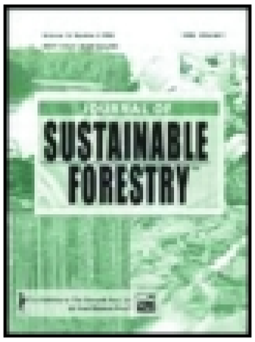

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Amenability of African baobab (*Adansonia digitata* L.) to vegetative propagation techniques

Herbert Jenya [a,b], Chimuleke R. Y. Munthali[a], and Jarret Mhango[a]

[a]Forestry Department, Mzuzu University, Mzuzu, Malawi; [b]Department of Forestry, Forestry Research Institute of Malawi, Zomba, Malawi

ABSTRACT

Adansonia digitata L. is a multi-purpose indigenous fruit tree. Rural communities in most parts of Africa depend on it as a source of food, medicine, and income. Developing vegetative propagation protocols would enhance domestication of this species and increase the supply of its products. Two grafting methods were assessed in the months of October and November 2016. The graft take and shooting were assessed 6 and 5 months after propagation. Significant difference ($P \leq 0.003$) was observed between grafting methods in October and November. Top cleft in October attained the highest grafting success rate of 66.6 ± 3.33%, whilst in November the success rate was 33.3 ± 16.7%. Side veneer attained 63.3 ± 12.0% grafting success in October as opposed to 30.0 ± 17.3% in November. The results indicate that baobab is easily amenable to grafting when done at the right time with the correct size of scions. Therefore, to promote the cultivation of the species in the agroforestry systems, grafting using scions from mother trees possessing desired attributes should be used and promoted.

KEYWORDS
Domestication; grafting; top cleft; side veneer

Introduction

The African baobab tree (*Adansonia digitata* L.) is deciduous and characterized by its massive size (reaching a height of 18–25 m), has huge branches and swollen trunk that can grow up to more than 10 m in diameter (Baum, 1995; Bosch, Sié, & Asafa, 2004; Sidibé & Williams, 2002; Wickens, 1982). It is native to semi-arid sub-Saharan Africa (Sidibé & Williams, 2002; Wickens, 1982; Yazzie, VanderJagt, Pastuszyn, Okolo, & Glew, 1994), due to its high levels of drought tolerance at both the seedling and adult stages (De Smedt et al., 2012) and became iconic for Sudano-Sahelian savannahs (Diop, Sakho, Dornier, Cisse, & Reynes, 2006; Sidibé & Williams, 2002) and Sahelian tropical grasslands (Diop et al., 2006). It is distributed in a large area and the species can be found in most of sub-Sahara Africa's semi-arid and sub-humid regions as well as in western Madagascar (Diop et al., 2006). It extends from northern Transvaal and Namibia to Ethiopia, Sudan and fringes of the Sahara (Gebauer, El-Siddig, & Ebert, 2002; Sidibé & Williams, 2002).

The species is widely used by local communities in areas where it occurs to improve nutrition and income (Chikamai, Eyog-Matig, & Mbogga, 2004). Baobab is used to treat up to more than 20 diseases (Diop et al., 2006) and every part of the tree is used: roots,

CONTACT Herbert Jenya herbertjenya@gmail.com Forestry Department, Mzuzu University, Mzuzu, Malawi
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bark, wood, leaves, flowers, capsules, gum, seeds, and fruits (Buchmann, Prehsler, Hartl, & Vogl, 2010; Wickens & Lowe, 2008). Leaves are well-sought important vegetables in many parts of Africa (ICUC, 2002). The baobab fruit pulp is rich in vitamin C so much so that it contains 10 times more vitamin C as compared to that of an orange (De Caluwé, Halamová, & Van Damme, 2009; Gustad, Dhillion, & Sidibé, 2004; Sidibé & Williams, 2002). The fruit pulp is also a rich source of calcium, containing more calcium than milk (Simbo et al., 2013). The pulp can be used in the manufacturing of juice (Akinnifesi et al., 2008) and also has a huge potential for making jam and wine (Akinnifesi et al., 2008). Oil from baobab seed is used for cooking (ICUC, 2002) and can also be used as an ingredient in the international cosmetic industry (Gruenwald & Galizia, 2005; Venter & Witkowski, 2013). Edible parts of the African baobab supply vitamins, minerals, proteins, and energy that are not commonly obtained from the cereal-dominated diets of drylands of Africa (Muthai et al., 2017).

Baobab products are sold in informal markets, forming an important source of income to many rural communities (Sidibé & Williams, 2002). Both formal and informal trade in baobab products is currently taking place in southern Africa contributing to the economic improvement of rural communities. Baobab products are also traded in Malawi (Munthali, 2012) and there is potential for their commercialization. The fruit pulp is now being sold in EU (2008/575/EC) and USA (GRAS Notice No. GRN 000273) (Cuni Sanchez, De Smedt, Haq, & Samson, 2011), thus it has now entered the international market and is an opportunity for income generation for rural communities (De Smedt et al., 2011).

