Annex 1. Novella Project Baseline elements: a detailed review of domestication activities on *Allanblackia*

Compiled November 2006[1]

Introduction

In order for the full opportunities of the Novella Project for raising rural livelihoods to be realised, it became evident at an early stage in the initiative that the establishment of a domestication programme was crucial, as currently accessible natural stands of *Allanblackia* were insufficient to supply, in a sustainable manner, the potential demand of the edible oil industry.

Since 2003, the domestication of *Allanblackia* has received considerable attention in humid areas of Cameroon, Ghana, Nigeria and Tanzania. In order to ensure that poor communities benefit most from the Novella Project, and supported by favourable economic and policy analyses of such production systems, a decision was made to focus on smallholder farm cultivation to supply seed to the global oil industry. In addition to supporting the rural poor, it was anticipated that a focus on smallholder production would minimise risks to the environment sometimes associated with the global edible oil business, such as the displacement of forest and traditional farm crops that has on occasions been observed (e.g. establishment of large-scale palm oil monocultures in a number of tropical countries).

The intention of the Novella Project is that most *Allanblackia* planting will occur in multi-component agroforestry systems that neighbour natural forest, with some degree of enrichment planting also taking place within forest itself. The ongoing domestication programme is expected, after a number of years, to bring tens of millions of trees into cultivation and result in a significant increase in the availability of oil for the global food market.

Until now *Allanblackia* has had no history of planting. Bringing the genus into cultivation for the first time requires considerable effort, especially when the large volumes of material required for oil production are considered. By 2017, the Novella Project intends to have brought significant benefits to 90,000 farmers; for this target to be reached, the planting of several million trees across countries will be required annually (for a number of years) from 2008 onwards.

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The main objectives of ongoing domestication work by ICRAF, the Forest Research Institute of Ghana (FORIG), the Forest Research Institute of Nigeria (FRIN), Amani Nature Reserve (ANR, in Tanzania), the Tanzania Forestry Research Institute (TAFORI) and other partners in each participating country are to overcome some of the major challenges faced in bringing *Allanblackia* into cultivation. A prime objective is to provide germplasm in sufficient quantities and in a timely manner for planting; at the same time, supplied planting material should be capable of consistently producing good quantities of high quality oil. Furthermore, cultivated trees must occupy appropriate niches on farms, and suitable silvicultural management techniques that optimise oil production must be developed and disseminated to planters. Moreover, the impact of domestication activities within the wider context of the *Allanblackia* initiative must continually be reviewed, and work adjusted accordingly, to ensure a balance is maintained in Novella Project development.

To date, domestication work has focused on the following areas: developing propagation techniques, selecting and collecting elite material; and initiating central and community nursery activities. This review details activity in each of these areas, summarises key progress to date, and identifies where further work is required; although much progress has been made, domestication still presents considerable hurdles to the development of an efficient germplasm supply chain for the *Allanblackia* business.

1. Developing propagation techniques

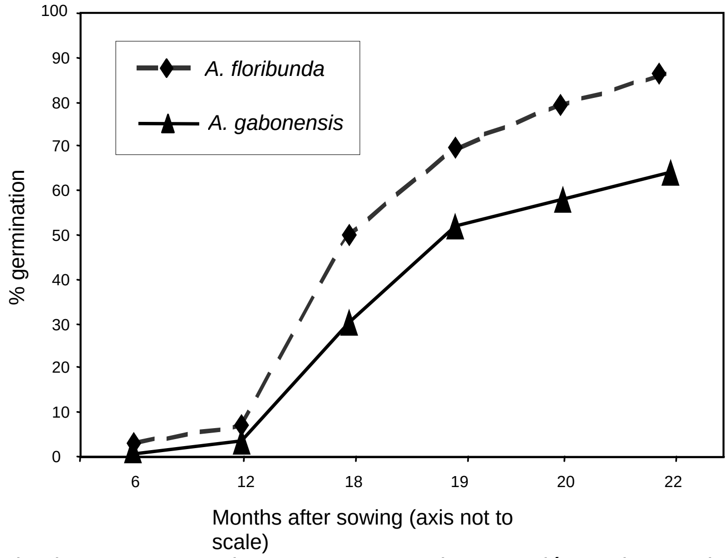
Studies on *Allanblackia* propagation have considered a number of methods for supplying planting material to growers, with activities being undertaken on seed germination, vegetative propagation and wilding transplantation.

Seed germination

Germination under research conditions

Small-scale nursery-based research trials in Cameroon (on *A. floribunda* and *A. gabonensis*) and Ghana (on *A. parviflora*) indicate that seed is very slow to germinate. In a trial in Cameroon, first germinants did not emerge until six months after seeding, while significant germination was not observed until after 12 months (Fig. D1). It took 18 (*A. floribunda*) and 19 (*A. gabonensis*) months for germination levels to reach 50%. Although initial germination was very slow, after a period of almost two years (22 months) overall germination had reached quite high levels in the Cameroonian trial, being more than 80% for *A. floribunda* and more than 60% for *A. gabonensis*.

Figure D1. Germination profiles for *A. floribunda* and *A. gabonensis* seed, Cameroon



Germination percentages in ICRAF's nursery in Yaoundé are shown. Figures are based on a total of 102 seed for *A. floribunda* and 450 seed for *A. gabonensis*. Germination began very slowly, with a big increase in rate only after 12 months. Overall levels of germination after 22 months were, however, quite high, especially for *A. floribunda*. Note the change is scale on the x-axis, and that sample numbers are relatively small. Source: ICRAF Cameroon

Germination during practical deployment

Considering the less controlled environment of practical deployment, the best information on germination to date comes from nurseries in Ghana and Tanzania that have seeded very large quantities of *Allanblackia* into germination beds, with a view to raising seedlings for farm, enrichment and research trial establishment. In common with the slow germination rate observed during research in Cameroon, levels of germination in nursery beds were very low in both Ghana and Tanzania one year after seeding. In Ghana, one year after the International Tree Seed Centre (ITSC) planted 600,000 seed (of *A. parviflora*) in it's central nursery at Offinso (near Kumasi), less than 0.2% emergence had been observed (February 2005 to February 2006). Over the same period at FORIG HQ's central nursery in Kumasi, where more than 60,000 seed (of *A. parviflora*) were planted, only a slightly higher emergence level was observed. Interestingly, in the FORIG nursery, germination level varied greatly depending on the mother tree sampled. In Tanzania, one year after ANR planted 160,000 seed (of *A. stuhlmannii*) in it's central nursery facility at Kwamkoro in the East Usambara, germination was higher that in Ghana, although still very low, at ~ 4 % (March 2005 to March 2006).

Based on results from the Cameroonian trial (Fig. D1), we expect that germination levels in all three of the above nurseries will accelerate leading up to February 2007. At the halfway point between February 2006 and 2007 (October 2006), some acceleration had indeed already been observed in Ghana; taking ITSC as an example, a total conversion level of ~ 5% (seed to potted seedlings) had been reached. In both Ghana and Tanzania, it will be important to observe the 'absolute' level of germination reached under the field conditions provided by these nurseries, for comparison with data collected during controlled research. It would appear, however, that overall germination levels are likely to be considerably lower under field conditions than in controlled studies, since the 5% conversion rate observed at ITSC (after 18 months) compares unfavourably with the germination levels observed in the controlled Cameroonian trial after a similar period (~ 30% and 50% for *A. gabonensis* and *A. floribunda*, respectively).

Further observation is required to determine whether the difference in germination level observed after one year in the nurseries in Ghana (ITSC and FORIG, ~ 0.2%) and Tanzania (ANR, ~4%) can be ascribed to particular factors. Differences may relate to the different species in question and/or to the particular nursery environment. The research trial quoted above from Cameroon (Fig. D1) appears to indicate that there is some, rather limited, difference between species. At ANR central nursery, seed germination beds are liberally watered (more than would normally be the case), and nursery workers consider this to be an important factor in promoting relative success (although it should be noted that liberal watering could also result in seed rotting).

