Diversity of Allanblackia parviflora A. Chev. in Ghana

Subjects: Biodiversity Conservation

Contributor: Dennis Kyereh, Prasad Hendre, Choungo Nguekeng Patrick Bustrel

Allanblackia parviflora A. Chev. is an indigenous tree species that are found in West African rainforest zones. It is an underutilized fruit tree species that have been targeted for improvement as part of efforts to domesticate high-value indigenous multi-purpose trees for fruit and seed production in Africa. Allanblackia has several benefits, such as providing shade, timber, and medicine; however, the production of edible oil from its seeds is the economically most important use. There is evidence that the Allanblackia seed oil, which is used for cooking, the production of margarine and the manufacturing of ointments and soap, is being developed as a new agri-business in Ghana, Nigeria, Cameroon, and Tanzania. Despite the nutritional and socio-economic importance of A. parviflora, it is still at the early stages of its domestication process.

Keywords: morphology ; genetic diversity ; nutrition ; seed oil ; domestication strategies ; fruit tree

1. Introduction

Forests and especially trees in the humid tropics of Africa provide a high number of non-timber forest products (NTFPs) which are important to the livelihoods of local populations [1][2]. Meanwhile, most farming systems in these areas often eliminate trees from the landscape, which has significantly contributed to deforestation and biodiversity loss [3]. The cultivation and incorporation of high-value indigenous fruit trees into the local farming systems could potentially stabilize smallholder production systems and ensure sustainability [4]. The African Orphan Crop Consortium (AOCC) [5], in collaboration with the World Agroforestry (ICRAF) [6], has been promoting studies on tree genomic resources for the improvement of selected underutilized fruit trees which have, over the years, received little or no attention from scientific research and development [7][8]. The target species for genetic improvement have products that are rich in vitamins, minerals, and other essential micronutrients in the diets of local communities [9].

Allanblackia parviflora A. Chev., also called the vegetable tallow tree, is a high-value indigenous fruit tree species native to the humid tropics of West Africa. It is a neglected fruit tree species that has been targeted for improvement as part of efforts to domesticate high-value indigenous multipurpose trees in the humid tropics of Africa [10][11][12][13]. *A. parviflora* has several other benefits which include the provision of shade, timber, and medicine. The dried kernels consist of about 67%–73% white solid fat [14][15]. Ofori et al. [16] highlighted the importance of *Allanblackia* seed oil for cooking, the production of margarine, and the manufacturing of ointments and soap. Recent studies have also suggested the use of *A. parviflora* seed oil as an alternative feedstock for biodiesel production [17]. The extracted seeds from *Allanblackia* fruits are traded by local communities, since a supply chain has been developed in Ghana, Nigeria, Cameroon, and Tanzania [18]. This market value would potentially increase livelihood opportunities for farmers and ensure the retention of trees on farms for environmental conservation. However, it has been argued that seed extraction from fruits collected from wild stands alone is not enough to meet the increasing market demand for *Allanblackia* seed oil [14][18].

2. Genus *Allanblackia*

Nine species exist in the *Allanblackia* genus and all of them are native to tropical Africa [19]. The species include *A. parviflora* A. Chevalier, *A. floribunda* Oliv., *A. gabonensis* (Pellegr.) Bamps, *A. stanerana* Exell & Mendonça, *A. kisonghi* Vermoesen, *A. marienii* Staner, *A. ulugurensis* Engl., *A. stuhlmannii* Engl., and *A. kimbiliensis* Spirl. [19][20]. However, only three of all the *Allanblackia* species (**Figure 1**), namely *A. parviflora*, *A. floribunda*, and *A. stuhlmannii*, are considered to have substantial socio-economic benefits [21]. *A. floribunda* is distributed from the extreme southeast of Benin through Nigeria, Cameroon, and Gabon to Congo. It is a lowland forest tree species growing up to an altitude of 800 m above sea level (asl). *A. gabonensis* is a sub-montane species, found above 500 m altitude asl. It is hardly possible to use its fruits because it occurs in less accessible areas. *A. stanerana* is distributed in the coastal forests of Cameroon to Angola. The fruits are smaller, around 7 cm, and therefore are not considered as economically important. *A. kisonghi and A. marienii* also occur in the Congo basin. In east Tanzania, the species *A. ulugurensis* and *A. stuhlmannii* can be found in small very wet remnant forests of the Usumbara and Uluguru mountains. These species have a small forest cover and are under high pressure. Moreover, the economic use of fruits was prevalent in the 1950s. Bamps [22] reported *A. kimbiliensis* to exist in Congo-Kinshasa and Uganda, between 1250 and 1800 m asl.