Reports indicate that baobab is poorly recruited in most areas where it exists and this is clearly explained by having populations with positively skewed stem diameters (Assogbadjo, Sinsin, Codjia, & Van Damme, 2005; Chirwa, Chithila, Kayambazinthu, & Dohse, 2006; Dhillion & Gustad, 2004; Edkins, Kruger, Harris, & Midgley, 2007; Venter & Witkowski, 2010). There is need to artificially balance the population structure of the baobab trees, in order to have a continued supply of baobab products on the market. Previously artificial planting was a challenge due to poor seed viability. High germination rate has recently been achieved following pretreatment (Esenowo, 1991; Falemara, Chomini, Thlama, & Udenkwere, 2014; Niang et al., 2015). The length of time required to reach reproductive maturity discourages cultivating the species for fruit production as growers will need to wait for 8 to 23 years (Sidibé & Williams, 2002).

Recent information has reported a possibility of reducing juvenile phase through vegetative propagation from 23 years to about 3 to 5 years (ICUC, 2002; Sidibé & Williams, 2002). Also, vegetative propagation is known to conserve traits of interest (Tchoundjeu et al., 2006) and in baobab vegetative propagation by grafting has been recommended (Simbo et al., 2013). Further, the species has been shown to have trees within the population which do not produce fruits despite having normal flowering (Venter & Witkowski, 2011). Therefore, propagation by seed cannot help to control the presence of non-fruit bearing trees as well as reduce the length of the juvenile phase so that farmers get early returns on investment. Vegetative propagation of baobab trees has shown that top and side grafting methods can achieve high success rates of about 85% (Kalinganire, Weber, Uwamariya, & Kone, 2008). Therefore, the objectives of the study were to investigate: (1) When is the right month for grafting? (2) Which grafting method is more appropriate? (3) Whether individual tree variation is a factor in grafting?

Materials and methods

Study sites

Scions were collected from Karonga (Figure 1) at two time intervals (October and November). Grafting trials were conducted in the shed net at Forestry Department, Mzuzu University, between 6th October 2016 and 27th November 2016. Mzuzu University is located at latitude 11° 28′ S and longitude 34° 01′ E, at an altitude of 1270 m above sea level (m.a.s.l) and average annual temperatures ranging from 13.5° C to 24°C. Karonga experiences mean annual maximum temperature ranging from

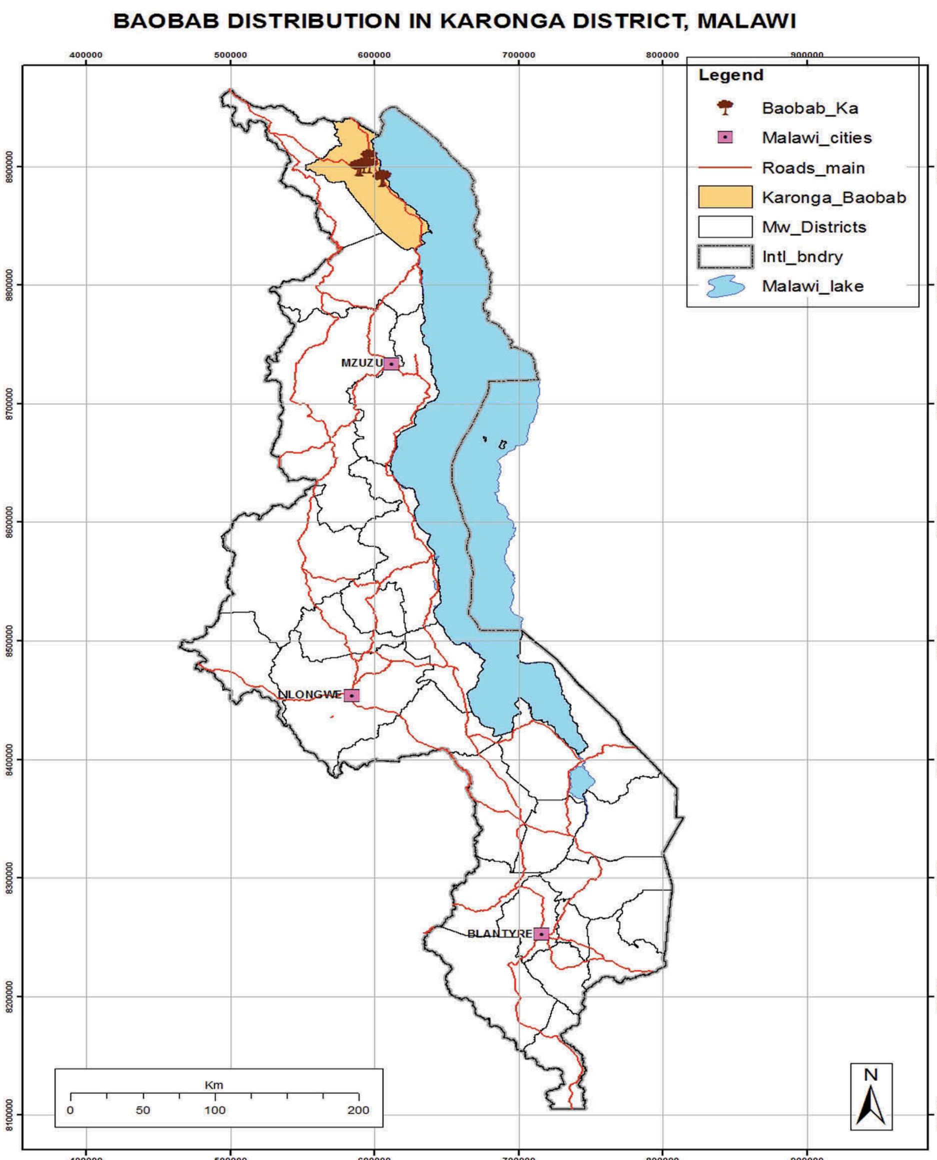

Figure 1. Map of Malawi showing position of Karonga district and distribution of Baobab.

