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# LOCAL EXPLOITATION AND CHARACTERIZATION OF *BALANITES AEGYPTIACA* (L.) DEL PARKS IN THE SUDANO-SAHELIAN ZONE OF CAMEROON, FAR-NORTH, CAMEROON

**MUNTING DIVINE TII[1*], TCHOBSALA[1]**

[1*]*University of Maroua, Faculty of Science, Department of Biological Sciences, BP:814 Maroua, Cameroon;*

[*]Corresponding Author MUNTING DIVINE TII, e-mail: tiimunting@yahoo.com;

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**ABSTRACT**

*Balanites aegyptiaca* is a valuable resource for local African populations. However, this natural resource is managed in an irrational and abusive way by local communities. In order to contribute to the enhancement and sustainable management of *B. aegyptiaca*, an approach combining two methods has been adopted. The first is based on an ethnobotanical survey relating to local knowledge of *B. aegyptiaca* products and the second is focused on the surface survey in 4 Divisions of the Far North Region of Cameroon. In total, 400 people aged at least 15 years were chosen according to their knowledge of *B. aegyptiaca*, ie 100 people in each Division. The experimental design is a split-plot (4 x 4), then Sub-Divisions (Kalfou, Mindif, Moutourwa and Pette) constitute the main treatment. *B. aegyptiaca* is an agroforestry species that plays a very important role in the life of local communities. The main products used are leaves (100%), fruits (98.19%) and seeds (90.06%). They are used mainly in consumption (98.19%) and marketing (91.67%). Garawa Park in Moutourwa Sub-Division is the richest in taxonomic diversity, with 20 species, divided into 14 genera and 11 families. On the other hand, *B. aegyptiaca* park of Ourosambo located in Kalfou Division is the least diversified with 9 species, divided into 7 genera and 6 families. The other parks show intermediate specific diversity, with the number of species varying from 10 species (Doyang) to 18 species (Toutka). The Shannon diversity index varies in the parks from 1.77 bit (Ourosambo) to 2.86 bit (Maoudine). Parkland vegetation has an "L" structure based on crown diameter and diameter at breast height (DBH). Depending on the heights, the vegetation presents an inverted "U" structure. These results could serve as a reference for the elaboration of strategies for the development and sustainable management of *B. aegyptiaca* parks in the Sudano-Sahelian zone of Cameroon.

**Keywords:** *Balanites aegyptiaca*, Exploitation, Far North, Park, sustainable management.

**RESUMÉ**

*Balanite aegyptiaca* constitue une ressource précieuse pour les populations locales africaines. Cependant, cette ressource naturelle est gérée de manière irrationnelle et abusive par les communautés locales. Afin de contribuer à la valorisation et à la gestion durable de *B. aegyptiaca*, une approche associant deux méthodes a été adoptée. La première est basée sur une enquête ethnobotanique relative aux connaissances locales des produits de *B. aegyptiaca* et la deuxième est focalisée sur le relevé de surface dans 4 Arrondissements de la Région de l'Extrême-Nord du Cameroun. Au total, 400 personnes âgées d'au moins 15 ans ont été choisies selon leur connaissance sur *B.*

*aegyptiaca*, soit 100 personnes dans chaque Arrondissement. Le plan expérimental installé est un split-plot (4 x 4) où les Arrondissements (Kalfou, Mindif, Moutourwa et Petté) constituent le traitement principal. *B. aegyptiaca* est une espèce agroforestière qui joue un rôle très important dans la vie des communautés locales. Les principaux produits utilisés sont les feuilles (100%), les fruits (98,19%) et les graines (90,06%). Ils sont utilisés principalement dans la consommation (98,19 %) et la commercialisation (91,67%). Le parc de Garawa dans l'Arrondissement de Moutourwa est la plus riche en diversité taxonomique, avec 20 espèces, réparties en 14 genres et 11 familles. En revanche, le parc à *B. aegyptiaca* de Ourosambo situé dans l'Arrondissement de Kalfou est la moins diversifié avec 9 espèces, réparties en 7 genres et 6 familles. Les autres parcs présentent une diversité spécifique intermédiaire, avec le nombre d'espèces variant de 10 espèces (Doyang) à 18 espèces (Toutka). L'indice de diversité de Shannon varie dans les parcs de 1,77 bit (Ourosambo) à 2,86 bit (Maoudine). La végétation des parcs présente une structure en « L » en fonction de diamètre de houppier et de diamètre à la hauteur de poitrine (DHP). En fonction des hauteurs, la végétation présente une structure en « U » renversé. Ces résultats pourraient servir de référence pour la recherche de stratégies de valorisation et de gestion durable des parcs à *B. aegyptiaca* dans la zone soudano-sahélienne du Cameroun.