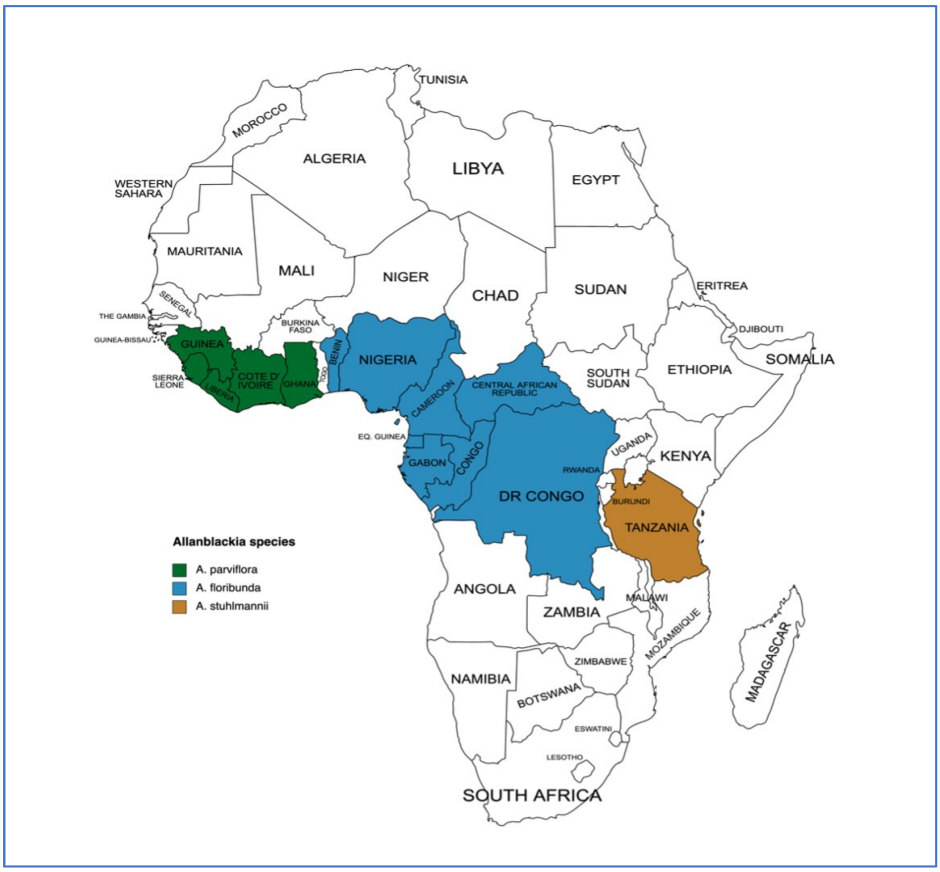

Figure 1. Distribution of key *Allanblackia* species across the African continent (source: author's drawing).

A. parviflora is a high-value multipurpose tree indigenous to West Africa [10][11][12][13]. The species native zone of distribution includes Guinea, Sierra Leone, Liberia, Cote d'Ivoire, and Ghana (**Figure 1**) [23][24]. *A. parviflora* is more abundant in evergreen forest types, especially on slopes and away from disturbed areas, and as well being found in semi-deciduous forest types [14][24][25]. For example, in Ghana, the tallow tree occurs across three main ecological zones; moist semi-deciduous, moist evergreen, and wet evergreen forest zones with annual rainfall ranging between 1250 and 1500 mm, 1500 and 1750 mm, and >1750 mm, respectively [4][26], with monthly minimum and maximum temperatures of 22–34 °C. The species thrives well in soils low in calcium, potassium, magnesium, and base saturation with optimum pH ranging from 3.8 to 4.1 [27].

