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Editorial

Dear reader

Hello, hoorah... Let the show begin! I've been ready!

Excuse me for this rather unacademic opener, borrowing from (of all 'performers') Alice Cooper, but... you are now looking at the first completely virtual issue of Afrika Focus. This special number is devoted to agroforestry, and consists of several papers that were presented at the 2012 Yaoundé conference organized by ICRAF, the World Agroforestry Centre (www.worldagroforestrycentre.org) and its Agroforestry Tree Products for Africa project (AFTP4A). The latter project contributed to helping poor farmers become more actively involved in agroforestry tree-product value-chains and markets, which in turn helps them increase and diversify their incomes. The project followed the value-chain approach, involving all economic actors who contribute directly to the production, processing, transport and commercialisation of agroforestry products up to the consumption stage.

Towards the end of the AFTP4A project, an International Symposium, `Tree Product Value Chains in Africa: Sharing Innovations that Work for Smallholders´, was organized and held in Yaoundé, Cameroon, from 26 to 28 November 2012. The main conference themes focused on Production, Harvest and Post-Harvest Techniques (theme 1), Collective Actions (theme 2), Policies and institutions (theme 3) and Green markets (theme 4).

This issue of Afrika Focus has 3 contributions on what might be termed domestication and propagation of lesser known tree species from Central Africa. *Gnetum africanum* is a rich source of leaves that has become somewhat overharvested and is therefore threatened in its natural distribution environment. *Dacryodes* is an interesting fruit species that can easily be integrated into existing agroforestry systems in order to make the latter more resilient, and also provide a richer source of vitamins and proteins. *Garcinia* has medicinal value and is thus a profitable source of income for those farmers who grow it. A fourth article deals with the socio-economics of land tenure in a largely agricultural area in Cameroon. Recent economic development is exerting pressure on the people and their production environment, thus making secure rights over land a critical issue.

These contributions are a valuable addition to the growing body of scientific evidence showing that agroforestrees, as we have come to name them, can make important contributions to food safety and nutrition. The latter has been acknowledged by international organisations such as the FAO, which brought the theme to the fore during an international conference held in May 2013. Moreover, the IUFRO is currently preparing a white paper on Forests and Food Security through a high-level panel of global forestry experts, and it is expected that the latter will attract substantial amounts of donor money to finance research and development on the role of trees and forests for nutrition and food.

So, enough food for thought... By the way, Alice Cooper goes on to sing:

Ready as this audience that's coming here to dream
Loving every second, every moment, every scream
I've been waiting so long to sing my song...

So, I hope you will indeed like the 'tune' of this first-ever fully digital issue of Afrika Focus – we will be interested to hear your comments!

Patrick Van Damme
Editor-in-Chief

Nursery substrates and provenances influence rooting performance of juvenile, single-node vine cuttings of *Gnetum africanum* Welw. (Gnetaceae)

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Gnetum africanum Welw. (Gnetaceae) is a forest vine that is highly valued for its leaves which are a source of food and income. Because wild populations are threatened by over-harvesting, there is an increasing need to cultivate the plant, which in turn entails a need for developing good quality planting material. This study investigates the effects of four provenances, four substrates and their interactions on rooting and shoot development of vine cuttings of *G. africanum* using the non-mist propagation system developed by ICRAF. Single-node, half-leafed vine cuttings were used and data on rooting and leaf production were collected monthly from the second to the fifth months. Rooting percentages were subjected to analysis of variance using logistic regression procedures in Genstat version 12. Provenance ($P<0.001$), substrate ($P<0.001$) and interaction between provenance and substrate ($P<0.001$) showed highly significant effects on rooting. Excel was used to determine rooting percentages, with the highest observed in fine sand on cuttings from Lekie-Assi (81%) and Boumnyebel (79%) which are high *G. africanum* exploitation areas in the Centre Region of Cameroon. Boumnyebel showed a significantly higher shoot development than the other provenances. Fine sand and sharp sand can be recommended for rapid, low-cost production of *G. africanum* planting material.

Key words: domestication, rooting substrate, non-mist propagator, vine cuttings

Introduction

Vegetative propagation of plants is the process whereby an exact copy of the genome of a mother plant is produced. This is made possible because the system uses meristematic, undifferentiated cells that can differentiate into organs necessary to form a whole new plant (Wiesman & Jaenicke, 2002). The classic approach is propagation by stem cuttings, in which roots are induced to form on a piece of stem detached from a donor plant (Libby, 2004). Several endogenous and exogenous factors such as water and energy status, hormonal balance, mineral and health status of cuttings, age of the cutting, propagation environment and stock plant management influence the success of this process (Wiesman & Jaenicke, 2002). Adequate stock plant management gives the opportunity to enhance the rooting ability of cuttings by providing the appropriate morphological and physiological conditions for shoot development (Leakey, 2004).

Gnetum africanum Welw. (Gnetaceae) is an understorey liana found in the humid tropical forests of Nigeria, Cameroon, Central African Republic, the Republic of Congo, Gabon, Democratic Republic of Congo and Angola (Mialoundama, 1980). Some thirty species of the genus *Gnetum* occur in the tropics, but only two of these, *G. africanum* and *G. buchholzianum*, are found in Africa (Mialoundama & Paulet, 1986). In Cameroon, *G. africanum* is often found in fallow farmlands and secondary and closed forests. The vines climb on trees, saplings and shrubs for support in the complex tropical humid forest where they grow abundantly producing great quantities of leaf biomass (Shiembo *et al.*, 1996). *G. africanum* has a tap root system, bearing numerous hair roots (Onguene & Kuyper, 2001) and is capable of generating root suckers, as offshoots of lateral adventitious roots (Halle *et al.*, 1978; Nkefor *et al.*, 2000). This suckering can be quite prolific in the wild, suggesting that vegetative regeneration is important (Sunderland, 2001). *Gnetum* is shade-tolerant and does not do well in full sunlight (Schippers, 2000; Shiembo, 1997). However, *G. africanum* growth may be favored by forest disturbance, which may explain its abundance in degraded forests, bush fallows and crop fields (Fondoun & Tiki Manga, 2000; Mialoundama, 1993). Ectomycorrhizae (*Scleroderma sinnamariense*) have been found in association with cultivated and wild *Gnetum* plants (Limbe Botanic Garden, 1998; Onguene, 2000) and this symbiotic relationship is believed to enhance the species' ability to take up nutrients from the soil. According to Bechem and Alexander (2012), plants of *G. africanum* are almost always colonized by ectomycorrhizae, suggesting that colonization might be a prerequisite for normal growth, development and survival of the young plants. The latter authors further point out that *Gnetum* species are tropical plants, thriving in environments where there is a seasonal fluctuation of nutrients. Hence, mycorrhization would help the plant to survive such nutrient fluctuations and the competition that thus arises. However, such dependence on one or a few fungi places the plant at risk, as in the absence of this particular inoculum, environmental factors would greatly affect the plants' establishment and survival (Bechem & Alexander, 2012). Kitchen ash (2400 kg/ha) and poultry manure (2400 kg/ha) have been shown to enable better field establishment, leaf production and survival of *G. africanum* plants on highly leached and strongly acidic soils (Ultisols), as opposed to single super phosphate (400 kg/ha) and urea (400 kg/ha) in southern Nigeria (Ibeawuchi *et al.*, 2008).

In many forest communities *G. africanum* is highly valued as a vegetable playing a significant nutritional and social role across the sub-region where it is found and consumed by people of all social strata (Mialoundama, 1993). Leaves are shredded and prepared in soups and eaten with fermented cassava paste locally called "water fufu" in Cameroon.

It is also added to stews or eaten raw. The nutritive value of *G. africanum* is reported by Mialoundama (1980) to be very high. The leaves present an important source of proteins, essential amino acids and minerals. A chemical analysis identifies the leaves as a good source of sodium, potassium, calcium, magnesium and iron (Okafor *et al.*, 1994).

In Cameroon, leaves of both species are harvested on a daily basis for sale in local and regional markets. Plants are evergreen and therefore leaves are available throughout the year (Shiembo *et al.*, 1996). The leaves are collected either during specific collection trips or opportunistically, in the course of other activities (Henkemans, 1995). A number of sources indicate that currently all *Gnetum* leaves marketed in Cameroon are harvested directly from the wild (Nchinda *et al.*, 2008; Clark and Sunderland, 2004). Actual harvesting of leaves often entails plucking them from the slender vines and side shoots, which if done carefully allows the individual plant to regenerate. According to Shiembo (1997), there are increasing reports of destructive and unsustainable harvesting practices, such as the cutting and removal of entire plants and/or felling of support trees. Moreover, both *Gnetum* types are Red List classified as near-threatened species (Lakeman Fraser & Bachman 2008; Baloch 2009). According to Bokwe and Ngatoum (1994), there is an urgent need to ensure conservation of these species. In 2009, the Ministry of Agriculture and Rural Development of the Republic of Cameroon approved a project to support the domestication of *Gnetum* species.

Most of the *Gnetum* from Cameroon is transported by road to Idenau near Limbe in the South West Region of the country. From there it is exported by boat to Nigeria which is a major market for the resource (Awono *et al.*, 2002). Export markets to the African diaspora in Europe are large, as is commercial activity from Nigeria to the United States of America (Shiembo 1997; Tabuna 1999; Ladipo 1997). According to Nkwatoh *et al.* (2010), about 610,000 metric tons of *Gnetum* was produced and traded in Cameroon and Nigeria between 2002 and 2008. This was valued at about 630,000,000 F (CFA), which is the equivalent to approximately $1,250,000 (USD) of internally generated revenue (IGR) for the economies of Cameroon and Nigeria. Trade in the leaves of *G. africanum* and *G. buchholzianum* is important within and between the countries of the Congo Basin. These include Cameroon, Gabon, Equatorial Guinea, Congo-Brazzaville, Democratic Republic of Congo, the south of the Central African Republic, and the humid zones of Nigeria (Ladipo 1997; Shiembo 1997; Sunderland and Obama 1999; Yembi 1999).

In addition to being a major source of food and income, *G. africanum* has medicinal properties. Leaves are used in Nigeria for the treatment of enlarged spleen and sore throats, and are also considered as an antidote to some poisons. Leaves are also used as a dressing for warts and boils and as a decoction to reduce pains during child birth in Congo-Brazzaville (Shiembo, 1999).

G. africanum can be considered a 'Cinderella' species overlooked by science (Leakey and Newton, 1994). It provides nutritional, economic and environmental benefits. Farmers view such species as a natural resource and have not nurtured them. However, the sustainability of the species continues to be threatened by deforestation (Leakey, 1999). To arrest this unfortunate situation, *G. africanum* has been subjected to domestication over the past fifteen years (Tchoundjeu *et al.*, 2006). Seed germination trials under nursery conditions have not been encouraging as seeds often take up to 7 months to one year to germinate (Okafor, 1997; Shiembo, 1999; Ndam *et al.*, 1997). The rooting of vine cuttings was then resorted to as a low-cost solution to the problem of providing sufficient quantities of improved planting material for on-farm cultivation. In doing so, cuttings from different provenances were set in different substrates to evaluate their effects on the rooting success and shoot development of *G. africanum* vine cuttings.

Materials and Methods

Study Site

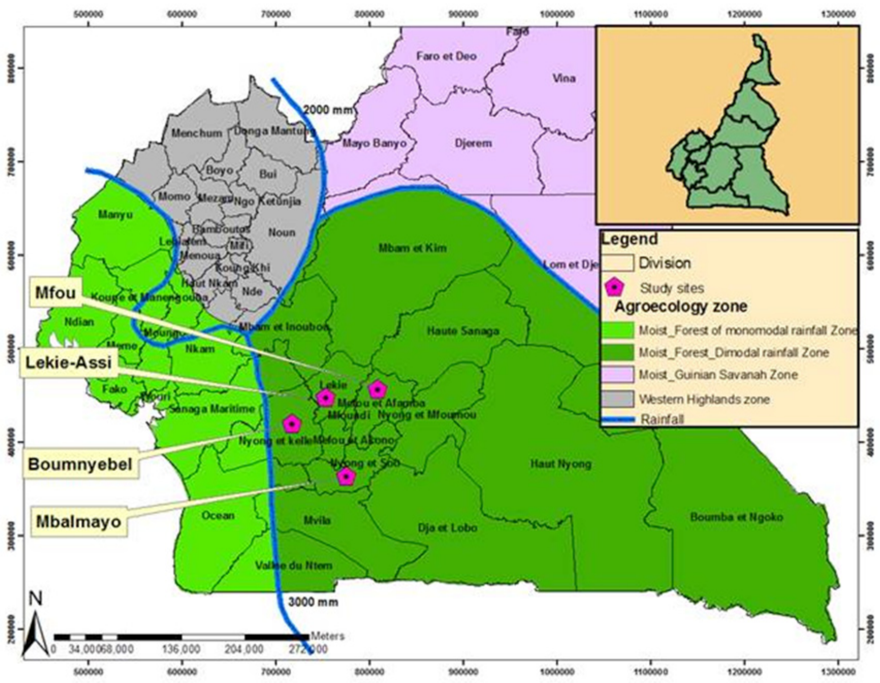

Figure 1. Map of Cameroon showing provenances of G. africanum vine collection used in this study (Source: Ngaunkam, 2014)

Plant material used in this trial was collected from four locations (Lekie-Assi, Boumnyebel, Mbalmayo and Mfou) where *Gnetum* is gathered extensively in the Centre Region of Cameroon for marketing and household consumption (Figure 1). All four provenances are located within the bimodal (two rainy and two dry seasons) rainfall zone with altitudes of between 500-1000 m asl. Lekie-Assi and Boumnyebel have a sub-equatorial climate with mean temperature of 25°C and relative humidity of 75%. The average annual rainfall ranges from 1300-2500 mm while the soils are sandy, sandy clay loam or clay in texture (Ndo *et al.*, 2010). Mbalmayo (640 m above sea level; 3°25N, 11°28E), has a total annual rainfall of about 1 500 mm. The soil type is an Ultisol derived from schist band (De Cauver *et al.*, 1995). The mean annual temperature is approximately 24°C and the soils are deep ferralitic (Ambassa-Kiki, 2000). Mfou (3o 69'N, 11o 69'E) is located within the equatorial climatic zone. It has a mean annual rainfall of 1530 mm and the soils are acid ultisols (Duindam and Hauser, 2008). Hulugalle and Ndam (1993) however, identify the soils of Mfou as clayey or kaolinitic. The trial was conducted at the ICRAF nursery in Nkolbisson, Yaoundé, Cameroon (altitude: 700m above sea level, latitude 3o 52'-3o 53'N, and longitude 11o 25'-11o 27'E). The average annual rainfall is 1692 mm and the rainfall pattern is bimodal. Relative humidity varies generally between 73% and 84%, and the average temperature is 25°C (Ambassa-Kiki, 2002).

Collection of plant material and setting of cuttings

About fifty young vines of *G. africanum* growing wild in the forest were collected (above the third node from the base) from each provenance, watered and stored in a disinfected, humid polythene bag. They were transported in a closed-back pick-up vehicle to the nursery (a journey of no more than 45 minutes) where vines were watered again using a knapsack sprayer before cuttings were prepared. Cuttings were cut to about 5 cm lengths with circular base to allow for uniform root distribution and slanting upper surface to ease run-off during watering (Tchoundjeu, 1989); whereas leaves were halved to about 50 cm^2 surface area to reduce transpiration and maintain photosynthesis to allow for cutting survival (Longman, 1993). Each prepared cutting was dropped into a bucket of clean water to prevent water loss. Cuttings were then set on four substrates including fine sand dug from a sand pit (with fine particles of less than 0.2 mm), sharp sand from a river (with coarse particles of about 1-2 mm), decomposed sawdust from an abandoned saw milling site and a 50:50 mixture of decomposed sawdust and sharp sand) which had been treated with fungicide containing dimethoate (50 g/16 litres of water) as active ingredient and insecticide containing cypermethrine (50 ml/16 litres of water) as active ingredient five days before use. The trial was conducted in a non-mist propagator (Leakey *et al.*, 1990) divided into twelve compartments in which the four substrates were randomly allocated. Each compartment was subdivided into four sub-units in which cuttings from the 4 provenances were randomly allocated (Figure 2). Ten cuttings were set per sub-unit, resulting in 120 cuttings per provenance and 120 per substrate making a total of 480 cuttings for the trial. Watering was carried out using plastic tubes with water allowed to flow until it reached the same level as the gravel layer, keeping the overlying substrate moist. The propagator was placed in a shade house which has alternating rows of translucent and corrugated iron roofing sheets (Longman, 1993). It is bordered with shade cloth allowing about 70 percent of irradiance to enter the propagator.

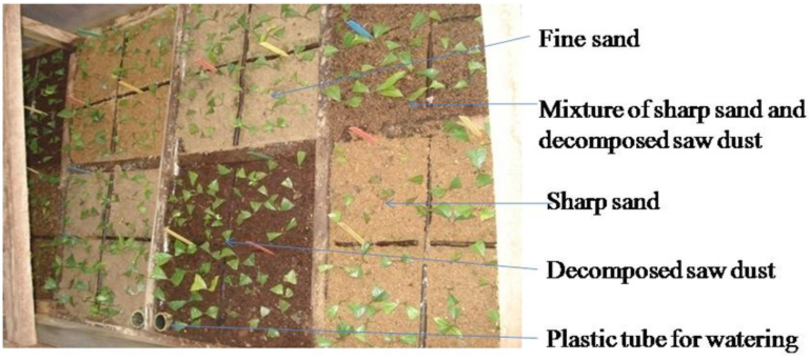

Figure 2. Partial view of propagator

Observations and measurements

The propagator was opened daily in the morning to verify the water level, which had to be at the same level as the gravel layer for adjustment, a check was carried out for fallen leaves which were removed to avoid microbial attack from decaying leaves. The inner surface of the transparent polythene sheet covering the propagator was cleared of mist which had settled on it. To minimize water loss, cuttings were watered using a knapsack sprayer whenever the propagator was opened. From the second month after setting, measurements were taken once a month for four months. Each cutting was lifted from the substrate and examined for the presence of roots. A cutting was considered as having rooted if there was one or more roots that were at least 1 cm in length (Atangana *et al.*, 2006). Rooted cuttings were assessed for number of main roots (primary roots originating from cutting base), length of longest root, number of new leaves, number of new vines and vine length. Rooted cuttings were then transplanted into polythene bags containing forest soil and sharp sand (2:1) to ease percolation after watering. Forest soil was collected from a *Gnetum* stand in Lekie-Assi (within 15 to 25 cm below ground) and supposed to contain mycorrhiza which enhances nutrient uptake and growth of *G. africanum.* Cuttings that had not rooted were put back into the substrate.

