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Research Application Summary

Baobab leaves production for household consumption: A synthesis of existing techniques

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Abstract

African baobab (*Adansonia digitata* L.) leaves constitute the second most harvested and used organ by local populations for various purposes, namely food and medicine in sub-saharan Africa. Faced with increasing anthropogenic pressure on the natural population of the species, the definition of sustainable management strategies becomes necessary to sustain the growing demand, including the baobab leaf cultivation. The current review is an attempt to synthesize and critically examine the existing technical routes for the species leaves production, from germination to leaves' harvesting. Data were collected through thirty-seven eligible articles we found a diversity of seed pre-treatments: physical, chemical and thermic. Seed scarification was often considered safer and yielded good germination rates (100 %). There was also a large variation of sowing density (from 10 × 20 cm to 250 × 250 cm). Substrates often used are enriched with compost or manure (44.44 - 6250 kg per 100 m^2) and sometimes chemical fertilizers with lack of precision regarding doses used. Frequency of leaves harvesting varied from two to eight weeks. Leaves biomass lacks consistent data, making hard to derive a consistent trend. Harvested leaves biomass for a sowing density of 15 × 15 cm yielded 400 kg / 100 m^2 / month for the first two months after germination and 200 kg / 100 m^2 / month from the 3rd month. Further experimentations are still needed to optimize baobab leaves' production. Suggested foci include: providing consistent data on leaves biomass in relationships to technical routes and elucidating profitability of the activity.

Key words: *Adansonia digitata*, density of sowing, fertilization, harvesting frequency, seeds' pre-treatment

Résumé

Les feuilles du baobab africain (*Adansonia digitata* L.) constituent la deuxième partie de plante la plus récoltée et utilisée par les populations locales à diverses fins, notamment alimentaire et médicinale. Face à la pression anthropique grandissante exercée sur la population naturelle de cette espèce, la définition des stratégies durables de gestion est nécessaire pour soutenir la demande y compris la production de feuilles de baobab. La présente synthèse bibliographique a fait l'état des lieux et une analyse critique des techniques de production des feuilles de baobab, plus précisément, de la germination à la récolte des feuilles. Des 37 articles éligibles examinés, différentes techniques de prétraitements des graines (physiques, chimiques et thermiques) ont été décrites, mais la scarification des graines est rapportée comme la technique la plus efficace avec des taux de germination assez élevés (100%). Une importante variation existait pour la densité de semis (10 20 cm à 250 250 cm). La fertilisation des substrats est généralement basée sur le compost ou fumier (44,44 - 6250 kg pour 100 m2) ainsi qu'en engrais chimique qui quelques fois manquent de précision sur les doses utilisées. La fréquence de récolte des feuilles a varié de toutes les deux à toutes les huit semaines. La biomasse foliaire manque de données conséquentes, ce qui rend difficile la définition d'une tendance. Cependant, la biomasse des feuilles récoltées pour une densité de semis de 15   15 cm a donné 400 kg / 100 m^2 / mois pendant les deux premiers mois après la germination et 200 kg / 100 m^2 / mois à partir du troisième mois. Il en ressort de cette étude que la conduite d'autres expérimentations est encore nécessaire pour optimiser la production de feuilles de baobab. Nous suggérons que des études futures fournissent de données conséquentes sur la biomasse des feuilles en relation avec les itinéraires techniques et élucident la rentabilité de la production.

Mots clés: Adansonia digitata, densité de semis, fertilisation, fréquence de récolte, prétraitement des graines

