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# *Allanblackia floribunda*: a new oil tree crop for Africa: amenability to grafting

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**Abstract** Three *Allanblackia* species (*A. floribunda*, *A. stuhlmannii* and *A. parviflora*) with high nutritive, medicinal, cosmetic and economic values are currently being domesticated as new oil tree crops. *Allanblackia* seeds contain a hard white fat consisting mostly of stearic (52–58%) and oleic (39–49%) acids. This unusual fatty acid content has the right properties for many different food and cosmetic products making them commercially interesting. Vegetative propagation studies on *A. floribunda*, which grows naturally in the moist forest of Cameroon and Nigeria, were initiated aimed at evaluating its amenability to grafting. Scions were grafted onto 18 month old rootstocks of *A. floribunda* using side tongue, top cleft, side veneer, whip-and-tongue methods under nursery conditions in Cameroon. In parallel, side tongue and inverted 'T' budding methods were also tested in situ on young *A. floribunda* wildings growing under semi-deciduous and evergreen tree covers. In addition, the effects of protecting side tongue new grafts with non perforated translucent plastic, perforated translucent plastic and aluminium foil were assessed. Under nursery conditions, side tongue grafts were significantly more successful (80.0 ± 6.3%), than grafts of side veneer (52.5 ± 7.9%), top cleft (55.0 ± 7.9%) and whip and tongue (50.0 ± 7.9%). The success of side tongue graft was further increased (86.7 ± 6.2%) under the shade of evergreen trees when protected by non perforated translucent plastic. These results indicate the potential for in situ grafting and 'top working' to promote cultivation of more productive germplasm of *Allanblackia* within multifunctional agricultural systems.

**Keywords** *Allanblackia* · Domestication · In situ grafting · Oil · Vegetative propagation

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## Introduction

Nine species of *Allanblackia* (Clusiaceae) are indigenous to the African tropics (van Rompaey 2003). *Allanblackia* is dioecious and three species (*A. stuhlmannii*, *A. floribunda and A. parviflora*) have been noted for their importance in food (margarine) and cosmetic (soap and detergent) industries (Foma and Abdala 1985). The oil from the seeds containing 52–58% stearic acid and 39–45% oleic acid is of high commercial importance (Eckey 1954). *Allanblackia* oil is also of commercial interest because it requires less chemical processing and refraction than palm oil. The fatty acid profile of the oil has been reported to lower plasma cholesterol levels (Bonanome and Grundy 1988), and thereby reduce the risk of heart attacks. In Ghana, its bark is used to relieve toothache (Abbiw 1990) while in Cameroon it is used against coughs, dysentery, toothache and as an aphrodisiac and pain reliever (Laird 1996). Other possible uses include the treatment of HIV-Aids as Guttiferone F, an HIV-inhibitor, has been reported in bark extracts of *Allanblackia stuhlmannii* (Fuller et al. 2003). Unilever is engaged in the process of building an *Allanblackia* oil production industry in Africa based on small-holder oil production and local supply chain development which could give fair returns to farmers, collectors and local processors (Egyir 2007).

*Allanblackia floribunda* is found in the humid forests of Cameroon (Letouzey 1985). The trees grow to a height of 30 m. The large elongated, five-sided fruits (1–2.5 kg) are light brown with chestnut spots and contain seeds in a gelatinous pulp. *Allanblackia* species are 'Cinderella' species overlooked by science (Leakey and Newton 1994) which provide nutritional, economic or environmental benefits but have been neglected by mainstream domestication (Leakey and Simons 1998). Farmers have viewed these species as nature's gifts, but they are now disappearing through forest clearance for modern agriculture (Leakey 1999). However, in the last 15 years such high-value agroforestry trees, especially those for fruit/nut production, have been the subject of domestication and improvement of yield and quality (Tchoundjeu et al. 2006) for the alleviation of poverty, hunger, malnutrition and environmental degradation (Leakey et al. 2005).

To further promote *Allanblackia* species as a new oil tree crop, tree domestication techniques that offer an opportunity to improve the productivity and quality of the trees are required. This is achievable through simple genetic selection of marketable fruit/nut and oil traits which in turn increases the market value of the products so that farmers could start to produce new oil tree crops appropriate to market demands.