Data analysis

The rooting percentage in each treatment was assessed using graphical tools in Excel 2007. To determine the effect of experimental factors on rooting ability and shoot development of cuttings, data were subjected to analysis of variance using Generalized Linear Model procedures in Genstat version 12 software. Effects of provenance, substrate and their interactions on the percentage of rooted cuttings were assessed using the logistic regression model (binary data), while a log linear regression model was fitted to the root number data following the *Poisson* distribution. Factors having a significant effect on cutting rooting ability were compared among treatments using the Least Significant Difference (LSD) procedure considering confidence interval of 0.05.

Results

The results of analysis of variance showed that time ($P = 0.004$), provenance ($P<0.001$), substrate ($P<0.001$) and the interaction between provenance and substrate ($P<0.001$) had significant effects on rooting.

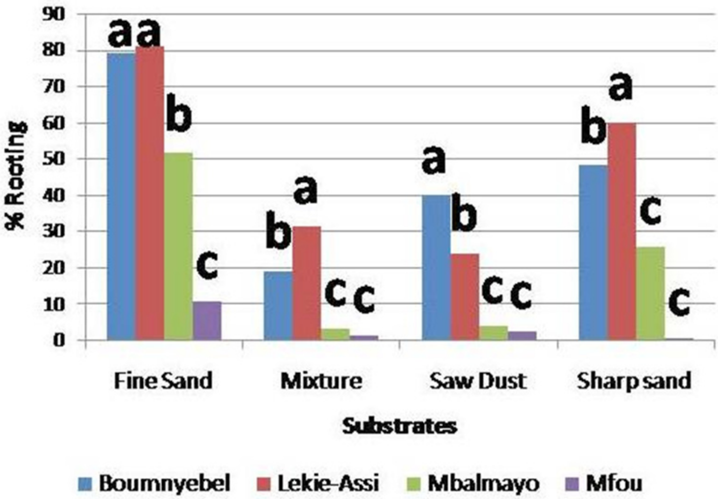

Figure 3. Rooting percentage (%) of 4 provenances of G. africanum cuttings in 4 nursery substrates

Cuttings from Lekie-Assi on fine sand had the highest rooting rate followed by those from Boumnyebel, also on fine sand, but there was no significant difference between them. Rooting rates of cuttings from these two provenances were significantly higher than the Mbalmayo rooting rate, which was also significantly higher than the rooting rate for cuttings from Mfou. Cuttings from Lekie-Assi showed a significantly higher rate of rooting on sharp sand, compared to those from Boumnyebel, which was also significantly higher than those from Mbalmayo and Mfou, between which there was no significant difference. For the mixture of sawdust and sharp sand, cuttings from Lekie-Assi had the highest rooting percentage, followed by cuttings from Boumnyebel that had a significantly lower rate of root production, which was, however, significantly higher than root production on cuttings from Mbalmayo and Mfou, between which there was no significant difference. The highest rate of rooting on sawdust was observed on cuttings from Boumnyebel, which had a significantly higher rate than that of cuttings from Lekie-Assi (Figure 3). In terms of number of roots per rooted cutting, Figure 4 shows that fine sand induced significantly higher numbers of roots on cuttings regardless of provenance, compared to the other substrates. This was followed by sharp sand, mixture and sawdust. On the other hand, the number of roots produced per cutting from different provenances showed that cuttings from Lekie-Assi produced significantly more roots followed by those from Boumnyebel, Mbalmayo and Mfou.

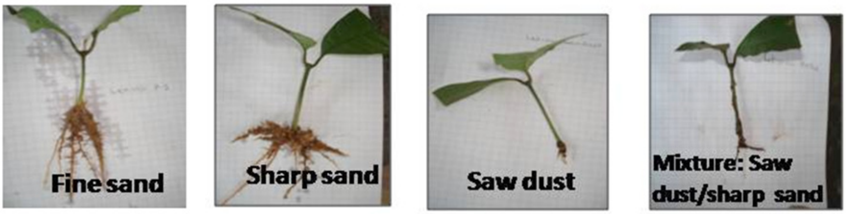

Figure 4. Root production of G. africanum vine cuttings from Lekie-Assi on different substrates at 2 months after setting

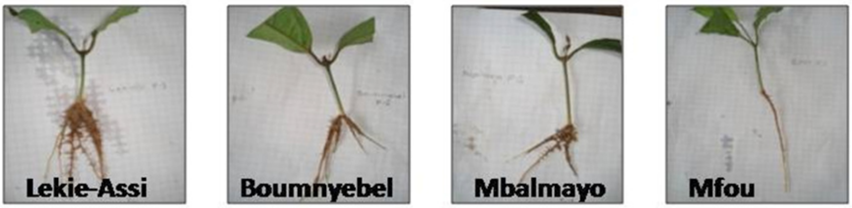

Figure 5. Root production of G. africanum vine cuttings from different provenances in fine sand at 2 months after setting

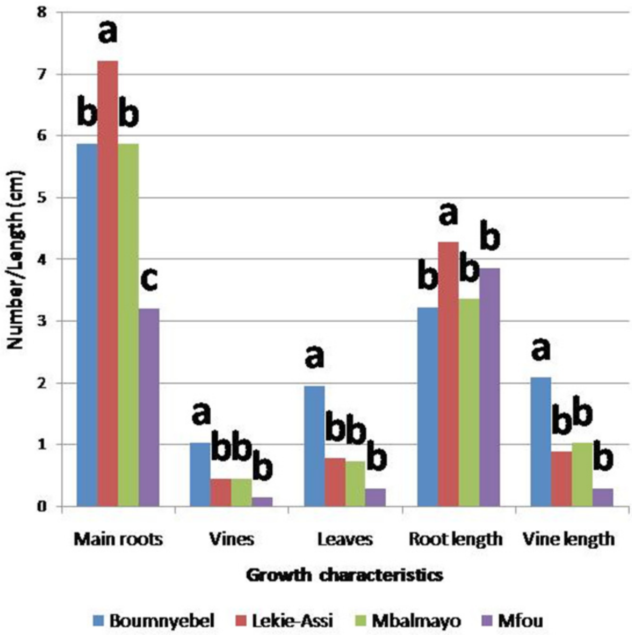

Figure 6. Effects of four provenances on growth characteristics of rooted cuttings of G. africanum

Cuttings from Lekie-Assi produced a significantly higher number of main roots than cuttings from Boumnyebel and Mbalmayo, between which there was no significant difference, whereas both produced significantly higher numbers of main roots than cuttings from Mfou. Cuttings from Boumnyebel produced significantly longer and higher numbers of vines and leaves respectively, than those from Lekie-Assi, Mbalmayo and Mfou, which showed no significant differences for these growth characteristics. Roots produced on cuttings from Lekie-Assi were significantly longer than those on cuttings from the other three provenances, between which there was no significant difference as shown in Figure 6.

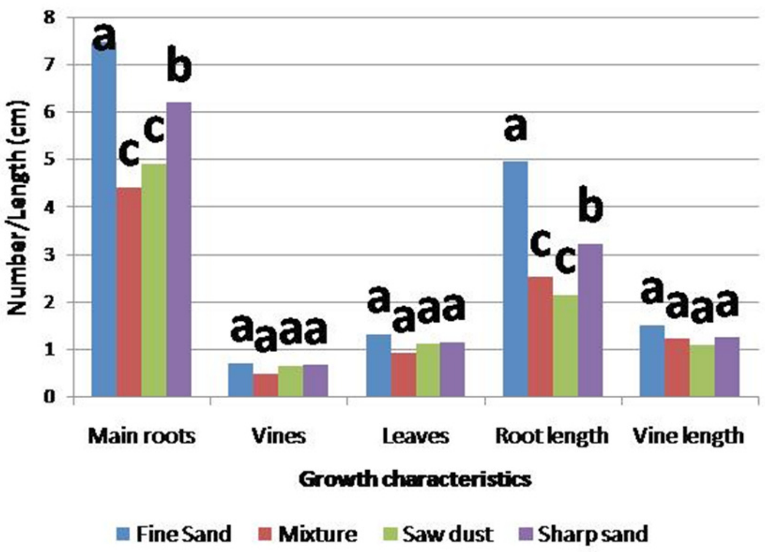

Figure 7. Effects of four substrates on growth characteristics of rooted cuttings of G. africanum

Fine sand allowed the production of a significantly higher number of main roots than sharp sand, which in turn induced a significantly higher number of main roots than sawdust and the mixture of sharp sand and sawdust. No significant difference was observed in the number of vines, number of leaves and vine length of cuttings on any of the four substrates. Roots produced on fine sand were significantly longer than those produced on sharp sand, which were also significantly longer than those produced on sawdust and the mixture of sharp sand and sawdust as shown in Figure 7.

Discussion

This study revealed that fine sand was the best substrate for inducing the rooting of *G. africanum* cuttings among the four substrates tested. Lekie-Assi was the best of the four provenances used. The findings of this investigation are in line with those of Caspa *et al.* (2009) and Mesen *et al.* (1997) who found that fine sand induces better rooting on juvenile stem cuttings of *Nauclea diderrichii* and *Cordia alliodora*, respectively, than sawdust. Opposed to this, Ndam *et al.* (1997) recommended a mixture of 50% sawdust and 50% sand, while Shiembo (1997) suggested the use of 100% decomposed sawdust in a propagator for rooting *G. africanum* vine cuttings.

It is probable that fine sand, and to an extent, sharp sand have the properties of an adequate rooting substrate as described by Anderson (1986) as one with an optimal volume of gas-filled pore space and an oxygen diffusion rate that allows proper respiration. Contrasting reports from different authors on the rooting of *G. africanum* could be due to differences specific to the plant materials used. From the top of a plant to the bottom, there is a within-shoot gradient in age that affects the leaf size, leaf water potential, leaf carbon balance, leaf senescence, internode length, internode diameter, stem lignification, nutrient and stem carbohydrate content and respiration.

The gradients in some of these factors mean that no two cuttings are physiologically identical and hence no two cuttings have the same rooting capacity (Leakey, 2004), the substrate notwithstanding. The latter author points out that the same species propagated under relatively similar conditions by different persons can produce results that appear to be contradictory, while in fact their results are expressions of the different physiological and morphological conditions of the tissues being propagated. Stock plants used by the cited authors grew in different environments with varying soil and climatic conditions which can affect their morphology and physiology (Leakey, 2004), and possibly the rooting abilities of cuttings obtained from them. This is further illustrated by Tchoundjeu and Leakey (2000) who found that relative concentrations of carbohydrates and nutrients in cutting tissues as stored reserves for successful rooting vary between node positions and over time in *Khaya ivorensis*.

Hartman *et al.* (1990) recognized the importance of using the “right” propagation substrate for optimal rooting of leafy cuttings, while Loach (1986) suggested that substrates with relatively high water content like sawdust are generally associated with higher rates of water uptake in the cuttings and consequently higher rooting percentages. However, the latter author also warns that water can present a major diffusion barrier to oxygen so that excess water may result in anoxia at the cutting base. In this trial, some cuttings that had been set on sawdust and to a smaller extent on the mixture of sharp sand and sawdust showed signs of rotting at cutting base starting one month after setting. When rot occurred, this was followed by leaf yellowing, leaf fall and complete death of affected cuttings. The number of cuttings with these symptoms increased with time. The reason for this is not clear since the water level was controlled through daily observation of water level and the substrate disinfected with fungicide (dimethoate (50 g/16 litres of water)) and insecticide (cypermethrine (50 ml/16 litres of water)) before cuttings were set. The substrates in this trial were moist, but not too wet. However, it is possible that sawdust and the mixture of sharp sand and sawdust retained most of the water that was taken up, resulting in the rotting of some cuttings. The reason for better rooting of cuttings from Lekie-Assi and Boumnyebel could be genetic or possibly due to juvenility of plant material from which cuttings were collected. From field observations, these populations underwent more active exploitation; so the material sourced here was possibly relatively young compared to those from Mbalmayo and Mfou which only experienced occasional exploitation. It is also possible that better performance of growth indicators observed on cuttings from Boumnyebel is due to juvenility of plant material used.

Conclusion and Recommendations

The results of this study indicate that *G. africanum* can be propagated vegetatively from leafy vine cuttings with fine sand and sharp sand as rooting substrates in a non-mist propagator. Cuttings from Lekie-Assi and Boumnyebel showed better rooting than those from Mbalmayo and Mfou. Fine sand recorded a rooting success of up to 80% for cuttings from Lekie-Assi and Boumnyebel, followed by sharp sand with 60%. With the dwindling population of *Gnetum* in the wild and the increasing need for its domestication to meet high demand, farmers can depend on this low-cost technology using fine sand and sharp sand to produce improved planting material in adequate quantities for on-farm planting operations. As a follow up to this study, it will be necessary to investigate the effects of cutting age/position and mixtures of substrates in different proportions in combination with other factors such as cutting length and provenance to optimize the rooting performance of *G. africanum*.

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Small-holder farmers' access and rights to land: the case of Njombé in the littoral region of Cameroon

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In Cameroon, agriculture constitutes the main livelihood for a large portion of the population. Against this background, land tenure security is of crucial importance for agricultural production and off-farm activities. This article aims to foster understanding of small-holder farmers' access to land in the Njombé-Penja district of Cameroon. Data was collected using focus group discussions with small-holders, key informant interviews, field observations and formal surveys. Results indicate that the current land tenure situation often limits small-holder farmers' access to productive land. This often results in conflicts between various actors including plantation agriculture, rural elites and research institutions, and hence threatens small-holders' security for food and livelihoods. We conclude that there is a need to revisit existing policies for land allocation to multinational companies in order to protect small-holder producers' rights and security, and to harmonize the various tenure systems as a means to avoid competing claims among various actors.

Key words: land tenure, small holder, rights, access

Introduction and background

In much of rural Africa, land is of crucial importance to economies and societies, and therefore land-based enterprises such as agriculture constitute the main livelihood base for a large portion of the population (Cotula, 2007:3). Land is an economic resource and an important factor in the formation of individual and collective identity, and in the day-to-day organization of social, cultural and religious life (IFAD, 2008:5). Thus, secure access to productive land is critical to the millions of poor people who live in rural areas and depend on agriculture for their livelihoods. Adequate access to land reduces their vulnerability to hunger and poverty, and influences the capacity of the poor to invest in productive activities. Titled ownership of land encourages people to practice sustainable management of natural resources and develop more equitable relations with the rest of their society, thus contributing to justice, peace and sustainable development (Cotula, 2007:3; IFAD, 2008:4).

In Cameroon, as in most other African countries, land access, ownership and rights have been influenced by a mix of former colonial policies and customary practices, as well as post-independence land reforms (IFAD, 2008:6; Puépi, 2010). These include a wide array of overlapping (at times contradictory) rules, laws, customs/traditions, perceptions and regulations that govern how people's rights to use, control and transfer land are exercised (IFAD 2008:6). Cameroon has been beset by a number of conflicting claims regarding rights to land, leading at times, to inter-ethnic conflicts, farmer-pastoralist disputes, loss of property and lives, and the aggravation of poverty in rural areas (Amungwa, 2011:55). The controversy between customary and statutory land rights often culminates in the loss of land rights for the poorest and most vulnerable groups (Puépi, 2010), who compete for land rights with urban elites and large-scale agricultural enterprises/plantations mostly in the coastal regions of Cameroon (e.g. the case of Njombé). Furthermore, the mounting incidence of soil nutrient depletion especially in the Sudano-Sahelian and western zones of Cameroon, coupled with inappropriate land use and management practices such as overgrazing, slash-and-burn farming practices and increased competition over land, tend to diminish small-holder farmers' access to good-quality acreage (ANoRF, 2010). High population growth, food prices and the impact of climate change are increasing the competition for land which in turn threatens land ownership and tenure security. This affects the livelihoods of millions of poor rural people/small-holder farmers who ironically account for over 80% of domestic food production (ANoRF, 2010; IFAD, 2008:4) and yet face regular disputes over access to and ownership of land in Cameroon (USAID, 2010:11). Thus, land tenure security is not only important for agricultural production and the future of the rural masses, it also enables the poor to equitably negotiate their future and build their capacity to undertake viable, alternative off-farm activities. Effective land tenure helps the rural poor to use their land as collateral, renting it out or realizing its true value (IFAD 2008:8). Despite the importance of land tenure and its relevance to rural livelihoods, little is known in the context of Cameroon in general and the Njombe-Penja district in particular, resulting in substantial gaps in knowledge on options to address land-related conflicts.

The research reported in this article aims to shed light on small-holder farmers' access to land by assessing the key land tenure issues including access, rights and conflicts in the Njombé-Penja district of Cameroon. In particular, the study identifies and characterizes the various forms of land tenure prevailing in the study area, the key actors involved and their competing claims. The remaining sections of the article are organized as following. First, we present the conceptual framework used for the analysis. This is followed by the description of methodology for data collection. Next, we present the results and discussions. We conclude the article with some recommendations for policy formulation

Land tenure studies in Cameroon-literature review

Land tenure is central to the development strategies of communities as well as the organizational structures of political societies (Nguiffo *et al.*, 2009). Bearing in mind its socio-economic significance, it is not surprising that social or ethnic conflicts are occasioned by inequitable access to and control over land (Sone, 2012). Various land tenure studies in Cameroon focus on understanding how colonial and post-colonial land laws have impacted on customary laws and the livelihood of rural communities and indigenous peoples. A general study on the status of customary land tenure in Cameroon by Alden (2010) shows that rural people are deeply insecure with regard to their land rights as Cameroonian law fails to acknowledge that customary land-holding amounts to real property. Thus, the *de jure* reality is that most people living in rural areas in Cameroon are squatters on their own land.