***Mots clés :*** *Balanites aegyptiaca*, Exploitation, Extrême-Nord, Parc, Gestion durable

## INTRODUCTION

In Sahelian countries, agroforestry species such as *Balanites aegyptiaca* play a fundamental role in the food and nutritional security of farmers through non-timber forest products and wood production (Larwanou, 2005; Adamou et al. 2020). *B. aegyptiaca* is a multipurpose tree, widespread in dry tropical Africa (Boffa, 2000). Among all forest products, firewood remains the most commonly used domestic fuel in Africa (Fosa, 2003; Habou et al. 2020). The leaves, flowers and young twigs are cherished in cooking. The fruit pulp with a bittersweet taste is sucked like candy. Its drupes marketed by women are also macerated in water and replace sugar in palp (Idrissa et al. 2012; Abdoulaye et al. 2017). They extract almonds, an oil for cooking and making soap. The fruits, leaves and twigs are enjoyed by livestock. The solid and resistant wood is a fuel with a high calorific value and is used for fences, in the manufacture of mortars, pestles, Koranic tablets and tool handles (Ganaba et al. 2004; Doulane, 2014; Habou , 2019). The local populations find in the ligneous stratum fruits and supplementary foods, medicines, a source of energy, materials essential for the manufacture of objects for everyday use and a substantial increase in the income of disadvantaged households (Belem et al. 2008; Mapongmetsem et al. 2012). This situation leads to overexploitation of multiple-use trees, resulting in the regression of many woody species such as *B. aegyptiaca* (Tchobsala et al. 2003; Noubissie-Tiagam et al. 2011). However, *B. aegyptiaca* parks constitute a large reservoir of carbon sequestration. The involvement of this local species in food, traditional care and the creation of income for populations is well established (Chevalier et al. 2004; Mapongmetsem et al. 2010). This is why, haven been overexploited, it is now threatened with extinction and its weak regeneration associated with unsustainable harvesting practices for its products is accelerating the process of disappearance. Although *B. aegyptiaca* is ecologically considered as a resilient species adapted to different types of soils and to varied climatic conditions (Elfeel and Warrag, 2011), the risks of decreasing the potential tree production are real. Indeed, all parts of the plant (roots, leaves, fruits, thorns, wood) are used for food, therapeutic, economic or socio-cultural purposes (Elfeel and Warrag, 2011; Chahad et al. 2015). Due to high demands, *B. aegyptiaca* is thus subject to permanent anthropogenic pressure to which are added environmental challenges that dangerously threaten its survival. Overexploited, threatened by fires, overgrazing and drought, this species is in sharp decline in the Sudano-Sahelian zone of Cameroon. This study aims to characterize *B. aegyptiaca* parks and to show the local exploitation of its products in the Sudano-Sahelian zone of Cameroon.

## MATERIALS AND METHODS

### *Study sites*

The study was conducted in four Sub-Divisions of the Far North Region, located in the Sudano-Sahelian zone of Cameroon, with geographical coordinates of 10°30”0’00N and 11°12”0’00N of latitude North and 13°54”0’00E and

15º18”0’00E longitude East (Figure 1). The study area covers Moutourwa and Mindif Sub-Divisions in Mayo-Kani Division, Pette Sub-Division in Diamare Division and Kalfou Sub-Division in Mayo-Danay Division. It covers an area of approximately 5,425 km² (MINADT., 2010; Fotsing, 2009). The study area is characterized by a Sudano-Sahelian climatic regime. Rainfall is of the monomodal type with duration and intensity varying on average between 800 and 1000 mm/year (Gerhard, 2003). The average annual temperature is 28º C. The soil is sandy-clayey and sandy. The plant formation is of the Sudano-Sahelian type characterized by steppe dominated by thorny shrubs and by its extreme fragmentation due to natural conditions and human actions. The population of the area is estimated in 2005 at approximately 249,285 inhabitants (BUCREP, 2005). The main economic activities carried out are agriculture, trade, livestock and handicrafts.

