and diseases (Kouame 2013). The project employed micropropagation (tissue culture and somatic embryogenesis; Figure 13.3) to mass propagate clean elite clones that were later distributed to smallholder farmers to revive cocoa farming. The project was scaled up using village cocoa centres that are equivalent to the RRC model.

Figure 13.3: *Cacao plantlets production through somatic embryogenesis: a. primary embryos induced from callus b. germinated embryos c. explants d. plantlets ready for transplanting*

Credit: ICRAF-CDI Tissue Culture Laboratory safeguarding the diversity of native tree crops are becoming increasingly important. Therefore, as tree commodity species are highly valued by farmers, it is crucial that their genetic resources be managed and conserved on farms and *ex-situ* genebanks by various interested parties, e.g. governments, private sector and farmers' associations for further improvement/breeding and scaling-up.

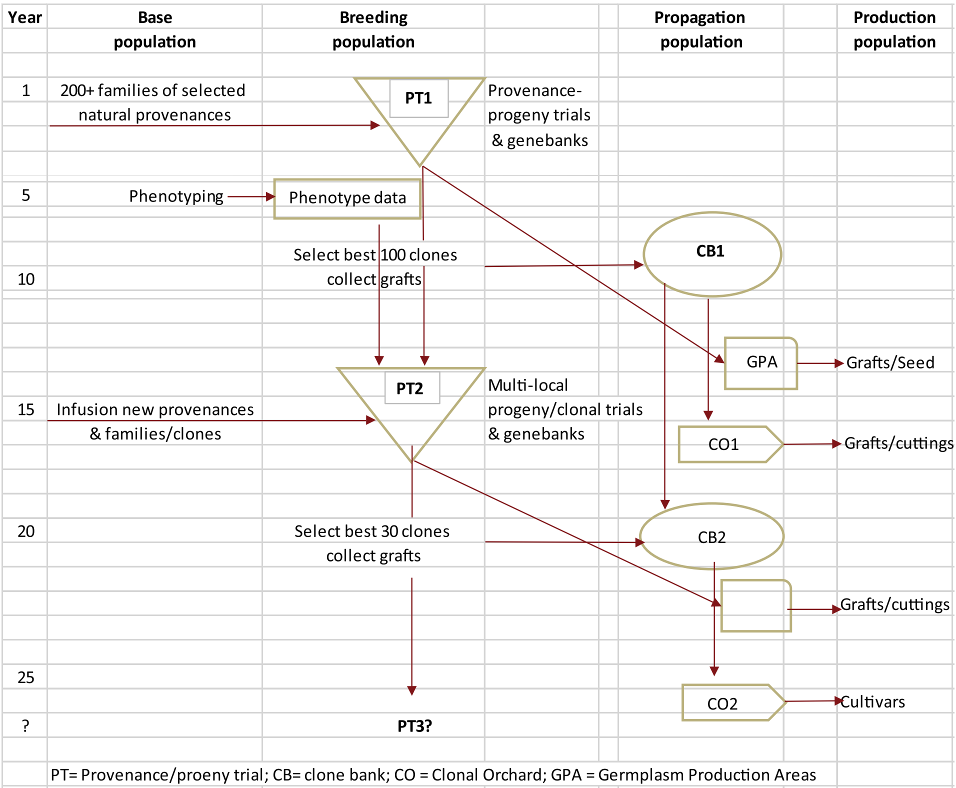

Figure 13.4: *Shea (Vitellaria paradoxa) breeding strategy in the Sahel.*
(Antoine Kalinganire 2019: unpublished data)

3. Selected tree commodities planting material infrastructure in Africa

This section gives an overview of the propagation methods adopted for each of the selected tree crops and their improvement/breeding efforts to produce high quality, genetically superior planting material. The selected tree commodities grown widely in the African tropics include cashew nuts (*Anacardium occidentale*), cocoa (*Theobroma cacao*), coffee (*Coffea arabica* and *C. canephora*), palm oil (*Elaeis guineensis*), rubber (*Hevea brasiliensis*), shea butter (*Vitellaria paradoxa*) and tea (*Camellia sinensis).*

3.1. Cashew (*Anacardium occidentale* L.)

Most cashew production in Africa is undertaken by about two million poor smallholders who own an estimated 70% of cashew farms. The main producing African countries are Nigeria, Côte d'Ivoire, Tanzania, Mozambique, and Guinea Bissau, while countries such as Ghana, Burkina Faso, and Benin are currently expanding areas under cultivation (Oluyole et al 2017).