Germination of *Allanblackia* species is very slow, with *A. floribunda* reported to have a germination rate less than 5% (Vivien and Faure 1996). Consequently the cultivation of *Allanblackia* species on farm is constrained by propagation techniques (Munjuga et al. 2008). Recently however, a breakthrough in Ghana and Tanzania with *A. parviflora* and *A. stuhlmannii* has greatly improved nursery germination success (Ofori and Munjuga unpublished). Notwithstanding, as an allogamous species, vegetative propagation techniques are needed to capture certain desirable fruit or tree traits so as to produce cultivars which have the same genetic characteristics as the mother trees. Vegetative propagation (grafting, budding and marcotting) have been used to achieve a number of horticultural benefits such as early fruiting, tree dwarfing, capturing and fixing desirable tree and fruit traits (Akinnifesi et al. 2008). Relevant vegetative propagation techniques include the rooting of stem cuttings, marcotting and grafting. Recent studies using leafy stem cuttings have shown this approach to vegetative propagation to be successful for juvenile shoots, although the rooting process is slow and few roots are produced per cutting. For example, 68.7% of cuttings obtained from coppiced juvenile shoots of an *A. floribunda* clone after optimizing important factors (substrate, clone and leaf area) produced roots after 25 weeks which did not change till the end of the experiment at 38 weeks (Atangana et al. 2006). However, further work is needed to speed up rooting and increase root number (Leakey 2009). Grafting, like marcotting, has the major advantage of multiplying mature elite trees for use in a seed orchard, or for producing clonal planting stock for a production orchard. Frequently, trees selected for breeding or seed orchard purposes are too old (often greater than 15 or 20 years) for clonal production by direct rooting of cuttings. Thus, the capture of mature phenotypes in the reproductive phase has to involve grafting or marcotting before they can be multiplied by stem cuttings (Hartmann et al. 2002; Mng'omba et al. 2008). Grafting involves the collection of scions from the ontogenetically mature crowns of large trees identified through plus tree selection (Atangana et al. 2002). In this way, the juvenile phase of trees is greatly shortened or avoided (Hartmann et al. 2002) and flowering and fruiting can be expected within 2–4 years. For example grafted *Uapaca kirkiana* began to produce fruits only after 2–3 years, while those derived from seedlings took 12–15 years before fruiting (Akinnifesi et al. 2008).

Although considerable information is available on vegetative propagation of tropical African species using stem cuttings (Leakey et al. 1990; Leakey 2004; Tchoundjeu et al. 2006; Mng'omba et al. 2008) as a simple and inexpensive technology, much less is known about grafting. This study therefore aims to improve grafting techniques in *A. floridunda* by investigating different grafting methods, the effects of new graft protection and its development under semi-deciduous and evergreen tree cover on graft success and survival. Research was carried out under both nursery and on-farm conditions. The objectives were to (1) determine the effectiveness of four grafting methods (side tongue, side veneer, top cleft and whip and tongue) on graft success, (2) determine if protecting the new grafts improved graft success, and (3) determine if shade affected graft success. This study complements other grafting studies in *Allanblackia* species in Ghana (Ofori et al. 2008) and Tanzania (Munjuga unpublished).

## Materials and methods

### Study site

The trials were carried out on station and on farm. On-station trials were conducted at ICRAF experimental nursery—Nkolbisson Yaoundé (altitude: 700 m above sea level, latitude 3°52′–3°53′ North, and longitude 11°25′–11°27′ East) and in situ trails carried out on farms at Essang and Ngoumou (altitude: 695 m above sea level, latitude 2.1°–4.9 North and longitude 10.5°–16.2° East). The former is dominated by semi-deciduous trees and the latter by evergreen trees. The rainfall pattern is bimodal with an annual average of 1,672 mm. The relative humidity varies between 73 and 84% while the average temperature is 25°C (Ambassa-Kiki 2002).

### Experiment 1: nursery trial to compare grafting methods on *A. floribunda* rootstocks

The effectiveness of grafting methods was tested on 18 month old seedlings of *A. floribunda* that were at the vegetative growth phase. Scions were taken from twigs of the previous year's growth on branches in the crown of mature *A. floribunda* trees with buds which were about to sprout. Four grafting methods (side tongue, side veneer, top cleft and whip and tongue) were tested in a completely randomized design. Each method was applied to 40 plants selected at random, giving a total of 160 plants for the experiment.