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Introduction

African baobab (*Adansonia digitata* L.) is a multipurpose tree species for which the products have numerous food uses and medicinal properties. The pulp, the seeds, and the leaves are all utilized and are essentially wild-gathered foods, daily consumed and commercialized by rural populations in Africa (Kamatou *et al*., 2011). Various plant parts (e.g. leaves, bark, fruit and pulp), have traditionally been used for immuno-stimulant, anti-inflammatory, analgesic, insect repellent and pesticidal properties, in the treatment of diarrhea and dysentery in many African countries, and have been evaluated as a substitute for imported western drugs (Kamatou *et al*., 2011; Namratha and Sahithi, 2015). Baobab products (e.g. seed oil and fruit pulp) are increasingly being commercialized and exported around the world (Vermaak *et al*., 2011) leading to increased pressure on its natural populations. The tuberous taproot of seedlings and young saplings are also eaten, especially in times of famine. A decade ago, the European Commission authorized baobab fruit pulp as a novel food (Buchmann *et al*., 2010) while it was approved in 2009 by the Food and Drug Administration as a food ingredient in the United States of America (Addy, 2009). Due to the high demand for commercial baobab products in EU and United States, this tree with its edible fruits requires implementation of timely sustainable management strategies (Sanchez *et al*., 2010a).

Leaves of baobab young trees are often simple and highly appreciated for food, because their leaves are particularly rich in calcium, and they are known to contain good quality proteins (Chadare *et al*., 2009). For example, in 1988–1989 in the region of Ségou (Mali) alone, 3,600 tons of dried leaves were consumed, corresponding to 2.49 kg per person per year and the average daily consumption of baobab leaves is estimated to 11 - 50 g per person (Savard *et al*., 2006). All the baobab leaves are harvested from wild populations and the intensity and traditional methods for the leaves' collection have negative impact on the species reproduction, hence its persistence (Assogbadjo, 2006; Korbo *et al*., 2013). The increasing awareness of these drawbacks combined with the increasing demand of baobab leaves have led to many trials on the production of baobab leaves as vegetables at early stage (Pye-Smith, 2010; Korbo *et al*., 2013). Existing literature on baobab provided substantial information on the species taxonomy, distribution, properties, utilization, agronomy, agroecology, nutritional value of their food products and commercial importance by (Diop *et al*., 2005; Gruenwald and Galizia, 2005; Assogbadjo, 2006; Kalinganire *et al*., 2007; Teklehaimanot, 2008; Chadare *et al*., 2009; De Caluwé *et al*., 2010; Jamnadass *et al*., 2011, Kaboré *et al*., 2011; Kamatou *et al*., 2011; Stadlmayr *et al*., 2013; Zahra'u *et al*., 2014; Namratha and Sahithi, 2015; Gebauer *et al*., 2016). However, those studies failed to provide adequate knowledge on the various techniques used for baobab leaves production. Yet, information on the existing knowledge, gaps, and how such gaps might be filled is needed to speed the domestication of baobab.

This study is an attempt to present the various techniques reported on baobab leaves production. Subsequently, suggestions are made for future research prospects to advance the field.

Methodology

Numerous literature searches were conducted, primarily using Google™, Google Scholar™, ResearchGate™ and Academia™ and African Journal Online (AJOL). A variety of terms and combinations of terms were used including 'African baobab', 'baobab', 'Adansonia digitata', 'baobab production', 'baobab domestication', 'baobab seedlings', 'baobab leaves production', and 'baobab seeds germination'. These searches were supplemented by documents from the grey literature. For each baobab leaves cultivation step (seed pre-treatment, irrigation, harvesting techniques, density of sowing, fertilization, harvesting frequency), various techniques were proposed according to each author. Yields variation were also extracted to compare different techniques identified by authors in synoptic tables (see Tables 1 and 2). We also included articles that focused on germination ability of baobab but not necessary aiming at production of its leaves. This was done since those articles provide basic information on germination which is a key step for the species cultivation. During our literature survey, a large variation in information and data was encountered and the reported values were converted into the same units.