Smallholder farmers manage their cashew trees in mixed farming systems. Cashew is established amongst short-term intercrops, and intercropping is continued if space and soil fertility allow. The cashew tree is propagated either from seedlings or from vegetative material. Cashew planting materials by smallholders are usually unimproved open-pollinated seed nuts that do not breed true to type (Adeigbe et al 2015). Vegetative propagation (true-to-type seedlings) provides the most reliable progeny because the tree is highly cross-pollinated, and the yield of clones is better than that of trees raised from seeds.

The major obstacle in the production of cashew is the unavailability of large quantities of high yielding elite varieties for multiplication. Moreover, the conventional vegetative propagation methods, viz. air layering, grafting or cutting, are not rapid enough to meet the need for elite varieties in time. Micropropagation techniques, particularly somatic embryogenesis, offers prospects for fast multiplication of elite genotypes (Martin 2003). Since the phenotypic expression is a function of genotype and environment interaction, the expected level of productivity may not be realised due to insect pests (stem girdler, foliage thrips, fruit scrapper, stem and root borer), diseases (floral shoot and twig die-back, root-rot, anthracnose, powdery mildew and damping off), poor soil nutrition, as well as poor agronomical practices.

Therefore, there is a need to provide avenues for increased and sustained cashew production in Africa. This may require strengthening research and extension institutions to adequately address constraints in production and to provide credit to producers. Breeding would target increased production/yield of nuts, big kernel size, apple quality, and tolerance to diseases and pests. Furthermore, a bigger and juicy apple would be additional traits that need to be considered. Easy kernel removal would be a desirable trait in cashew breeding. Drought tolerance is a relevant attribute in the evaluation of genotypes. Thus, there is a need to produce cashew varieties/clones with improved yields and quality as well as standardise effective propagation methods to clone them (Refer to de Paiva et al 2009 for cashew breeding techniques).

Most farmers suffer poor access to improved cashew planting materials owing to inadequate dissemination capacity in target countries. Most producer countries rely on poor or inadequate, undocumented sources of clonal materials that barely meet the needs of expanding cashew cultivation. Cashew yield enhancement is impaired mostly by limited access to elite genotypes/ clones by smallholders. To avoid farmers travelling long distances for the acquisition of improved planting materials, it is recommended to establish seed gardens at strategic places, e.g. farmer's associations, farmers' cooperatives, rural resource centers etc., that are easily accessible to farmers (Adeigbe et al 2015). Improved elite well-adapted seedlings or grafted materials should be availed to such centers for multiplication and distribution to smallholders. The establishment of such germplasm banks would enhance the use of improved materials available within the reach of smallholders, eradicating landraces of cashew from farmers' fields. Such tree germplasm distribution and delivery systems for improved planting materials have been successful for several agroforestry tree species.

3.2. Cocoa (*Theobroma cacao* L.)

Cocoa trees are typically grown under shade in agroforestry systems (Somarriba and Lopez-Sampson 2018). More than 90% of all cocoa produced worldwide comes from small farms (Lillesø et al 2018). In Africa, planting materials are mainly produced in seed gardens (nurseries). The major constraints in cacao cultivation are aging plantations, depleted soils, poor and insufficient improved planting materials and emerging pests and diseases. Moreover, climatic change and weather variations are threatening yields in the major producing countries. Therefore, there is a need of having cacao-based systems showing increased productivity, tolerance to major pests (e.g. capsid), diseases (e.g. black pod disease) and resilience to climate risks. The cocoa collections represent the base for the cocoa breeders to develop improved varieties for commercial plantings. In these collections, the genes are kept as live plants that can be considered as 'protecting shields' for the development of new varieties whenever new pests or diseases eventually occur (Monteiro et al 2009).

Monteiro et al (2009) detail the breeding approaches for cacao. Moreover, future breeding needs to develop cultivars adapted to shade conditions as most planting materials target sun appropriate varieties. The major objectives of cocoa breeding programmes in Africa are productivity, seed quality (seed size, seed shell, fat content, hardness of the butter etc.), pest and disease resistance. The main sources of planting materials are elite clones introduced from other countries, on-farm selections, and on-station selections through recurrent selection programs. For clones, it is usually necessary to establish clonal trials for verification of the traits for which they were selected.