It is also possible that relatively higher success in Tanzania is attributable to the ANR nursery being located right next to the forest from which seed was collected, meaning that climatic conditions are likely to be optimal for promoting germination. This is different from the situation in Ghana, where ITSC and FORIG nurseries are both some distance from seed sample sites. However, small natural stands of *A. parviflora* do grow in the immediate vicinity of the ITSC nursery, indicating that the conditions here are suitable for raising seedlings of the species (these small stands were insufficient to supply the volume of seed required by ITSC, hence the decision to source germplasm from elsewhere). The observation that *A. parviflora* grows proximate to the ITSC site does not, however, exclude the possibility that particular populations of the species are adapted to the environmental conditions of specific sites (such adaptation is common in tree species). The different germination levels observed for *A. parviflora* seed sampled from different eco-zones at FORIG's central nursery provides some support for this view, as considerable variation was noted.

Impact of germination medium

Although the time that must be allowed for germination to take place makes observations laborious, it would appear that the medium in which seed is placed does have some impact on the overall level of *Allanblackia* seed germination; nursery and greenhouse experiments in Cameroon (on *A. floribunda*) and Ghana (on *A. parviflora*) appear to indicate that a mixture of sand and soil is more effective than soil alone, possibly because of the increased aeration provided by the inclusion of sand. Based on this information, nursery germination beds established in Tanzania in 2006 have used sand in preference to soil (as was used in 2005) as a medium.

Seed pre-treatments

It would appear that slow germination in *Allanblackia* is due in part to dormancy. Preliminary data from a small controlled experiment applying gibberellic acid treatment (an agent that can break embryonic dormancy) to seed in Cameroon (of *A. floribunda*) have suggested a possible reduction from 18 to 8 months in the time taken to obtain 50% germination. Similar studies on the possible effects of gibberellic acid treatment have begun in Ghana (on *A. parviflora*), but no results are yet available. In Ghana, nursery greenhouse trials (on *A. parviflora*) have indicated that partial removal of the seed testa also appears to accelerate and/or increase absolute levels of germination.

In early 2006, gibberellic acid treatment was applied on a large-scale (to more than 100,000 seed) under field conditions in Tanzania (on *A. stuhlmannii*). Seed was soaked for 48 hours in a 1 g per litre solution of acid. To facilitate the entry of acid, the seed testa was first nicked (or 'cracked') with a knife; this procedure was undertaken at the distal end of the seed, away from the embryo. No significant data on the efficacy of this approach, this being the first examples of gibberellic acid being used under field conditions, is yet available; it is hoped that results will show a similar level of acceleration in germination to controlled research in Cameroon (on *A. floribunda*), but this should not be assumed. Unfortunately, acid pre-treatment in Tanzania was not coupled with the establishment of non-treated controls, which would have allowed useful comparison.

In 2006, further controlled research on seed pre-treatment, using potassium nitrate as a possible agent to break physiological dormancy, in combination with gibberellic acid, began at ICRAF HQ in Nairobi (on *A. stuhlmannii*, sampled from Tanzania); no results are yet available from this study.

The use of local knowledge

Community knowledge and local experimentation have a role to play in devising appropriate procedures for handling and treating *Allanblackia* seed (at least in defining approaches worthy of further testing). In the East Usambara of Tanzania in 2005, villagers adopted two interesting methods when stocking their community nurseries. First, they collected seed (of *A. stuhlmannii*) from buried rat caches (or burrows?) that they located in neighbouring forest. In this procedure, villagers searched for emergents and then dug around these to find further un-germinated seed.

The seed collected in this way showed faster germination than that collected at the same time from fruit; it is likely that this is because seed had already been buried for a considerable period. This procedure, then, effectively transfers the seedbed stage of germination from the nursery to the forest. Second, villagers collected and then buried (at nursery sites) whole fruit with the seed inside; after a few months, fruit were dug up and seed extracted and planted. Communities related that seed treated in this way germinated more quickly than when the normal procedure of extraction (seed removed from fruit within a week or two of collection) was applied. Both these observations allow the formulation of interesting hypotheses that should in the future be tested against appropriate controls.

Vegetative propagation

Studies on the vegetative propagation of *Allanblackia* have been initiated for a number of reasons. First, the difficulties in handling seed, especially very slow germination, mean that alternative means of propagation are desirable. Second, the clonal nature of vegetative techniques brings certain clear advantages, including the opportunity while planting to control the female to male ratio of *Allanblackia* trees on farms (the genus being dioecious), and the ability to sample and then multiply 'true-to-type' elite varieties that have superior production characteristics (the issue of elite material and the efficacy of field selection is addressed separately below). Finally, a concern with *Allanblackia* grown from seed is the relatively long time taken to produce fruit; experience from other tropical fruit trees suggests that the period to maturation may be reduced by at least half through vegetative propagation, allowing on-farm production from planted stands to begin considerably earlier than would otherwise be the case.

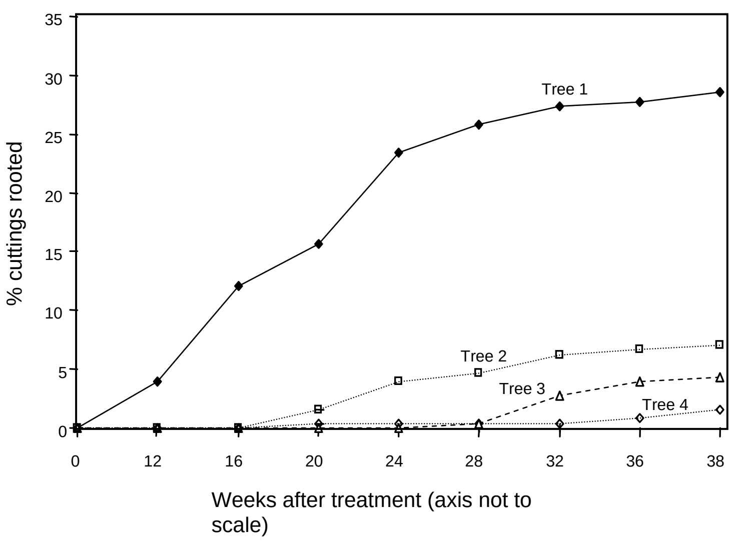
While seed propagation will be more important than vegetative techniques in the early stages of the *Allanblackia* initiative, it is expected that clonal multiplication of elite material will predominate in subsequent years; from 2008 onwards, it is anticipated that several million vegetative propagules will need to be made available each year for planting in farmland.

Rooting leafy cuttings from mature trees

The development of vegetative propagation techniques has involved trials on the rooting of leafy stem cuttings in non-mist propagators. In nursery research undertaken by ICRAF in Cameroon (at Yaoundé), single-node leafy stem cuttings taken from coppiced shoots of cut mature female *A. floribunda* trees were rooted successfully, although the time taken for first rooting (10 weeks) was long. The success of rooting depended on the different media in which cuttings were set: sand proved considerably more effective than a sand/sawdust mixture. In addition, success depended on cuttings having some leaf area: cuttings with no leaf did not root at all. Different amounts of leaf area retained on cuttings before setting (12.5 cm^2, 25cm^2 or 50 cm^2) did not further influence rooting success. Furthermore, auxin application (three different types tried) did not appear to increase rooting ability.

Nursery research in Cameroon has also indicated that the source of cuttings (the particular mature female tree sampled) appears to be an important factor in determining rooting success; in fact, in an experiment sampling different sources, an approximate 10-fold difference was observed between cuttings taken from the best and worst trees tested (Fig. D2). If further research confirms this variation, it indicates that the ability to clone particular trees will be an important consideration in the selection of elite germplasm (see below). When combining the best clone source with the best treatments for planting medium and leaf area, an excellent success rate of ~ 70% rooting was obtained for *A. floribunda* (six months after setting cuttings). Rooting of leafy stem cuttings from mature trees has also been achieved in preliminary studies in Ghana (*A. parviflora*) and Nigeria (*A. floribunda*), although to date experiments have been less successful than in Cameroon.