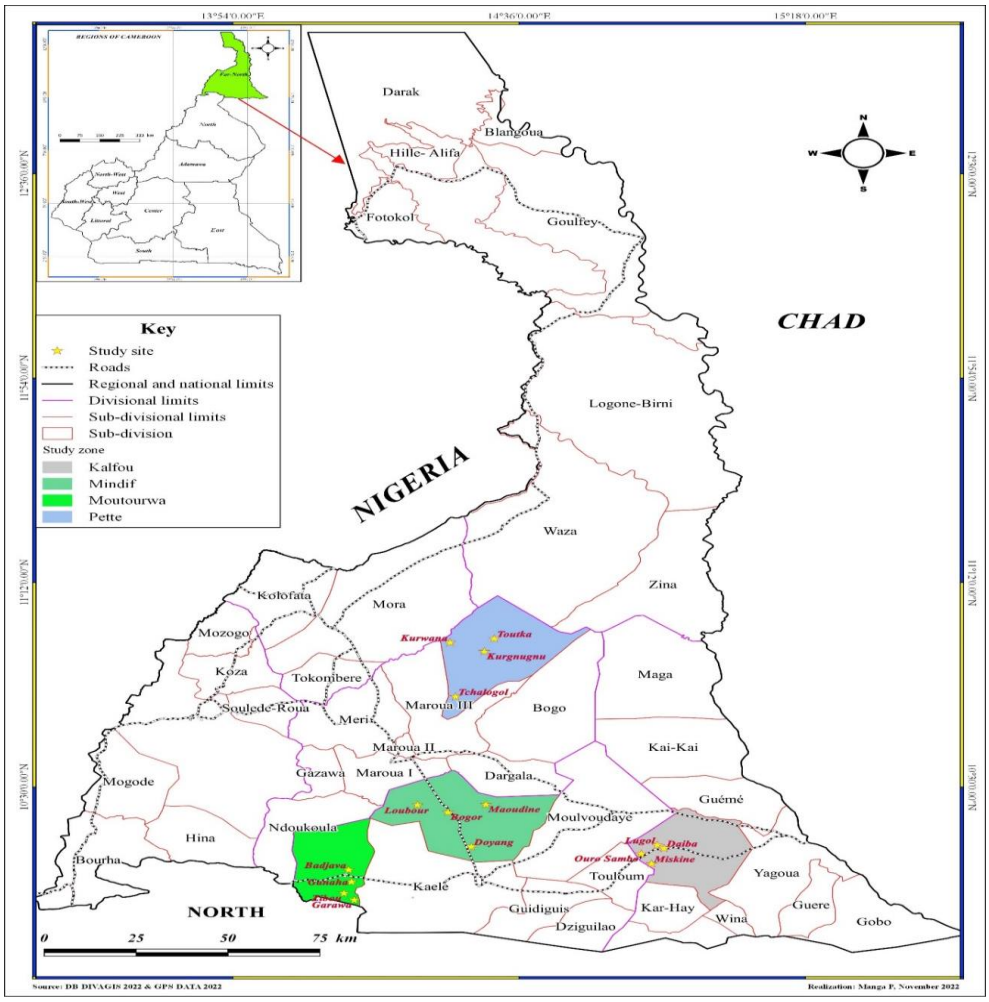


Figure 1. Location map of the study area

***Technical material***

The technical equipment used includes a global positioning system (GPS) which is used to take geographical coordinates; a digital camera, used to take photos of anthropogenic traces or rare or unidentified species.