Standard grafting procedures, as described by Hartmann et al. (2002) and Crasweller (2005), were followed and grafts were assessed weekly for graft success or mortality from the third to the twelfth week. Success was assessed by the healing of the graft union, sprouting of scion buds and leaf formation, while mortality was determined by the lack of sprouting from green scions or by the dehydration of scions. Data were collected in binary form: graft success '1' and graft mortality '0'. Owing to the binomial distribution of the data collected, an analysis of deviance (ANODE) using Generalized Liner Model (GLM) procedures of Genstat 12th Edition with the logit function as the link function was carried out to assess the effect of grafting methods on graft success probability. Below is the equation of the fitted model for any specific week.

$$\text{Logit}\,(p_i) = \log\left(p_i/(1-p_i)\right)$$
$$= \text{constant and grafting method effect,}$$

where $p_i$, the probability of success of a branch grafted with method $i$, is computed as the ratio of successful grafts over the total number of grafts per method ($n = 40$).

Then chi-square test associated with the analysis of deviance table was used to access whether the graft success rate differed among graft methods. Thereafter, estimates of the grafting methods success rate ($P_1$) along with their respective standard errors were obtained and back transformed to the probability scale via the predict options of the dialog box. Finally, treatment means were compared using Tukey's Honestly Significant Difference Test. Unless otherwise stated, statistical significance is given at the 5% level.

### Experiment 2: in situ grafting of young wildings of *A. floribunda* under evergreen and deciduous forests

Investigations to assess in situ graft success of *A. floribunda* were carried out in two experimental sites—Essang with semi-deciduous trees as the dominant vegetation and Ngoumou with evergreen trees as the dominant vegetation. Tree cover, assumed to affect light penetration, was used to investigate the effect of shade on graft success and survival in both sites. Two grafting methods [side tongue (ST) and budding] were tested in both sites. For side tongue grafts, three graft protection methods were applied: non perforated translucent plastic (ST-NPP), perforated translucent plastic (ST-PP) and aluminium foil (ST-Al) making a total of four experimental treatments evaluated. The aluminium foil was wound around the plastic to increase the reflection of light and reduce heat absorption by the scion. In each site, 120 young wildings of *A. floribunda* at the vegetative growth phase were identified, and 30 of the 120 were randomly assigned to each treatment. Side tongue and budding methods were chosen because side tongue graft success was highest in experiment 1 while the budding method is widely used for in situ grafting in *Citrus* spp and *Hevea brasiliensi*. Grafting success was assessed as described in experiment 1 and success rate among graft protection methods compared within and between sites.

## Results

### Nursery trial: effect of grafting methods on *A. floribunda* graft success

The evolution of *A. floribunda* graft success per grafting methods tested over 12 weeks is presented in Figs. 1 and 2. No graft unions were formed up to 3 weeks after grafting.

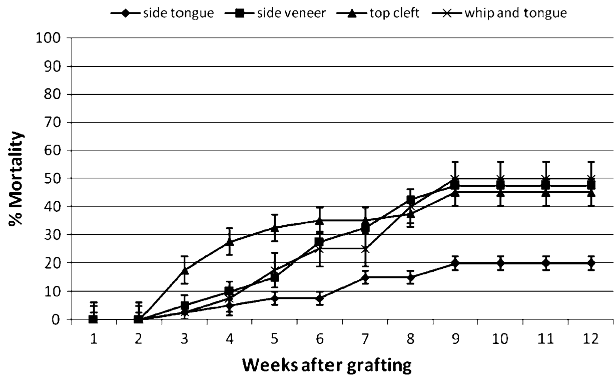


**Fig. 1** Mortality rate in four grafting methods tested on *A. floribunda*

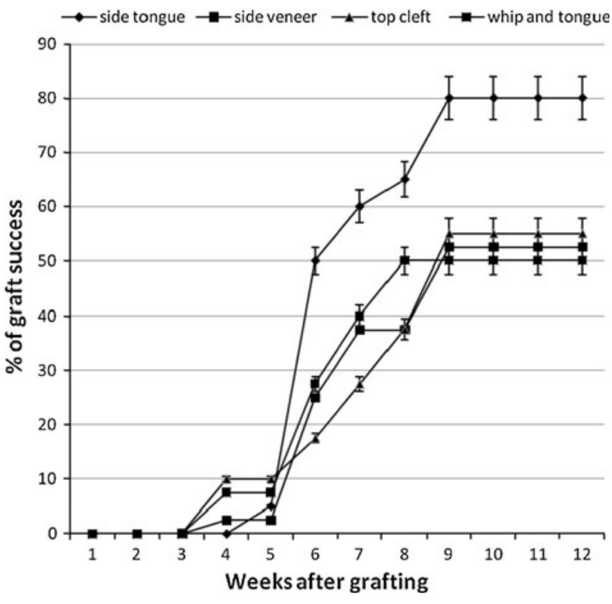


**Fig. 2** Grafting success in four grafting methods tested on *A. floribunda*. *T-Budding* T-budded graft, *ST-Al* side tongue graft protected with aluminium foil, *ST-NPP* side tongue graft protected with non perforated plastic, *ST-PP* side tongue graft protected with perforated plastic