Figure D2. Variation in rooting success for *A. floribunda* leafy stem cuttings taken from different coppiced mature female trees, Cameroon



Rooting percentages in non-mist propagators in ICRAF's nursery in Yaoundé are shown. Observations are based on 64 single-node leafy stem cuttings taken from each of four different mature female trees. Significant variation in the success of rooting was seen for cuttings taken from different trees, with an approximately 10-fold difference for clones taken from trees 1 and 4. Note the change is scale on the x-axis. Source: ICRAF Cameroon

Considering the less controlled environment of practical deployment, the most significant current work on vegetative propagation is in Tanzania. In January 2006, in farmland around ANR, 100 high-yielding mature female trees (of *A. stuhlmannii*) were felled for the specific purpose of collecting cuttings that will feed into farmer planting programmes. Trees were cut at a height of 1.5 m (although ~ 75 cm is probably the best height); coppice regrowth was observed in March 2006, and material is now being collected for rooting in non-mist propagators (each of which can hold around 300 cuttings).

Grafting and marcotting

Although grafting studies on *Allanblackia* are in their infancy, research in Cameroon (on *A. floribunda* and *A. gabonensis*) indicates that grafting of seedling rootstocks with scions taken from mature female trees is possible with good success rates. The side-tongue procedure was more successful than side veneer or whip and tongue approaches. Using the first approach, an 80% success rate was achieved with *A. gabonensis* (with careful choice of scion and under experimental conditions). As might be expected, survival rate was better when grafted plants were placed in partial shade rather than in full sunlight. Some of the grafted plants flowered (though aborted) a few months later.

In the future, grafting will likely provide the most important method for propagating female *Allanblackia* trees. In addition, grafting may be an important procedure for producing monoecious plants (that is, grafting female scions into male trees, or *vice versa*, in order to produce individuals with both male and female flowers) that are capable of self-pollination, obviating the need for separate male individuals that occupy 'unproductive' space on farmland.

Marcotting studies on *Allanblackia* (stimulating rooting of branches through air-layering) are also in their infancy; currently, the approach is being tested on mature female trees in Cameroon (on *A. floribunda*) and Ghana (on *A. parviflora*), with some success. In the future, it is intended that this approach will be used for the collection of elite clones of *Allanblackia*, allowing 'superior' types to be brought back to nurseries where they can then be further multiplied through rooted-cutting and grafting methods.

Accelerating fruit production

Experience from other tropical fruit trees suggests that when *Allanblackia* is propagated vegetatively from mature trees it should fruit more quickly than when raised from seed. It has been suggested that *Allanblackia* raised from seed in a farm environment should fruit after ~ 12 years (though some farmers think faster), whereas extrapolations from other species would suggest that material propagated vegetatively will fruit before it's 5th year.

The degree to which fruiting is accelerated through vegetative propagation is a key issue, because it will determine the economic profitability of the *Allanblackia* agri-business to farmers. At present, no hard information is available on the period to maturation for either seed- or vegetatively-propagated *Allanblackia* in a farm environment; in 2005, small field trials containing both seedlings and rooted cuttings from mature trees were established in Cameroon in order to assess this. In the present absence of definitive information on the period taken to reach maturity, economic models for the *Allanblackia* initiative must be based on conservative estimates.

The above field trials will also assess the ability of the architecture of young vegetatively propagated trees to support fruit production; since *Allanblackia* fruit are heavy, it is possible that younger-fruiting trees could collapse under their weight. Furthermore, these trials will determine whether trees propagated in different ways occupy different niches as they develop on farms; this issue is crucial for understanding the comparative long-term productivities of trees propagated using different approaches, and also has implications for on-farm biodiversity (addressed in the Novella Project Biodiversity Baseline of this proposal).

Wilding transplantation

Although the approach is not likely to be used widely (because of the potentially high negative impact on forest regeneration), wilding transplantation is being considered as an interim method for *Allanblackia* propagation, while difficulties experienced in the development of suitable seed germination protocols are being overcome and vegetative propagation techniques continue to be developed.

In Tanzania, local communities working with the Tanzania Forest Conservation Group (TFCG) around ANR in the East Usambara have successfully collected and transplanted wildings of *A. stuhlmannii*. Wildings, which were up to 20 cm tall, were removed from forest (digging out with the aid of a stick) and transplanted as bare rooted seedlings into nursery pots. After potting, wildings were sometimes pruned back with a view to promoting root development, but successful transplantation was also achieved without this procedure. Transplantation was carried out into nurseries very local to wilding collection sites, using locally collected forest soil as the potting substrate.

In Ghana, early experience in transplanting wildings (of *A. parviflora*) from cocoa farms into nurseries had little success. In this instance, wildings were transferred as bare rooted seedlings across some distance between collection and nursery sites. A similar failure to establish was observed with wildings collected as bare rooted seedlings in Tanzania (*A. stuhlmannii*) and transferred to ICRAF HQ in Nairobi for potting. In neither case were wildings transplanted into soil sampled from collection sites.

Although absence of appropriate controls makes determination difficult, it appears likely that at least two factors are responsible for the different experiences related above. First, the length of time taken to transport collected wildings between forest and nursery may be an important issue; local transplantation is likely to reduce the stress placed on wildings and thereby enhance success. Second, local soil (used singly or mixed with other media) may be important for success, possibly due to a mycorrhizal requirement of the genus (more recent work in Ghana, in which wildings were transplanted into local nurseries, has been much more successful than earlier experience, reinforcing the importance of the above two factors).

The observation that nursery seedlings raised from seed planted in non-forest soil sometimes display symptoms of nutrient/mineral deficiencies does suggest an important association between *Allanblackia* and mycorrhizae. The association appears to be endomycorrhizal, since external examination of roots indicates an absence of root hairs. Indeed, research undertaken in the UK by staff from the Botany Department of the University of Dar es Salaam has confirmed the presence of endomycorrhiza in the roots of *A. ulugurensis* sampled from Tanzania. It is possible that in nature rodent seed dispersers may be important in spreading mycorrhizae.

2. Selecting and collecting elite material

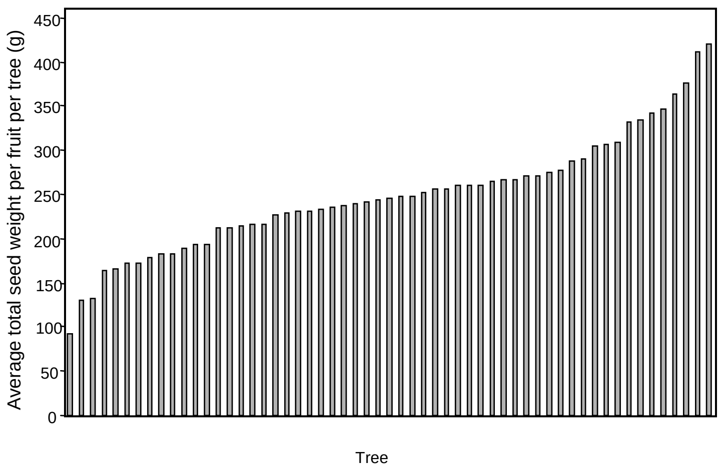
With possible genetic gains in mind, germplasm collection strategies for indigenous fruit trees are often based on 'selective' (or 'targeted') methods of sampling rather than on 'random' (or 'representative') approaches. In the case of *Allanblackia*, if superior (high oil-producing) germplasm can be identified and distributed, important productivity gains could accrue to planters.

Field observations on fruit variation

In order to assess the possibilities for selection, research has been undertaken to test whether significant variation exists in *Allanblackia* fruit yield characteristics at three levels: between trees within stands, between stands, and between species. Field observations in Cameroon, Ghana, Nigeria and Tanzania (observing natural stands of *A. floribunda*, *A. parviflora* and *A. stuhlmannii*) indicate that considerable variation in fruit size exists at all tested levels. Observations also confirmed previous inventory studies that suggested that *A. stuhlmannii* has particularly large fruit, and demonstrated that this species has on average a greater number of fruit per tree than other surveyed members of the genus.