Results

Brief description of the scope of examined articles. From the raw articles initially collected, thirty-seven (37) articles were considered and examined in this review and covered the time period from 1991 to 2018. Several studies focused on the development of suitable techniques for baobab leaves production as vegetable to ensure the availability of the species fresh leaves throughout the year. These studies were mostly conducted in Mali (7 articles = 19 %), Nigeria (6 articles = 16 %), Burkina Faso (4 articles = 11 %), Senegal (3 articles = 8 %), Benin, India and Malawi (2 articles = 5 % respectively), Niger, Madagascar, Denmark, Italy, Kenya and Southern Africa (1 article = 3 % respectively ; Fig. 1). These studies focused on effects of seed pre-treatment (74 %), density of sowing (34 %), fertilization and irrigation (29 % respectively), harvesting frequency (17 %), in vitro propagation (11 %), impact of harvesting techniques on the variation of the yield of baobab leaves and profitability (9 % respectively) and macropropagation using grafting methods (6 % ; Fig. 2).

Seed pre-treatment. In natural conditions, low seed germination is often mentioned for the African baobab (Esenowo, 1991; Sidibé and Williams, 2002); thus, leading to test several pre-treatments methods. As a consequence, several techniques have been tested. It was reported that seed scarification with a razor blade can lead to high germination rate (almost 100 %) (Maghembe *et al*., 1994; IER/ICRAF, 2001; Assogbadjo, 2006; Olivier *et al*., 2006; Savard *et al*., 2006; Olivier *et al*., 2006; Razanameharizaka *et al*., 2006; SCUC, 2006; Kalinganire *et al*., 2007; Munthali *et al*., 2008; Assogbadjo *et al*., 2010). Lower germination percentage (85 – 92 %) was reported for cutting the seed coat and then soaking in cold water for 72 h (SCUC, 2006), putting the seeds in a container of boiling water for 48 h (58 – 96 %) (IER/ICRAF, 2001; Savard, 2003; Olivier *et al*., 2006; Savard *et al*., 2006; Kalinganire *et al*., 2007), or boiling the seeds in a container for 5 to 7 min (> 90 %) (SCUC, 2006).

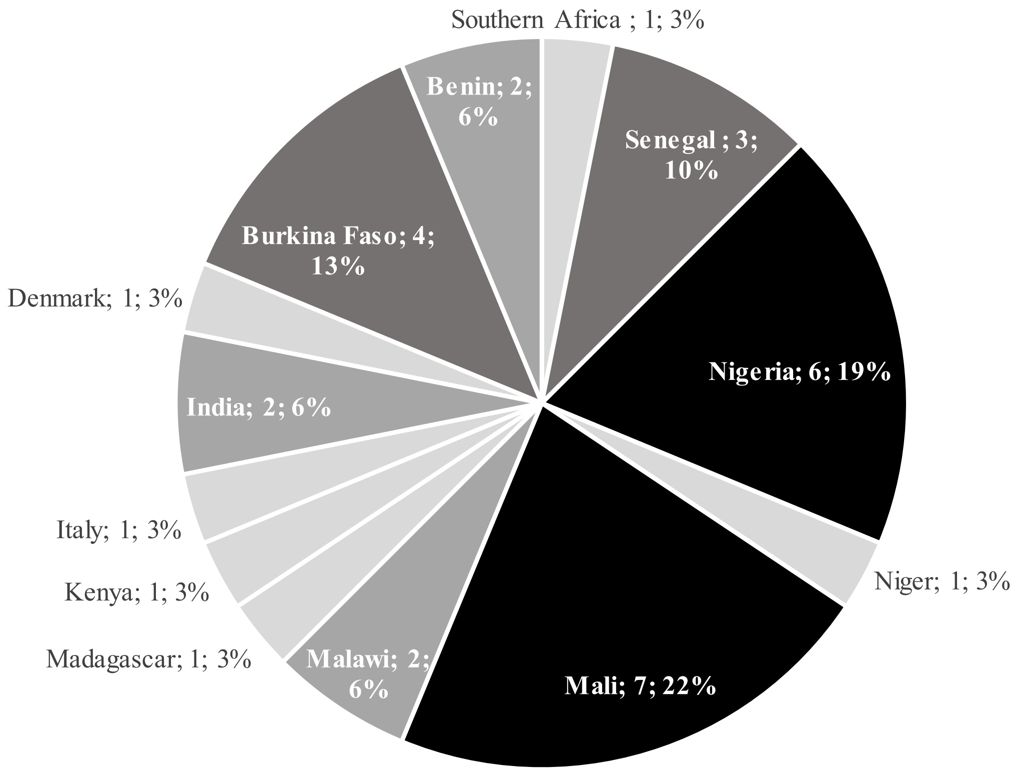

Figure 1. Trends of study focusingon baobab leaves production per country of interest