28°C to 30°C with mean annual minimum temperature of 22°C to 25°C and mean annual rainfall ranging from 500 mm to 1200 mm. The climate of Karonga is tropical and has a wet and dry season. The wet season starts in November and ends in April or May while the dry season occurs from May to October with occasional rains during the month of June in some parts of the District. The lakeshore plain zone where baobab thrives covers an area from the lake at an altitude of between 500 and 600 m.a.s.l. Baobab mostly exists in depositional sites comprising alluvial soils, often calcimorphic (Hardcastle, 1978). The lakeshore plain is largely cultivated with isolated trees and small patches or relict woodland of baobab and palm (*Hyphanene ventricosa)* being dominant vegetation (Hardcastle, 1978).

Sampling and data collection

Scions of 50 mm–120 mm diameter were harvested from three ortets. Scions were collected in the morning and kept wet in hessian sacs. Upon arrival (approximately after 4 hours) in Mzuzu, the samples were stored in the shed net which experiences cool temperature (10–18° C) at night. Grafting was done the following day from 7:30 am to 5:00 pm. Only one person performed the grafting. Ten grafts were top cleft and ten grafts were side veneer for each ortet (Figure 2). The mean diameter for scions was 85 mm, and they were 30 cm long. Grafting

Figure 2. Grafting methods: Top cleft (A) and side veneer (B).

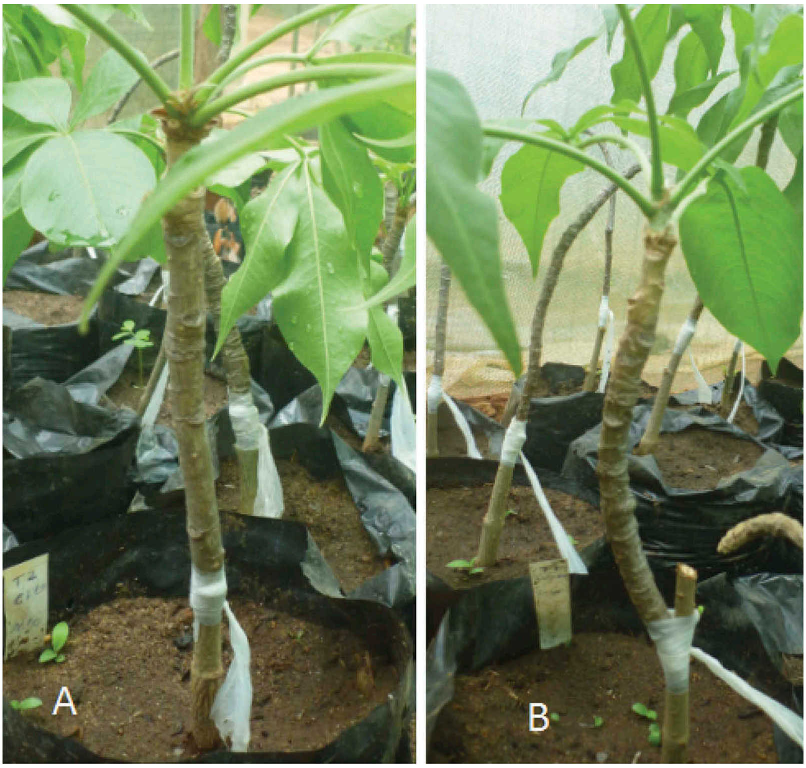

Figure 3. Baobab plantlets showing successful top-cleft grafts (A) and side veneer grafts (B).

was done on one-year-old rootstocks growing in polythene tubes of size (40 cm long by 20 cm wide) filled with fertile black Miombo soil mixed with sand (2:1, w/w).

The study was arranged in a three-factorial design (factor 1 = grafting time; factor 2 = grafting method; factor 3 = mother tree) with two replicates of 5 ramets per treatment for October and November, with each of the two grafting methods and three mother trees. A sum of 60 grafted baobab plants were obtained per grafting time and a total of 120 grafted baobab plants were obtained for the whole experiment. Grafting success (Figure 3) was monitored continuously and final assessment was done at six months after establishment. The data collected included grafting success, length of new shoot, and number of leaves. Shoot length (mm) was measured using a linear tape to the nearest mm.