3. Botanical Description

A. parviflora is an evergreen, medium-sized tree that grows to a height of about 40 m [4]. The stem is cylindrical or slightly fluted, the diameter at breast height (DBH) is rarely greater than 50 cm with narrow crown architecture, the branches are short and horizontal, while the leaves are large, having a shiny surface and numerous lateral nerves forked near the margins (**Figure 2**). The bark is reddish-brown, with small circular or rectangular scales over small red pits. Additionally, the inner bark is reddish-brown with sometimes pale-yellow streaks, exuding a colourless or pale yellowish sap [23][28]. Flowers are unisexual, fragrant, regular, five-merous and of pink/red or white/cream colour (**Figure 3**). The pedicel is 1–3 cm long, sepals are ovate or obovate, unequal, 6–18 mm × 4–15 mm, and glabrous, whereas the petals are obovate, and 20 mm long. The male flowers have several stamens in five bundles opposite the petals, which are 18 mm long, and the anthers are arranged on the internal face of the bundle, while the disk is star-shaped with smooth or slightly folded glands. Female flowers have a superior, incompletely five-celled ovary and sessile stigma. Fruits are large, ellipsoid berries 10–50 cm × 15 cm in size, with five longitudinal ridges and are brown and warty. Seeds are ovoid 3 cm × 2 cm × 1.5 cm, enclosed by a pinkish aril. Seedlings with hypogeal germination and epicotyl are 4–5 cm long [24]. The species is dioecious [4] and can produce more than 250 fruits per year [14], with about 24 seeds per fruit on average (**Figure 4**) [29].

Figure 2. A typical *A. parviflora* A. Chev. tree growing in the wet evergreen forest zone of Ghana (source: author's archive).

Figure 3. *A. parviflora* flowers showing different colors and sexes. (**a**) White/cream female flower with a developing fruit, (**b**) white/cream male flower, (**c**) pink/red female flower, (**d**) pink/red male flower (source: author's archive).