In a bid to understand the impact of historical and contemporary land laws on the land rights of indigenous peoples in the forest zones of Cameroon, Nguiffo *et al.*, (2009) underscore that indigenous forest dwellers are gradually losing their full and complete rights to the land and its resources (by virtue of their customary rights). This seriously affects their everyday choices and prospects such as the extent to which they are prepared to invest in proposed forest management frameworks and ecosystem conservation since access to secure land is widely accepted as a precondition for access to other services and livelihood opportunities (Robiglio *et al.*, 2010:64).

In the grasslands of Cameroon, land tenure studies have focused on understanding land ownership conflicts between farmers and nomads (Sone, 2012), as well as studying attempts to resolve the land/boundary disputes in the areas resulting from disruptive colonial boundaries (Mbah, 2009). In his study, Mbah (2009) observes that even though colonialists made attempts to resolve the land/boundary disputes through an Inter-Tribal Boundaries Settlement Ordinance (ITBSO) which combined Native Court (NC) and administrative procedures in the resolution of boundary disputes, the successive Governments of Cameroon after independence have failed to follow through. This failure has provoked some communities to revisit previous boundary resolutions for political and economic reasons (Mbah, 2009), thereby reviving these land/boundary disputes. Sone (2012), on her part, argues that the recurrent conflicts involving farmers and cattle grazers over land ownership in the grass fields of Cameroon have their roots in colonial policies to promote herding practices (that were more revenue generating) leading to scarcity of land and 'poor' application of statutory laws which guarantees landownership. These resulted in limited usufruct rights of farmers which often prohibit them from using land as a form of collateral security to have access to other resources which may be useful for their livelihoods.

In the coastal regions of Cameroon, land tenure studies have focused on the history and development of the "Bakweri Land Problem". This is a conflict between the indigenous Bakweri ethnic group (of the South West region of Cameroon) and the CDC (Cameroon Development Corporation). Studies show that this problem remains unresolved and the Bakweri people still hold strong claims over the land where CDC plantations are located

(Ngwasiri, 1995; Tande, 2006). To the best of our knowledge, no study has been carried out to investigate the challenges involved in small-holder farmers' access and rights to land in the face of expanding plantation agriculture in the coastal regions of Cameroon. Thus, this study adds to the existing literature on land tenure studies in Cameroon, but is unique in being one of the first land tenure studies in the coastal regions which seeks to understand the effects of plantation agriculture on the livelihoods of small-holder farmers in the area.

Methods

Conceptual framework

The main conceptual framework used for this study is the Rapid Land Tenure Assessment (RaTA) (Galudra *et al.*, 2010). RaTA is an analytical tool which seeks to provide policy options and interventions as an alternative solution to settle land tenure conflicts, by exploring the competing claims among different actors, who hold different rights and powers. These competing claims are often related to competing or changing land tenure policies, developed in different historical periods and for various purposes. Five main objectives underpin the framework. These include:

- description of the general reading on land use and conflict linkages to a particular context; political, cultural, economic, etc.;
- identification and analysis of actors;
- identification of the various forms of historical and legal claims by actors;
- identification of the institutions and rules governing the management of natural resources and analysis of the linkage of various claims to policy and (customary) land laws;
- determination of policy options/interventions for conflict resolution mechanism.

In order to achieve these objectives, a stepwise analytical framework is used as is shown in Figure 1. This framework has been tried and tested in Indonesia in World Agroforestry Centre-South East Asia projects, ranging from understanding how land tenure claims differ from tree tenure claims to responding to the REDD + plan of climate change mitigation, particularly in dealing with land and resource tenure (Galudra *et al.*, 2010). In Cameroon, within the context of REALU (Reducing Emissions from All Land Uses), the RaTA framework was applied to understand its implications for emission reduction effectiveness in Cameroon landscapes (Robiglio *et al.*, 2010). One must bear in mind that RaTA is not a purely 'scientific' and 'legal' assessment tool; it extensively uses 'citizen perceived legality' and the knowledge of local actors to understand competing land claims. Its advantages include its time-effectiveness, its ease of use and flexibility in combination with other 'legal' approaches, and its ability to foster the development of a relationship between researchers, advocates and local communities (Galudra *et al.*, 2010:16). Unlike other frameworks that only concentrate on existing land tenure systems and general conflicts, the RaTA framework explores competing claims among different actors who hold different rights and powers, as these competing claims are often related to competing or changing land tenure policies developed in different historical periods and for various purposes. RaTA can provide policy options and intervention as an alternative solution to settle land conflicts. It can also be applied to sites where conflicts have not yet happened, in order to understand the potential impact of implementing a development project on natural resource use and access (Galudra *et al.*, 2010:11-14).

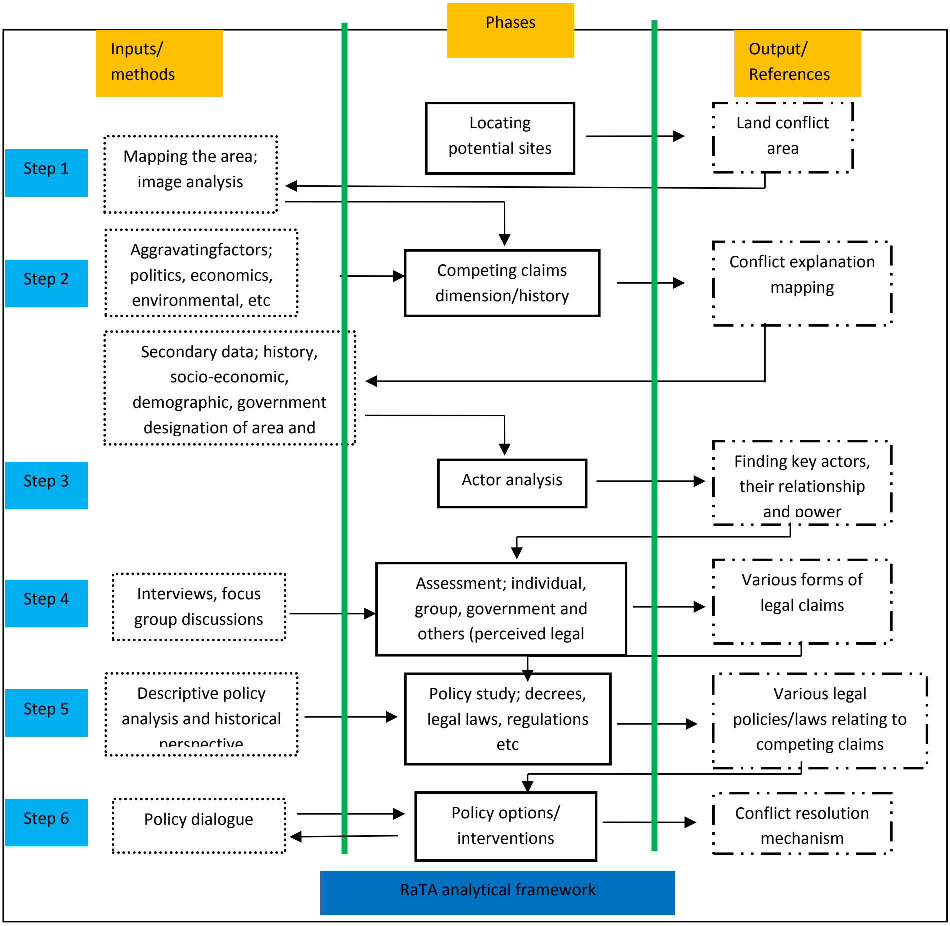

Figure 1. The steps in RaTA analysis (Source: Galudra et al. 2010:14)

Description of the study area

The study was carried out in Njombé which is a mono-modal humid forest zone in Cameroon. The area was selected because it has many land related conflicts. Furthermore, the area has experienced various forms of colonial regimes and hence has many tenure systems in its history making it suitable for land tenure and conflict analysis.

Njombe is an agricultural community located in the Njombé-Penja sub-division of Mungo division of the Littoral region of Cameroon. It is located between latitudes 4°30`-4°40`N and longitudes 9°30`-9°45`E (Azah, 2009:13). The area is bounded to the North by Penja, to the South by Mbanga, to the West by Tombel, and to the East by the Nkam (Figure 2). The climate of the area is equatorial with a long rainy season which runs from March to November and a short dry season which runs from November to February. It is a hot and humid climate with temperatures of 25-30°C and an average relative humidity of 80%. Cumulative average annual potential evapo-transpiration is 1055.6 mm with annual rainfall averaging about 2550 mm (Thome, 2007). Trees species found in the area as stated by Van de Pol *et al.*, (2005) include Bidou (*Saccaglottis gabonensis*) and Azobe (*Lophira alata*). Due to the high fertility of soils, there has been serious deforestation due to the activities of either large plantations or small farms. The area is made up of a very heterogeneous population, composed of a mixture of tribes including the Bafouns and Bonkengs (indigenes) and the Bamilekes Mbo, Haoussa, Bamoun and other small tribes (non-indigenes/migrants). Immigrants were attracted to the area by the large industrial plantations located in the area as well as by the fertile soils.

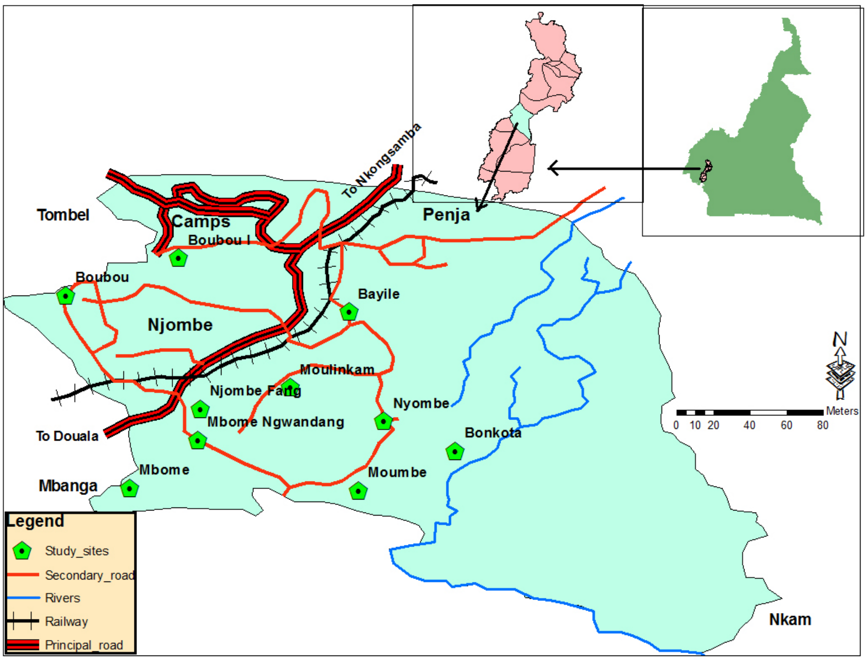

Figure 2. Location of study area (Source: Adapted from Boa, 2007:30)

Data collection and analysis

This study used a combination of qualitative and quantitative methods including key informant surveys, focus group discussions and semi-structured interviews. Purposive sampling techniques were used to select key informants (including representatives of both customary and administrative institutions), and participants for the focus groups (Katz, 2006; Marshall, 1996:524). To ensure representativeness, participants were selected based on the following criteria: land ownership (land owner, tenants, and intermediaries); gender; origin (indigenous and non-indigenous/migrants;) and age. Fifteen key informant interviews and three focus group discussions were conducted on the following topics: means of accessing land; tenure system used in accessing farmland; rights over accessed land; causes of land tenure conflicts and resolution mechanisms; actors involved in land related conflicts and origin and resolution mechanisms. Methods used to collect information are presented in Table 1.

Objective	Information sought for	Means of data collection
Identify and characterize the various forms of land tenure issues existing in the area	• Forms of rights, ownership and access to land • Acknowledgment of land rights • Tenure system used to access land	• Interview • Questionnaire
Identify and analyze the actors involved and their competing claims	• Identify actors, their land interest/ competing claims and the relative importance each actor gives to the claims (based on interest, feelings and perceptions) • Actor categories (primary and secondary) • Degree of interaction of actors land interest (based on perceptions) • Existence of conflicts/disputes/ competing claims (causes, origin manifestations and methods of resolution) associated to these • Map out land-related conflict sites • Actors' potential role in influencing land tenure dispute resolution	• Interview of stakeholders and key informants • Focus group discussion • Questionnaires
Analyze the effects of land tenure systems on land use pattern and livelihoods (based on perceptions)	• Preference with regards to land use pattern • Map out the land use pattern of the area • Effects on rural population and small-scale agriculture	• Questionnaire • Focus group discussion • Interview

Table 1. Study objectives, information sought for and method of data collection

Data collected through focus group discussions and interviews were manually stripped and transcribed respectively, and later separated with respect to the different objectives. In order to obtain quantitative information, semi-structured questionnaires were manually stripped and analysed using SPSS (Statistical Package for Social Sciences) version 17. Statistical analyses used include frequency distribution and chi-square test.

Results and discussions

Demographic characteristics of respondents

Over 29% of the respondents were indigenous people and 70.6% were migrants (31.3% from North West and 68.7% from the West Regions). Immigrants reported that they had been attracted to the area by the job opportunities offered by the large industrial plantations located in the area as well as by the fertile soils which are suitable for agriculture. The movement of people into the area dates back to the colonial period, as people moved into the area either voluntarily or forcefully to work as labourers on German colonial plantations. However, many people migrated to the area in order to seek refuge from the "maquisards" or "rebels" in the Western region during the pre-independence period. Others simply migrated to reunite with family and friends who were already residing in the area. Most of our respondents were between the ages of 31 and 60 years old. More than 80% of the respondents practice agriculture as their main occupation, confirming Boukar's (2011:v) assertion that agriculture employs more than 60% of Cameroon's active population. This is also attributed to the fact that Njombé has suitable conditions for agriculture due to the nature of soil and its climate. Agriculture is therefore the livelihood base for most of its inhabitants.

Variable	Number	%
Gender		
Male	41	60.3
Female	27	39.7
Native Origine		
Indigenous people	20	29.4
Non-indigenous (Migrants)	48	70.6
Age		
Young farmers (<30 years)	1	1.5
Middle-aged (31-60 years)	58	85.3
Older (61 years and above)	9	13.2
Level of education		
No education (never been to school)	4	5.9
Primary school	10	14.7
Secondary school	48	70.6
Main occupation		
Agriculture	57	83.8
Contract worker	3	4.4
Service industry	8	11.8

Table 2. Characteristics of respondents

Method of land acquisition

The main forms of land acquisition are inheritance (39%), rent/lease (32%) purchase (25%), and sharecropping (4%). Renting/leasing depends on the contract terms between the landowner and the tenant. Lease contract varies from seasonal, annual, to biannual, and can be renewable or not. Rent for farmland varies with its accessibility i.e. with its distance from a road (tarmac road) and whether it is an unplanted/empty plot or farmland with crops, particularly cocoa. The rent for leasing an unplanted plot is 12 francs CFA per square metre per annum (a lunar year) if the farm is close to a paved highway or 5 francs CFA if located in the middle of the forest. Farms with crops, particularly cocoa, usually attract higher prices ranging from 20-25 FCFA/M^2/year depending on their accessibility. There is also a special land renting system in the area known in the local jargon as the "bon" in which a fully cultivated farm with exploitable crops is given as collateral to borrow money for a given time period. During this period, the tenant exploits the farm in order to recover the money borrowed, and returns the land to its owner at the end of the "bon" period. Land is rented from any individual who has a plot or farm to rent out. It is also rented from research institutions such as IRAD (*Institut de la Recherche Agronomique pour le Développement*) and CARBAP (*Centre Africain des Recherches sur Bananiers et Plantains*), as well as agro-industrial plantations (PHP). About 25% of small-scale producers in this area acquire farmland through purchasing. Land is usually purchased with capital accumulated while working in other agricultural as well as non-agricultural activities. Purchase is a legitimate action, giving the buyer full ownership rights over the land. The contract is usually made up in the presence of a village chief, as well as neighbours of the piece of land in question. This is to avoid any future problems such as double sales and overlapping land rights over the land. Land in Njombé is generally purchased from indigenes (the Bafouns and Bonkengs of Njombé).

Twenty-five percent of small-scale farmers acquire farmland through inheritance from their ancestors or a late spouse who could either have appropriated the land as first occupants or bought the land from other landowners. This method of acquiring land also gives its owner full rights over the land. Sharecropping is mainly practised on cocoa farms and occassionally on other perennials but cocoa is usually the base. Two types of sharecropping exist in Njombé: in the first case, the tenant (sharecropper) takes care of the cocoa plants and all other crops associated with it, and shares the net produce with the landowner, i.e. the landowner is entitled only to the proceeds from cocoa sales after the tenant has deducted his/her expenses. In the second case, the landowner pays for expenses involved in taking care of the cocoa, the two will then share the net produce and any other crops harvested from the land after deducting the landowner's expenses.

Tenure system used in accessing land

In general, 61.8% of small-scale producers' access land under customary tenure and 38.2% under statutory tenure, mostly leases/rents without land titles. This is consistent with Cotula's (2007:5) study suggesting that most resource users across rural Africa gain access to land through local land tenure systems commonly referred to as "Customary Land Law". The customary system is seen by farmers as a peaceful and affordable means of land acquisition, contrary to the statutory system which is expensive. Furthermore, many farmers are ignorant of the State's land legislations. Thus the denial of "customary Land Law" as private property lies at the heart of land tenure insecurity. This situation is a considerable challenge for small-holder farmers as tenure security is not only important to guarantee continuous agricultural production but it also provides them with the means to equitably negotiate the diversification of their livelihoods and build up their capacity to undertake viable, alternative off-farm activities by using their land as collateral, renting it out or realizing its true value through sale.