Data analysis

Firstly, the grafting success data (in the binary form: '1′ for grafting success and '0′ for not successfully grafted) was analyzed using descriptive statistics for percentages of per tree, per grafting method, and finally per grafting month success. Secondly, due to the binomial distribution of the data, an analysis of deviance (ANODE) using Generalized Linear Model (GLM) procedures of Genstat 4th Edition with the logit function as the link function was carried out to assess the effect of grafting date and grafting methods on graft success probability. Below is the equation of the fitted model.

$$\mathrm{Logit}(\mathrm{p}_i) = \log\left(\mathrm{p}_i/(1-\mathrm{p}_i)\right)$$

$$= \text{constant, grafting time, mother tree and grafting method effect}$$

where p_i, the probability of success of baobab plants grafted with method i, is computed as the ratio of successful grafts over the total number of grafts per date, mother and method (n = 60, 20 and 30, respectively).

Shoot growth (length) and the number of leaves data were analyzed using paired t-test in MINITAB 16.1 in order to test whether there were significant differences between means during propagation period (October and November) and between grafting methods. Before analysis, data for the number of leaves was normalized using arcsine transformation (Fowler, Cohen, & Jarvis, 2013).

Results

Variation in grafting success between grafting methods and between times

There were significant differences ($P \leq 0.003$) in grafting success (%) between the two grafting methods (top cleft and side veneer) in the month of October and November (Table 1). Top cleft in October attained the highest grafting success rate of 66.6 ± 3.33%, whilst side veneer attained 63.3 ± 12.0%. In November, top cleft attained grafting success of 33.3 ± 16.7% whilst side veneer achieved 30.0 ± 17.3% in the month of November. Mean grafting success in October was 65.00 ± 7.64% and in November was 31.7 ± 16.4%.

Variation in grafting success between ortets

There was a significant difference ($P \leq 0.001$) in grafting success between ortets (Table 2). In the month of October, scions collected from tree 2 produced the best success rate (75 ± 5.00%) while scions from tree 1 were the least performers (50 ± 10.00%). To the contrary, scions from tree 1 performed well (55 ± 5.00%) in November and scions from tree 3 were the poorest (0%) in the month of November. On average, grafting success in October was (65.0 ± 7.64%) whilst in November was (31.7 ± 16.4%).

Table 1. Grafting month and grafting method on grafting success (%) of A. digitata plantlets.

Grafting month	Grafting method	Grafting success (%)
October	Top cleft	66.6 ± 3.33*
	Side veneer	63.3 ± 12.0
November	Top cleft	33.3 ± 16.7
	Side veneer	30.0 ± 17.3

Note: n = 20 per grafting method, * = grafting success is followed by the standard error of the mean.

Table 2. Variation in grafting success (%) in two months for the tree ortets.

Grafting month	Ortets	Grafting success (%)
October	Tree 1	50 ± 10*
	Tree 2	75 ± 5
	Tree 3	70
November	Tree 1	55 ± 5
	Tree 2	40 ± 10
	Tree 3	0

Note: n = 10 per ortet, * = grafting success is followed by the standard error of the mean

Variations in growth (shoot length) of A. digitata plants after grafting success

Shoot growth

There was a significant difference (t = 3.62, P ≤ 0.001) in shoot growth attained by grafts propagated in October and November (Figure 4). Shoots for grafts propagated in the month of October (3.0 ± 0.497 cm) outgrew shoots of grafts propagated in the month of November (1.21 ± 0.104 cm).

No significant difference (t = 0.47, P = 0.640) was observed in shoot growth between side veneer and top cleft in the month of October and November (Figure 5). Shoot growth for side veneer was 3.30 ± 0.708 cm and shoot growth for top cleft was 2.70 ± 0.713 cm. No significant difference (t = 0.40, *P* = 0.690) was observed in shoot growth between side veneer and top cleft in the month of November. Shoot growth for side veneer was 1.24 ± 0.166 cm and shoot growth for top cleft was 1.17 ± 0.122.

Number of leaves

Significant difference (t = 2.66, P = 0.01) was observed in the number of leaves for plantlets propagated in October and plantlets propagated in November (Figure 6). Mean number of leaves for plantlets propagated in October was 5 leaves and 3 leaves for plantlets propagated in November.

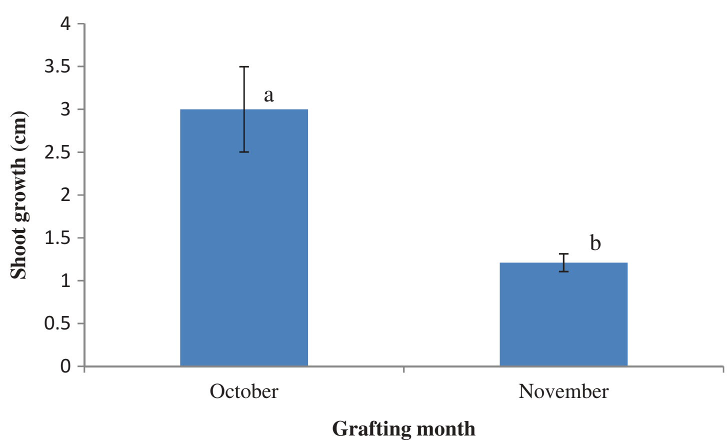

Figure 4. Variation of shoot growth between grafting months. Letters show a significant difference ($p < 0.05$) of shoot growth between grafting months.