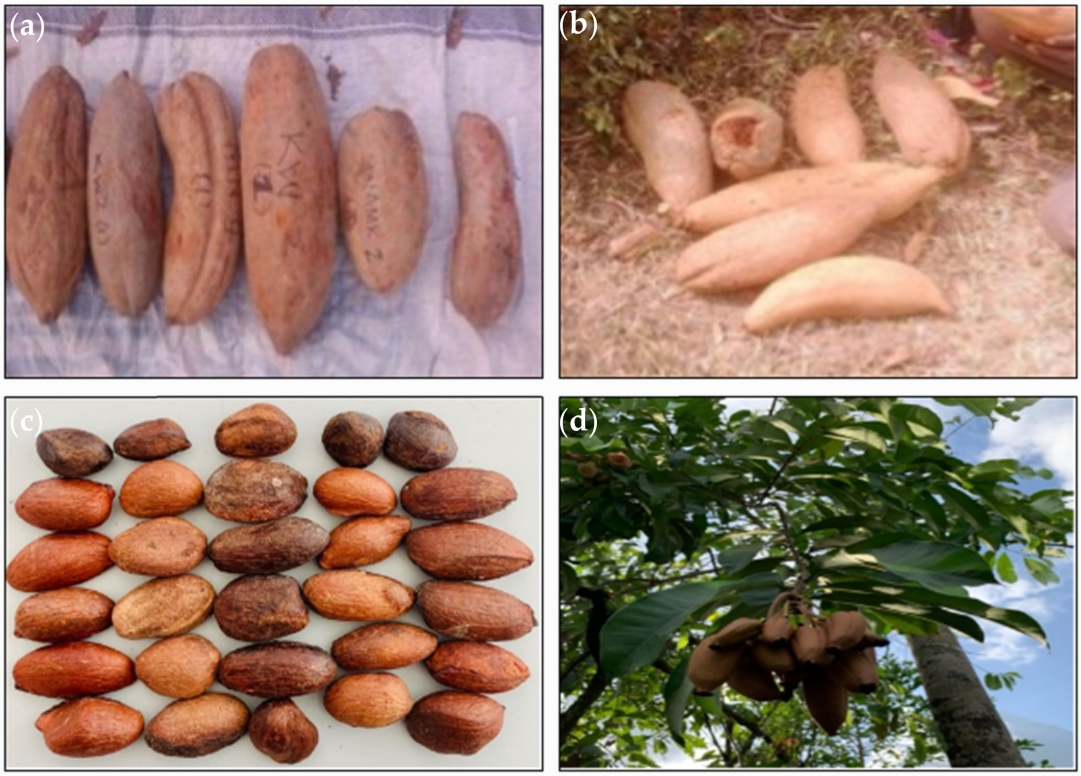

Figure 4. Morphological features of *A. parviflora*. (**a**) Fruits with round or large ends; (**b**) elongated fruits with long ends (adapted from [4] with permission from Springer Science + Business Media B.V. 2009); (**c**) seeds with various shapes and sizes; (**d**) branches with leaves, flowers and developing fruits (source: author's archive).

4. Propagation

Under nursery conditions, untreated *Allanblackia* seeds can take more than a year to germinate at success rates lower than 20% [30]. The thick hard nature of the seed coat, as well as the long seed dormancy period, result in a lack of uniformity in germination and subsequent plant growth. The use of seeds and seedlings in *A. parviflora* cultivation is therefore limited by not only the long period of seed dormancy but also its recalcitrant nature and poor seed storage techniques. In Ghana, Ofori et al. [31] observed that removal of the seed coat and incubating the seeds in polythene bags at a temperature range of 23–31 °C improved seed germination, with seed germination starting from week two and reaching a rate of up to 75% at 10 months. Another limitation associated with the fruit production of *Allanblackia* species is the dioecious nature of the species, which relates to the production of either male or female seedlings. This makes it difficult to identify the sex of the tree at the juvenile stage. Therefore, the assessment of genetic diversity and the selection of desired tree traits could significantly enhance efforts in developing quality planting materials of a known sex for propagation [4].

Vegetative propagation methods were also developed to produce quality planting stocks with a known genetic quality, sex, and decreased gestation period when ontogenetically matured parts were employed. Grafting, leafy stem cuttings, and air layering were used, leading to the first flowering on one- to two-year-old grafts [32][33][34][35]. Some of the challenges faced with the vegetative multiplication procedure were that the root system quality was poor and the rate of rooting was low, leading to a reduced number of roots per cutting. Plagiotropism in *Allanblackia* has also been detected in cuttings, but this issue has already been resolved through the adoption of orthotropic (vertically oriented) shoots [29][30]. However, since vegetative propagation alone is unlikely to deliver any lasting advantage, cloning needs to be closely integrated with upstream breeding and conservation efforts. The poor seed germination capability of *A. parviflora* should not be a basis for abandoning the production of planting stocks through seeds. This is because the species population should have the ability to recombine to add to the gene pools of later generations for the preservation of genetic heterogeneity in populations [36][37] and to allow the selection to be made from successive generations [38]. Ennos et al. [39] pointed out that in doing so, the species would have the ability to tolerate changing environmental conditions for long-term sustainability.