The most detailed study to date on fruit characteristics has been undertaken in Cameroon (on *A. floribunda*). For a range of trees at each of three locations, measurements were made on the number of fruit per tree, fruit dimensions, the number and total weight of seed per fruit, and total seed weight per tree. Based on observations from one fruiting season, results indicated statistically significant differences between trees at individual sites and between sites. At one site, Yalpenda, average seed weight per fruit varied from less than 100 g for one tree to more than 400 g for the best performing tree (Fig. D3). More importantly, the study detected significant variation in total seed weight per tree (the crucial characteristic from an overall commercial production perspective). Furthermore, measurements indicated that total seed weight per fruit was positively correlated with fruit dimensions, meaning that it should be possible to use fruit size as a *proxy* for selecting trees with the more important attribute of high seed yield (although anecdotal evidence from elsewhere suggests that large fruit do not always contain more seed than small ones).

Figure D3. Tree-to-tree variation in seed weight per fruit for *A. floribunda* trees sampled at the Yalpenda site, Cameroon



Values of average total seed weight per fruit per tree in a single population are shown for 57 trees, based on one seasons observations, with measurements based on 40 fruit per tree. Values varied widely between trees, and differences between ‘low’ and ‘high’ producers were statistically significant. Source: ICRAF Cameroon

Collection of elite material

The large variation observed between trees and sites for fruit production characteristics (with at least some correlation with seed yield) would suggest that selection of superior-yielding *Allanblackia* types is possible from field observations. However, undertaking effective selection based on observations made in natural stands is not a straightforward process, particularly for fruit trees; differences observed between trees both within and between populations may reflect in part the vagaries of pollinator activity in the particular year in which observations are made. Furthermore, for genera such as *Allanblackia* that appear to be 'mast' fruiters, not all trees within a population are expected to respond equally to the stimuli which determine whether a particular year is a 'good' or 'bad' one for production. For these reasons, observations on fruit production should ideally be undertaken over a number of years before phenotypic selection is practiced.

In addition to the above complications, variation in fruit production may reflect micro-environmental differences within natural stands and wider ecological differences between stands. Within stands, for example, particular trees may yield more because they grow near water or in other niches that are particularly fertile. Differences based on such factors are not heritable and therefore will not be carried over into subsequent generations of material derived from 'superior' trees.

Despite these concerns, it seems reasonable to assume, based on experiences with other indigenous fruit trees that suggest fruit trait heritabilities are reasonably high, that some level of genetic gain is possible through selection during collection from natural *Allanblackia* stands (selection applied both within individual populations and between sites), even when selection is based on only a single round of field observations. The level of gain, however, may be lower than many collectors would anticipate. Gain is likely to be greater if vegetative- rather than seed-based approaches to collection are used, since in the first instance collected material is an exact genetic copy of the sampled tree, while in the second case only the maternal component of 'eliteness' is sampled (the paternal parent, contributing pollen during fertilisation, remains unknown and unselected). An additional advantage of a selective sampling approach is that it provides a good opportunity to involve communities directly in the domestication process, by asking then what traits are important to them and then training them to sample germplasm accordingly. This (along with other measures) should help facilitate community adoption of *Allanblackia* cultivation.

As noted in the previous section, vegetative collection (of stem cuttings) from high-yielding trees (of *A. stuhlmannii*) is currently underway in Tanzania; no controls are however in place to determine the efficacy of a targeted versus random sampling approach. The vegetative collection of germplasm using the marcotting technique is also under research in Cameroon (on *A. floribunda*) and Ghana (on *A. parviflora*); although this approach has not yet been applied at any significant level to undertake targeted sampling, in the future it is likely that it will be.

While vegetative collection techniques continue to be refined, targeted seed collection has been applied to superior fruit producing trees at many sites in Cameroon, Ghana, Nigeria and Tanzania (selection based on a single seasons observations). So far, seed has been collected from more than 350 selected trees (sampled over a range of ecological zones, within and between countries), and it is this material that forms the basis of much of the current research and wider deployment activities of the Novella initiative (the large-scale seedings mentioned above in FORIG and ANR central nurseries used phenotypically targeted trees). Some seed, however, has also been collected using a random sampling approach (no selection applied; the large-scale seeding mentioned above in ITSC's nursery is an example).

The efficacy of the targeted approach to seed collection will be tested in controlled field trials that will be established later in 2006. These trials, coordinated by ICRAF and national partners in Cameroon (on *A. floribunda*), by FORIG in Ghana (on *A. parviflora*), and by ICRAF, ANR and others in Tanzania (on *A. stuhlmannii*), will minimise the impact of the environment in determining phenotypic differences and will allow multiple observations on fruiting to be taken over a number of years. Trials will assess variation between trees sampled from within and between a range of natural stands, indicating particular trees and populations of merit for selected propagation. Later, trials will be converted into 'gene bank' stands to ensure the conservation of *Allanblackia* genetic resources.

Genetic diversity as a component in selection

Inbreeding depression caused by a narrow genetic base is considered to be an important limitation on yield for some out-crossing fruit tree species under cultivation, and it is important that such a situation is prevented for *Allanblackia*. Therefore, in addition to selection for fruit yield during domestication, an additional characteristic of 'elite' material is that it should have a sufficiently large effective population size to prevent from taking place any level of related mating that would lead to significant inbreeding.

To ensure high effective population sizes are maintained in cultivated material, FORIG have begun a molecular study, using random amplified polymorphic DNA (RAPD) analysis, to assess the genetic diversity of *A. parviflora* collected from across Ghana. Using this approach, germplasm that is not only phenotypically superior, but is above a certain minimum level of genetic diversity, will be prioritised for cultivation.

Molecular work on genetic composition (on *A. floribunda* from Cameroon) has also begun in a joint project between ICRAF and the University of Laval in Canada. In this instance, simple sequence repeat (SSR) markers will be used to assess the relationship between fruit phenotypes and their genotypes, in order to determine if fruit selection (compared to a random sampling approach) causes a significant reduction in the effective population size of germplasm entering cultivation.

Finally, further molecular genetic work is underway at the Scottish Centre for Research Innovation (SCRI) in Dundee (UK), involving ICRAF and the Field Museum of Chicago as partners. The main purpose here is to study the ecology of *Allanblackia* (see under 'ecology research' in the Novella Project Baseline), but it is possible that this research may also yield sex-specific markers in the genus. If identified, these markers would allow both the ratio and genetic composition of female and male trees to be controlled at planting; in this way, productivity could be promoted by establishing more female than male trees, while at the same time safeguarding against inbreeding by making sure that those male trees that do enter cultivation are genetically diverse (effective population size of male trees not reduced too greatly, preventing 'bottlenecks' in pollen sources).

No significant results are yet available from any of the above three studies, since all are still at an early stage of implementation.

3. Initiating central and community nursery activities

Very large quantities of both seed- and vegetatively-propagated plants will be required by the Novella Project in the coming years; to supply this demand, a significant number of nurseries will need to be established in each country participating in the initiative. Nurseries will need to be networked with each other in order to exchange germplasm and information on appropriate nursery approaches; in particular, nursery managers must be able to continually update their knowledge on current best practice for raising planting material, as this practice quickly and continually evolves through ongoing research and innovation.

Nurseries will need to operate at different geographic scales, in a spectrum from a few large centralised nurseries at the macro-geographic level (supplying material by country region), through medium-scale community nurseries (supplying material at a local landscape level), down to many small-scale farmer initiatives at a micro-geographic level (farmers raising material for their own farms and those of their neighbours). Communication between nurseries operating at these different levels must be bi-directional: community-based innovations at lower levels must be fed upwards to provide hypotheses for testing in centralised studies; at the same time, revised technical support methods developed from formal research must be disseminated downwards to farmer nurseries, through written guidelines, face-to-face training and related activities.