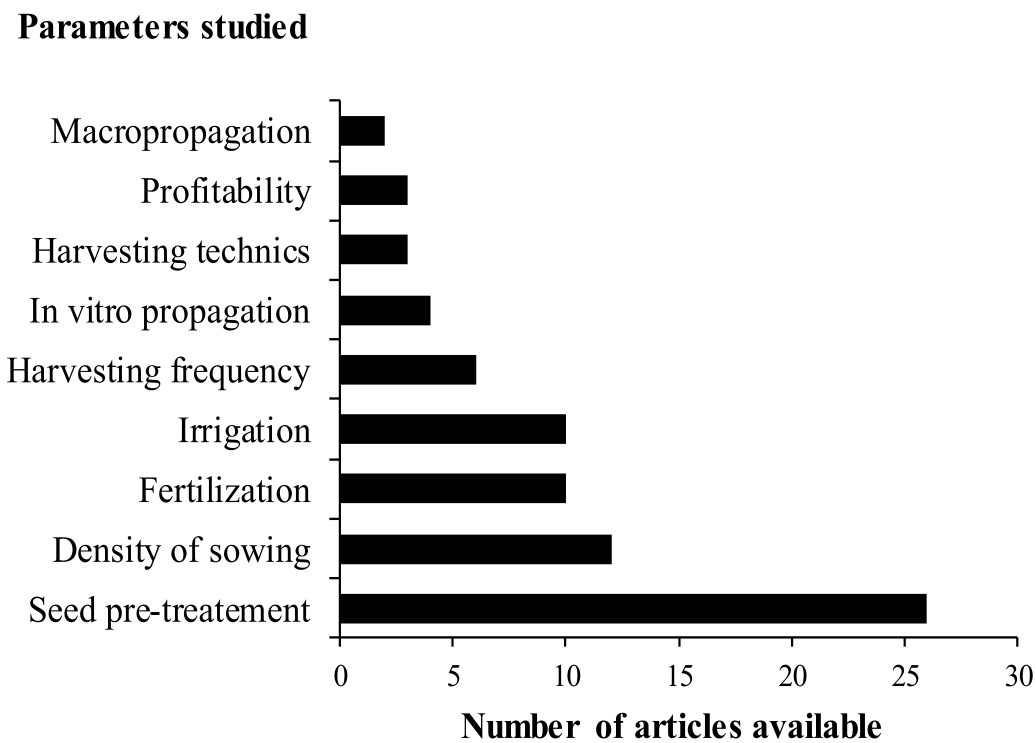

Figure 2. Study trend focused on the techniques of baobab leaves production

Other seed treatments such as with sulphuric acid for 6 to 12 h (Esenowo, 1991; Danthu *et al.*, 1995; IER/ICRAF, 2001; Sidibé and Williams, 2002; Savard, 2003; Savard *et al.*, 2006; Olivier *et al.*, 2006; Kalinganire *et al.*, 2007; Gahane and Ogje, 2013; Van den Bilcke *et al.*, 2013; Niang *et al.*, 2015), or putting the seeds in concentrated 98% sulphuric acid for 1 hour (Falemara *et al.*, 2014), in 95% sulfuric acid for 45 min (Bationo, 2003; Bonneville *et al.*, 2007; Bationo *et al.*, 2009), or in nitric acid for 15 min (IER/ICRAF, 2001; Sidibé and Williams, 2002; Savard, 2003; Savard *et al.*, 2006; Olivier *et al.*, 2006; Razanameharizaka *et al.*, 2006; Kalinganire *et al.*, 2007) were reported in the literature with up to 98% germination. However, these treatments have the drawbacks of being dangerous to be handled by non-specialists with some environment's issues if not well managed.