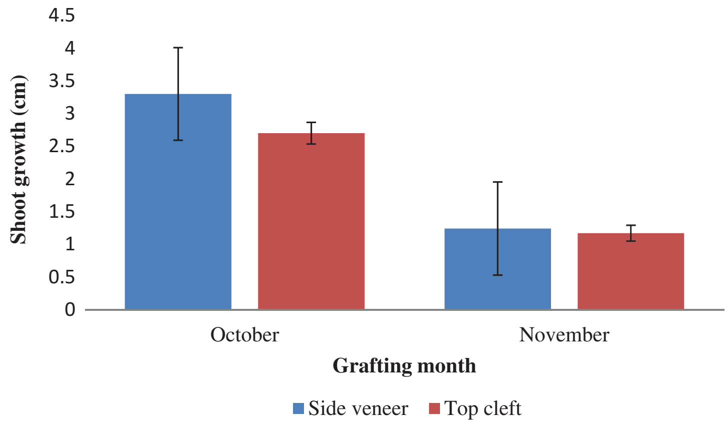

Figure 5. Variations in shoot growth between grafting methods.

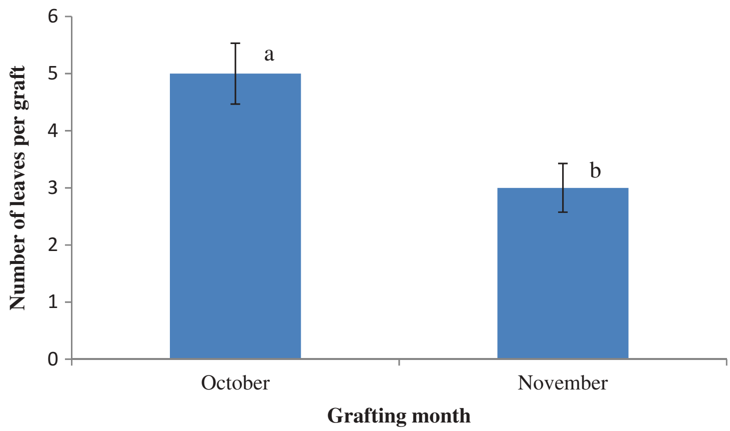

Figure 6. Variation of the number of leaves per plantlet between grafting months. Letters show a significant difference ($p < 0.05$) of the number of leaves between grafting months.

There was no significant difference in the number of leaves for plantlets propagated using side veneer and top cleft for both October and November (Figure 7).

Discussion

Variation in grafting success between grafting methods

The study found that baobab is amenable to grafting techniques. Both methods (top cleft and side veneer) were successful in the month of October. The level of success reported here for the month of October (top cleft (66.6%) and side veneer (63.3%)) are in agreement with what Anjarwalla et al. (2016) reported for top cleft (71%) and side veneer (55%). In contrast, Kalinganire et al. (2008) reported a higher success rate of 85% for both top and side grafting methods. The success rate of top cleft (80%) has also been reported to be higher than side veneer (50%) on *Allanblackia parviflora* in Ghana (Ofori et al.,

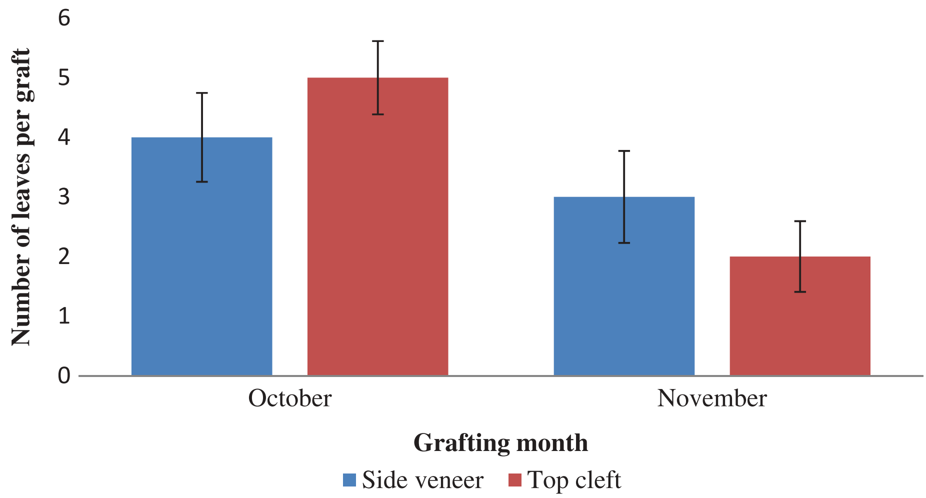

Figure 7. Variation of the number of leaves per plantlet between grafting methods.

2008). In our case, the success rate of top cleft grafting method may be attributed to the fact that it is easy to make a cambium to cambium fusion between the scion and the rootstock (Kalinganire et al., 2008; Mannan, Islam, & Khan, 2006). In many species, top cleft has been reported to be more successful than any other grafting method (Hibbert-Frey, Frampton, Blazich, & Hinesley, 2010). High grafting success rate for top cleft has also been attributed to reduced dehydration at the grafting union (Hartmann, Kester, Davies, & Geneve, 2002).