Rights over land

Limited land rights (use or control rights) granted to tenants and sharecroppers negatively affect land use by the farmers as they are mostly restricted to the type of crops which they can cultivate on the farms. The landlord or landowner determines what crops should or should not be cultivated on the land rented or leased. Also, these limited land rights negatively affect the farmers' abilities to invest in the land or take advantage of other productive opportunities.

The land rights are sometimes backed by legal documents such as land title, sales agreement and/ or rental contracts. Although a land title is the only legal document recognized by the Cameroon government as proof of land rights as stipulated under Decree No. 76/165 of 27 April 1976 laying down the conditions for obtaining land certificates (ADB, 2009:7), only 8.8% of respondents who had purchased or inherited land actually had land titles. This low rate of land titling in rural areas is very common throughout Cameroon and can be attributed to the expensive and cumbersome nature of the land-titling process (Nguiffo *et al.*, 2009; ADB, 2009:2). This process begins with the land-owner filling in a stamped application to the sub-prefect of the jurisdiction where the land is located. Upon receipt of the file and within seventy-two hours, the sub-prefect issues a receipt to the address stated (applicant) therein and passes the application within eight days to the departmental delegation of Land Affairs, who within a period of fifteen days publishes an extract of the request for public scrutiny and objection in case of any. With no opposition, a date is set for acknowledgement of occupation and boundary demarcations by the *advisory committee* and surveyors sent to the field in the presence of the village chief and other witnesses. Within thirty days after this field visit, the findings of the committee together with the application are forwarded to the provincial delegate of Land Affairs, who assigns a number, examines the regularity of the documents produced and establishes a notice of boundary closure that is published in the bulletin of property and real estate advice (organization and operating procedures are established by a decree of the Prime Minister). From the date of filing the application at the sub-prefecture, until thirty days after the publication in the bulletin of property and real estate advice, any interested person may object. In case of no objection the land conservative registers the documents in the land registrar for the establishment of a title deed. The above processes can be expensive and sometimes provides an avenue for corruption as people often use their position and wealth to speed up or slow down the process. This often discourages small-holder farmers with limited resources from securing land-title. Research by the African Development Bank shows the low rate of land-titling is attributed to the fact that land tittles can be revoked and hence do not guarantee permanent ownership (ADB 2009: iv). There is an annulment procedure provided for and this is very often applied (ADB, 2009:10). Although about 60.3% of the population is conscious of the advantages a land title provides, and also agrees that a land title is the most effective method of protecting land rights, 91.2% of these people still rely on customs to protect their land rights based on the sales or rental agreements they possess.

Conflict awareness and experience

About 63% of respondents claimed never to have experienced any land-related disputes. Yet, 81.8% are conscious of the existence and causes of land-related conflicts in the area. Boundary dispute is the most frequent form of land related conflict followed by multiple sale of the same piece of land (Table 3) in the various villages of Njombé. Unauthorized sale of land and expansion of large scale industrial plantations are less common forms of disputes.

Location of respondents	**Causes of land disputes**					
	Expansion of plantation	Unclear land registry records	Overlapping land rights	Boundary dispute	Multiple sales of same land to different parties	Unautho-rised sales of others' land
Bayeli	1	0	2	3	2	0
Bonandam	0	0	0	2	2	0
Mbome-Ngwanda	0	0	2	2	2	0
Mbouale	3	7	9	12	9	1
Moulinkam	1	3	6	8	5	1
Njombé Fang	2	2	3	4	4	0
Total	**7**	**12**	**22**	**31**	**24**	**2**
Percentage (%)	**7.1**	**12.2**	**22.4**	**31.6**	**24.5**	**2.0**

Table 3. Perceived cause of land related conflicts as reported by respondents in Njombé

Approximately 36.8% of respondents admitted having had one or more disputes over their land. The causes of these land disputes include land border disputes, overlapping rights by different parties over the same piece of land and plantation expansion in which people's land is appropriated without compensation (Table 4). Land border disputes and overlapping land rights seem to be the most probable causes of land disputes. This is due to increased pressure on land as every farmer wants more land or wants to acquire farmland by any means.

Location of respondents	**Causes of land disputes**					
	Expansion of plantation	Unclear land registry records	Overlapping land rights	Boundary dispute	Multiple sales of same land to different parties	Unautho-rised sales of others' land
Bayeli	0	0	1	2	0	0
Bonandam	0	0	3	0	0	0
Mbome-Ngwanda	0	0	1	3	0	0
Mbouale	1	0	5	6	0	0
Moulinkam	0	0	3	5	0	0
Njombé Fang	0	0	2	1	0	0
Total	**1**	**0**	**15**	**17**	**0**	**0**
Percentage (%)	**3.0**	**0.0**	**45.5**	**51.5**	**0.0**	**0.0**

Table 4. Actual causes of land disputes as stated by the respondents in Njombé

Conflict origin

Location of respondents	**Actors at the origin of Conflicts**		
	Small-holder farmers	**Plantation owners**	**Elites**
Bayeli	4	0	1
Bonandam	3	0	0
Mbome-Ngwanda	5	0	0
Mbouale	18	5	5
Moulinkam	13	1	3
Njombé Fang	8	2	3
Total	**51**	**8**	**12**
Percentage (%)	**71.8**	**11.3**	**16.9**

Table 5. Actors at the origin of land disputes

Three categories of actors were identified by respondents as the originators of land-related conflicts in the Njombé community. They include: elites, plantation owners and small-holder farmers. Elites who desire land for commercial agriculture (as a source of revenue during their retirement period) use their wealth and power to forcefully acquire vast expanses of land, including the farms of some small-scale producers for the cultivation of predominantly oil palm (*Elaeis* spp). Small-scale farmers, who are poor and politically powerless, are usually left landless, especially if they are not compensated or given alternative farmland. This situation accounted for 16.9% of land-related conflicts in

Njombé. The presence of agro-industrial plantations such as PHP with a surface area of approximately 1250 hectares of land in Njombé (Boa, 2007:29) is another cause of land disputes in the area. While PHP uses large expanses of land for the production of bananas (*Musa* spp), pineapples (*Ananas comosus*), and ornamental flowers for export, their desire to expand their production area directly or indirectly leads to land conflicts. About 11.3% of all land disputes in Njombé directly result from the appropriation of small-holders' land, especially lands which border the big plantations such as PHP, without fair compensation. This leads to disputes between small-holder farmers and plantation owners as each actor is trying to protect his/her land interest. The expansion of PHP indirectly results in land scarcity and increased population pressure on land, due to the influx of migrants to work as plantation labourers. This aggravates the conflict situation of the area. These conflicts, according to the farmers, will continue as long as the plantation is expanding and appropriating their land.

Conflict manifestations and method of resolutions

Principal forms of conflict manifestations in Njombé are quarrels (55.1%), destruction of farm crops (29.6%), destruction of other properties such as houses (9.2%) and destruction of boundary plants (6.1%). Violent confrontations were generally not observed in Njombé. According to the respondents this is so because land is considered a gift from the "gods" or ancestors and hence no reason to be violent. While quarrels are the most common forms of land dispute amongst small-scale producers, destruction of farm crops, other properties and boundary plants are common between small-scale producers and other stakeholders. Often small-scale producers are victimized when the land dispute involves more powerful actors. Traditional leaders are often used as arbitrators in land dispute resolutions due to their proximity, the respect the people have for their traditional power as guardians/custodians of the land, and for their extensive knowledge of the territory. They are witnesses/signatories to almost all land transactions. They also seem to provide rapid judgment, are less expensive, and strive to preserve peace in the community. Landlord/neighbours of the disputed land, as well as family members and friends, are solicited because they can help to resolve conflicts without incurring financial expenses and also because it preserves the peace and social relationship between the conflicting parties.

As such, 40.4% of respondents use traditional leaders to resolve conflicts over land. This is followed by landlords/neighbours of the disputed land (23.6%) and family members/friends (21.4%). Administrative authorities and forces of law and order such as the law courts and the police are the least solicited due to the high costs involved. However, 9% of respondents choose this method of conflict resolution because they have the legal means and power to re-establish law and order on disputed land. They also believe in the force of the court to maintain peace. Nevertheless, although traditional leaders are highly solicited for in land conflict resolution, land dispute management in Njombé seems less organized as the conflicting parties can directly turn to any of the arbitrators for resolution. The type of arbitrator used depends on the social interests as well as the financial capacity of the conflicting parties.

Perceived effects of land tenure on farmers' livelihoods

Land use pattern of the area

Land use pattern in the area is a direct effect of the past and therefore how land is used today is determined by how it was used in the past (colonial period). Land in Njombé is used for various purposes including subsistence agriculture, commercial agriculture, experimental trials, plantation agriculture, real estate and other developmental projects. The presence of the agro-industrial plantations in the centre of the town makes access to farmland difficult as small-scale producers are forced to go far into the forest (say about 20 to 25 km from their homes) in search of farmland.

Small-holder farmers' land is either used for subsistence or commercial agriculture. However, this varies with gender, as 82.0% of male farmers use their farmland for commercial agriculture; cultivating crops such as cocoa, palm nuts, pineapples, pawpaw and citrus fruits. Sixty-two percent of female farmers use their farms for subsistence agriculture, cultivating food crops such as maize, groundnuts, leafy vegetables, cassava, sweet potatoes and beans.

Farmers' perceptions of the effects of land tenure system on their livelihoods

Although small-scale producers account for over 80% of domestic food production (ANoRF, 2010; IFAD, 2008:4), the presence of agro-industrial plantations in the centre of Njombé has some negative consequences on the livelihoods of small-scale producers. For instance, farmers were of the view that the presence of plantations undermines access to and control of resources of the local population now and/or in future, as it takes up the best lands pushing the rural people to cultivate on marginal lands that are hardly productive enough to feed them and secure surplus for market. This therefore affects their rights to adequate living standards and increases their vulnerability to hunger and poverty as they rely heavily on land for their livelihood.

Secondly, farmers were of the view that plantation estates displace local producers (small-holder farmers) who often have the knowledge of producing sustainably, and would be in a position to do so with even higher yields if they were provided with an enabling agricultural policy environment. Furthermore, respondents remarked that their health is threatened as aerial spraying of banana crops leads to air pollution. River water, formerly used by the inhabitants, is now confiscated and used for irrigating plantations. Irrigation channels of these plantations are being emptied into the residential areas leading to water-borne diseases especially during the rainy season. This reduces the farmers´ capacity to invest in other productive activities as they say "health *is wealth*".

Conclusion

This study has revealed that Njombé is an area with great agricultural potential which could play a very important role in poverty reduction and sustainable food production. In spite of this, the presence of agro-industrial plantations, while providing jobs, presents challenges in terms of land access and tenure security to the inhabitants who are often pushed to farm on marginal lands. Large plantations also cause air and water pollution which destabilizes the socio-economic system and the natural environment of the area. The findings from the study provides an opportunity to enhance the peaceful co-existence between private companies involved in large-scale plantations and small-holder farmers who depend on agriculture for their livelihoods. For instance there is the need for the government of Cameroon to revisit existing land policies relating to procedures for the allocation of lands to multinational companies involved in plantation agriculture. The revised policies must protect small-holder farmers' access to land and enhance their sovereignty as many have been pushed to marginal lands which are often less productive and not within easy access to markets. Once these challenges are addressed small-holders will be able to engage in long-term investments on their lands and improve their productivity. Secondly, there is the need to recognise the land rights of indigenous peoples through land reforms that reconcile state laws and customary laws, in order to prevent conflicts arising from competing claims based on different rights. This may include the adoption of laws that promote a land tenure system which protects the land rights of all actors, particularly small-scale producers and rural inhabitants, with a view to achieving food security.

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Multiplication végétative de *Dacryodes edulis* (G. Don) H.J. Lam. par marcottage aérien

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Dacryodes edulis (G. Don) H.J. Lam. (Burseraceae), est un arbre fruitier à haute valeur dans les régions de l'Afrique de l'Ouest et du Centre. Le marcottage aérien de cette espèce est aujourd'hui maîtrisé, mais l'effet du clone et du type de propagule sur l'enracinement des marcottes reste des points d'ombre, ainsi que l'orientation de la branche et la position de la marcotte dans le houppier. Des essais ont été mis en place afin de tester l'effet du clone, du type de propagule (bouture et marcotte), du houppier (bas et haut) et de l'orientation de la branche (plagiotrope, oblique et orthotrope) sur l'enracinement des marcottes. Pour les trois premiers facteurs, les clones âgés de 10 ans à maturation normale et un mélange sciure décomposée – terre arable à proportions égales, ont été utilisés pendant la mise en place des essais. Les arbres à maturation tardive de plus de 20 ans et la sciure de bois décomposé ont été utilisés pour le facteur orientation. Dix mois après la pose des marcottes, les résultats ont révélé que l'effet clonal affecte très significativement l'enracinement des marcottes ($p<0,001$). Le meilleur résultat a été obtenu pour les clones, MA/DE/40M, BUM/DE/36M et DE/M/2-70C. Le type de propagule a eu un effet significatif sur l'enracinement des marcottes ($p<0,012$) et concernant le paramètre mortalité, cet effet a été significatif au huitième mois ($p<0,038$). Aucun effet significatif ($p = 0,12$) de la position de la branche dans le houppier sur l'enracinement des marcottes n'a été enregistré. Toutefois le haut houppier a eu un pourcentage d'enracinement élevé (39,59 ± 3,37 %) par rapport à celui du bas houppier (31,94 ± 3,44%) à 10 mois. Le taux de mortalité est élevé chez les marcottes du bas houppier (40,28 ± 4,08%) et le nombre moyen de racines primaires (6,97 ± 0,87%) a été bas par rapport aux résultats du haut houppier (33,33 ± 3,91 et 7,36 ± 0,8 % respectivement). Neuf mois après la pose des marcottes, les branches orthotropes ont présenté un nombre de racines primaires élevé (13,55 ± 1,22%) et un faible taux de mortalité des marcottes (6,67 ± 4,55%) contrairement aux pourcentages des branches plagiotropes (7,84 ± 0,77 %, 26,67 ± 8,05% respectivement). Aucun effet significatif ($p = 0,45$) de l'orientation de la branche n'a été enregistré, mais le pourcentage d'enracinement des marcottes des branches plagiotropes et obliques est élevé (43,33± 9,05%), comparé à celui des branches orthotropes (30 ± 8,34%). Ainsi donc, nous pouvons conclure de cette étude que, le haut houppier et les branches orthotropes sont adaptés pour le marcottage aérien de *D. edulis*.

Mots clés: domestication, safoutier, clone, marcotte, Cameroun

Dacryodes edulis (G. Don) H. J. Lam. (Burseraceae) is a high-value fruit tree in West and Central Africa. Air layering of this species is now under control, but uncertainty remains as to the effect of a number of factors on rooting; these include cloning the type of propagule, the orientation of branches and the position of the marcots in the crown. A series of experiments were conducted to evaluate the effect of cloning, the type of propagule (cuttings and marcots), position in the crown (lower and upper) and the orientation of branches (plagiotropic, oblic and orthotropic) on the tree´s rooting ability. For the first three factors, older clones of 10 years with a normal maturation were bedded in equal proportions of decomposed sawdust and arable soil. To test the orientation factor late maturing trees of over 20 years bedded in, decomposed sawdust were used. Ten months after the setting up of marcots, the results showed that the clonal effect significantly ($p<0.001$) affects the rooting of marcots. The best result was obtained for clones MA/DE/40M, BUM/DE/36M and DE/M/2-70C. The type of propagule had a significant effect ($p<0.012$) on percentage of rooting marcots. On the dead marcots, this effect was significant ($p<0.038$) from the eighth month. No significant effect ($p = 0.124$) of the position of the branch in the crown was recorded on the rooting of marcots. However, the upper crown had apparently a high percentage of rooting (39.59 ± 3.37%) compared to that of the lower crown (31.94 ± 3.44%) at 10 months. The percentage of dead marcots recorded was high at lower crown marcots (40.28 ± 4.08%) and the mean number of primary roots was low (6.97 ± 0.87 %) compared to the upper part (33.33 ± 3.91 and 7.36 ± 0.8% respectively). Nine months after the setting up of marcots, the orthotropic branches showed a high number of primary roots (13.55 ± 1.22%) and a low percentage of dead marcots (6.67 ± 4.55%) compared to plagiotropic branches (7.84 ± 0.77 and 26.67 ± 8.05% respectively). With respect to the orientation of branches, no significant ($p = 0.45$) effect on the rooting of marcots was recorded, but the rooting percentage of marcots on plagiotropic and oblic branches (43.33 ± 9.05%) was high compared to the percentage of orthotropic branch (30 ± 8.34%). It can therefore be concluded from this study that orthotropic branches of *D. edulis*, upper crown are among the best parameters for air layering.

Key words: domestication, African plum tree, clone, marcots, Cameroon

Introduction

Dacryodes edulis (G. Don) H.J. Lam., dont le fruit est communément appelé safou est une espèce de la famille des Burseraceae, originaire de l'Afrique Centrale et du Golfe de Guinée (Sonwa *et al.*, 2002). Il pousse dans les champs depuis la Sierra Léone jusqu'au Sud de l'Angola et à l'Est de l'Ouganda (Kengue, 2011). Classé parmi les cinq fruitiers locaux prioritaires identifiés pour l'Afrique (Franzel *et al.*, 2008), *D. edulis* est très utilisé dans la pharmacopée traditionnelle. Les feuilles ou les écorces bouillies dans une eau fermentée à base de graines sont administrées aux enfants nigérians pour le traitement de l'épilepsie et le retard de croissance (Omonhinmin, 2012). La valeur de son fruit est remarquable aussi bien sur le plan nutritionnel qu'économique. Très riche en protéines, lipides et hydrates de carbones, le safou peut être utilisé pour traiter les enfants mal nourris (Ajayi & Adesanwo, 2009). En outre, les exportations de safou à partir de l'Afrique Centrale et du Nigéria vers la France, la Grande Bretagne et la Belgique sont estimées à 2 millions de dollars américains (Awono *et al.*, 2002).