5. Uses

The importance of *A. parviflora* includes the provision of timber, shade, and medicine, while the production of oil from seeds is considered the most important economic use [16][31][40]. In Liberia, the wood (usually called lacewood) is traditionally used in house construction for walls, doors and window frames [24]. It is a potential candidate species for use in agroforestry systems due to its attributes as an alternative income source as well as its ability to provide shade to other crops such as cocoa [41]. The pounded bark can be rubbed on the body to relieve pain. In Côte d'Ivoire, a decoction of the fruit pulp is used to treat elephantiasis of the scrotum [24]. The seeds are usually eaten by children as a high-energy snack [42][43]. Some wild animals such as the giant rat, squirrels, and brush-tailed porcupine also depend on *Allanblackia* seeds for their survival [14]. The kernel consists of about 67%–73% solid white fat when dried [14][15]. The pressed crude oil from the dry seeds is approximately one-third of the seed dry weight [44][45], and has traditionally been used for cooking and soap making [16][46][47]. It has also been reported that the seedcake can be used as a protein-rich animal feed after the seeds are ground and pressed to extract the oil [43]. A recent study also suggests the potential of *A. parviflora* seed oil as an alternative for biodiesel production [17]. The seeds, when harvested in large quantities for export, could serve as an important income generation source for producing countries. Market value chains for *Allanblackia* seeds collected from wild stands and/or remnants from farmlands have been developed by Unilever (which provides a guaranteed price for harvested seeds) and other commercial parties in Ghana, Nigeria, Cameroon, and Tanzania [18][41][44]. Aside from the increase in livelihood opportunities for farmers participating in this rural-based enterprise, it also contributes to biodiversity conservation in these landscapes. Unilever discovered new uses of *Allanblackia* seed oil at an industrial level to produce cosmetic products and margarine [18], thus raising the international demand to a commercial scale. The *Allanblackia* seed oil is superior to other alternative oils such as palm oil due to its moderately high melting point [14][15]. Oppong [48] pointed out that Unilever needs 2000 t of *A. parviflora* seeds from Ghana; however, only 110 t (just 5.5%) on average are supplied annually [49], emphasizing its importance and need for large-scale planting. The *Allanblackia* seed oil has received an endorsement from the European Union (EU) Novel Food Regulations that approves its safe usage in food products [50].

6. Chemical Composition of *A. parviflora* Seeds

A study conducted on the fatty acid composition of *A. parviflora* seeds revealed that their composition is primarily of stearic (51.6%) and oleic acid (43.9%), with minor quantities of myristic (1.8%), palmitic (2.5%), and eicosanoic acid (0.2%). The main triglyceride constituents were identified as 2-oleostearin (60.1%), 1-stearo-diolein (26.9%) and 2-oleopalmitostearin (6.9%) [51]. Stearic acid percentages ranging from 44% to 66% and oleic acid ranging from 25% to 48% per tree sample were documented for *A. floribunda* [52]. *A. floribunda* seeds have also been reported to contain a lot of edible oil (67.6%) which is rich in stearic acid [53], and these values are similar to those observed for *A. parviflora* seeds. The values confirm the high fat content in the seeds of *Allanblackia* species. Adubofuor et al. [47] researched the seeds of *A. parviflora* grown in Ghana, from which oil was extracted by either the use of a screw press or Soxhlet extraction (petroleum ether), revealing an average of 68% oil. The gas chromatography method was employed to assess the fatty

acid composition of the seed oil as 2.9% palmitic acid, 52.3% stearic acid, and 44.8% oleic acid. The key minerals found in the seeds were potassium (8.41 mg/kg) and phosphorus (8.34 mg/kg). Nutritional analyses showed that the seeds contained 4.3% protein, 2.0% ash, 5.7% crude fibre and 17.1% carbohydrates, with the moisture content being 3.4%. Additionally, Sefah et al. [54] confirmed the moisture content of *A. parviflora* seeds to be 3.2%.

7. Morphological and Genetic Diversity

Genetic diversity analysis is very essential in any tree improvement programme for the identification of quality genotypes and proper clonal deployment. Both morphological [4] and molecular [55][56] differences among *Allanblackia* tree species show significant genetic diversity within the species. Peprah et al. [4], in a study on variation in fruits and seed morphology of 109 *A. parviflora* trees growing in different parts of Ghana, reported no differences in fruit yield, fruit shape and seed health among the ecological zones. However, significant differences in fruit shape and size were observed among the individual trees sampled (**Figure 4**). According to Leakey et al. [57], variation in fruit parameters at the level of the provenance indicates that genetic variation exists within the species since the environment is similar. The results suggest a high genetic improvement potential through individual selection [4]. In the interim, the adoption of fruit size and seed yield as targeted selection criteria is assumed to be a valid approach for collection and has been used in sampling. The seedlings and grafts raised from these selected trees are disseminated to farmers for farmland cultivation. Moreover, the vegetative propagules (grafts, seedlings, and cuttings) from these superior trees are employed for the setting up of mother blocks, i.e., constructed plots consisting of grafts, seedlings, and cuttings for advanced (vegetative) propagation, and the creation of gene banks for the purposes of conservation [29][58]. In Ghana, two mother blocks have been constructed with 20 superior clones. Moreover, a 3 ha gene bank established with seedlings from 120 mother trees has been constructed in addition to the clonal stocks in the mother blocks [30].