In vitro propagation was reported with 77% germination by Singh *et al.* (2010), Fasola and Okerenkporo (2012), N'Doye *et al.* (2012) and Rolli *et al.* (2014). Vegetative propagation using various grafting methods was reported with 82 % success rate by Anjarwalla *et al.* (2017) and Jenya *et al.* (2018) (Table 1).

Density of sowing. Two propagation techniques were identified: transplantation and direct sowing. Transplantation consists in passing the seeds in nursery followed by transplantation on prepared plots. Kalinganire *et al.* (2007) proposed the use of 10 25 cm in nursery and transplanted with 250 250 cm (Sidibé and Williams, 2002). Direct sowing is carried out on prepared plots. Numerous sowing densities were used: 15 x 15 cm (Bationo, 2003; Bonneville *et al.*, 2007; Bationo *et al.*, 2009); 10 20 cm (IER/ICRAF, 2001; Savard, 2003; Savard *et al.*, 2006; Olivier *et al.*, 2006); 50 x 20 cm (SCUC, 2006; Assogbadjo *et al.*, 2010; Korbo *et al.*, 2013) (Table 2).

Harvesting frequency. Seedlings raised in nursery are transplanted when they are aged 3 to 4 months. Then, the first harvest began 45 days after transplantation, and every 2 to 3 weeks (Kalinganire *et al.*, 2007). After direct sowing of seeds on prepared plots, Bationo (2003), Bonneville *et al.* (2007) and Bationo *et al.* (2009) reported 40th day, for the first harvest followed monthly harvests. IER/ICRAF (2001) reported first harvest 6 weeks after sowing, then between 3 and 8 weeks. Also, the first harvest began 45th day after sowing, and every 2 to 3 weeks (Kalinganire *et al.*, 2007), or every month (Korbo *et al.*, 2013). Overall, the first harvest took place between the 40^{th} and the 45^{th} day after sowing/transplanting. The following harvests took place between every 3 to 8 weeks but the most common is every month (Table 2).

Harvesting techniques. Two harvesting technique of baobab seedlings leaves were identified. The first technique which intensifies the production of fresh leaves and produces vigorous plant stock for agroforestry schemes, consists in harvesting all leaves but sparing the terminal buds (Bonneville *et al.*, 2007; Bationo *et al.*, 2009). The second technique consists in cutting the plants 15 cm above ground (Kalinganire *et al.*, 2007; Table 2).

Fertilization. In Burkina Faso, the substrates are enriched with compost or manure 44.44 kg per 100 m^2 per month (Bationo, 2003; Bonneville *et al.*, 2007; Bationo *et al.*, 2009). In Mali, the substrates are enriched with 6250 kg manure per 100 m^2 (SCUC, 2006) or 100 kg of compost or manure per 100 m^2 (Kalinganire *et al.*, 2007). IER/ICRAF (2001), Sidibé and Williams (2002), Savard (2003), Savard *et al.* (2006), Olivier *et al.* (2006) reported without, dose precision, the use of chemical fertilizers, bi- or tricalcium phosphate, potassium chloride and urea with 46 % N (Table 2).