In each participating country in the next five years, the development of nurseries (including in total at least 45 large- and medium-scale nurseries), and the networks between them, will be one of the most important undertakings of the Novella Project; by the end of 2011, it is anticipated that the annual value of the nursery market for supplying *Allanblackia* seedlings to farmers will exceed USD 4 million (see section on 'economic analysis' in the Novella Project Baseline).

To date, nursery activities have focused on the establishment of a small number of large-scale central and (mostly) medium-scale community nurseries as models for further development. In Ghana, FORIG and ITSC have been responsible for establishing large nurseries and are just beginning to develop decentralised community nurseries. In Tanzania, ANR has been involved with large-scale nursery development and, with TFCG and other institutions, is already well underway in developing medium-scale community nurseries, through the provision to village groups of inputs such as construction materials and *Allanblackia* seed. As noted below, the number of plants raised for farmer planting, through either central or community nurseries, has so far been limited.

Large-scale central nurseries

As reported above, ITSC in 2005 planted 600,000 seed (of *A. parviflora*) in nursery beds at their central facility at Offinso in Ghana; this material was planted with a view to raising seedlings for distribution to smallholder farmers in the cocoa growing region in the southwest of the country. The initial collection of seed came from the same area (Ashanti and Western regions), and involved 'random' sampling by local communities of more than 20,000 fruit from ~ 700 trees. Village collectors, who were paid ~ 10 US cents for every three fruit that they sampled, delivered fruit to local focal persons, from whom fruit was collected by ITSC, who extracted seed at their central nursery site. Over the same period, FORIG collected seed from the same region of Ghana (in this case using a 'targeted' approach) for establishment in their central nursery in Kumasi;

seedlings produced here, however, are destined for research purposes (controlled field trials) rather than for distribution to farmers.

Also in 2005 (again, as reported above), 160,000 seed (of *A. stuhlmannii*) was planted in nursery beds in ANR's central nursery facility in the East Usambara of Tanzania, with a view both to providing seedlings for distribution to farmers in the surrounding area and for the establishment of controlled field trials. The initial collection of seed, in which fruit were sampled selectively, was undertaken by ANR and ICRAF staff and came from the Amani Nature Reserve itself.

Although both ITSC and ANR central nurseries were established with an objective of raising seedlings for farmer establishment, to date the number of plants produced has been considerably lower than was first expected, due in large part to the slow rate and/or overall low level of germination observed with the genus (see above). In the first half of 2006, large-scale seed collections (using similar sampling strategies to 2005) were again undertaken in both Ghana and Tanzania in order to provide, through ITSC and ANR central nurseries, respectively, further seedlings for planting. In Tanzania, the same collection was also used to provide seed for a new central nursery in West Usambara (established by TAFORI) and for community nursery development (see below).

In Tanzania, at the same time as raising planting stock for farmers from seed, the process of providing material for smallholders via vegetative propagation has begun. As reported above, leafy cuttings are currently being collected from cut *A. stuhlmannii* trees in farmland in the East Usambara region. In this scheme, farmers receiving one-off financial payments for felling trees on their land and annual compensation (planned for three years) for maintaining stumps and allowing access in order to harvest regrowth. Cuttings are beginning to be rooted in non-mist propagators constructed in ANR's central nursery facility. It is anticipated that trees cut in the region will produce more than 100,000 coppice shoots, of which it is anticipated that at least 15,000 will successfully root in non-mist propagators; propagules will be shared among farmers and communities participating in the initiative.

Meanwhile, distribution of the limited number of seedlings already produced by the ANR central nursery has begun around the Amani Reserve, with a special tree planting launch ceremony in May 2006, in which farmers each received a maximum of 20 seedlings. A 'Farmer's *Allanblackia* tree planting logbook' is distributed with seedlings to record and monitor farm establishment and management. This logbook also contains tips on how to raise, plant and manage seedlings. Plans are also in place for the ITSC central nursery in Ghana to distribute some seedlings to smallholder farmers early in 2007 (the rest of their stock will be used for grafting purposes). Planting schemes provide some incentives to farmers to maintain trees, though the extent to which these incentives should be financial or otherwise, and the timescales involved, have not yet been fully delineated (see under 'economic analysis' in the Novella Project Baseline).

Medium-scale community nurseries

Some production of *Allanblackia* seedlings in (mostly) medium-scale community nurseries has begun, most significantly in the area around ANR in Tanzania. Here, in 2005 and early 2006, the ANR project and TFCG helped to establish with local community groups a number of tree nurseries. In most cases, nurseries were established specifically under the *Allanblackia* initiative; in a few cases, however, *Allanblackia* was introduced into pre-existing nurseries. In the second half of 2006, another *Allanblackia* community nursery was established in Tanzania by TAFORI (in the West Usambara). Community nurseries around ANR have begun to distribute *Allanblackia* seedlings to their members and other villagers.

As well as being provided with *Allanblackia* seed, Tanzanian community nurseries have been supplied with guidelines that follow current best practice for how to raise seedlings. Guidelines include information on seed pre-treatments, suitable substrates for nursery seed germination beds, and appropriate transplantation and potting-up procedures. In addition, nurseries have received some assistance with construction and other required materials (such as sand for seed germination beds), and receive regular advisory visits by staff from supporting institutions.

Furthermore, community nursery groups in the Amani region have been encouraged by supporting partners to themselves experiment in the collection and handling of *Allanblackia* germplasm; in some cases, groups have very successfully sampled both their own seed and wildings. This community experimentation has resulted in the identification of potential innovations that, if confirmed through more formal testing, could be applied more widely to *Allanblackia* domestication (as related above in discussions on seed collection, seed pre-treatments and wilding sampling).

In addition to seed and wilding propagation, community nursery groups will in the future become involved with vegetative techniques. Around Amani, some non-mist propagators have already been established in community nurseries, for the distribution of planting material to those farmers and other community and nursery members that are currently participating in the coppicing of trees (see above). To facilitate community vegetative propagation of *Allanblackia*, written guidelines for the rooting of cuttings, based on current knowledge of best practice, have already been produced. These guidelines include information on how to collect and set cuttings and a design for non-mist propagator construction.

In addition to being provided with (and being encouraged to collect) *Allanblackia* germplasm, community nursery groups in Tanzania are collecting, from farmland and neighbouring forest, seed and wildings from other trees that they regard as appropriate for on-farm planting. Furthermore, TFCG have given to community nurseries the seed of a range of other tree species that farmers consider to be important for planting, but which they were not able to themselves otherwise source. During a brief inventory in March 2006, TFCG community nurseries in the East Usambara were found to include seedlings of the following mixture of exotic and indigenous trees (in addition to a total of ~ 4,000 *A. stuhlmannii* plants): *Acacia melanoxylon*, *Albizia schimperana*, *Cedrela odorata*, *Enantia kummeriae*, *Grevillea robusta*, *Khaya anthotheca*, *Markhamia lutea*, *Newtonia* sp. and *Syzygium aromaticum* (cloves). Nursery groups are engaged in selling seedlings of all of these species to members of the local community. It is important to note that while planting of some of the above species should have a beneficial impact on the local environment, this may not always be the case: for example, *Cedrela odorata* is considered an invasive species in the neighbouring ANR, and proper consideration/sensitisation to potential weediness is something that needs be emphasised in nursery species-prioritisation exercises.

In Ghana, Cameroon and Nigeria, significant production of *Allanblackia* plants in community nurseries will begin in 2007. In Cameroon and Nigeria, this will involve using community nurseries that have already been established over a number of years (by ICRAF and other partners) for 'village-level' promotion of a range of other indigenous fruit trees, such as *Dacryodes edulis* (safou) and *Irvingia gabonensis* (bush mango). The advantage in these two countries is that these established nursery groups routinely use (and have all the necessary infrastructure for) vegetative propagation techniques on other fruit trees, and this should greatly facilitate uptake for *Allanblackia*. Although the particular village-level tree domestication approach pioneered by ICRAF in Cameroon and Nigeria has yet to be widely adopted in Ghana (or Tanzania), the intention is that a similar procedure will be followed there.