The grafting success for October was 51% better than that of November for both top cleft and side veneer (Table 1). Akinnifesi et al. (2008) reported the best time for conducting grafting and scion collection to be from August to December for baobab in Southern Malawi. Taylor et al. (1996) found September and October as the best time for grafting *Sclerocarya birrea*. Our results have found October as the better time compared to November for grafting baobab with scions from Karonga. Baobab populations in the country differ in their phenological events following rainfall pattern. Therefore, further research should help find an appropriate time for grafting baobab in different populations. Successful grafting in October could be as a result of an accumulation of auxin in the trees prior to shooting. Accumulation of auxin is effective in inducing differentiation of the vascular elements in the tissues (Hartmann et al., 2002). Starting of meristematic activities help the scion-rootstock union to be established quickly (Sanou et al., 2004; Yelleshkumar, Swamy, Patil, Kanamadi, & Kumar, 2010).

Variation in grafting success between ortets

Grafting success varied from one ortet to another (Table 2). The difference could be genetic or due to environmental effects. Zero grafting in case of tree three in November is suspected to be due to small scions that were used. The observation showed that scions of about 80 mm diameter have higher success of grafting than small scions (60 mm).

Similarly, Anjarwalla et al. (2016) in Kenya found variation in grafting success from one ortet to another. The authors attributed variation in grafting success between ortets to better compatibility of the mother tree with the rootstock. The differences in grafting success among ortets could also be attributed to differences in the age of the tree, although that has not been measured in this study. Ortets with high grafting success are hypothesized to have higher cellular activities (Hartmann et al., 2002). Thus, differences in physiological and growth stages between ortets during scion collection can influence grafting success.

Variation in growth on A. digitata plantlets after grafting success

A significant difference in shoot growth and number of leaves has been observed only between the grafting months. Obviously, this could be due to differences in the time of grafting. October grafts attained the highest growth in shoot length and number of leaves due to the early establishment as compared to November grafts and presence of nutrition in the stock (Akinnifesi et al., 2008). The absence of significant differences in shoot growth between the grafting method and scion source is in agreement with the findings of Anjarwalla et al. (2016) in Kenya. The authors have observed that this trait is highly variable by nature, due to the differences in phenological stages and conditions of rootstocks and scions at the time of grafting. Therefore, in most grafting studies it is not put into consideration.

Conclusion

The results have shown the possibility of vegetatively propagating baobab through both top cleft and side veneer grafting in October soon before bud burst. The technology is not very involving such that it could be disseminated to farmers for them to mass propagate the species. Vegetative propagation will see a reduction in precocity period to 3–5 years from about 8–23 years. Domestication of the species will reduce reliance on the dwindling natural population in the wild. Hence, it might improve the supply of the products on the growing local, regional and international market. Further, it will help in balancing the population structure of the baobab trees where now it is difficult to find young trees growing naturally.

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Conflict of interest

The authors declare no conflicts of interest.

ORCID

Herbert Jenya http://orcid.org/0000-0001-5574-6772

References

Akinnifesi, F. K., Ajayi, O. C., Sileshi, G., Matakala, P., Kwesiga, F. R., Ham, C., … Mkonda, A. (2008). *Creating opportunities for domesticating and commercializing Miombo indigenous fruit trees in southern Africa* (pp. 137–170). Wallingford, UK: CAB International Publishing.

Anjarwalla, P., Ofori, D., Owino, A., Matuku, D., Adika, W., Njogu, K., & Kehlenbeck, K. (2016). Testing different grafting methods for vegetative propagation of baobab (*Adansonia digitata* L.) in Kenya to assist its domestication and promote cultivation. *Forests, Trees and Livelihoods*, *26*(2), 85–95. doi:10.1080/14728028.2016.1202791

Assogbadjo, A. E., Sinsin, B., Codjia, J. T. C., & Van Damme, P. (2005). Ecological diversity and pulp, seed and kernel production of the baobab (*Adansonia digitata*) in Benin. *Belgian Journal of Botany*, *138*(1), 47–56.

Baum, D. A. (1995). The comparative pollination and floral biology of baobabs (Adansonia-Bombacaceae). *Annals of the Missouri Botanical Garden*, *82*, 322–348. doi:10.2307/2399883

Bosch, C. H., Sié, K., & Asafa, B. A. (2004). *Adansonia digitata*. In G. J. H. Grubben & O. A. Denton (Eds.), *Species record*. Wageningen, Netherlands: PROTA. Retrieved from https://www.prota4u.org/database/searchresults.asp

Buchmann, C., Prehsler, S., Hartl, A., & Vogl, C. R. (2010). The importance of baobab (*Adansonia digitata* L.) in rural West African subsistence suggestion of a cautionary approach to international market export of baobab fruits. *Ecology of Food and Nutrition*, *49*(3), 145–172. doi:10.1080/03670241003766014

Chikamai, B., Eyog-Matig, O., & Mbogga, M. (2004). *Review and appraisal on the status of indigenous fruits in Eastern Africa*. Nairobi, kenya: A report prepared for IPGRI-SAFORGEN in the framework of AFREA/FORNESSA, IPGRI (International Plant Genetic Resources Institute) SSA.