Though West Africa is the largest cocoa producing region in the world, the use of improved materials such as elite clones remains very low (Lillesø et al 2018). To maintain a livelihood, farmers periodically need to rehabilitate their farms by replacing old trees with high-yielding varieties. Therefore, there are opportunities to promote improved cocoa germplasm to enhance smallholders' productivity (see Box 13.2). To guarantee supply of cocoa scions, clean and affordable planting material for smallholder farmers in Africa, the planting material delivery systems should be organized collectively in central units managed by communities (e.g. Village cocoa centers, RRCs, Farmers Associations and Cooperatives). These centers can initially multiply the released clones through vegetative propagation, mainly grafting. An efficient tissue culture multiplication of the elite clones is needed to support smallholders. Tissue culture propagation system may also be used to salvage elite clones affected by devastating viral cocoa diseases.

3.3. Coffee (*Coffea arabica* L. and *C. canephora* Pierre ex A. Froehner)

Coffee is typically a smallholder crop that produces over 90% of the volume traded in most African countries (Somarriba and Lopez-Sampson 2018), with exceptions for Kenya, Malawi and Zambia, where estates contribute 40%, 75% and 95% of total production, respectively (ICO 2015). Large estates, mostly owned and managed by multinational companies, have their own breeding/improvement programs, whereas smallholders rely on national research programs for improved germplasm, which is mainly distributed through farmer associations and cooperative societies. Smallholder coffee production is characterised by old varieties released over several decades ago from relatively simple selection and breeding programs and often multiplied by seed. These plantings are low yielding, susceptible to diseases and pests, and may be vulnerable to drought and temperature fluctuations.

Cultivars of the self-pollinating *arabica* are true-breeding lines, while those of the outbreeding *robusta* are open-pollinated and cultivars are produced from selected seedlings and clonal gardens. Production is mainly through selected seeds (Figure 13.5) but *in situ* grafting is also practiced to improve established trees with better cultivars. Improved hybrid varieties and micropropagation techniques have been developed (Philippe et al 2009, Lillesø et al 2018). Clearly, more effort and investments are needed for future breeding to develop varieties adapted to shade conditions, rising temperatures, erratic rainfall, reduced soil water availability, diseases and pest resistance. In addition to the respective national coffee research institutes, the World Coffee Research, based in Rwanda, also undertakes coffee breeding and improvement. In several countries, national regulatory organisations are mandated to coordinate the coffee value chain, including the multiplication and dissemination of improved varieties from research institutes. However, smallholder farmers' access to improved material is constrained by the limited availability of production orchards and poor distribution networks (Lillesø et al 2018). Therefore, there is a need to develop a scaling-up strategy for the dissemination of the best-performing varieties of coffee to different coffee production zones and systems. In some instances, entrepreneur farmers have stepped in to fill the gap (CGTN Africa 2017).

Figure 13.5: *Coffee seeds germination.*
Credit: Roger Burger, Wikimedia.org

3.4. Oil palm (*Elaeis guineensis* Jacq.)

Oil palm is grown by smallholders in mixed systems using unimproved 'seeds', including wildings from forests. Improved planting materials are not readily available or accessible to smallholder farmers. Commercial plantations develop their own selected seeds of elite trees. However, segregation in the seed-derived progenies persists (Sambanthamurthi et al 2009); sometimes, elite trees are multiplied clonally using splits. *In-vitro* clonal propagation of superior mother oil palms may offer a better option for faster multiplication. Low palm oil yield production by smallholders is also due to the use of counterfeit seeds (Woittiez et al 2017). Therefore, for scaling-up of elite genotypes of oil palm for smallholders, governments and rural development agents need to support farmers' associations and cooperatives in maintaining community nurseries for multiplication of planting materials from improved (and certified) seed of existing and newly developed varieties.