However, mortality was significantly greater ($P < 0.001$) in top cleft grafts (17.5%) than in side veneer (5%) or side tongue and whip and tongue (2.5%; Fig. 1). By week six some grafts had successfully formed unions with side tongue being significantly ($P < 0.001$) better than the others (Fig. 2: side tongue = 50.0 ± 7.9%; whip and tongue = 27.5 ± 7.1%; top cleft = 17.5 ± 6.0%; side veneer = 25.0 ± 6.8%). After 9 weeks till the end of the experiment, all grafts were either dead or fully healed (success = 80% for side tongue and 50–55% for others).

In situ trial: effect of shade and new graft protection on grafting success in *A. floribunda*

The number of successfully grafted plants reached maximum between the 3rd and 7th week after grafting irrespective of the sites (semi-deciduous and evergreen tree covers). Under semi-deciduous tree cover (Fig. 3) graft success on wildings after 5 weeks was similar for side tongue grafts covered by non perforated translucent plastic (46.7 ± 9.1%) and perforated translucent plastic (40.0 ± 9.8%) and both were significantly ($P < 0.001$) better than those under aluminium foil (10.0 ± 5.5%). Budding was the least successful (3.3 ± 3.3%). Success rates did not improve after week nine.

Under the evergreen tree cover (Fig. 4) only side tongue grafts covered with non perforated and perforated translucent plastic were successful by week three (86.7 ± 6.2% and 83.3 ± 6.8%, respectively), but by week five aluminium covered scions and budded plants achieved 70.0 ± 8.5% and 3.3 ± 3.3% success, respectively. By the 7th week,

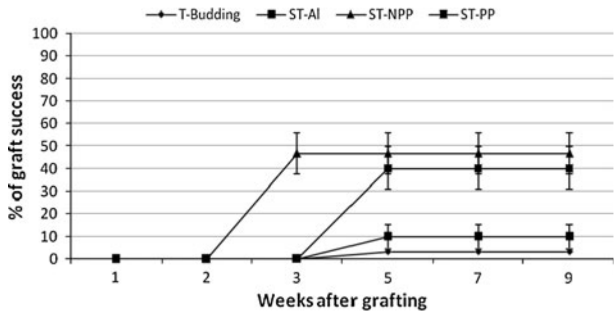


**Fig. 3** Graft success of *A. floribunda* under semi-deciduous tree cover, Essang, Cameroon. *T-Budding* T-budded graft, *ST-Al* side tongue graft protected with aluminium foil, *ST-NPP* side tongue graft protected with non perforated plastic, *ST-PP* side tongue graft protected with perforated plastic

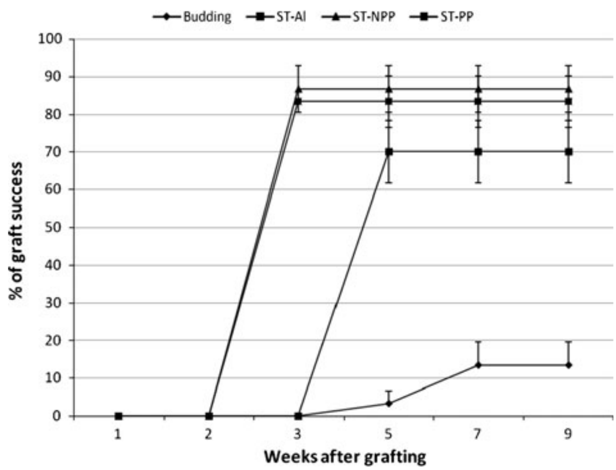


**Fig. 4** Graft success of *A. floribunda* under evergreen tree cover, Ngoumou, Cameroon

success in budded plants had risen to 13.3 ± 6.2% and remained constant during the remaining weeks of the experiment.