4. Progress on *Allanblackia* domestication and areas for continued work

Progress to date

Domestication work on *Allanblackia* has made progress. Studies to date show that it is possible to germinate *Allanblackia* seed in the nursery, and indicate that appropriate nursery conditions offer opportunities to increase overall levels of germination. Propagation via a number of vegetative techniques has proved possible, with good success achieved (under the right conditions) in rooting leafy stem cuttings in non-mist propagators and in grafting. Studies indicate that wilding transplantation, if proper attention is given to reducing stress and to the use of appropriate potting media, can also be a useful alternative method for propagation that obviates problems with seed germination (although the wilding approach is only ever likely to provide a small proportion of the planting material needed by the initiative).

Morphological observations show very high variation in fruit yield characteristics in *Allanblackia* and, although there are a number of qualifications that must be considered, indicate possibilities for genetic gain through selection. It should be possible to select superior trees based on field observations in natural stands, both at local (community) and wider (district and national) levels. The observation of high variation within stands raises particular prospects for improvement through linkage with the local or 'village-level' indigenous fruit tree domestication programmes that are already established in two of the countries (Cameroon and Nigeria) participating in the *Allanblackia* initiative. Collection from apparently superior trees has begun, both for field trials and for the production of planting material to distribute to farmers. To date, collection has been based primarily around sampling seed, although vegetative sampling from selected individuals has also commenced. Studies to establish the genetic base of collected germplasm, with a view to safeguarding productivity during distribution by preventing inbreeding depression, have also begun.

The development of large-scale central and medium-scale community nurseries for the supply of *Allanblackia* planting material to farmers has started. To date, these nurseries have mostly been involved in raising seedlings rather than in vegetative propagation. Guidelines summarising current best practice for propagation (via seed and vegetatively) have been produced and are being distributed to nurseries, both in written form and through face-to-face discussions with supporting institutions. Some nurseries are experimenting with their own collection of *Allanblackia* germplasm and are also supplying farmers with planting material of other tree species. Distribution of small quantities of planting material from nurseries to farmers began in the second-half of 2006, with greater distribution anticipated for 2007.

Particular areas for continued work

Although progress in *Allanblackia* domestication has been made, the overall level of advance has been at a slower rate than was initially expected by the partners in the initiative. However, as no work at all had been done before 2003, it should be no surprise to observe that progress in bringing the genus into cultivation is incremental.

Continued advances in the domestication of *Allanblackia* will be crucial if the overall objectives of the Novella Project are to be met. Where relevant, 'best bet' options for management should be applied based on lessons learnt from more studied tree genera that are either phylogenetically related to *Allanblackia* (e.g. *Garcinia*), have the same tree form (e.g. *Durio*), or have a similar fruit size (e.g. *Artocarpus*). As well as constantly improving best practice for cultivation through research and innovation, a key issue is to ensure that practitioners are kept up to date with advances in knowledge. In this respect, the first international training workshop on *Allanblackia* domestication, which was held in Nairobi in October 2006, was an important event (see Box D1 at bottom of this annex). Some of the main areas where ongoing activity is likely to be crucial in the coming years are summarised in Table D1, with key elements discussed further below.

Developing propagation techniques

The volume of *Allanblackia* planting material produced by nurseries has, to date, been disappointing. Primarily, this is due to difficulties experienced in the germination of *Allanblackia* seed. Although it is expected that adjustments already made to best practice in 2006 will help obviate some earlier problems, it is clear that further studies into approaches that accelerate and increase overall levels of germination for *Allanblackia* are important for the Novella Project. Experiments need to be conducted more creatively and efficiently than has previously been the case, in part by building suitable controls onto practical deployment activities. This means that a way needs to be found to encourage non-governmental and community-based organisations to become more involved in research.

One area where research is particularly required is in testing the utility of gibberellic acid as a seed pre-treatment. In addition, even if gibberellic acid is proven to be effective, the development of methods that promote germination but are simpler and more accessible (especially to local communities) than the use of plant growth regulators is required. For example, gibberellic acid is expensive to purchase (in small volumes, ~ USD 25 per gram in Nairobi) and is therefore unlikely in most locations to represent a viable approach for seed pre-treatment during wide-scale deployment activities.

Since it is anticipated that several million vegetative propagules will be required by the *Allanblackia* initiative every year from 2008 onwards, further improvements in vegetative propagation techniques are absolutely key to the whole Novella Project. This work will continue to be led by ICRAF in Cameroon, who will disseminate methods first developed there to other sites. One current concern is the large variation in success rate (10-fold) observed for rooting of leafy stem cuttings taken from different source plants (in experiments in Cameroon); if possible, more uniform results for cloning need to be achieved, since otherwise the range of source plants available for propagation will be restricted. In addition, a varying ability to clone source trees could have implications for the genetic base of cultivated stands, with bottlenecks and inbreeding depression possible as some genotypes become dominant. These effects would not be evident in the short-term, but could be important in second-generation plantings (when farmers collect propagules for further establishment from already planted clones on their land).

When collecting cuttings from mature felled trees, it is also important to establish the best methods for optimising cutting yield; can techniques such as cutting back initial regrowth significantly increase yields, and how is regrowth influenced by the height and angle at which trees are cut? Do shaded stumps produce more regrowth, when is the best time of year to fell trees in order to promote coppicing, and when is the best time of year to harvest and successfully propagate regrowth?

Also crucial is an assessment of the degree of acceleration of fruiting that is possible by different vegetative propagation techniques (compared to raising trees from seed), if this varies depending on what part of the mother tree vegetative material is sampled from, and whether additional acceleration can be obtained through approaches such as grafting into rootstocks of faster-growing related species. Furthermore, the ability of the architecture of young vegetatively propagated trees to support fruit production (will trees collapse, and what could be done to prevent this?) needs to be determined.

For all propagation methods (seed, vegetative and wildings), reasons for current varied success across populations and species need to be further assessed through controlled experiments. This is necessary in order to determine how much currently observed differences reflect variations in protocols and the different sites where studies have been undertaken, and how much represents genuine genetic differences. This is important for determining the general applicability of current best practice guidelines, which although currently being recommended across countries and species, are generally based on single-site and single-species research.

Selecting and collecting elite material

Although field observations indicate considerable variation in fruit yield characteristics within and among *Allanblackia* stands and species, the level to which selection from natural populations is effective in capturing superior genotypes for propagation is currently unknown. The utility of a 'targeted' compared to a 'random' method of sampling will only become evident through continued observations of natural stands (monitoring the ranking of trees for yield across years) and by measurements in controlled field trials. Since these field trials (based on seed) will only be established later in 2006, observations on fruit production will likely only be possible some date after 2016.

In the meantime, the establishment of trials that compare 'targeted' and 'random' sampling of stem cuttings from mature female trees would be useful. Since vegetatively propagated trees should fruit before individuals propagated from seed, such trials (if established in the next few years) would provide some indication of the efficacy of field selection before seed-based trials can. Furthermore, since vegetative collection is likely to become the favoured approach as the Novella initiative develops, early research on this would appear to be better than the 'default' option of waiting to observe seed-based trials some time in the future, at a point when propagation via seed is anyway likely to be less important. However, if seed-based propagation is to remain an option, trials should also be established that involve comparisons of seed- and vegetatively-propagated individuals collected from the same mother trees, in order to provide an indication of the relative genetic gains that can be expected by the two approaches to propagation. That is, during seed collection, how does the inability to select for the paternal parent impact on genetic gain?

In addition to overall yield characteristics, selection needs to be broadened to consider other traits, including the production of:

- More stable production types, with reduced year-to-year variation in seed yield (reduced 'mast' fruiting). This may be the most crucial trait for consideration, if the supply chain of the *Allanblackia* initiative is to be effectively sustained, because across-season predictability of income may be a very important characteristic for growers (this issue is addressed further in the Novella Project Biodiversity Baseline of this proposal).