Chirwa, M., Chithila, V., Kayambazinthu, D., & Dohse, C. (2006). *Distribution and population structures of Adansonia digitata in Malawi*. Zomba, Malawi: FRIM.

Cuni Sanchez, A., De Smedt, S., Haq, N., & Samson, R. (2011). Comparative study on baobab fruit morphological variation between Western and South-eastern Africa: Opportunities for domestication. *Genetic Resource and Crop Evolution*, *58*, 1143–1156. doi:10.1007/s10722-010-9647-4

De Caluwé, E., Halamová, K., & Van Damme, P. (2009). Baobab (*Adansonia digitata* L.): A review of traditional uses, phytochemistry and pharmacology. In R. H. Juliani, J. E. Simon, & C. T. Ho (Eds.), *African natural plant products: New discoveries and challenges in chemistry and quality* (pp. 51–84). Washington, D.C.: American Chemical Society.

De Smedt, S., Alaerts, K., Kouyate, A. M., Van Damme, P., Potters, G., & Samson, R. (2011). Phenotypic variation of baobab (*Adansonia digitata* L.) fruit traits in Mali. *Agroforestry Systems*, *82*(1), 87–97. doi:10.1007/s10457-010-9357-0

De Smedt, S., Sanchez, A. C., Van den Bilcke, N., Simbo, D., Potters, G., & Samson, R. (2012). Functional responses of baobab (*Adansonia digitata* L.) seedlings to drought conditions: Differences between western and south-eastern Africa. *Environmental and Experimental Botany*, *75*, 181–187. doi:10.1016/j.envexpbot.2011.09.011

Dhillion, S. S., & Gustad, G. (2004). Local management practices influence the viability of the baobab (*Adansonia digitata* Linn.) in different land use types, Cinzana, Mali. *Agriculture, Ecosystems & Environment*, *101*(1), 85–103. doi:10.1016/S0167-8809(03)00170-1

Diop, A. G., Sakho, M., Dornier, M., Cisse, M., & Reynes, M. (2006). The African baobab (*Adansonia digitata* L.): Main characteristics and uses. *Fruit*, *61*(1), 55–69. doi:10.1051/fruits:2006005

Edkins, M. T., Kruger, L. M., Harris, K., & Midgley, J. J. (2007). Baobabs and elephants in the Kruger National Park: Nowhere to hide. *African Journal of Ecology*, *46*, 119–129.

Esenowo, G. J. (1991). Studies on germination of *Adansonia digitata* seeds. *The Journal of Agricultural Science*, *117*(1), 81–84. doi:10.1017/S0021859600078990
Falemara, B. C., Chomini, M. S., Thlama, D. M., & Udenkwere, M. (2014). Pre-germination and dormancy response of *Adansonia digitata* L. seeds to pre-treatment techniques and growth media. *European Journal of Agriculture and Forestry Research*, *2*(1), 31–41.
Fowler, J., Cohen, L., & Jarvis, P. (2013). *Practical statistics for field biology*. Chichester, UK: John Wiley & Sons.
Gebauer, J., El-Siddig, K., & Ebert, G. (2002). Baobab (*Adansonia digitata* L.): A review on a multipurpose tree with promising future in the Sudan. *European Journal of Horticultural Science*, *67*, 155–160.
Gruenwald, J., & Galizia, M. (2005). *Market brief in the European Union for selected natural ingredients derived from native species. Adansonia digitata L.,* Baobab United Nations Conference on Trade and Development, United Nations, Schweiz.
Gustad, G., Dhillion, S. S., & Sidibé, D. (2004). Local use and cultural and economic value of products from trees in the parklands of the municipality of Cinzana, Mali. *Economic Botany*, *58*(4), 578–587. doi:10.1663/0013-0001(2004)058[0578:LUACAE]2.0.CO;2
Hardcastle, P. D. (1978). *A preliminary silvicultural classification of Malawi*. Forestry Research Institute of Malawi. Forestry Research Record No. 57, Zomba, Malawi.
Hartmann, H. T., Kester, D. E., Davies, F. T., & Geneve, R. L. (2002). *Plant propagation: Principles and practices* (7th ed., 849 pp.). Upper Saddle River, NJ: Prentice-Hall Inc.
Hibbert-Frey, H., Frampton, J., Blazich, F. A., & Hinesley, L. E. (2010). Grafting fraser fir (*Abies fraseri*): Effect of grafting date, shade, and irrigation. *Horticulture Science*, *45*, 617–620.
ICUC. (2002). *Fruits for the future, Baobab. International Center for underutilized crops. Factsheet No.4, March 2002*. University of South Southampton, Southampton, UK.
Kalinganire, A., Weber, J. C., Uwamariya, A., & Kone, B. (2008). Improving rural livelihoods through domestication of indigenous fruit trees in the parklands of the Sahel. *Indigenous fruit trees in the tropics: Domestication, utilization and commercialization* (pp. 186–203). Wallingford, UK: CAB International Publishing.
Mannan, M. A., Islam, M. M., & Khan, S. A. K. U. (2006). Effects of methods of grafting and age of rootstock on propagation of off-season germplasms of jackfruit. *Khulna University Studies*, *7*(2), 77–82.
Munthali, C. R. Y. (2012). Use, physiology and genetic characterisation of selected natural populations of Adansonia Digitata in Malawi (Doctoral dissertation). Stellenbosch University, Stellenbosch, RSA.
Muthai, K. U., Karori, M. S., Muchugi, A., Indieka, A. S., Dembele, C., Mng'omba, S., & Jamnadass, R. (2017). Nutritional variation in baobab (*Adansonia digitata* L.) fruit pulp and seeds based on Africa geographical regions. *Food Science & Nutrition*, *5*(6), 1116–1129. doi:10.1002/fsn3.502
Niang, M., Diouf, M., Samba, S. A. N., Ndoye, O., Cissé, N., & Van Damme, P. (2015). Difference in germination rate of Baobab (*Adansonia digitata* L.) provenances contrasting in their seed morphometrics when pretreated with concentrated sulfuric acid. *African Journal of Agricultural Research*, *10*(12), 1412–1420. doi:10.5897/AJAR2014.9426
Ofori, D. A., Peprah, T., Henneh, S., Von Berg, J. B., Tchoundjeu, Z., Jamnadass, R., & Simons, A. J. (2008). Utility of grafting in tree domestication programme with special reference to *Allanblackia parviflora* A. Chev. *Ghana Journal of Forestry*, *23*(24), 42–48.
Sanou, H., Kambou, S., Teklehaimanot, Z., Dembélé, M., Yossi, H., Sina, S., … Bouvet, J. M. (2004). Vegetative propagation of *Vitellaria paradoxa* by grafting. *Agroforestry Systems*, *60*(1), 93–99. doi:10.1023/B:AGFO.0000009408.03728.46
Sidibé, M., & Williams, J. T. (2002). *Baobab, Adansonia digitata* L. International Centre for Underutilised Crops. University of Southampton, Southampton, pp. 1–99
Simbo, D. J., De Smedt, S., Van den Bilcke, N., De Meulenaer, B., Van Camp, J., Uytterhoeven, V., … Samson, R. (2013). Opportunities for domesticating the African baobab (Adansonia digitata L.): Multi-trait fruit selection. *Agroforestry Systems*, *87*(3), 493–505. doi:10.1007/s10457-012-9568-7