Overall, the difference in graft success rate was highly significant ($P < 0.0001$) among the graft protection methods tested and between the two sites. The most successful grafts were observed under evergreen tree cover in Ngoumou compared to semi-deciduous forest in Essang (Figs. 3 and 4). Side tongue grafts protected with non perforated translucent plastic had the highest graft success rate under evergreen and semi-deciduous tree covers (86.7 ± 6.2% and 46.7 ± 9.1%, respectively). This was followed by grafts protected with perforated translucent plastic under evergreen and semi-deciduous tree covers (83.3 ± 6.8% and 40.0 ± 9.8%, respectively), and grafts protected with aluminium foil under evergreen and semi-deciduous tree covers (70.0 ± 8.4% and 10.0 ± 5.5%, respectively). In contrast, budding success under evergreen and semi-deciduous tree covers was only 13.3 ± 6.2% and 3.6 ± 3.1%, respectively by week nine (Figs. 3 and 4).

## Discussion

This study found that *A. floribunda* is amenable to grafting techniques. Other indigenous dioecious fruit trees such as *Uapaca kirkiana*, *Sclerocarya birrea* (Mng'omba et al. 2007, 2008), *Vitellaria paradoxa* (Sanou et al. 2004) have been reported to be similarly amenable to grafting techniques. The level of success reported here for side tongue grafts (80%) is greater than those reported for other indigenous fruit and nut trees of Africa, such as *U. kirkiana* (65% graft success for in situ top wedge grafts: Mkonda et al. 2001).

It is well known that grafting is more successful under conditions which minimize the risks of dehydration in the adjoining cut tissues, and that the maintenance of reduced dehydration is beneficial to successful graft fusion (Hartmann et al. 2002), as found in apples when air moisture falls below saturation point. This is said to be because the cambium and parenchyma cells of callus tissues are thin-walled and tender. The results of the present study substantiate these findings in two ways. Firstly, protecting the graft with translucent plastic increased grafting success, and this success was marginally reduced by perforating the plastic (increased dehydration), and secondly, success was greater under evergreen tree cover with presumably lower irradiance and hence higher humidity, lower temperature and consequently lower water stress. Shade (reduced irradiance and lower red:far red ratios) was reported by Leakey (2004) to precondition shoots morphologically and physiologically so that the rooting ability of stem cuttings is enhanced. The present study suggests that shade has similar effects on the ability of shoots to produce callus and successfully form graft unions. This possibility requires further investigation to determine both the mechanism and the optimum conditions.

This study also found that under all the conditions of these experiments *A. floribunda* was most amenable to the side tongue grafting technique. Next was top cleft grafting, while side veneer, whip-and-tongue and budding were increasingly less successful. The amenability of *A. floribunda* to in situ grafting implies that 'top-working' techniques can be used to rejuvenate and convert old and unproductive trees growing in a wild stand or farmers' field to elite trees, so extending the production cycle and improving the value of such trees (Mng'omba et al. 2008). Top working can also be used to introduce tissue from male trees (staminate flowers) or branches into an existing male-deficient orchard or a wild stand with predominantly female (pistillate) trees, or vice versa, as has been reported to be necessary for dioecious species such as *Allanblackia* (Amanor et al. 2008). Currently, farmers in Ghana, Nigeria, Cameroon and Tanzania are planting unimproved *Allanblackia* seedlings, so the graft success reported in this study for *A. floribunda* under nursery and in situ conditions opens the way for farmers to start growing selected cultivars of this and other *Allanblackia* species. In this way, farmers can through grafting techniques develop cultivars with greater potential for fruit/nut production, as well as with desirable oil traits. This should increase the benefits being achieved by the local people from agroforestry tree domestication as currently practiced in west and central Africa (Tchoundjeu et al. 1998, 2006, 2010). These developments should also have important quality benefits for the edible oil processing industries.

## Conclusions

Grafting is a promising technique for the propagation of *A. floribunda* trees both in nursery and shaded in situ conditions. Five grafting methods were tested in two experiments and *A. floribunda* graft success was found to decline in the following order: side tongue 80%, side veneer 53%, top cleft 50%, whip-and-tongue 50% and budding 13%. Protecting scions from dehydration with non perforated translucent plastic was found to enhance success rates. These results have important practical implications for the domestication of *Allanblackia* species as a new crop for edible oil production using agroforestry as a means to create multifunctional agricultural systems (Leakey 2009; Jamnadass et al. 2010). Further work is needed to understand the reproductive biology of *Allanblackia* spp., and to optimize propagation techniques important for tree domestication.

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