Fruitier tant utilisé par les populations, *D. edulis* ne semble pas être une espèce gravement menacée, mais ses populations locales diminuent dans de nombreuses régions à cause de la déforestation et de la dégradation des forêts (Kengue, 2011). C'est la raison pour laquelle il est nécessaire de mener des propagations clonales des arbres supérieurs (Tchoundjeu *et al.*, 2002) pour l'intégration des cultivars dans des systèmes de culture afin de former des agroforêts (Sado *et al.*, 2011) où ils peuvent jouer un rôle d'ombrage principalement pour les cultures pérennes comme le cacao et le café (Orwa *et al.*, 2009).

Dacryodes edulis est à reproduction sexuée essentiellement allogame et la multiplication par semis induit une descendance à forte variabilité (Youmbi, 2000). Cette variabilité peut se manifester sur des différences phénotypiques comme la maturation des fruits ou la floraison. Il s'observe ainsi des individus à maturation précoce dont la période de fructification a lieu entre le mois d'avril et mai, des individus à maturation normale (juillet – septembre) et des individus à maturation tardive (novembre – décembre) (Kengue, 2002). En outre, les travaux effectués par Biakaiy (2008) ont permis de classer les arbres de *D. edulis* par catégorie en fonction de l'épaisseur de la pulpe, la grosseur, la longueur, le goût du fruit et la production. Sur la base de toutes ces diversités de caractères, la sélection et le clonage des individus sont nécessaires pour l'obtention des clones supérieurs de meilleures qualités gustatives et à fort rendement économique. Pour ce faire, la multiplication végétative reste la méthode la plus commune permettant de reproduire des copies conformes des individus sélectionnés.

Parmi les techniques de multiplication végétative, le greffage s'est soldé par un échec (Kengue, 2002 ; Verheij, 2002). Le bouturage a connu des avancées considérables (Mialoundama *et al.*, 2002 et Assah *et al.*, sous presse) malgré quelques points à raffiner. Le marcottage aérien a présenté les meilleurs résultats jusqu'aujourd'hui. La série de résultats obtenue pendant les travaux de marcottage aérien menés par Kengue (1998) sur le diamètre de la branche (Mialoundama *et al.*, 2002), le substrat d'enracinement de *D. edulis* pourrait être complétée par la position de la marcotte dans le houppier, jusqu'ici mené uniquement sur *Irvingia gabonensis* (Tchoundjeu *et al.*, 2010). En outre, l'on pourrait penser que le microclimat qui règne autour des marcottes dans le houppier est supposé varier en fonction du niveau où se trouve celle-ci et pourrait influencer son enracinement. Les travaux menés par Mialoundama *et al.*, (2000) et Mbondo (2000) portaient sur l'orientation des branches et n'étaient pas précis car les angles d'inclinaison entre les branches n'avaient pas été définis. C'est la raison pour laquelle, ils avaient recommandé des études plus approfondies sur ce facteur. Les travaux sur l'influence du type de propagule sur l'enracinement des marcottes de *D. edulis* n'ont pas encore fait l'objet d'une étude.

Les objectifs globaux de la présente étude sont d'évaluer, l'influence du clone et du type de propagule sur l'enracinement des marcottes, ensuite l'influence de la position de la marcotte dans le houppier sur l'enracinement des marcottes, et enfin l'influence de l'orientation de la branche sur l'enracinement des marcottes.

Matériels et méthodes

Sites de l'étude

Cette étude a été menée dans les parcelles expérimentales de l'ICRAF, Région du Centre au Cameroun à Mbalmayo, Minkoa-Meyos et à Makénéné (en champ) comme illustré ci-dessus (Tableau I et Fig. 1).

Localités/Paramètres	Makénéné	Mbalmayo	Minkoa-Meyos
Latitude	4°28 N	3°10 N	3°51 N
Longitude	10°28 E	11°00 E	11°25 E
Altitude	650 m	650 m	813 m
Pluviométrie moyenne	2088 mm	1802 mm	1400 mm
Température moyenne	25°C	24°C	25°C
Type de sol	Ferralitique	Ferralitique	Acide

Tableau 1. Caractéristiques des sites d'études (Ambassa Kiki, 2000)

Figure 1. Carte présentant les sites d'étude adaptée de l'IRAD (2006)

Caractéristiques des clones

Dans la parcelle mixte boutures/marcottes, les clones de safoutier ont été plantés en association avec d'autres espèces ligneuses. Il s'agit de l'ayous (*Triplochiton scleroxylon*) et du bibolo (*Lovoa trichilioides*). Ces espèces à bois d'œuvre très utilisées dans notre pays (Cameroun) ont été suivies en pépinière et ensuite associées aux clones de *Dacryodes edulis* dans la parcelle expérimentale. Cette association avait pour but de diversifier des produits dans la parcelle. La parcelle composée uniquement des clones de marcottes a aussi servi pour le test des marcottes. Dans ces parcelles, les plants de boutures et de marcottes ont été transplantés en avril de l'an 2000.

Les clones étaient de quatre provenances : trois de Boumnyebel (BUM/DE/16M, BUM/DE/17M, BUM/DE/36M) ; sept clones provenant du parc à bois de Mbalmayo (DE/M/2-102C, DE/M/242C, DE/M/2-70C, DE/M/2-91C, DE/M/2-92C, DE/M/2-96C, DE/M/C) ; un clone de Makénéné (MA/DE/40M) et un de Mbouda (MB/DE/11M). Actuellement les clones BUM/DE/16M, BUM/DE/17M, DE/M/C et DE/M/242C sont présents dans la parcelle expérimentale de Minkoa-Meyos et les autres dans celle de Mbalmayo.

Code dans la banque de gènes	Type de propagule	Site de collecte des clones	Latitude	Longitude	Altitude (m)
BUM/DE/16M	Marcotte	Boumnyebel	3°50′39.09″ N	10°54′33.08″ E	796
BUM/DE/17M	Marcotte	Boumnyebel	3°49′19.36″N	10°55′18.25″E	796
BUM/DE/36M	Marcotte	Boumnyebel	3° 51′ 48.41″N	10° 56′ 32.19″E	796
DE/M/2-102C	Bouture	Mbalmayo	3° 28′ 18.86″N	11° 29′ 32.13″E	677
DE/M/242C	Bouture	Mbalmayo	3° 28′ 27.94″N	11° 28′ 04.25″E	676
DE/M/2-70C	Bouture	Mbalmayo	3° 28′ 01.75″N	11° 28′ 58.93″E	677
DE/M/2-91C	Bouture	Mbalmayo	3° 28′ 01.38″ N	11° 28′ 46.40″E	673
DE/M/2-92C	Bouture	Mbalmayo	3° 27′ 52.08″N	11° 28′ 58.38″E	678
DE/M/2-96C	Bouture	Mbalmayo	3° 28′ 05.32″N	11° 28′ 57.64″E	677
DE/M/C	Bouture	Mbalmayo	3° 28′ 16.89″N	11° 28′ 58.19″E	677
MA/DE/40M	Marcotte	Makénéné	4° 53′ 08.71″N	10° 49′ 01.85″E	718
MB/DE/11M	Marcotte	Mbouda	5° 35′ 97.01″N	10° 19′ 04.78″E	1301

Tableau 2. Informations générales sur les clones marcottés

Pratique du marcottage

La pose des marcottes a eu lieu entre mai et juin 2009 pour les marcottes posées sur les clones et au mois de mai 2010 pour le reste. Sur le plan pratique, le marcottage aérien a été réalisé suivant la méthode décrite par Kengue (2002). Le dispositif expérimental a été le plan en bloc complet randomisé, chaque arbre constituant un bloc et l'unité expérimentale a été la marcotte pour tous nos essais.

Expérience 1 : Effet clonal et du type de propagule sur l'aptitude à l'enracinement des marcottes de Dacroydes edulis

Nous avons pris en compte deux facteurs, l'effet clonal et le type de propagule. L'on a posé les marcottes sur les branches de diamètre compris entre 3 et 5 cm des arbres de 10 ans d'âge et le mélange sciure décomposée et terre arable à proportion égale a servi comme substrat d'enracinement.

Pour l'effet clone, 12 traitements (clones) ont été appliqués. Ceux-ci ont été identifiés et testés à partir des résultats des études précédentes comme étant les meilleurs sur la base de leur rendement, de la taille et du goût de leurs fruits (Biakaiy, 2008). Il s'agit de: BUM/DE/16M, BUM/DE/17M, BUM/DE/36M, DE/M/2-102C, DE/M/242C, DE/M/2-70C, DE/M/2-91C, DE/M/2-92C, DE/M/2-96C, DE/M/C, MA/DE/40M et MB/DE/11M. Trois arbres ont été marcottés par traitement dont huit marcottes par arbre, vingt-quatre marcottes par clone et deux cent quatre-vingt-huit marcottes posées au total.

Deux traitements ont été appliqués pour le facteur type de propagule ; les arbres issus du bouturage et ceux issus du marcottage. Cinq arbres sont issus des marcottes et sept issus des boutures. Pour chaque type de propagule, trois arbres ont été marcottés, huit marcottes par arbres, soit cent vingt marcottes pour les arbres issus des marcottes et cent soixante-huit pour ceux issus des boutures.

Expérience 2 : Effet de la position de la marcotte dans le houppier sur l'aptitude à l'enracinement des marcottes de Dacroydes edulis

Nous avons utilisé le même matériel végétal de l'expérience 1 pour tester les paramètres de ce facteur. Deux niveaux d'houppier ont été considérés : le niveau bas qui part des branches les plus basses à la moitié supérieure du houppier et le niveau haut qui va de la moitié supérieure du houppier au sommet de l'arbre. Pour chaque niveau de houppier considéré, huit marcottes ont été posées à raison de quatre marcottes par niveau de houppier, pour un total de deux cent quatre-vingt-huit marcottes sur trente-six arbres.

Expérience 3 : Effet de l'orientation de la branche sur l'aptitude à l'enracinement des marcottes

Nous avons marcotté des arbres de plus de 20 ans d'âge caractérisés par une maturation tardive ou/et précoce. Le substrat d'enracinement a été la sciure de bois décomposé. On a utilisé les branches de diamètre 4 à 5 cm. Trois traitements ont été appliqués: l'orientation orthotrope (où l'angle varie de 0 à 45°), l'orientation oblique (45 et 75°) et l'orientation plagiotrope (75 et 90°). Ces angles d'inclinaison ont été déterminés suivant l'angle que fait la branche à marcotter avec l'axe principal de l'arbre ou avec une ramification. Dix arbres ont été marcottés à raison de, neuf marcottes par arbre, soit trois marcottes pour chaque traitement, pour un total de quatre-vingt-dix marcottes.

Collecte des données

Les données liées à l'état général de la marcotte (enracinée, morte et non enracinée) et le nombre de racines émises par marcotte enracinée ont été pris en compte. Pour les essais effet clonal, type de propagule et position de la branche dans le houppier, trois évaluations ont été faites à l'intervalle d'un mois et les trois dernières dans un intervalle de deux mois. En ce qui concerne l'essai orientation, six évaluations ont été faites, la première a eu lieu deux mois après la pose des marcottes (juillet 2010), trois ont eu lieu à l'intervalle d'un mois (août, septembre, octobre 2010) et les deux dernières en un intervalle de deux mois (décembre 2010 et février 2011). Le nombre de racines a été compté après le sevrage.

Les marcottes présentant des racines visibles à travers le plastique, encore individualisées ou commençant à peine à se ramifier et à former des poils absorbants ont été sevrées de l'arbre mère à l'aide d'une scie horticole. Elles ont été ensuite mouillées à l'eau, étiquetées et mises dans de sacs appropriés en vue de faciliter leur transport pour la pépinière. En pépinière, le substrat enrobant la partie écorcée a été partiellement défaite avec précaution pour éviter d'endommager les racines. Le nombre de racines a été compté et enregistré, ensuite les marcottes ont été plantées dans de sachets en polyéthylène noirs, perforés d'une contenance de quatre litres, préalablement remplis d'un mélange de terre arable et de sable dans les proportions 3/1. Elles ont été stockées dans un châssis de rééducation du genre décrit par Tchoundjeu *et al.*, (2010). Toute branche marcottée desséchée a été considérée comme morte et immédiatement détruite pour éviter toute confusion lors des futures évaluations. Toute branche marcottée restée verte mais ne présentant aucune racine visible, a été notée vivante car susceptible de s'enraciner ultérieurement.

Analyse statistique

Les données collectées ont été codifiées sous forme binaire ("0" signifiant marcotte non enracinée et "1" marcotte enracinée en cas d'enracinement et "0" pour la marcotte vivante et "1" pour la morte en cas de mortalité). Elles ont été par la suite saisies dans le tableur Excel 2010 puis transportées dans le logiciel GenStat V pour analyse afin de déterminer les effets sur les différents facteurs étudiés (clone, type de propagule, orientation et position de la branche dans le houppier). L'ensemble des données a été soumis à un modèle d'analyse de régression, celles relatives à l'enracinement et à la mortalité des marcottes ont été soumises à une analyse de variance à l'aide du modèle de régression logistique pour déterminer les différences significatives entre les moyennes calculées (taux d'enracinement et de mortalité) des différents traitements. Pour évaluer l'effet des différents traitements sur le nombre de racines primaires par marcotte enracinée, les données ont été soumises à des analyses en utilisant le modèle log linéaire. La différence significative entre les taux d'enracinement, de mortalité et le nombre moyen de racines primaires par marcotte enracinée a été évaluée grâce à la plus petite différence significative au seuil de 5%.

Résultats

Effet du clone et du type de propagule sur l'aptitude à l'enracinement des marcottes de Dacroydes edulis

L'analyse de la variance multiple a montré que l'effet clonal a significativement influencé l'enracinement des marcottes tout au long de l'essai ($p<0{,}001$). Il ressort de la figure 2 que, le temps mis par les marcottes pour s'enraciner a varié d'un clone à l'autre. 50% des 12 clones testés ont fourni des marcottes enracinées au bout de 3 mois et la proportion a atteint 75% soit 9 clones sur 12 au quatrième mois. Les clones DE/M/C, DE/M/2-96C et BUM/DE/16M ont présenté les premières marcottes enracinées au sixième et huitième mois respectivement. Trois clones seulement ont présenté un pourcentage d'enracinement supérieur ou égal à 50% 10 mois après la pose des marcottes. Il est apparu sur cette figure que les clones MA/DE/40M, BUM/DE/36M et DE/M/2-70C ont présenté les pourcentages de marcottes enracinées les plus élevés tandis que BUM/DE/16M, DE/M/C et DE/M/2-91C ont présenté le plus faible pourcentage de marcottes enracinées.

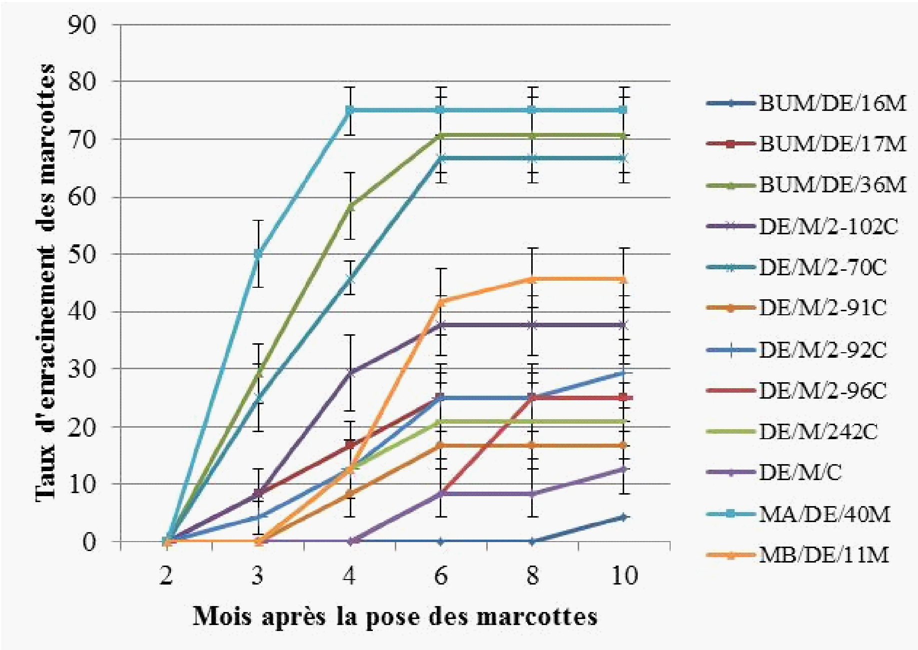

Figure 2. Évolution du pourcentage de marcottes enracinées en fonction du temps pour chaque clone

Le clone n'a pas affecté la mortalité 3 mois après la pose des marcottes ($p = 0{,}07$). Par contre son effet est significatif à partir du 4ème mois ($p = 0{,}04$) jusqu'à la fin de l'essai ($p<0{,}001$ à 10 mois). Il ressort de la figure 3 que, seul le clone DE/M/242C a présenté des marcottes mortes au 10ème mois. Tandis que DE/M/2-91, DE/M/2-96 et DE/M/2-102C sont apparus comme les plus susceptibles à la dégénérescence avec 25% de marcottes mortes au 3ème mois. Au 10ème mois, à ceux-ci se sont ajoutés BUM/DE/16M et DE/M/C. Par contre les clones MA/DE/40M et BUM/DE/36M ont présenté des taux de mortalité constant depuis la première évaluation et ceux-ci sont les plus faibles à la fin de l'essai. Il a été constaté, à partir des figures 2 et 3, que certains clones (BUM/DE/16 M) dont l'apparition des racines a été tardive ont présenté les taux de mortalité les plus élevés.