***Methodological approach***

To achieve the objective of this work, investigations were carried out in two phases. The first phase consisted in carrying out ethnobotanical surveys among the populations in the villages bordering the *B. aegyptiaca* parks and among those involved in the exploitation of natural resources, to assess and determine the importance, causes and consequences of the exploitation of non-timber forest products in *B. aegyptiaca* parks. The second phase consisted in carrying out a floristic inventory and a count of the individuals of the existing species in the *B. aegyptiaca* parks.

***Ethnobotanical survey***

The assessment of the population's perception of the exploitation of non-timber forest products (NTFPs) from *B. aegyptiaca* parks was based on ethnobotanical surveys supplemented by direct observations in the field (Tchobsala, 2011). These surveys were carried out on the basis of questionnaires previously established in survey sheets (Martin, 1995). They were carried out in the different districts (Kalfou, Mindif, Moutourwa and Pette). The interview used is of the semi-structured type comprising closed questions (which are answered with yes or no), open-ended (which are answered deliberately according to one's point of view) and guided (some answers of which are offered to the respondents). In total, 400 people aged at least 15 years were chosen according to their knowledge of *B. aegyptiaca*, ie 100 people in each Sub division. The populations questioned are those of the villages surrounding the *B. aegyptiaca* parks. The Accelerated Method of Participatory Research (MARP), was used to achieve this objective. It is based on questionnaires administered to populations on the exploitation of *B. aegyptiaca* products and the management of these resources. The methodology adopted is a participatory approach described by Guedje (2002) which consists of structured and semi-structured interviews with populations exploiting the natural resources of *B. aegyptiaca*. The people surveyed are interviewed individually on the basis of a questionnaire based on the following points: knowledge of *B. aegyptiaca*, the modes of exploitation of *B. aegyptiaca* resources, plant parts exploited, quantities of products collected, collection periods, the social and economic importance of the products collected for the populations (food and marketing) and the income generated (Froumsia, 2012).

***Floristic survey***

The evaluation of the floristic composition of *B. aegyptiaca* parks was carried out thanks to floristic surveys. Inventories were conducted from July to October 2022, in *B. aegyptiaca* parks. The experimental design is a split-plot (4 x 4) where the Sub-divisions (Kalfou, Mindif, Moutourwa and Pette) constitute the main treatment. The villages of the *B. aegyptiaca* parks chosen in each of the four Arrondissements (four villages per Arrondissement) serve as secondary treatment. The choice of these villages depends on their representativeness in all the Sub-divisions, the presence of *B. aegyptiaca* parks and according to the four cardinal points. The 100m x 100m plots in each park are considered replicates (Tchobsala et al. 2016); Abdoulaye et al. 2017). A total of 80 hectares were explored i.e 20 hectares per Sub-division. A 250 m long string was used to demarcate these plots, including a labeled stake attached to each of the four corners. Each site was prospected then the samples were taken by the method of floristic survey carried out meticulously on 10 strips 10 m wide and 100 m long (figure 2) one after the other using a double decameter or a graduated rope for the delimitation of these lines (Tchobsala, 2011; Haiwa, 2017). In each plot, all woody plants with 10cm of diameter at 1.30 m high were inventoried. Their total height and the diameter of their crown were measured using a graduated pole and tape measure respectively. For species not identified in the field, images are taken using a digital camera or a plant organ sample (stems, leaves, flowers or fruits) is taken for identification at the herbarium or by experts like Tchobsala et al. (2018).

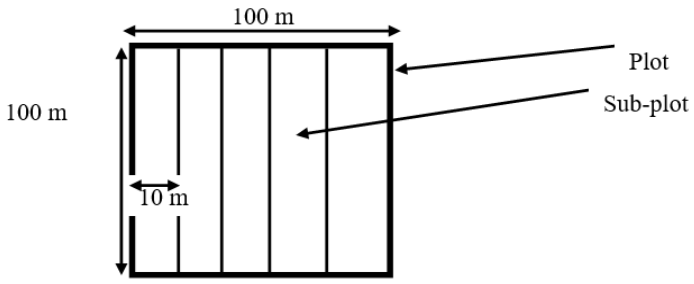


Figure 2. Plan of floristic survey

**Data processing**

***Calculations of diversity indices***

The Shannon Wiener Index was calculated using the following formula:

$$H' = -\Sigma\, ni/N \log 2\ ni/N,$$

*Where H' is the Shannon diversity index, ni is the number of individuals of species i and N is the total number of individuals of all species combined.*