Taylor, F., Mateke, S. M., Butterworth, K. J., Temu, A. B., Melnyk, M., & Vantomme, P. (1996). A holistic approach to the domestication and commercialization of non-timber forest products. Domestication and commercialization of non-timber forest products in agroforestry systems. Proceedings of an international conference held in Nairobi (Kenya) 19-23 Feb 1996. Non-Wood forest products (FAO). Nairobi (Kenya), FAO, Roma (Italia) International Center for Research in Agroforestry.

Tchoundjeu, Z., Asaah, E. K., Anegbeh, P., Degrande, A., Mbile, P., Facheux, C., … Simons, A. J. (2006). Putting participatory domestication into practice in West and Central Africa. *Forests, Trees and Livelihoods*, *16*, 53–69. doi:10.1080/14728028.2006.9752545

Venter, S. M., & Witkowski, E. T. F. (2010). Baobab (*Adansonia digitata* L.) density, size-class distribution and population trends between four land-use types in northern Venda, South Africa. *Forest Ecology and Management*, *259*(3), 294–300. doi:10.1016/j.foreco.2009.10.016

Venter, S. M., & Witkowski, E. T. F. (2011). Baobab (*Adansonia digitata* L.) fruit production in communal and conservation land-use types in Southern Africa. *Forest Ecology and Management*, *261*, 630–639. doi:10.1016/j.foreco.2010.11.017

Venter, S. M., & Witkowski, E. T. F. (2013). Where are the young baobabs? Factors affecting regeneration of *Adansonia digitata* L. in a communally managed region of southern Africa. *Journal of Arid Environments*, *92*, 1–13. doi:10.1016/j.jaridenv.2012.12.010

Wickens, G. E. (1982). The Baobab-Africa's upside-down tree. *Kew Bulletin*, *37*(2), 173–209. doi:10.2307/4109961

Wickens, G. E., & Lowe, P. (2008). *The Baobabs: The pachycauls of Africa, Madagascar and Australia*. New York, NY, United States: Springer-Verlag New York.

Yazzie, D., VanderJagt, D. J., Pastuszyn, A., Okolo, A., & Glew, R. H. (1994). The amino acid and mineral content of baobab (*Adansonia digitata* L.) leaves. *Journal of Food Composition and Analysis*, *7*(3), 189–193. doi:10.1006/jfca.1994.1018

Yelleshkumar, H. S., Swamy, G. S. K., Patil, C. P., Kanamadi, V. C., & Kumar, P. (2010). Effect of pre-soaking treatments on the success of softwood grafting and growth of mango grafts. *Karnataka Journal of Agricultural Sciences*, *21*(3), 471–472.