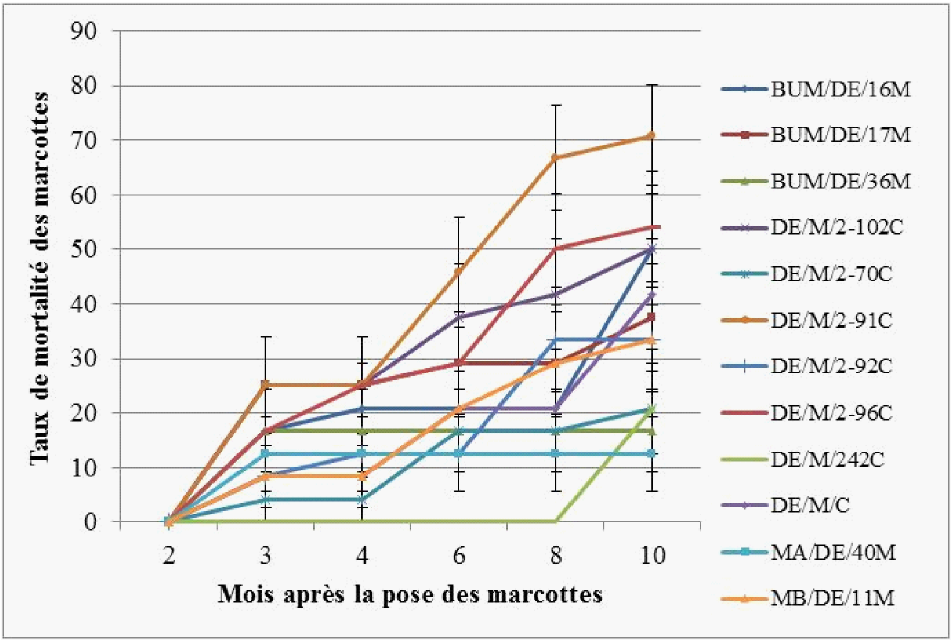

Figure 3. Évolution du taux de mortalité des marcottes en fonction du temps pour chaque clone de D. edulis

L'influence du clone sur le nombre moyen de racines formées par marcotte enracinée a été hautement significative (P<0,001). Le nombre moyen de racines par marcotte enracinée a varié de 1,40 ± 1,5 pour DE/M/242C à 16,00 ± 3,96 pour DE/M/2-91C.

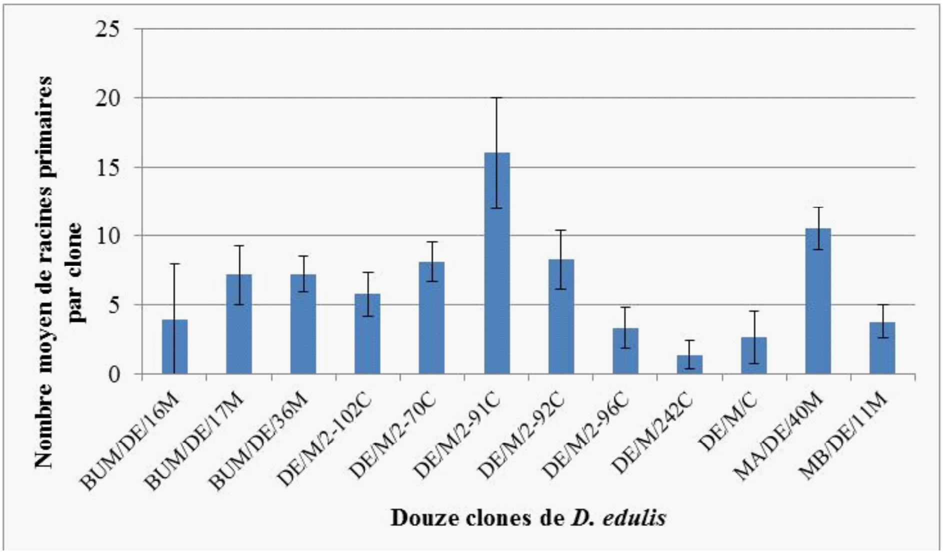

Figure 4. Nombre moyen de racines primaires par clone

Dix mois après la pose des marcottes, le type de propagule a affecté significativement l'enracinement des marcottes (p = 0,012). Les arbres issus des marcottes ont été les meilleurs en termes de taux d'enracinement soit 44,17 ± 4,53% contre 29,76 ± 3,51% pour les arbres issus des boutures. L'influence significative du type de propagule sur la mortalité des marcottes a été observée le 8ème mois après la pose (p = 0,04). Les arbres issus des boutures ont favorisé le dépérissement des marcottes (41,67 ± 3,80%) par rapport aux arbres issus des marcottes (30 ± 4,17%) au $10^{ème}$ mois après la pose des marcottes. Le nombre de racines n'a pas eu un effet significatif (p = 0,20), cela s'est illustré par les valeurs suivantes : 6,78 ± 0,36% pour les marcottes issues des boutures et 7,44 ± 0,37% pour celles issues des marcottes, à la fin de l'essai.

Effet de la position de la branche sur l'aptitude à l'enracinement des marcottes de Dacroydes edulis

L'analyse de la variance multiple (MANOVA) a montré que la position de la marcotte dans le houppier n'a pas eu d'effet sur l'enracinement des marcottes (p = 0,12 au $10^{ème}$ mois après la pose). Les marcottes posées sur le houppier bas ont présenté un pourcentage d'enracinement élevé (11,81 ± 2,18 % et 23,61 ± 3 %) respectivement au $3^{ème}$ et $4^{ème}$ mois par rapport à celles posées sur le houppier haut (9,03 ± 2,05% et 21,53 ± 2,54%), mais la tendance a changé à partir du 6ème mois jusqu'à la fin de l'essai.

En ce qui concerne la mortalité, la position de la branche a eu un effet significatif du $3^{ème}$ au $4^{ème}$ mois (p<0,001). Cet effet n'a pas été observé du $6^{ème}$ mois (p = 0,11) jusqu'à la fin des essais (p = 0,22). Au $10^{ème}$ mois, les taux de mortalité enregistrés ont été de 40,28 ± 4,08% pour le bas houppier contre 33,33 ± 3,92% pour le haut houppier.

La position de la branche dans le houppier n'a pas eu d'effet significatif sur le nombre moyen de racines par marcotte enracinée (p = 0,74). Les nombres moyens des racines par marcottes enracinée ont été de 6.97 ± 0.86% pour le bas houppier et 7.36 ± 0.80% pour le haut houppier.

Effet de l'orientation de la branche sur l'aptitude à l'enracinement des marcottes de Dacroydes edulis

L'analyse de variance multiple (MANOVA) a montré que l'orientation de la branche n'a pas eu un effet significatif sur l'enracinement des marcottes (p = 0,46) neuf mois après la pose. Les taux cumulés d'enracinement des branches orthotropes et plagiotropes ont été respectivement de: 30 ± 8,34% et 43,33 ± 9,05%. Celui des marcottes posées sur les branches obliques est le même que le taux d'enracinement des marcottes posées sur les branches obliques.

Par contre, l'orientation a significativement eu une influence sur la mortalité des marcottes (p<0,01 et p = 0,05 respectivement à trois et neuf mois). Les branches orthotropes ont présenté les taux cumulés de mortalité les plus faibles (Fig.5).

L'orientation a affecté le nombre moyen de racines sur les marcottes (p<0,001). Les pourcentages en nombre moyen de racines primaires ont été élevés pour les marcottes enracinées des branches orthotropes (13 ± 1,22%) et bas pour les marcottes enracinées des branches obliques (7,69 ± 0,77 %) (Fig.6).

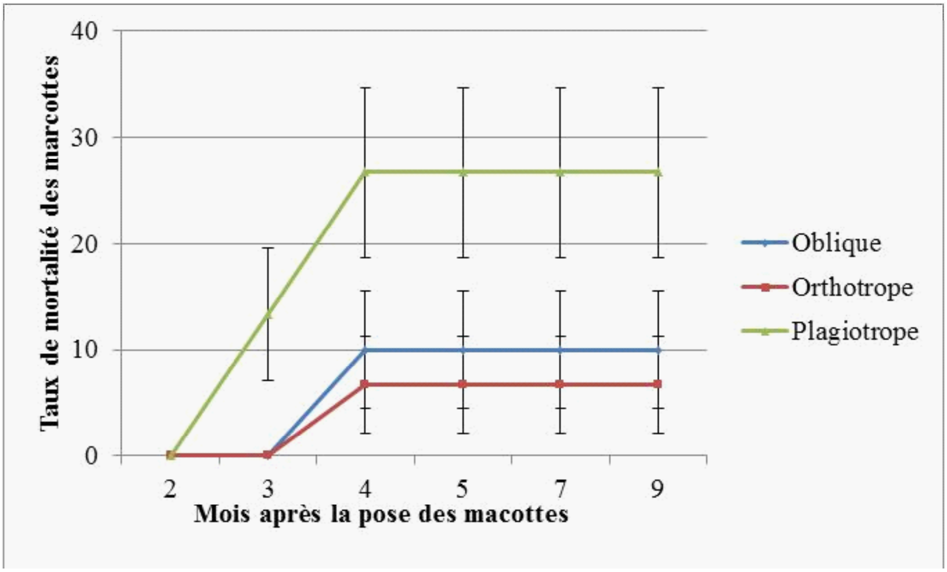

Figure 5. Influence de l'orientation de la branche sur la mortalité des marcottes

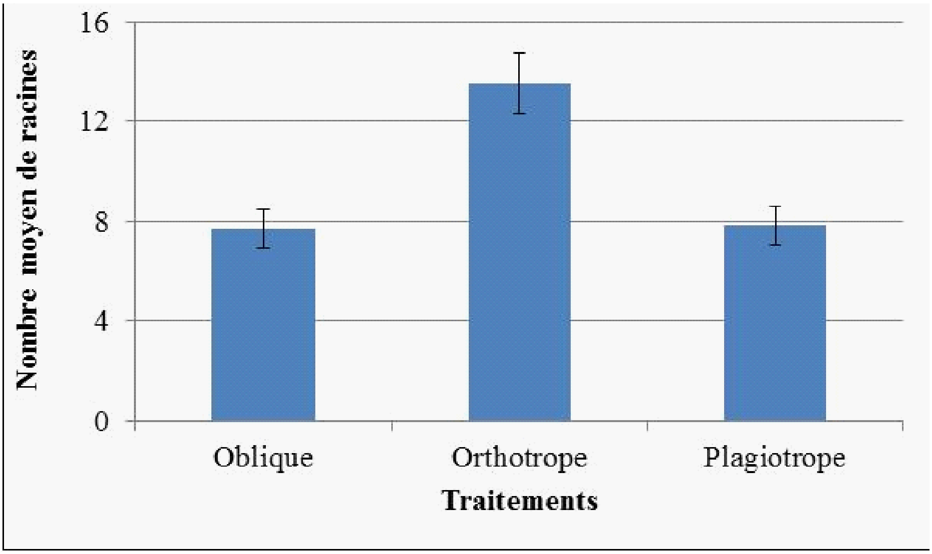

Figure 6. Nombre moyen de racines principales par marcotte enracinée

Discussion

Les études menées par Tchio et Kengue (1998) et Mialoundama *et al.*, (2002) ont montré que le premier sevrage des marcottes de *D. edulis* se fait à 5 mois pour des marcottes n'ayant pas reçu d'hormones de croissance. Selon Mialoundama et ses collaborateurs, ces hormones accélèrent l'enracinement et réduisent le délai de sevrage des marcottes de *D. edulis* de cinq à trois mois. Or pour la présente étude, le premier sevrage s'est réalisé trois mois après la pose des marcottes pour les clones (10 ans) comme pour les arbres en champ (plus de 20 ans). Ceci peut être qualifié de précoce comparativement aux résultats précédemment obtenus. Ces résultats se justifient par le fait que, dans les mêmes conditions de climats, certains arbres réagissent rapidement et à 100%, alors que d'autres se montrent plutôt réfractaires au marcottage aérien (Kengue, 2002). En ce qui concerne les arbres de plus de 20 ans d'âge, ils sont caractérisés par une maturation tardive ou précoce des fruits. Selon la déclaration de Tchaya Paul originaire et résident de l'arrondissement de Makénéné, ces individus pourraient fructifier une à deux fois par an. De ce fait, l'activité physiologique des arbres à maturité tardive pourrait alors être très intense favorisant ainsi l'enracinement précoce des marcottes. La différence observée par rapport au pourcentage des marcottes enracinées, le taux de mortalité et le nombre moyen de racines chez les différents clones corrobore les résultats obtenus par Kengue *et al.*, (1998). Cette différence de comportement peut être liée à l'état physiologique de l'arbre au moment où la marcotte a été posée (Kengue *et al.*, 1998).

Au premier abord, nous avons pensé que les arbres issus les boutures auraient des meilleurs résultats car ils sont issus des tissus juvéniles (Jaenicke & Beniest, 2003) qui entrainent une activité physiologique intense. Cela s'est démontré par les résultats de

Atiojio *et al.*, (2011), où les arbres issus des boutures ont une forte biomasse aérienne, souterraine et par conséquent un stock de carbone élevé et une capacité élevée de séquestration de gaz carbonique. Mais cela n'a pas été le cas, nos résultats pourraient alors aller dans le même sens que ceux de Akinnifesi *et al.*, (2009), qui ont montré que les propagules de *Uapaca kirkiana* issus des marcottes ont un bon rendement en termes de fructification, une bonne croissance et une meilleure matière sèche par rapport aux arbres issus de greffons. Ils justifient cela par le fait que les marcottes sont issues des tissus matures et se développent sur leurs propres racines alors que les arbres issus des greffons se sont développés sur des racines juvéniles appartenant à un autre plant. De plus, l'on pourrait ajouter que les meilleurs résultats obtenus pour les arbres issus des marcottes sont dus au fait que celles-ci ont été posées sur l'arbre mère en champs alors que les boutures sont issues des tissus juvéniles dans un milieu contrôlé. De ce fait, pour ce cas nous pouvons penser à une meilleure adaptabilité des marcottes en milieu naturel par rapport aux boutures.

Cette étude a révélé que la position de la branche dans le houppier n'a pas d'effet significatif sur l'enracinement des marcottes ainsi que sur le nombre moyen de racines par marcotte enracinée. Ces résultats corroborent ceux de Tchoundjeu *et al.*, (2010) sur le marcottage du manguier sauvage (*Irvingia gabonensis*). Ils expliquent ces résultats par une égale distribution le long du houppier des hydrates de carbones provenant de la photosynthèse, bien que le haut houppier soit supposé en produire davantage du fait de son exposition direct au soleil. La différence observée sur l'enracinement du troisième au quatrième mois après la mise en place des marcottes et le pourcentage de mortalité toujours élevé des marcottes posées sur le niveau bas du houppier pourraient probablement se justifier par à une diminution progressive de l'intensité lumineuse au fur et à mesure que l'on décroit du houppier (Sellin & Kupper, 2004) et par conséquent, la diminution de l'activité photosynthétique des branches de cette partie de l'arbre. Cependant, l'évolution de nos résultats nous amène à confirmer ceux de Tchoundjeu *et al.*, (2010) sur le fait que toute position de la marcotte dans le houppier est apte pour l'enracinement des marcottes du moment qu'il y a une égale distribution des facteurs physiologiques favorisant l'enracinement.

Les branches plagiotropes favorisent l'enracinement des marcottes de *D. edulis* en termes de pourcentage d'enracinement. Par contre, les branches orthotropes, développent un nombre élevé de racines primaires. Ce nombre de racines est déterminant pour la survie des arbres en champ. Or, les travaux de Asaah (2010) ont montré que, les racines secondaires qui deviennent par la suite des racines adventives se développent à partir des racines primaires. Autrement dit, plus le nombre de racines primaires est élevé, plus son nombre en racines secondaires l'est aussi. Cela entraine par conséquent, une meilleure stabilité des marcottes en champ. De ce fait, l'on pourra affirmer comme Mbondo (2000) et Mialoundama (2000) que les branches orthotropes sont les plus adaptées au marcottage aérien de *D. edulis*. Ces résultats pourraient se justifier par le fait que les arbres marcottés étaient à plus de 20 ans d'âge et possédaient en majorité des branches de gros diamètre qui émettaient des rejets qui ont servi de matériel végétal pour les branches orthotropes. Ces rejets sont constitués par des tissus juvéniles qui sont caractérisés par la vigueur et la facilité à s'enraciner (Jaenicke & Beniest, 2003). En outre, les enzymes comme les auxines stimulatrices de la formation des racines et augmentatrices du nombre moyen de racines primaires sont en grande quantité dans les tissus juvéniles par rapport aux tissus matures (Wesley, 1988). Parlant de la grande mortalité observée chez les branches plagiotropes, cela pourrait s'expliquer par le vieillissement des tissus végétatifs dû à l'âge des arbres marcottés.

Conclusion

Il ressort de cette étude que l'enracinement des marcottes est possible à trois mois autant pour les clones que pour les arbres en champs chez le safoutier. L'aptitude à l'enracinement des marcottes des clones de *D. edulis* varie d'un clone à l'autre. MA/DE/40M, BUM/DE/36M et DE/M/2-70C sont ceux qui se sont démarqués par leur pourcentage élevé de marcottes enracinées (≥50%), leur nombre moyen de racines supérieur à six et leur faible taux de mortalité. La pose des marcottes pourrait être prioritaire sur des arbres issus du marcottage et quel que soit leur lieu de provenance. La partie supérieure du houppier pourrait être plus favorable au marcottage aérien que la partie inférieure. Les rameaux orthotropes se prêtent mieux au marcottage aérien chez le safoutier, bien qu'ils présentent le plus faible taux d'enracinement. Pourtant, les marcottes issues de cette orientation ont un pourcentage élevé en termes de nombre de racines qui détermine la stabilité du plant en champ et un faible taux de mortalité.