Genetic improvement programs in Africa should target increasing yield of oil palm primarily designed specifically to suit both African consumers and smallholder farmers. An overview of the breeding strategies and techniques for the species is detailed in Sambanthamurthi et al (2009). Oil palm has a long breeding cycle; therefore, molecular breeding tools are recommended. The genomics approach for selection reduces the number of breeding cycles. Breeding should target varieties of oil palm for cultivation by smallholders that produce non-refined crude oil with improved qualities to satisfy diverse consumer markets, nutritional needs including pro-vitamin A & E, lower saturated fat and improved shelf-life.

As stated by Woittiez et al (2017), improving yields in existing plantations using models that are environmentally sound, while targeting expansion of oil palm cultivation into degraded lands only, appears to be the most responsible way forward for producing sufficient palm oil to meet future demands while preventing further loss of tropical rainforests.

3.5. Rubber [*Hevea brasiliensis* (Willd. ex. Adr. de. Juss.) Muell-Arg].

Rubber is traditionally propagated through bud grafting. Grafting enables the multiplication of elite genotypes. Variations among a bud-grafted population are significant and can influence productivity levels. As tissue culture techniques are yet to make a commercial impact in rubber, propagation approaches that can circumvent the influence of rootstock–scion interactions are needed. One way is to derive somatic seeds that can produce 'true-to-type' mother plants (Priyadarshan et al 2009). There is limited rubber tree breeding in Africa. Any rubber breeding program would aim at providing superior planting material (varieties) mainly for latex and wood production, pest and disease (leaf and root diseases) tolerance and ideotypes that respond better to intercropping. Grafted superior clones would be then introduced in plantations and on farms to maintain the profitability of rubber cropping.

Improving dry rubber yield is the exclusive objective of *H. brasiliensis* breeding. However, resistance to biotic stresses (root and leaf diseases), abiotic stresses (wind damage) and climatic variations (high temperature and moisture deficit) are key for African smallholders. Rubber breeding and selection are exclusively applied to the clonal aerial part of the tree. The choice of seedling families to be used as rootstock is very limited. Among different potential advantages, the possibility of cloning a whole plant *in-vitro* would allow breeding to be applied to the root system for resistance to root diseases (Rivano et al 2013), for better adaptation to specific soils (marginal lands), and for better anchorage (resistance to wind uprooting) of the tree. The development of hybrids that can grow and adapt to different ecozones, including climatic variations, would also be explored. The biochemical and genomics tools would help in accelerating breeding in deriving and evaluating new recombinants/clones in a shorter time. Somatic embryogenesis and meristem culture are key in the reproduction of clones, although not adapted to smallholders' conditions. As rootstocks affect the yield of scions, efforts need to be deployed to produce vigorous hybrid seedlings (monoclonal seedlings) from poly cross, providing better rootstocks or from self-pollinated seedlings.

The production of high-yielding clonal planting material for farmers should be through 'model farms' with rubber-based agroforestry systems and the establishment of 'Rural Resource Centers (RRC)' to produce clonal seedlings by smallholders. Such farms and centers would host nurseries for grafted plants for distribution to farmers. Supporting such initiatives with appropriate rootstocks and clonal mother trees would help scaling-up the production and distribution of improved planting materials to smallholders in African rubber-growing countries. Diversification of clones adapted to various production conditions, mixed agroforestry systems for smallholders would be targeted.

3.6. Shea (*Vitellaria paradoxa* C.F Gaertn.)

Vitellaria paradoxa (Gaertn C. F.) (Sapotaceae), commonly known as Karité in French or Shea in English, is a nutritional and economic resource for women across Africa, providing an annual bounty of fruit, food-oil and cash income for an estimated 10 million households over a wide geographic range from eastern Senegal to northern Uganda (Trade Hub and African Partners Network 2014). The greatest barrier toward conventional improvement of the shea crop is lack of a culture of planting indigenous trees species. However, farmers generally express keen interest in integrating improved shea varieties into their farms, thus providing a strong justification for shea improvement programs (Boffa 2015, Kalinganire et al 2020). Shea butter tree displays a high level of genetic variation within populations.