Table 1. Reported techniques for baobab seed pre-treatment and its propagation

Techniques	Germination	Authors
Scarification/cutting the seed coat	60 - 100 %	Maghembe *et al.* (1994); IER/ICRAF (2001); Sidibé and Williams (2002); Savard (2003); Assogbadjo (2006); Savard et al. (2006) ; Olivier *et al.* (2006); Razanameharizaka *et al.* (2006); SCUC (2006); Kalinganire *et al.* (2007); Munthali *et al.* (2008); Assogbadjo e*t al.* (2010)
Cutting the seed coat and then soaking in cold water for 72 h	85 – 92 %	Maghembe e*t al.* (1994); SCUC (2006)
Putting the seeds in a container of boiled water for 48 h	58 – 96 %	Maghembe *et al*. (1994); Vogt (1996); IER/ICRAF (2001); Savard (2003); Savard *et al.* (2006); Olivier e*t al.* (2006); Kalinganire *et al.* (2007)
Boiling the seeds in water for 5 to 7 min	> 90 %	Razanameharizaka *et al.* (2006)
Putting the seeds in concentrated sulphuric acid for 6 to 12 h	68 - 98 %	Esenowo (1991); Danthu *et al.* (1995); IER/ICRAF (2001); Sidibé and Williams (2002); Savard (2003); Olivier *et al.* (2006); Savard *et al.* (2006); Kalinganire et al. (2007); Gahane and Ogje (2013); Van den Bilcke *et al.* (2013); Niang *et al.* (2015)
Putting the seeds in nitric acid for 15 min	86- 90 %	IER/ICRAF (2001); Sidibé and Williams (2002); Savard (2003); Savard *et al.* (2006); Olivier e*t al*. (2006); Razanameharizaka *et al.* (2006); Kalinganire *et al.* (2007)
Putting the seeds in concentrated 98% sulphuric acid for 1 h	62 - 85 %	Falemara *et al.* (2014); Usman and Asan (2017)
Putting the seeds in concentrated 95% sulfuric acid for 45 min	80 %	Bationo (2003); Bonneville *et al.* (2007); Bationo *et al.* (2009)
In vitro propagation	57 – 77 %	Singh *et al.* (2010); Fasola and Okerenkporo (2012); N'Doye *et al.* (2012); Rolli *et al.* (2014)
Macropropagation (grafting)	30 – 82 %	Anjarwalla *et al.* (2017); Jenya *et al.* (2018)

Table 2. Reported techniques for baobab leaves production

Density of sowing	Harvesting frequency	Fertilization	Variation in yields	Country	Authors
15 x 15 cm	40 days after establishment and every month	44.44 kg of compost or manure per 100 m^2 per month	-	Burkina Faso	Bationo (2003)
10 x 20 cm	Six weeks after planting, then between 3 and 8 weeks	Manure or bi- or tricalcium phosphate, potassium chloride and urea with 46 % N (Dose not precise)	-	Mali	IER/ICRAF (2001); Savard (2003), Savard *et al.* (2006); Olivier *et al.* (2006)
20 x 50 cm	Within the first year of planting	6250 kg manure per 100 m^2	-	Mali	SCUC (2006)
10 × 25 cm / 250 × 250 cm	45 days after establishment; The plants are cut to 15 cm from the ground and it every 2 to 3 weeks	100 kg of compost or manure per 100 m^2	-	Mali	Kalinganire *et al.* (2007)
15 x 15 cm	40 days after establishment and Every month; Harvesting sparing the terminal buds	44.44 kg of compost or manure per 100 m^2 per month	400 kg / 100 m^2 / month for the first two months after germination; 200 kg / 100 m^2 / from the 3rd month	Burkina Faso	Bonneville *et al.* (2007); Bationo et al. (2009)
20 x 50 cm	45 days after establishment and Every month	-	300 kg / 100 m^2 / month	Mali, Niger and Burkina Faso	Korbo *et al.* (2013)

Yield variation. Very large variation of the biomass production was found, presumably due to differences in technique and local environment conditions but also the genetic material. Leaf production is estimated to be 400 kg / 100 m^2 / month for the first two months after germination; and in average of 200 kg / 100 m^2 / month from the 3rd month (Bonneville *et al*., 2007; Bationo *et al*., 2009). Korbo *et al*. (2013) reported that the average leaf biomass is of 300 kg / 100 m^2 / month after germination (Table 2).

Irrigation. Growth of seedlings require watering morning and evening (IER/ICRAF, 2001; Savard, 2003, Savard *et al*., 2006; Olivier *et al*., 2006; SCUC, 2006; Kalinganire *et al*., 2007). Some 444.44 litres of water are sprayed on plots of 100 m^2 per day (Bationo, 2003; Bonneville *et al*., 2007; Bationo *et al*., 2009). Assogbadjo *et al*. (2010) reported watering once a day, preferably in the evening from sowing/transplanting day.