From this index, the evenness of Pielou (E) was calculated according to the following formula:

$$E = H'/ \log 2N,$$

*Where H' is the Shannon-Weaver diversity index and N is the number of species.*

The percentage of each category of use was calculated according to the following formula as done by Nabila et al. (2012):

$$C = \frac{n}{N} \times 100,$$

*Where C is the percentage of a given category, n is the number of people who gave a positive response for a species i and N, the total sample size.*

***Statistical analysis***

One-way analysis of variance (ANOVA) was used to compare *B. aegyptiaca* parks, followed by Duncan's test at the 5% threshold for comparison of means. The specific distribution of species in the parks and their correlation were carried out using principal component analysis of the variables. These tests were performed using EXCEL 2016 spreadsheet and XLSTAT 2007 software.

## RESULTS

***Plant products of Balanites aegyptiaca and their areas of use***

Several plant products are exploited in *B. aegyptiaca* parks. These are both timber products (PL) and non-timber forest products (NTFPs). Non-timber forest products are fruits, leaves, seeds, bark, root and fodder. The wood products exploited in the parks are firewood and service wood (Table 1). These plant organs of *B. aegyptiaca* are highly appreciated by local populations. These plant products are very important and of diverse uses. They are mainly used as food (leaves (100%), fruits (98.19%) and seeds (90.06%)); some are used in livestock feed (fodder (94.48%)) and others (bark (8.31%), root (37.38%), fruits (12.73%) and seeds (24.55%) are used in traditional human and veterinary medicine to treat several diseases (malaria, rheumatism, typhoid, cancers, hepatitis, tuberculosis, etc.) Firewood is used 100% for domestic energy purposes and service wood is used for construction (81.09%) of houses and sheds, for the manufacture of handicrafts and tool handles. A good part of these products is marketed to make money (leaves (99.81%), energy wood (96.57%) and fruit (89.58%).

Table 1. Products exploited and their use (%).

| Products | Human nutrition (%) | Cattle nutrition (%) | Medicine (%) | Energy (%) | Construction (%) | Commercialisation (%) |
|---|---|---|---|---|---|---|
| **Fire wood** | - | - | - | 100 | - | 96.57 |
| **Service wood** | - | - | - | 34.61 | 81.09 | 75.87 |
| **Bark** | - | - | 8.31 | - | - | 2.65 |
| **Leaves** | 100 | 97.77 | 27.89 | - | - | 99.81 |
| **Feed** | - | 94.48 | - | - | - | |
| **Fruits** | 98.19 | 94 | 12.73 | | - | 89.58 |
| **Grains** | 90.06 | - | 24.55 | - | - | 57.39 |
| **Roots** | - | - | 37.48 | - | - | - |

***Socio-economic use of products exploited on Balanites aegyptiaca***

Non-timber forest products and timber products harvested from parks are used for consumption, marketing and given as gifts to relatives, acquaintances and friends in varying proportions (Figure 3). The annual quantity of non-timber product and wood products used in consumption represents 98.19%, the quantity that goes into marketing is 91.67% and the quantity supplied represents a small proportion (18.65%). The quantities of products that enter into different transactions (consumption, marketing and supply) determine the social and economic character of the different non-timber forest products and timber products harvested in *B. aegyptiaca* parklands. The social character is translated by the quantities of products offered to acquaintances and relations who are not in close contact with the bush and who do not have access to these products. Giving as a gift represents a significant symbolic sign in African

society. These gestures help to strengthen family and friendly ties between different people. The state of poverty of the farmers means that most of the products collected are marketed. The marketing of these products allows poor local farmers to generate substantial income for their small needs. In general, the exploitation of plant genetic resources of *B. aegyptiaca* is the first factor in the destruction of plant cover in parks.