Shea is not a wild, but a semi-domesticated crop resulting from long-term anthropogenic selection by indigenous farming communities for specific desirable attributes (vigour, fruit productivity and sweetness, and size of the nut, combining ability with crops) through cultivation and fallow cycles (Boffa 2015). Selection in favour of superior trees by farmers may have improved the productivity (fruit yield and useful components of the fruit) of the species, but not to the extent that differences between improved and unimproved trees are easily observed. However, such selection would erode some useful genes, especially those that would help face future climatic scenarios. Selection and management activities by communities have been ongoing for centuries and have profoundly transformed landscapes increasing shea's abundance, gene flow between populations and productivity. Therefore, shea improvement strategy (refer to Figure 13.1) seeks to build upon existing parkland and tree management practices, indigenous know-how and local participation. Due to the long reproductive cycle, most farmers prefer *in situ* grafting of existing trees with scions from better performing trees (Figure 13.6) which can be from their farms or neighboring farmers.

The key objective of shea improvement is to maximise the production and quality of fruits from planted stands, on a per-year and per-hectare basis. The selection criteria include good growth of the tree, precociousness, high fruit production, big fruits, sweet fruit pulp, high oil content of the kernels, no pest and disease attacks, no *Tapinanthus* parasite attack, uniform and balanced crown. The strategy suggests provenance trials and/or genebanks as founding and breeding populations. Selected genotypes of shea can be captured for use in cultivation by seed and vegetative propagation techniques. The range-wide seed collection to be undertaken

Figure 13.6: *Removing lower shoots to encourage apical growth in an in situ grafted shea seedling.*
Credit: Patrice Savadogo, ICRAF Sahel, Mali

during the first stage of the strategy will provide interim resources for an expanded program during which superior populations (provenances) can be identified. Superior trees/provenances are needed to enable the establishment of breeding populations for major ongoing breeding programs, especially in West Africa.

3.7. Tea [*Camellia sinensis* (L) O. Kuntze]

In Africa, tea was originally established in large estates at the beginning of the 20th century and these are still major producers in countries such as Cameroon, Kenya, Malawi and Tanzania. However, after independence, smallholder farmers increasingly became important tea producers across Africa. Pioneer plantations were established with seed collected from landraces in Assam, India and subsequent introductions came from China and Sri Lanka. Tea growing expanded across Africa through clonal multiplication of introduced tea germplasm and later improvement resulting in African landraces. The original tea estates in major tea growing African countries (Burundi, Cameroon, Malawi, Kenya, Rwanda and Tanzania) maintain their individual tea improvement and multiplication programs. Large tea estates have private tea improvement programs and some still serve as sources of improved seedlings to small scale farmers in out-grower schemes. However, after independence, governments formed agricultural research institutes that were mandated to spearhead tea improvement and its multiplication (Figure 13.7) (Kamunya et al 2012). These institutes function as sources of improved planting material that is passed on to small scale farmers through cooperative schemes.

Development of improved planting material is carried out by the mandated national tea research institutes as well as by private estates owned by multinational companies. Tea genetic improvement details have been discussed by Mondal (2009). Tea breeding and improvement goals generally aim to develop varieties that are highly productive and tolerant to biotic and abiotic stress. The African landscape is highly heterogenous and focus should be geared towards developing varieties for adaptability to varying agroecological environments, rising temperatures, drought or frost. Leaf secondary metabolites that impart taste and flavour qualities are increasingly becoming important traits for speciality teas. Conventional tree breeding through hybridisation and clonal selection has been the main route of developing new cultivars. Future research could focus on understanding the mechanisms of biosynthesis and regulation of secondary metabolites for the development of varieties, the genetic basis of agronomic traits and mechanisms of biotic resistance and abiotic stress.

Figure 13.7: *Improved tea seedlings multiplication at the Tea Research Institute Kenya.*
Credit: S.M. Kamunya, TRI Kenya

Vegetative propagation is the most efficient and cost-effective means of multiplying tea planting material for commercial planting. Dissemination of improved planting materials is normally channelled from national research institutes through factories to affiliated licensed nurseries for multiplication of rooted cuttings to smallholder farmers (Kamunya et al 2012). Nursery tea plants are raised from both seed and stem cuttings under shade and the relative ease with which planting material can be produced clonally, has contributed to smallholder farmers adoption of improved varieties. Rooted cuttings are also available from experimental research stations nurseries situated in tea growing regions. Planting material is also sourced through bilateral agreements from major tea producing countries for the development of new cultivars.