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Vegetative propagation of *Garcinia lucida Vesque* (Clusiaceae) using leafy stem cuttings and grafting

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Garcinia lucida Vesque (Clusiaceae) is a tree species that is highly valued for its medicinal properties by rural households in the humid forest zone of Cameroon. However, the unsustainable exploitation of the species threatens its long-term regeneration. This study focuses on its vegetative propagation via stem cuttings in non-mist propagators and through grafting. The study tests the effects of three rooting media (sand, sawdust, sand + sawdust (1/1); three leaf sizes (0,25 and 50 cm^2); and three types of hormone [indole butyric acid (IBA), indole-3-acetic acid (IAA) and naphthalene acetic acid (NAA)], applied as a single dose. Furthermore, three grafting techniques (cleft, side tongue and whip-and-tongue grafting) were tested. All experiments were designed as completely randomized blocks with three replicates. Results showed that cuttings require a medium that has low water holding capacity and high porosity, and a leaf area of 50 cm^2 and NAA treatment; grafting success was affected by the technique used, with top cleft grafting yielding a 100% success rate. From this preliminary study, it is concluded that *G. lucida* is amenable to vegetative propagation by cuttings and grafting.

Key words: tree domestication, leaf area, non-mist propagator, rooting hormone, rooting medium, under-utilised species

Introduction

Garcinia lucida Vesque (Clusiaceae family) is a small, evergreen dioecious tree of the humid forest zone of west and central Africa, reaching 25-30 cm in trunk diameter at breast height (dbh) and 12-15 m in height in high-density stands. The trees provide a variety of non-timber forest products of great importance to rural households (Guedje and Fankap, 2002). Trees flower and produce fruits throughout the year and seeds germinate within a few weeks of falling. *G. lucida* is found in undisturbed or mature forests at altitudes above 500 m in Cameroon, Equatorial Guinea and Gabon where conditions such as a high annual rainfall (1600-1800 mm) and a mild average daily temperature (24-26°C) favour its growth and development (Bamps, 1970).

The species is highly valued for its medicinal and nutritional properties (Omode *et al.*, 1995). The seeds and bark, either dried or fresh, are widely used to relieve stomach and gynaecological pains (Sunderland and Obama, 1999; Van Dijk, 1999). In addition, the stem bark is traditionally used by forest dwellers in the fermentation of traditional alcohol obtained from palm or raffia trees (Guedje, 2003; Momo *et al.*, 2011).

The most popular method of harvesting the bark is to strip it from the full circumference of the stem. This practice is highly destructive and has been found to be responsible for 74% of tree deaths among harvested trees (Guedje and Nkongmeneck, 2001). This is having serious consequences for the species' regeneration. Tree mortality can be reduced by stripping bark from only one to two thirds of the circumference of the tree's stem. This allows the bark to regrow within about five years (Guedje and Fankap, 2002; Delvaux *et al.*, 2009).

Despite its socio-economic, medicinal and cultural importance, scant attention has been paid to *G. lucida* in terms of research and development. Little is known about its biology and there have been few attempts to improve the tree species, promote its cultivation and/or increase its production. A previous study found that the tree´s germination rate was very high (70-95%) (Guedje and Nkonmeneck, 1999). However, the high demand for seeds by traditional practitioners, coupled with the susceptibility of seeds to pests and diseases and their consumption by wild animals, limits the number of seeds available for germination. As a result, the regeneration of the species is limited.

In general, successful propagation cuttings and grafting depends on both genetic characteristics inherent to the species, as well as the environmental conditions in the nurseries (Leakey, 2004). This preliminary study was designed to determine the optimum conditions for propagation via leafy stem cuttings and grafting, in order to provide useful information on the species for domestication programmes.

Like most tropical trees, *G. lucida* has an allogamous reproductive system: the progeny is genetically distinct from the mother tree. This is a major constraint to domestication by breeding and generative propagation (Caspa *et al.*, 2009), but a benefit for the development of phenotypically superior cultivars by vegetative propagation (Akinifesi *et al.*, 2008). Vegetative propagation ensures that all plants within a cultivar are genetically identical (i.e. true-to-type planting materials) (Meunier *et al.*, 2006; Caspa *et al.*, 2009). Rooting of leafy stem cuttings and grafting have been tested successfully on some priority species at both research station and farm levels. This study on *G. lucida* specifically investigates the effects on the rooting ability of leafy cuttings of three types of rooting media, three auxin types and three different leaf areas, and then tests three grafting techniques.

Materials and methods

Study area

This research was carried out from April to August 2011 at the World Agroforestry Centre (ICRAF) research nursery in Yaoundé, Cameroon (3°52′N, 11°26′E). The site is located in the low altitude, semi-deciduous forest zone where the rainfall pattern is bimodal with 4 distinct seasons, 2 dry seasons (from November to March and in July), and two rainy seasons (from March to June and from August to October). Mean annual rainfall varies between 1600-1800 mm. Mean monthly temperature varies between 23 and 26°C, whereas mean relative humidity ranges between 73-84% (Ambassa Kiki, 2000). The cuttings and scions used in the study were collected at a field situated approximately 40 km from ICRAF's research nursery close enough to have similar weather characteristics as the nursery site in Yaoundé. The rootstocks used in the grafting experiment were produced at ICRAF's research nursery.

Collection and preparation of cuttings

Leafy stem cuttings were randomly harvested from seedlings in natural stands. Prior to taking cuttings seedlings were sprayed with water early in the morning. All tools (pruners, knives) used were disinfected before use. Materials harvested were conserved in a disinfected humid polythene bag: internally black and externally white to minimize heat stress. In the nursery, the leaves of the cuttings were trimmed to yield a surface area of 0, 25 and 50 cm^2. Cuttings were cut to a length of about 4 cm. The single node cuttings had a circular base to guarantee homogenous root distribution and a slantwise upper part to facilitate the runoff of water during watering (Tchoundjeu, 1989).

After this preparation, the basal end of each cutting was dipped briefly into 10 µl of a hormone solution prepared by mixing 50 mg of auxin and 10 ml of 95% ethanol (Avana, 2006). To minimize stress, cuttings were placed in a non-mist propagator following the procedure described by Leakey *et al.* (1990) as soon as they were prepared. The propagators were located in a shade house, allowing about 70% of ambient light to penetrate, in order to maintain constant climatic conditions and so minimize heat stress. Rooting media were treated 7 days prior to the beginning of the experiment with fungicide (Ridomil$^{+®}$, with mefenoxam and copper oxychloride as active ingredients produced by Syngenta; 50g/16 liters of water) and insecticide (Cyperdim 220 EC, with cypermethrin + dimethoate as active ingredients, at 50 ml/16 liters of water) and were kept closed for two days and opened for two days to maximize impact and then limit the risk of toxicity. Each cutting was placed in the propagator such that the medium was firmly placed around it. Cuttings in propagators were sprayed with a fine jet of water whenever the propagator lid was opened for inspection.

Experimental design

Effect of type of hormone on the rooting ability of cuttings

In addition to the control that received only water, three different auxins were tested as rooting hormones. They were indol butyric acid (IBA), indole-3-acetic acid (IAA) and naphthalene acetic acid (NAA) at a single dose/concentration of 10 µl l of each of the hormones as previously done by Avana (2006). The experiment was laid out as a completely randomized block with three replications. The rooting medium used in the experiment was washed river sand and each cutting had a leaf area of 50 cm^2. Sixty-three cuttings were set for each treatment. These were allocated to three replicates (n = 252 cuttings).

Effect of rooting medium on the rooting ability of cuttings

Three rooting media (sand, sawdust and a mixture at a ratio of 1:1 of sand and sawdust) were evaluated and the experiment was arranged as a completely randomized block. No hormone was used in the experiment and each cutting had a leaf area of 50 cm^2. Sixty-three cuttings were set for each treatment. These were allocated to three replicates (n = 189 cuttings).

Effect of leaf area on the rooting ability of cuttings

To investigate the effect of leaf area, the experiment was laid out as a completely randomized block with three treatments (0 cm^2, 25 cm^2 and 50 cm^2). River sand was used as the only rooting media and no hormone was used. Sixty-three cuttings were set for each treatment allocated to three replicates (n = 189 cuttings).

Management of the experiments and observations

Every morning, the water level in the propagator was checked and adjusted accordingly, while the transparent plastic was cleaned and the cuttings sprayed with water using a knapsack sprayer. Cuttings were assessed every two weeks for a period of 18 weeks. During each assessment, each cutting was lifted from the rooting media and rooting status noted ("1" for rooted or "0" for unrooted). Dead (rotted) cuttings were recorded ("1" for dead cutting or "0" for alive). Live, but unrooted cuttings were re-set in the media for subsequent observations. During each assessment, the number of roots per rooted cuttings was counted. The cutting was said to be rooted when it had more than one root exceeding 1 cm in length. Rooted cuttings were removed from the propagators and potted into perforated black polythene pots containing a 2:1 mixture of top soil and sand.

Effect of grafting technique on the propagation of G. lucida

Six-month old seedlings produced in the ICRAF nursery were used as rootstocks for the grafting experiments. All rootstocks were 60 cm long and had a collar diameter of about 1 cm. Scions used were collected from young and healthy branches of mature trees with known fruit characteristics located in multistrata secondary forests. Each scion was cut to a length of 20 cm with a diameter close to that of the rootstock.

After collecting the scions, the leaves were trimmed and the material placed in disinfected polythene bags for transportation to the nursery. In the nursery, scions were soaked in a solution of fungicide (Ridomil+®, with mefenoxam and copper oxychloride as active ingredients; 50g/16 liters of water) and placed in the propagator. Under the shade, different types of slits, corresponding to three different grafting techniques (top cleft, side tongue and whip-and-tongue grafting), were made in the stem of the rootstocks at about 20 cm above the collar. Scions were then inserted into these slits, tied and covered with transparent plastic. Grafted plants were then kept in the shade and monitored until the new leaves were completely green, after which they were exposed to direct sunlight for acclimation. All grafting was done by the same person to reduce experimental error.

The experiment was laid out as a randomized complete block design with each grafted plant considered as an experimental unit. Fifteen plants were used per treatment giving a total of forty-five plants. Every week, each grafted plant was assessed to register the growth of the scion ("0" for no growth and "1" for sprouting bud).

Statistical analysis

To determine the effect of experimental factors on grafting and rooting ability of cuttings, percentages of grafted plants budded and dead, percentage of cuttings rooted and dead, and mean number of roots developed per cutting collected were analysed using Linear Regression Model procedures of Genstat V.13 software. Specifically, percentage of grafted plants budded and dead, and cuttings rooted and dead were assessed using Logistic Regression while an unbalanced ANOVA model was fitted to the mean number of roots per rooted cutting. Factors having a significant effect were compared among treatment levels using the Least Significant Difference (LSD) procedure, considering a confidence interval of 0.05.

Results

Effect of type of hormone on the rooting ability of cuttings (Experiment 1)

Auxin-treated *G. lucida* cuttings rooted earlier (weeks 6 and 7) than the control (week 12) resulted in significantly greater rooting percentages (Figure 1) at week 18 ($P<0.001$). Auxin treatment also significantly affected the mortality rate of cuttings ($P = 0.003$). The treatment with NAA had the highest mortality rate, IBA the lowest while IAA was intermediate (Figure 2). The control had the lowest rate of mortality, a rate similar to that of IBA. The type of hormone did not significantly affect the mean number of roots per rooted cutting ($P = 0.498$), but few roots were produced per cutting (1.0 ± 0.41 for control against 1.62 ± 0.28 for IBA).

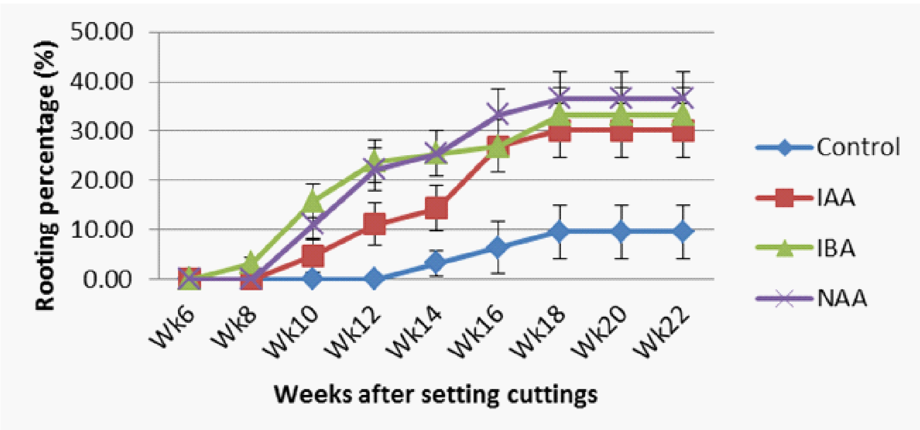

Figure 1. Effect of type of auxin on the rooting ability of cuttings of G. lucida

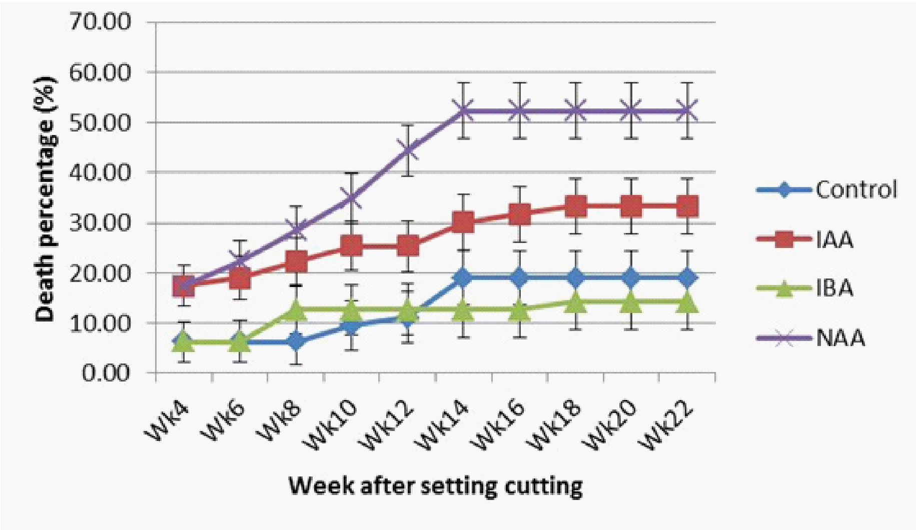

Figure 2. Effect of auxins on the mortality rate of cuttings of G. lucida

Effect of rooting media on the rooting ability of cuttings (Experiment 2)

The percentage of rooted cuttings set in sand was significantly ($P<0.0001$) higher than that of those set in sawdust and a mixture of sawdust and sand (1:1), but had only reached 27% by week 16. Adding sand to sawdust did not improve rooting. Rooting started at week 6 with sand, and at week 8 in sand + sawdust and sawdust (Figure 3). Cutting mortality was significantly affected by the rooting media ($P = 0.003$). Mortality started at 8 weeks for the three rooting media. It was greatest in sawdust (67%) and lowest (37%) in sand (Figure 4).

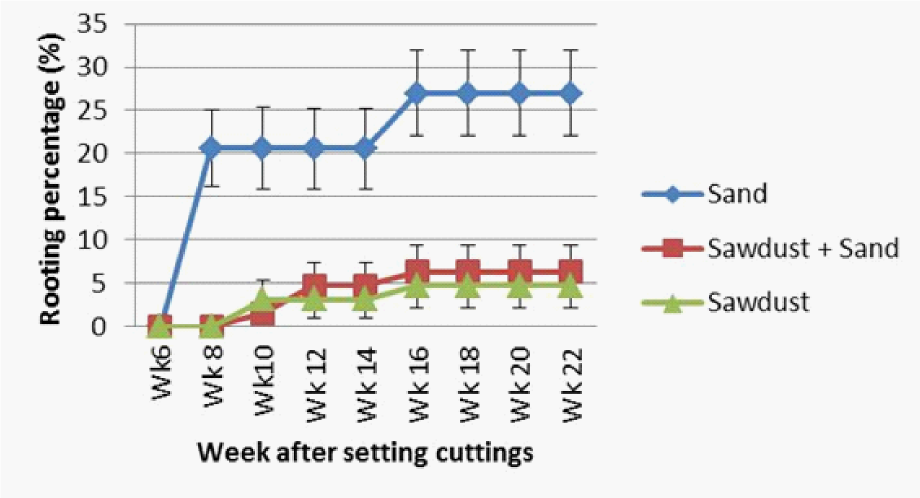

Figure 3. Effect of rooting media on the rooting ability of G. lucida cuttings, without auxin

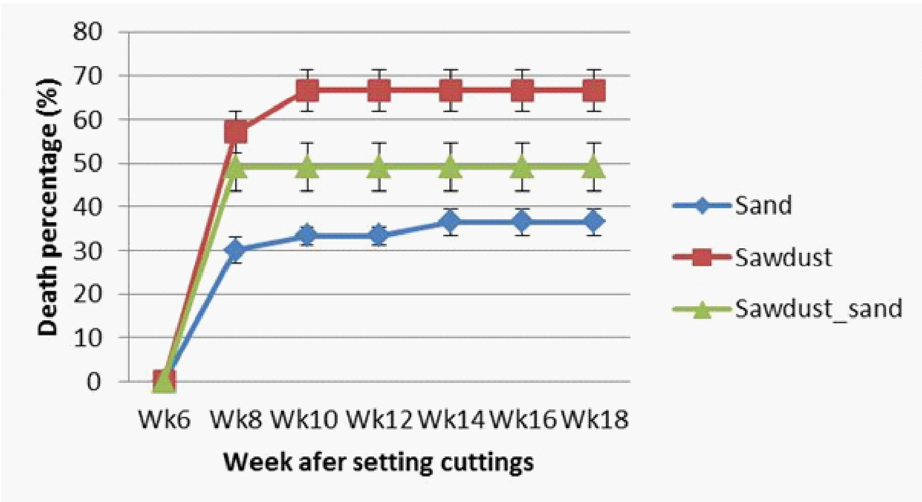

Figure 4. Effect of rooting media on the mortality of G. lucida cuttings without auxin

Effect of leaf area on the rooting ability of cuttings (Experiment 3)

Logical regression demonstrated the highly significant ($P<0.001$) effect of leaf area on the rooting ability of cuttings at week 18. The latency period was evidenced to be 8 weeks. It can be observed that the rooting percentage increased with leaf area (Figure 5) and that leafless cuttings did not root at all. Despite the fact that the highest percentage of rooting cuttings was observed with a leaf area of 50 cm^2, the difference with the 25 cm^2 treatment was not significant. It can further be observed that the mortality rate was significantly ($P<0.001$) higher with leafless cuttings followed by the area 25 and 50 cm^2 leaf area cuttings, respectively (Figure 6). The highest mortality rate occurred between week 6 and 8. On the other hand, no significant difference ($P = 0.62$) was observed for the number of roots per rooted cutting at week 18. The number of roots was 1 ± 0.32 and 1.21 ± 0.29 for 25 and 50 cm^2, respectively.