Other species of the *Allanblackia* genus have received some level of research attention in terms of comparing morphological data to the genetics of a given provenance which is vital for developing sound and effective domestication strategies. For instance, morphological and genetic diversity assessment using genetic markers have been reported for *A. floribunda* in Cameroon [55][56] and *A. stuhlmannii* in Tanzania [56][59]. However, there is very limited knowledge on studies focusing on the genetic diversity of *A. parviflora* in West Africa using molecular markers even though some work has been done on the morphological aspects in Ghana [4][14][54]. Genetic markers are employed, for instance, for the estimation of differences between natural and domesticated plant populations, gene flow, fingerprinting, genetic structure, and hybridization, and are therefore essential in breeding programmes and development of new varieties [60][61]. Modern molecular markers such as DNA chips and sequencing-based DNA markers (for example, single nucleotide polymorphisms—SNPs) are used for the assessment of genetic diversity and are based on phenotypic differences that are controlled genetically [62]. However, the use of genetic markers, such as SNPs, for genetic diversity studies of *Allanblackia* in the West African region where the species' occurrence has not been adequately explored. Several factors usually make SNPs the preferred choice of markers because they are platform-independent, reproducible across laboratories, and the subsequent databases can be shared worldwide. Moreover, due to the high frequency of SNPs, ease of design from transcriptome or genome assemblies, and the availability of high throughput SNP assay platforms, SNP genotype data are easy to collect in large amounts [63].

8. Conclusions

A. parviflora is one of the priority fruit tree species identified for improvement and domestication in Sub-Saharan Africa. It has been targeted for improvement for the production of oil from the seeds, for benefits not only to the local populations but also the economies of producing countries. Despite the great potential of this species, there are still significant knowledge gaps that require urgent research attention.

This entry shows that the most important economic use of A. parviflora is the production of edible oil from the seeds. This might justify why ICRAF and its partners already started with the first domestication steps by selecting superior individuals/populations in Ghana, Cameroon, Nigeria, and Tanzania, while Unilever remains a major buyer of the Allanblackia seed oil. However, scientific information on the seeds' phytochemical composition and variability is scarce. Additionally, only a little or no information is available on the diversity and management of the species in the regions where it is naturally found. More specifically, basic information on genetic diversity, silvicultural management, productivity, methods of propagation and cultivation are not well documented. The development of morphological descriptors, the use of modern molecular markers for genetic diversity assessment, and studies on the phytochemistry of seeds are therefore highly recommended. Moreover, qualitative research on the preferences of local populations who produce A. parviflora seeds should be conducted to reveal their preferred traits of interest for development. The selection of superior mother tree populations may begin once these attributes are determined. The next step after identifying trees with superior desirable traits will be the multiplication of best individuals. Extensive studies on vegetative propagation and propagule regeneration of the species are urgently needed, as the currently available information is not ample. Seedlings from generative propagation are currently the easiest solution for farmers, but there is a limitation to such a method due to the dioecious nature of the species which makes it difficult to identify the sex of the tree at the juvenile stage. While research efforts should be focused on determining the sex of trees at a young age, studies on multiplication by vegetative

propagation is crucial, since such a method of propagation assures the conservation of the traits of interest. The researchers conclude that A. parviflora has great potential to ensure food and nutritional security and alleviate poverty among rural populations in West Africa, and therefore could be domesticated to promote widespread planting in agroforestry systems and for the conservation of the genetic resource if the knowledge gaps identified here are fulfilled.

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