4. Social and financial aspects of tree commodities seed and seedling systems

Tree germplasm supply systems consist of three major players, namely the producers, distributors and users, usually the farmers. Tree germplasm supply may be centralized or decentralized, with several variations depending on the actors involved in production, distribution and use (Lillesø et al 2018). Tree germplasm is usually distributed either as seeds, seedlings or grafts. Distribution of tree germplasm is often a challenge in most developing countries where resource-poor smallholder farmers are the major users of the germplasm. Although demand for seed and seedlings is often high, most smallholder farmers do not have the capacity to purchase improved planting material. Both private and public sectors have a critical role to play in the production and distribution of improved germplasm of trees. Private companies on their own will not be able to develop and produce optimal amounts of improved germplasm for some of the tree species for economic reasons, especially if the market is composed of resource-poor smallholder farmers. Unlike hybrid seed of annual crops which is bought annually, tree germplasm usually has a low replacement rate. Farmers require small amounts of the improved tree germplasm infrequently; consequently, private companies often find such a business less profitable. Support in the form of subsidized prices is important to make them affordable to farmers. Only a public entity can afford to invest in an activity with such uncertainty.

Besides pricing, there are also challenges in the distribution of tree germplasm. With tree seeds, the packaging of seed in small quantities has been advocated as most smallholder farmers only require small amounts of seed. The difficulty, however, comes when germplasm is in the form of seedlings or grafted trees. Seedlings or grafted trees are bulky and distribution beyond the site of production results in an increased price of the planting material limiting its availability to many farmers. If benefits of improved tree seedling germplasm are to be realized by farmers beyond the production site, a deliberate subsidy may be necessary as well. There is some social value in subsidizing planting material of important trees, particularly those grown by resource-poor smallholder farmers.

Smallholders in the tropics have become the main producers of tree commodity crops. From a development perspective, there are two aspects to contemplate. On the one hand, from our descriptions of the crops, the efficiency of smallholder commodity production could be substantially improved. On the other hand, the potential of tree commodity crops could become an important vehicle of the structural transformation (Timmer 2014). The main constraints to overcome and improve are institutional and socio-political, rather than technical. Considering the importance of these crops not only for consumers in wealthy countries, but also their potential for improving the livelihoods and incomes of poor smallholders and more generally strengthening the development of societies in the tropics – it should be a highly prioritised goal for governments and development organisations to improve the conditions for smallholder producers, including enhancing their productivity.

Government programs that promote certain tree crops often provide free improved planting material to farmers, as do non-governmental organisations. The history of tropical countries abounds with cases of boom-and-bust cycles, where phases of high prices and rapid expansion of certain tree crops have been followed by economic decline caused by price crashes, emergent pests and diseases, or climate conditions affecting the tree crop. When there is a crop boom, demand for planting material exceeds supply; this presents a business opportunity for entrepreneurs to invest in seedling nurseries. Since tree seedlings production takes time, access to quality planting material cannot be guaranteed and small-scale tree crops farmers end up buying uncertified seedlings. Private seedling nurseries flood markets with planting material of uncertain origin, but because they are established in rural areas, they are more accessible to farmers.

Poor legislative and regulatory frameworks in tree crops seedling systems have adversely affected access to improved planting materials by smallholder farmers. Mechanisms to protect small-scale farmers from unscrupulous seedling producers and traders have not been put in place. In countries where standards have been developed (Chanyenga 2013), the challenge is usually on implementation, as most producers do not adhere to the set standards. On the other hand, farmers themselves are not aware of these standards; consequently, they end up accessing seedlings of unknown genetic, physiological and physical quality. Farmers employ various approaches based on their social networks to access planting material in the face of an ineffective formal seedling system. The extent to which access to improved planting material constraints farmers' decisions differs among crops, and between countries. The decision may be dependent on the availability of improved planting material and the capital to purchase for one crop, while for another crop in the same country, farmers may opt to plant unimproved seedlings even when they are aware of the benefits and availability of improved seedlings (Schroth and Ruf 2014). To some extent, social capital influences crop types, sourcing of planting material and even capital mobilisation.

Land tenure in many African countries is a major issue that could influence the decisions on investing in improved planting material. Migrant farmers can worsen already existing land tenure problems in countries where land is largely customary owned as they pursue land accumulation by planting available low-cost planting material to claim the land, whereas indigenous farmers seeking to maximise profit might decide to acquire improved seedlings. Thus, policies that strengthen land tenure security could influence decisions by farmers to acquire improved planting material. Secure land rights may also enable farmers to access capital for the purchase of improved seedlings.