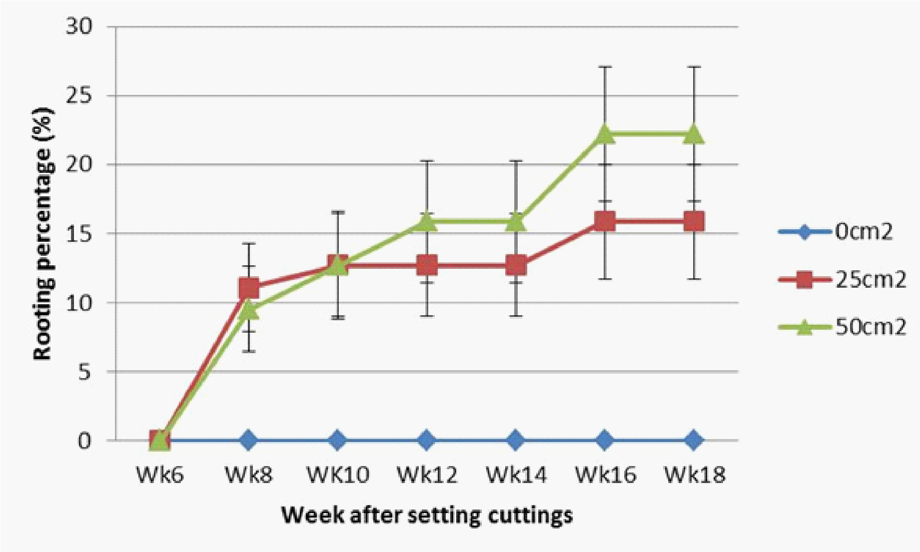

Figure 5. Effect of leaf area on the rooting ability of cuttings of G. lucida

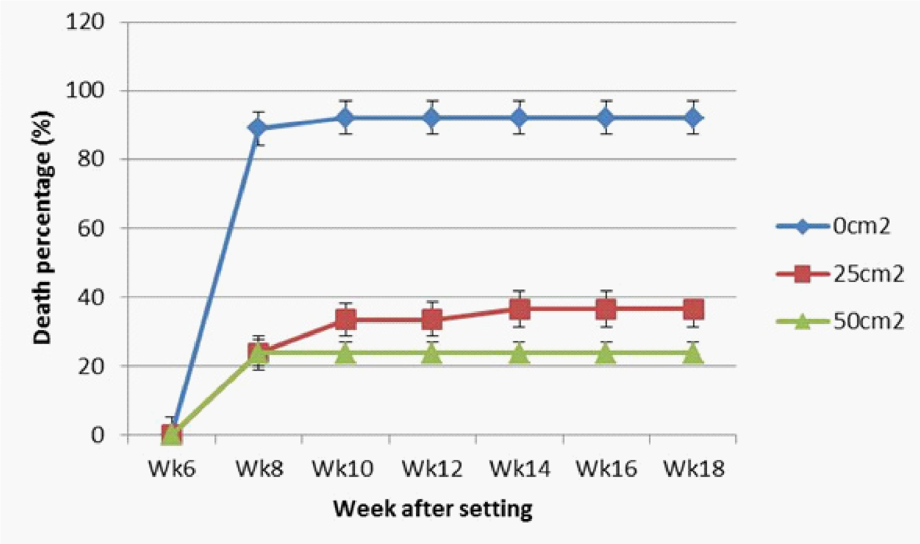

Figure 6. Effect of leaf area on the mortality of cuttings of G. lucida

Effect of grafting techniques on the propagation of G. lucida (Experiment 4)

Acceptable success rates (64–100%) were observed in *G. lucida* with all grafting techniques tested. However, there were significant differences between the techniques (P = 0.012). The best results were obtained with top cleft (100%) and side grafting (90%) (Figure 7).

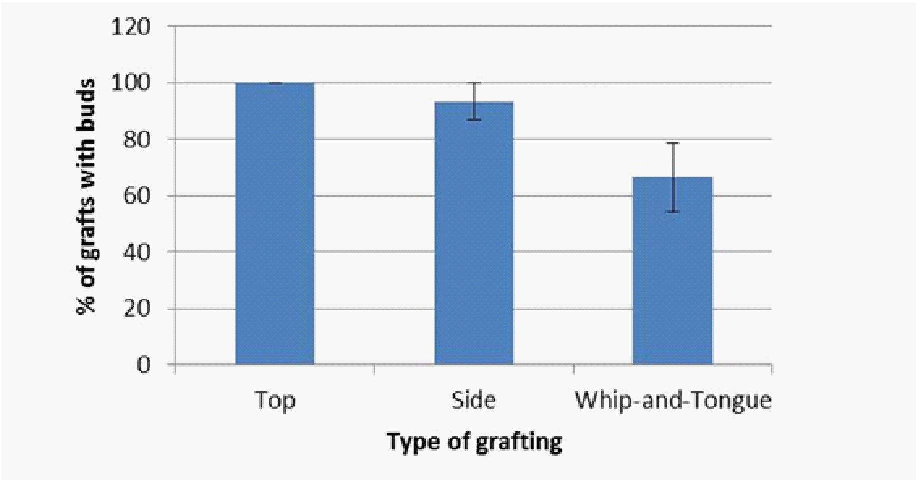

Figure 7. Effect of different grafting techniques on the propagation of G. lucida

Discussion

Effect of type of hormone on the rooting ability of cuttings (Experiment 1)

The application of root-promoting growth regulatory substances (auxins) to the base of cuttings was found to promote the development of roots, as has been documented for many other species (Hartmann *et al.*, 1997). In addition to their effects on cell differentiation, auxins have been found to promote adventitious root formation (Davis, 1988) as well as starch hydrolysis and the mobilization of sugars and nutrients to the cutting base (Das and Mukherjee, 1997; Das *et al.*, 1997). The results of this study agree with findings of studies carried out on other West African trees, such as *Prunus africana* (Tchoundjeu *et al.*, 2002), and *Pausinytalia johimbe* (Ngo-Mpeck *et al.*, 2003). However, behind this apparently 'cure-all' treatment there lies a considerable body of evidence showing that auxin applications interact with other treatments (Palanisamy and Kumar, 1997; Leakey, 2004), types of material (Brennan and Mudge, 1998), and environmental variables (Fett-Neto *et al.*, 2001) in the achievement of eventual rooting success of cuttings. This high degree of interaction is probably why there are many instances in the literature of apparently contradictory statements about the precise physiological role of auxins in the rooting process, a situation that cannot be resolved when authors do not present definitive information about either the physiological condition of their material or the propagation environment used (Leakey, 2004).

Generally, cuttings treated with auxins root more rapidly and produce more roots and usually with a higher percentage of cuttings rooted (Leakey, 2004). Indole-3-butyric acid (IBA) has been found to be the most effective root-promoting auxin, but occasionally α-naphalene acetic acid (NAA) has also been cited as effective; it has been successfully used for the rooting of *Parkia biglobosa* cuttings (Teklehaimanot *et al.*, 1996). However, tree species and even clones can respond differently to auxin applications at differing concentrations, even when other factors are kept constant. Interestingly, clones of *Triplochiton scleroxylon*, which appeared to have different dose response curves, all rooted equally well at 40 μg auxin per cutting (Leakey *et al.*, 1982).

In our study, we did not find any significant difference between the types of hormone applied. While the difference observed may be attributed to auxin concentrations, experience suggests that there are genetic differences between species (e.g. Hartmann *et al.*, 1997; Puri and Swamy, 1999), which could result in differences in rooting ability. Some authors reported that the factors explaining most of the variance are cutting length, leaf area, etc., whereas genetic differences between clones, explain relatively little of variance (Dick *et al.*, 1999). In addition, auxins have different chemical formulae which may act differently in different organisms.

Effect of rooting media on the rooting ability of cuttings (Experiment 2)

This study demonstrated that the best rooting medium for *G. lucida* when not treated with rooting hormone was sand, while the worst was sawdust (1:1). Most of the cuttings that did not root were dead, suggesting that the conditions of this experiment were not optimal. These observations indicate that though the conditions provided by sand were the best, the cuttings suffered from physiological stress. The relationship between rooting percentage and substrate is not as clearly defined as the relationship between substrate and root elongation. According to Kengue (2002), a good substrate should have low water holding capacity (optimum organic matter content) and have a considerable level of porosity (optimum percentage of sand). Therefore, the positive results obtained in this study may be attributed to the high porosity and low water holding capacity of the medium, as also observed by Takoutsing *et al.* (2013). These results also corroborate those of Atangana *et al.* (2006) who found that a suitable substrate for the rooting of *Allanblackia floribunda* can be obtained through modulating porosity by adding sand. Other authors suggested that a good substrate should contain adequate organic matter levels. In this line, a substrate blended with a good proportion of sawdust was successfully used to obtain satisfactory results for *Ricinodendron heudelotii* (Shiembo *et al.*, 1997) and *Diopyros crassiflora* (Tsobeng, 2011). The high mortality rate observed in this study in relation to the use of sawdust could be attributed to the fact that the roots of *G. lucida* are more susceptible to rotting which is promoted by water-logging and anoxia.

Effect of leaf area on the rooting ability of cutting (Experiment 3)

Generally, the rooting of cuttings depends on the presence of a leaf, and indeed on a number of physiological processes of the leaf such as photosynthesis and transpiration. Cuttings without a leaf are expected to quickly become moribund. The most common reason for cuttings failing to root is the death of the leaf due to rotting, necrosis, bleaching or leaf abscission (Leakey, 2004).

All these causes of failure are due to either the use of inappropriate tissues (e.g. photosynthetically inactive), or to an inadequate rooting environment (too hot, too wet or too dry) (Leakey, 2004).

Previous studies have demonstrated the importance of leaf on the cuttings' rooting ability. Rooting ability has been found to be maximized when the severed cutting is photosynthetically active and producing assimilates for the development and elongation of the root primordia, and when the leaf is not suffering from drought stress (Mesén *et al.*, 2001; Leakey, 2004). Consequently, there is an adequate leaf surface area at which the processes of photosynthesis and transpiration are optimal for the survival of the cuttings (Aminah *et al.*, 1997). This would definitely vary between species and clones, depending on specific leaf area (leaf thickness), stomatal density, leaf morphology (waxiness, etc.) and the age of the leaf (Leakey *et al.*, 2004).

Carbohydrate content and hence dry matter, rapidly decrease in cuttings if leaf area is too small, and increase if leaf area is adequate, at least until roots start to develop (Leakey and Coutts, 1989). In our study, leafless cuttings of *G. lucida* could not survive probably due to the rapid use of reserves and slow reconstitution by cuttings. Cuttings with an excessively large leaf area may suffer from transpiratory water loss and subsequent drought stress, and close their stomata, thereby limiting their capacity to photosynthesize and often triggering leaf abscission (Leakey, 2004).

Effect of grafting techniques on the propagation of G. lucida (Experiment 4)

The success rates of grafted plants decrease as the position of the graft on the stem moves from the top to the lowest part of the rootstocks. This might be explained by the gradient physiology in secondary thickening and lignification, the depth of correlative inhibition in buds and gradients in light (shade), humidity and temperature. All these factors may in one way or the other play a part in the success rate of grafting and further studies are needed to determine which are the most important. For instance, Asaah *et al.* (2012) found side tongue grafting to be the most appropriate grafting method for *Allanblackia floribunda*.

Conclusion

This study provides preliminary results indicating the amenability of *G. lucida* to vegetative propagation both for the capture of intraspecific variation in fruit characteristics by grafting, and the subsequent multiplication of a cultivar by leafy stem cuttings. The results obtained for the rooting of leafy stem cuttings of *G. lucida* (50%) are not as strong as those previously obtained by other authors on other West African indigenous fruit species. For example, Mialoundama *et al.* (2002) obtained 80% with *Dacryodes edulis*, Shiembo *et al.* (1997) obtained 80% with *Ricinodendron heudelotii* and Ngo-Mpeck *et al.* (2003) obtained 90% with *Pausinystalia johimbe*. There is clearly a need to improve the rooting success in stem cuttings. Our results suggest that *G. lucida* cuttings respond to auxins, and that both leaf area and rooting medium are important factors that should be optimized. The grafting results were very satisfactory as a success rate of 64-100% was obtained, with the highest value occurring with top cleft grafting.

Other aspects of the propagation environment, as well as pre- and post-severance factors that influence rooting percentage should be examined further: auxin concentration, stockplant management and environment, especially light and nutrient interactions. This will enhance the multiplication of the species through vegetative propagation and solve the problem of seed availability.

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(8) *Système de référence.* Afrika Focus suit en grandes lignes le système APA (http ://www.apastyle.org) pour l'intégration des références dans le texte et la mise en page de la liste des références à la fin de l'article.

(9) *Références dans le texte.* Dans le texte on réfère à la liste des références de la manière suivante :
- a) Le nom de l'auteur en minuscule, suivi d'une virgule, l'année de publication, éventuellement suivie d'un double point et de la page (Janssens, 1975 : 5-15);
- b) s'il y a deux auteurs : (Janssen & Peterson, 1975 : 5-15)
- c) plus de deux auteurs : (Janssen *et al.*, 1975 : 5-15).

(10) *Liste des références.* La liste des références vient à la fin de l'article et mentionne toutes les publications citées. Les références sont classées par ordre alphabétique et chronologique en fonction du nom du premier auteur (ou groupe d'auteurs). Les références bibliographiques suivent les règles suivantes :
- Pour un article dans une revue, on indiquera :
  Nom de l'auteur, Prénom (date). *Titre de l'article.* Titre de la revue, volume (numéro) : pages.
- Pour un article dans un livre, on indiquera :
  Nom de l'auteur, Prénom (date). *Titre de l'article.* Dans A. Rédacteur (red.), Titre du livre, pp. x-x. Lieu d'édition : Editeur.
- Pour un livre, on indiquera :
  Nom de l'auteur, Prénom (date). *Titre du livre.* Lieu d'édition : Editeur, pages.
- Pour les actes de colloques (congrès, symposium, etc...), on indiquera :
  Nom de l'auteur, Prénom (date). *Titre de l'article.* Dans : *Titre des actes*, pp. x-x. Lieu, date.

(11) *Tirés à part.* Chaque auteur recevra une version PDF de son article.

(12) *Proposition de lecteurs.* Les auteurs peuvent proposer 6 personnes au maximum (attachées à un institut de recherche) qu'ils estiment valables en tant que lecteur. La rédaction n'est pas obligée d'accepter ces suggestions mais respectera en outre la demande d'exclusion de certains lecteurs.

(13) *Indication de mise en page.* Le manuscrit doit être adressé en format Word, par courriel au secrétariat de rédaction. Les auteurs reçoivent un accusé de réception.

Description peer review process Afrika Focus

The review process of the journal Afrika Focus takes place according to the following procedure:

(1) Before submission, authors are requested to consult the journal's guidelines for authors: http://www.gap.ugent.be/For_authors. Authors are encouraged to bear in mind that Afrika Focus is a multidisciplinary journal with an academically and geographically diverse audience.
(2) After finalizing their paper according to these guidelines, authors submit it to the journal's secretariat: afrikafocus@UGent.be.
(3) The editorial secretariat sends an immediate acknowledgement of receipt of the submission.
(4) The paper will be pre-reviewed by one of the editors-in-chief and within a few days this editor-in-chief decides whether a submitted paper satisfies the journal's criteria for review. If the paper does not comply with the criteria of the journal, the editor sends a mail with arguments for rejection and, if possible, a helpful recommendation to the author(s) for submission elsewhere.
(5) When the article is accepted for review, the editor-in-chief selects three peer reviewers with an international publication record, upon which the paper and a standard evaluation form are forwarded to these reviewers by the editorial secretariat. The e-mail letter sent by the editorial secretariat will set a deadline of one month. The author(s) will be informed that the review process takes no longer than six weeks.
(6) Depending on the reviewers and the paper, reviews may take between a few days and two months. The average review time of a paper is one month.
(7) After one month, reviewers who have not yet sent a review will be reminded to send their review as soon as possible.
(8) In case a reviewer has requested more time, the author(s) will be kept informed of the delay.
(9) Reviewers decide whether a paper admitted to the review process is to be rejected, resubmitted or accepted by filling in the evaluation form. Accepted papers are commonly recommended to undergo a list of well-determined revisions. These qualify as 'minor changes'. Resubmission applies to papers attracting the reviewers yet requiring major amendments.
(10) The editorial secretariat informs the authors about the decision of the reviewer(s), sends them a copy of the review, and – if the paper is accepted – instructions for the preparation of the next draft version.
(11) Papers that have to be resubmitted are being evaluated as if they were new submissions; this usually happens by the same reviewer(s). This/these reviewer/s check/s whether the required alterations have been implemented and whether the end result can be accepted.
(12) Final versions of accepted papers should be sent to the editorial secretariat, together with a filled out, printed, signed and scanned Publishing Agreement. The editorial secretariat immediately acknowledges receipt of the final version.
(13) The review process ends with a concluding reading of the paper by one of the editors-in-chief for a final check-up; the author is told whether the final version is accepted for publication and when the paper will be published.
(14) Papers that have been accepted are usually published in the journal issue appearing between 4 and 6 months after acceptance. This means that there is a waiting list of several months before papers/issues are being sent to the publisher.
(15) Each author receives a PDF of the final version of the article. The paper will also be available through the Directory of Open Access Journals (http://www.gap.ugent.be/Online_en).
(16) Depending on the speed of the review and of the revision by the authors, as well as on the number of papers on the waiting list, total time between submission and publication of the papers may range between 6 and 12 months.