Discussion

Baobab seeds' pre-treatment. This review shows that the reported numerous techniques fall within chemical and mechanical seed pre-treatments. Esenowo (1991) and Danthu *et al.* (1995) revealed that seeds' pre-treatment consisting of scarification or with concentrated sulphuric acid or nitric acid led to germination of more than 90% in less than 24 hours and emergence is 4-6 days after sowing, and all those that will germinate will have emerged by 18 days (Sidibé and Williams, 2002). However, usage of such dangerous products though possible in laboratory, is not advisable for farmers. Studies by Assogbadjo *et al.* (2010) in Benin showed contrasting results in that scarification had negative effect in breaking seed dormancy. Thus, baobab seeds from Benin do not seem to have a strict physical dormancy compared to the Malagasy ones (Razanameharizaka *et al*., 2006) and the observed differences may be due to a physiological response lead by genetic and/or environmental factors. The scarification (cutting the seed coat) with a razor blade (Razanameharizaka *et al*., 2006; Assogbadjo, 2006) is not adapted to a production of great scale (hundreds of seed to be sown). It would be thus preferable to employ the mechanical methods of seeds pre-treatment in bulk: cutting the seed coat and then soaking in cold water for 72 hours (SCUC, 2006), putting the seeds in a container of boiled water for 48 hours (IER/ICRAF, 2001), for several minutes (Esenowo, 1991), boiling the seeds in water for 5 to 7 minutes (SCUC, 2006). Alternatively, one may initiate the manufacturing of the instrument adapted to the manual scarification of seeds. In addition, to ensure a good germination rate, the origin of seeds and the different ecotypes are a crucial factor to be taken into account to avoid exposing the seeds to climatic influences which are liable to mitigate the germination rates (Assogbadjo *et al*., 2010). Vegetative propagation techniques of young baobab by cutting, grafting, budding, tissue culture, and micropropagation needs to be further refined not only for growing suitable saplings and small trees as a vegetable crop, but also for reducing the time to first fruiting (Gebauer *et al*., 2016; Rashford, 2018).

Density of sowing. There was a large variation of sowing density (10 cm × 20 cm to 250 cm × 250 cm). Fang *et al*. (1999), Pinkard and Neilsen (2003) reported that, when spacing between trees is reduced, biomass that is allocated to branches and foliage usually decreases to the benefit of the stem. Root growth influences the provisioning of nutritive elements of a plant, and consequently, its growth and yield. It follows that the growth of the roots is correlated positively with the yield (Blomme *et al*., 2003). Plant spacing for vegetable cultivation is an important criterion for attaining maximum vegetative growth and an important aspect of crop production for maximizing the yield.

Optimum plant spacing ensures judicious use of natural resources and makes the intercultural operations easier. It helps to increase the number of leaves, branches and healthy foliage. Densely planted crop obstructs the proper growth and development. On the other hand, wider spacing ensures the basic nutritional requirements but decrease the total number of plants as well as total yield. Yield may be increased for any crop up to 25% by using optimum spacing in leafy vegetable (Bansal *et al.*, 1995). For example, Bationo (2003), Bonneville *et al.* (2007), Bationo *et al.* (2009) reported that 15 x 15 cm sowing density yielded 400 kg per 100 m^2 per month for the first two months after germination compared to 50 x 20 cm (SCUC, 2006; Assogbadjo *et al.*, 2010; Korbo *et al.*, 2013) which provided a yield relatively per month. These results are consistent with the idea that the variation of the density of sowing higher of 300 kg per 100 m^2 induces the variation of the yield. For this purpose, it is important to define optimum density of sowing to guarantee the profitability of the sector.