Generally, the advantages of seedlings raised from seed in tree crops cultivation are that they are cheap and easy to produce, while their genetic variability and the irregularity in flowering and fruiting for some species (e.g. cacao, cashew and shea) may be advantageous. Vegetative propagation (cloning) is a better way of quickly capturing and utilising selected and highly performing plant material to increase the productivity/yield of tree crops plantings and the quality of products. Cloning is prominent for the propagation of tree commodity crops that have been genetically tested for the superiority of individual genotypes across a range of environments (Lillesø et al 2018). However, planting material produced by vegetative propagation is generally more expensive than seed-derived seedlings. Also, vegetatively propagated trees are associated with uniformity and reduced genetic variability as only a few elite clones are usually deployed operationally. The reduced genetic diversity may render the tree crops susceptible to pests and diseases (Gibson and Nguyen 2019, Wingfield et al 2020). Options to use by smallholders need to be adapted to the biology of respective tree crops, access to quality germplasm and to the socio-economic environment of the smallholders. However, due to the specificities of some tree crops, (e.g. coffee, shea tree, oil palm, etc.) seeds/seedlings are easily utilised by farmers. As tropical tree commodities/crops are mainly grown as cash crops, farmers deploy efforts to access inputs enhancing crops' productivity.

5. Implications of challenges of seed and seedling supply systems on the future of tree commodity production

High-quality tree germplasm is essential for establishing productive agroforestry systems or commodity tree crop production systems. When farmers plant trees using germplasm of unknown quality, they take huge risks that can saddle them for a long time as most tree crops are planted and managed for many years before being replanted. Attributes of poor-quality planting material may take many years to be expressed, leaving the farmer to spend money managing trees that will not perform to expectation and consequently produce low yields (of fruits, nuts, timber, fodder, etc.). Poor quality seed and seedlings may be a result of genetics, physical and physiological attributes. Specific losses due to poor quality material include poor growth, uneven growth of trees, poor tree survival, and low yield (timber, fruit, nut, leaf, etc.). The devastating impact of the psyllid insect pest (*Heteropsylla cubana*) was attributed to a narrow genetic base of the seed that had been widely planted by farmers (Rao et al 2000). Trees established from such poor seed and seedlings do not develop into the desired tree and often fail to reach their yield potential. For example, trees established with seedlings that have poor root systems often topple over even in light winds.

The potential impact of high-value commodity tree crops may never be fully realised if the quality of planting material is not addressed. Major issues in the supply of high-quality germplasm include affordable pricing, accessibility, true to type, physical and physiological state. When prices are high, the germplasm is as good as not being available to the farmers as they cannot afford it. Although farmers may be aware of the need for using quality planting material, prices of good quality material from reputable producers are often prohibitive, forcing the resource-constraint smallholders to source from undocumented suppliers where the prices are usually cheaper. In some instances, however, there are cases where farmers are willing to pay for good quality material but are unable to find the material. They usually resort to 'backyard' nurseries or hawkers (see Box 13.2). Farmers who invest a lot of their effort in managing trees established from poor quality planting material will never fully realise the benefits of increased income, food and nutrition security associated with the use of high-quality germplasm. Even the indirect benefits such as environmental services are negatively impacted when poor quality planting material is used.

Box 13.2

Narration of disappointed tree farmer from Zimbabwe

Mr Musayemura Makuyana of Chako farming area, Chipinge, Zimbabwe is a farmer who recently ventured into macadamia. He bought 25 high quality macadamia grafted plants from a private reputable nursery. Since the nursery could not supply more, Mr Makuyana went on to buy a further 48 seedlings from hawkers. He later learnt that the seedlings he bought from the hawkers had been discarded after being judged to be unsuitable (because of coiling roots) by a nursery company. Hawkers collected the seedlings from the damp site and sold them to unsuspecting farmers after misrepresenting to the farmers the source of the seedlings. There are many similar stories of farmers being duped into buying poor quality germplasm.

Nyoka BI, (personal comm.) while engaging with farmers in the field in Chipinge, Zimbabwe.

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