- Types with more optimal oil composition. Although the oil profile of *Allanblackia* is generally excellent, biochemical analysis indicates that there is a natural spread around the 'ideal' composition. Some variation is observed within, as well as among, populations. There is therefore scope for selection to improve average oil profile, which would improve the unit value of the oil crop to Unilever and thus farmers.

In addition to the above general characteristics, other desirable traits may vary depending on the particular requirements of the different communities in which the *Allanblackia* business becomes established. This means that a certain amount of flexibility in trait selection may be required, and that at different sites a process of participatory priority setting for determining particular characteristics important for improvement may be necessary before collections begin. How realistic such an approach to selection will be (at what geographic scale it can operate) is currently difficult to judge, but the best prospects may be within the 'village-level' models of indigenous fruit tree domestication that are already established in Cameroon and Nigeria. Important characteristics for selection at particular locations and in different farming systems could include the following (see 'ecology research' in Novella Project Baseline for further relevant information):

- A 'spread' of fruiting over a longer time period, in order to reduce labour conflicts connected to harvesting at any given time of year and/or to spread collector revenues across the year. 'Spread' may be more relevant when no special effort is required to harvest *Allanblackia* trees, e.g. when they are fully integrated with other crops in farming systems.
- In other situations, a 'contraction' in harvesting season, to concentrate collection into a shorter time period, may be relevant. This may be important when a special effort is required to harvest *Allanblackia* fruit, e.g. if trees occupy their own 'block', separate from other crops (meaning that fruit can not be collected during other 'routine' farm operations).
- An alteration in fruit maturation period to minimise coincidence in harvesting with other important farm crops/forest products, again to reduce labour competition (e.g. it has been suggested that coincidence with cocoa harvesting may be an issue in Ghana).

In addition to the above, work is required to determine how seed yield and percentage oil content are related in *Allanblackia*. A negative relationship might be expected, in which case selection based on seed weight may not bring as great advantages as first thought. Ideally, selected material should produce high quantities of seed with high oil content, but experience with other fruit trees suggests that effective selection of both quantity and quality characteristics is sometimes difficult. Some preliminary research on this issue is beginning in Cameroon.

In deciding which material to sample to bring into cultivation, the question of adaptation is also an important issue. It is currently not known whether superior material collected from one eco-zone will also perform well in another. Some preliminary observations (on seed germination and wilding transplantation in Ghana and Tanzania; see above) suggest that questions of adaptation may be important leading up to seedling production, but how different environments impact on later performance is unknown. In the future, some information on this will become available from controlled field trials (mentioned above).

Finally, the way in which material is selected to enter cultivation has implications for the level of hybridisation that can be expected in *Allanblackia*, with any hybridisation that does occur being likely to impact on the future productivity of stands. If a policy of wide-scale distribution of particular selected individuals or populations is favoured, interactions between introduced and already existing plants (through species- and population-level hybridisation) are likely to occur. The impacts that these interactions will have on *Allanblackia* are unknown, but experience from other trees suggests that 'out-breeding depression' may follow. These interactions are less likely if a more local approach to selection and distribution is adopted. Together with issues of mal-adaptation, this would tend to favour a local or 'village-level' approach to the selection of elite material for planting, and local (at least, certainly not very highly centralised) nurseries for distribution of seedlings to farmers. Whether or not *Allanblackia* individuals of different provenance do actually hybridise when brought into proximity can be tested by some of the molecular marker techniques currently being developed for the genus.

Central and community nursery activities

Massive capacity development of central and community nurseries is required in the coming years if the planting projections of the Novella Project are to be met. Large financial investments in the development of central and community nursery capacity are planned, although these investments are only merited when appropriate germplasm, and efficient handling protocols, are also available. Protocols are still under development, but recent improvements have increased their practicality for large-scale deployment. Training activities with communities are beginning at country level (most notably in Tanzania), and these will need to be extended through the development of rural resource centres linked to tree nurseries. These centres will need to provide, and be able to certify, training in business skills, and should have demonstration plots related to various *Allanblackia* management techniques.

Systems for communication will need to be developed between nurseries, both to disseminate evolving current best practice on handling *Allanblackia* and to allow flows of germplasm. Networking is also necessary in order that nursery practitioners can communicate upwards (to a more centralised level) innovations that they have developed, for further testing and possible wider dissemination.

Before large-scale nursery production begins in earnest, work is required on determining the optimum pathways for bringing germplasm to nurseries, and for delivering planting material from nurseries to farmers. This requires an analysis of the germplasm supply chain in terms of the incentives needed to sustain it, an understanding of how the chain can be monitored in order to adapt it (if and when necessary), and a knowledge of how different incentives contribute to a centralised or decentralised (the latter possibly being more sustainable?) germplasm delivery system.

Defining appropriate on-farm management strategies

Apart from small trials planted in Cameroon in 2005, little research relevant to the development of appropriate on-farm management strategies for cultivated *Allanblackia* is yet underway. Partly, this reflects the sequence of events involved in bringing a new species into cultivation: basic propagation knowledge takes first priority, on-farm management research is easier to begin in earnest when farmers actually start to plant the tree during the 'early' practical deployment phase of a project. In addition, it is an indication of the time-scale involved in setting-up and monitoring such research. Furthermore, it reflects an understanding that generalisations based on previous experiences of smallholder cultivation of other indigenous fruit trees are relevant for the on-farm management of *Allanblackia* (that is, to some degree, we can depend on 'expert opinion' to devise 'best-bet' options).

While many generalisations should be possible, there are some issues where specific research is needed. Normally, this research should be incorporated into the ongoing practical deployment objectives of the Novella initiative. This means engaging those community organisations interested in *Allanblackia*, and those farmers that are planting *Allanblackia* for commercial oil production, into the research process.

One area where research is required is on the appropriate planting niche for *Allanblackia*. Ecology studies suggest that *Allanblackia* prefers some shade during initial establishment, and this should be confirmed in an on-farm setting, because it has important implications for the complexity and diversity of the agricultural systems in which the genus will be cultivated.

Another issue is how the niche that trees will occupy on farms will depend on the propagule type used during initial establishment. It appears highly likely that trees propagated vegetatively will occupy a different niche from those propagated by seed, but this needs testing. This is an important issue because it has significant implications for the on-farm management techniques that will need to be applied to optimise the productivity of *Allanblackia*. For example, vegetatively propagated trees are likely to be shorter in stature (just how short will depend on the particular vegetative technique used) than trees established from seedlings. Since evidence from ecology studies (see Novella Project Baseline) indicates that position in the canopy is important for productivity, with trees in more open areas yielding more fruit, it is possible that yield from vegetatively propagated trees will suffer due to shading, unless appropriate management action is taken. Intervention could involve clearing the canopy around vegetatively propagated trees, but this would have a 'knock on' effect on the range of other flora found on farms (this issue is addressed in the Novella Project Biodiversity Baseline of this proposal).

Propagation choice in relation to niche is also important because of the implications for competition with other farm crops. For example, some villagers in Ghana suggest that *Allanblackia* remnants that neighbour cacao trees can lower cocoa production – how would this situation change if shorter *Allanblackia* trees were introduced into these farming systems? The niche that cultivated trees come to occupy also has implications for best practice harvesting guidelines (see Novella Project Baseline), as current guidelines are based on fruit fall from tall seed-propagated trees.

Other issues that require consideration for on-farm management include appropriate silvicultural techniques to optimise yield (such as coppicing?), possible methods for stabilising *Allanblackia* fruit production across years, approaches to manage dioecy, and pest and disease control.

It is possible that coppicing of female trees may be useful in promoting branching and thereby provide more flowering (and fruiting) sites on *Allanblackia* trees. However, coppicing will also change the niche occupied by trees, with shorter stature having the possible negative implications for fruit production already related above. Furthermore, any loss in productivity caused by coppicing (recovery period to re-flowering and fruiting?) is currently unknown.