Harvesting frequency. Frequency of leaves harvesting varied from every two weeks to every eight weeks. Harvesting techniques consist in collecting all leaves but sparing the terminal buds. Investigations of the effect of cutting frequency on biomass production have been undertaken and differences in production due to various cutting regimes have been found with many species such as Leucaena leucocephala (Lam.) de Wit and Gliricidia sepium (Jacq.) Kunth ex Walp (Guevarra *et al.*, 1978; Latt *et al.*, 2000). Leaves biomass lacks consistent data, making hard to derive a consistent trend.

Fertilization. Chemical fertilizer (IER/ICRAF, 2001; Savard, 2003, Savard *et al.*, 2006; Olivier *et al.*, 2006) are not always hands-on; moreover, they contribute to soil and land degradation if not properly used (Rehm *et al.*, 1995). An alternative would be organic matter from either domestic dust composting or animals' dungs.

Organic matter (Bationo, 2003; SCUC, 2006; Bonneville *et al.*, 2007; Kalinganire *et al.*, 2007; Bationo *et al.*, 2009) needs to be added during planting (Sidibé and Williams, 2002) and it is advised that planting is done at the beginning of the rainy season. Supplying organic matter (Compost or organic manure) promoted further seedlings growth after 11 days of germination (Assogbadjo *et al.*, 2010). Organic matters from domestic breeding or compost from domestic organic waste are hypothesized to provide sustainable manure for sustainable production in smallholder farming systems (Assogba-Komlan, 2001). In this context, biological agriculture offers new prospects. Indeed, a husbandry which implies the consequent contribution of organic fertilizers such as the crop waste products or different standard from composts, could improve soil fertility (Weber *et al.*, 2007). The use of composts produced by organic waste improves their properties, makes available nutriments and reduces the risks of pollution (Douglas *et al.*, 2003), improves soil structure, increases the water holding capacity and in nutriments, stimulate the microbial activity and increase the outputs (Kowaljow and Mazzarino, 2007). Doses of organic manure in horticulture often varies between 10 t/ha to 40 t/ha (Olaniyi, 2008; Akparobi, 2009). This often leads to an excellent yield and rapid growth of cultivated vegetables.

Yield variation. As highlighted in this review, only a few studies have been carried out on technical route of baobab leaves production based on plots (Table 2). Several studies (IER/ICRAF, 2001; Bationo, 2003; Savard, 2003, Savard *et al.*, 2006; Olivier *et al.*, 2006; SCUC, 2006; Bonneville *et al.*, 2007 ; Bationo *et al.*, 2009; Assogbadjo *et al.*, 2010; Korbo *et al.*, 2013) mentioned direct sowing of seeds on prepared plots except Sidibé and Williams (2002) and

Kalinganire *et al*. (2007) who suggested that seedlings should have reached a height of 40 - 50 cm in nursery before transplanting with 250 × 250 cm sowing density. The variation of the yield observed would be related to the different technique used. Assogbadjo *et al*. (2010) reported that next to environmental factors, genetic factors can also have an influence on seed germination traits. The variation in germination rate could be due to seed size and provenances (Assogbadjo, 2006; Assogbadjo *et al*., 2010). Thus, part of this variation, due to genetic differences between provenances has been demonstrated Sanchez *et al*. (2010b) who showed that provenances from Benin differed in their leaf morphology, provenances from areas with low precipitation showing more xerophytic characters than provenances from more humid areas.

Conclusions and Research Avenues

This section has reviewed the literature on baobab leaves production whose primary purpose is production of food and sometimes herbs for home consumption. We found that reported data show considerable variation in the technique applied for baobab leaves production. Further research is however needed to optimize the baobab leaves production. In particular future research should: (i) provide consistent data on leaves biomass in response to technical routes used, clearly showing how yield of leaves is related to sowing density, harvesting frequency, type of fertilizers (chemical and organic) and its doses, etc., (ii) elucidate profitability of the activity, (iii) identify the potentials devastating of the seedlings and the effective fight techniques, and (iv) clarify the anti-nutritional properties of harvested leaves as the plant responses to stress due to frequent harvesting.

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