It is possible that on-farm management techniques could be used to reduce the current 'masting' observed in *Allanblackia* fruit production. Two approaches worthy of some consideration for testing are the application of fertiliser, to replenish nutrients that may become depleted in high fruiting years, and the promotion of pollinator populations on farms, by encouraging establishment of other flora on which the relevant birds and insects depend (also possible establishment of bee hives, if bees are a pollinator?). How practical the option of fertilisation is for low input subsistence farmers, and the level of benefit this would bring, are currently open questions.

In relation to dioecy, it has been suggested that a planting ratio of ~ 10 female trees to one male may be optimal, based on an assumption that male forest individuals can also to some degree successfully pollinate female farm trees. This proposed ratio is, however, highly speculative; for example, what happens if male forest trees do not flower at the same time as female farm individuals? Testing at a variety of different farm sites (at different distances from forest) needs to be undertaken in order to assess what ratio is really appropriate and under what conditions. These tests should involve using molecular markers to assess gene flow across the forest-farm 'boundary', as well as direct observations on pollinator movements, seed production and flowering index. Furthermore, research on the best configurations in which to plant male and female trees in order to optimise seed yield on-farm is required. One suggestion is that male trees could be planted around homesteads, where fruit fall from female trees might otherwise pose a safety risk to playing children. Would such a 'centralised' configuration for male tree planting be appropriate? Some information on the relationships between dioecy, sex ratio, flowering index, tree configurations and production will become available through ongoing ecology studies.

For pest management, observations made during seed collection from a number of natural stands indicate that *Allanblackia* seed sometimes suffers from insect attack. Larvae have been observed eating seed, making it useless for oil extraction purposes. Furthermore, a number of mammals are known to eat *Allanblackia* seed in forest (this issue is addressed in the Novella Project Biodiversity Baseline of this proposal). With a shift to on-farm cultivation, it is possible that these problem may be magnified, and pest risk assessment in a smallholder production context is therefore required.

Box D1. The first international training workshop on *Allanblackia* domestication, Nairobi, October 2006

This 'training of trainers' meeting (ICRAF, 2006) shared and discussed current best practice for *Allanblackia* domestication. The primary objectives of the workshop were to: (i) disseminate information on how to cultivate the genus more widely among Novella Project stakeholders; and (ii) ensure domestication activities are properly integrated within the wider context of the *Allanblackia* initiative, in order that practical deployment objectives are properly met. The following modules were included in the 'taught' element of the workshop:

Introduction to integrated thinking on *Allanblackia* domestication
Included were sessions on: understanding integrated domestication strategies, a detailed example of an integrated country strategy (Tanzania), an industry perspective on the *Allanblackia* business; and needs and approaches for diversification related to the Novella Project.

Domestication: germplasm collection and propagation
Included were sessions on: methods for germplasm collection and selection, approaches for seed germination; and techniques for vegetative propagation (with practical sessions on germination and vegetative propagation).

Domestication: nursery production to on-farm harvesting
Included were sessions on: nursery techniques; and approaches for scaling-up nursery production (with a practical session on nursery techniques).

Understanding context: cultivation, market and policy issues
Included were sessions on: appropriate on-farm tree management strategies, the development and scale-up of the oil market supply chain; and economic and policy incentives for planting and production.

A wide range of field implementation partners from Cameroon, Ghana, Nigeria and Tanzania, concerned with domestication and wider activities within the *Allanblackia* initiative, attended the meeting. By bringing together participants from all countries currently involved in the initiative, the workshop allowed consideration of where generalisations across the genus are possible for technical handling, and where country- and species-specific concerns remain. Time was also set aside in the workshop for country planning of activities for 2007 and 2008.

The meeting helped identify key gaps in knowledge where continued research action is a priority in *Allanblackia* domestication (these points are incorporated with other inputs into Table D1). In particular, the need to further develop vegetative propagation techniques was seen as key.

ICRAF (2006) *Workshop technical report*. SII Training workshop on *Allanblackia* domestication, 23-27 October 2006. ICRAF, Nairobi, Kenya.

Table D1. Some areas for future activity in *Allanblackia* domestication work

Area of activity	On what is work needed?
Developing propagation techniques	
Seed germination	- Confirm the general utility of currently used seed pre-treatments during practical deployment, especially gibberellic acid and 'nicking'. Use of controls, population/species variation? - Continue experimenting with additional pre-treatments, such as potassium nitrate, particularly methods that are cheap, simple and accessible to communities during practical deployment. - Determine the efficacy of community innovations as seed treatments (harvesting rat caches/burrows, burying fruit, etc.). - Determine if late germinants produce seedlings of equal or (possibly?) reduced vigour.
Nursery media	- Confirm the utility of various seed germination bed (sand or soil?) and potting-up substrates. - Assess the importance of mycorrhizal associations at potting-up (impact on seedling vigour).
Vegetative propagation	- Assess the best methods for optimising cutting yield from mature felled trees. - Confirm the general utility of rooting of mature stem cuttings as a protocol. Use of controls, tree (within population)/population/species variation? - Continue experimenting with protocols for grafting and marcotting. - Assess the reduction in time taken to fruiting for different vegetative techniques compared to propagation via seed, and how much this varies by what part of the mother tree material is sampled from. Assess whether further acceleration is possible, e.g. by grafting scions into rootstocks of fast-growing related species. - Determine clonal multiplication rates possible for elite material. Are multiplication rates adequate to supply requirements? - Determine if the architecture of young vegetatively propagated trees can adequately support fruit production.
Wilding propagation	- Assess the reasons for the varied success observed with wilding transplantation, including the effect of time in transit, site and possible mycorrhizal associations (use of forest soil). - Assess the effects of wilding size and the application of pruning and other possible treatments on transplantation success rate. - Assess if transplantation can be undertaken into degraded soils such as mine tailings.
Selecting and collecting elite material	
Selection traits	- Confirm the effectiveness of selection (from natural stands), through natural stand and controlled field trial observations (extend observations on natural stands over a number of years – what increases in selection efficiency are possible through longer observation?) How heritable are fruit traits? Controlled field trials should be based on vegetative propagules as well as on seed-propagated trees. - Undertake selection for characteristics other than fruit/seed yield, especially for across-season stability of production, though also (possibly) to spread fruiting over a greater number of months, or to select for oil quality as well as quantity. - Confirm the relationship between fruit size and seed yield. - Assess the relationship between oil quantity and seed yield.
Germplasm source issues	- Assess if sampling seed from forest stands versus farmland has any impact on subsequent tree vigour. - Assess ecological adaptation issues (does germplasm collected from one eco-zone perform equally well in other zones?). - Determine if trees from different populations will hybridise when brought together during cultivation. If hybridisation does occur, determine the impact on tree performance.
Central and community nurseries	
Nursery capacity	- Massive investment in physical nursery capacity infrastructure (seed and vegetative propagation). - Periodic distribution of improved written propagation protocols to nursery managers (knowledge capacity dissemination). - Group training of nursery managers (workshops, training of trainers?) in propagation techniques (knowledge capacity dissemination).
Germplasm pathways	- Undertake research on optimum pathways for delivering germplasm from the point of original collection to nurseries, and from nurseries to farmers. - Determine effective incentives for ensuring germplasm delivery to nurseries, and for *Allanblackia* planting and maintenance on-farm.
Defining appropriate on-farm management strategies	
Niche	- Assess whether trees propagated in different ways occupy different niches on-farm. - Assess impact of niche on productivity. - Assess impact of niche on ability to harvest. - Assess impact of niche on competition with other crops.
Silvicultural management	- Determine the effect of coppicing on seed yield. - Determine time from coppicing to fruit production.
Issues relating to dioecy	- Assess male to female ratio and planting configurations for optimal productivity during cultivation. Assess 'connectivity' between male forest and female farm trees.
Pests and diseases	- Assess potential pest and disease problems during cultivation. If major pest problems appear likely, how can these be managed?