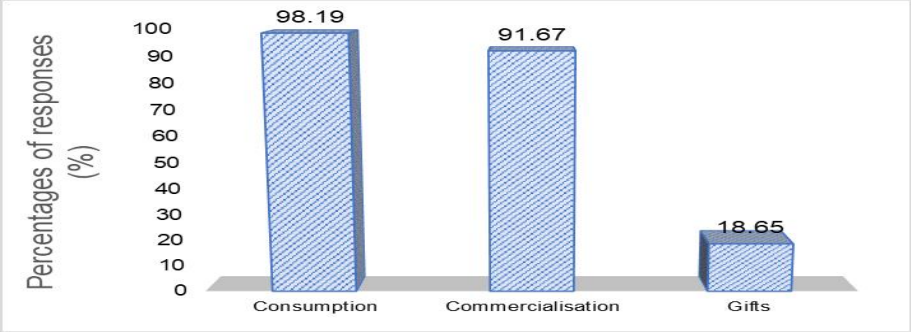


Figure 3. Usage of different non-forest products of *B. aegyptiaca*

***Use of different non-timber forest products of B. aegyptiaca***

The vast majority of plant genetic resources exploited in *B. aegyptiaca* parks are non-timber forest products. These are leaves, fruits, seeds, root, bark and fodder (Figure 4). These non-timber forest products exploited in the parks are used much more in consumption (leaves (96.44%), fruits (77.87%) and seeds (65.76%)). After consumption, the exploited products are intended for marketing (leaves (73.81%), fruits (44.64%) and seeds (33.87%)). In addition to consumption and marketing, non-timber forest products are also offered (leaves (14%), fruits (23.15%) and seeds (7.22%)) to relatives and acquaintances who are not in contact with *B. aegyptiaca*. These different plant genetic resources are appreciated by local residents and are a source of income for farmers.

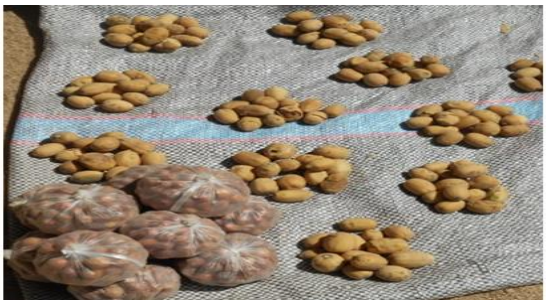

Photo 1. Fruts of *B. Aegyptiaca marceted*

Photo 1. Base sleeve sculptor

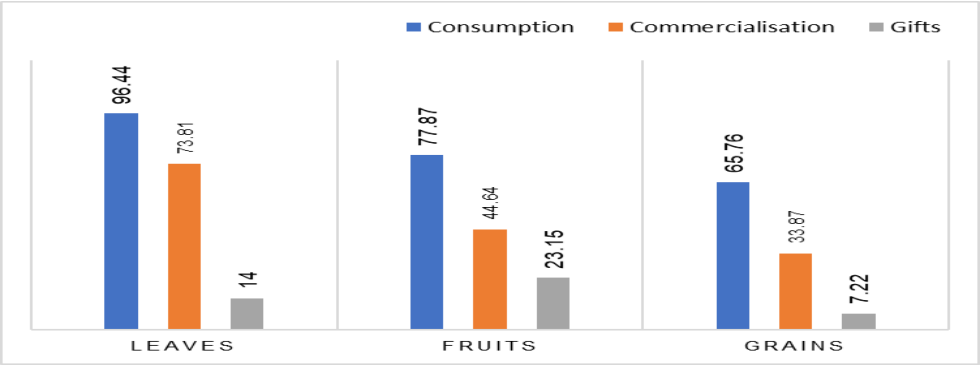


Figure 4. Destination of non-timber forest products (NTFPs)

**Seed transformation process ("Pouyadi") of *Balanites aegyptiaca***

The final *B. aegyptiaca* sheath product called "pouyadi" in Fulfulde comes from a long traditional procedure of preparing these *B. aegyptiaca* seeds. Seed processing of *B. aegyptiaca* is usually done by women. The preparation of the final consumable product follows 5 or 6 steps:

- the collection of ripe fruits: the ripe fruits are collected from the ground by the operators from the feet of *B. aegyptiaca*;
- crushing of the fruits in order to extract the seeds: the kernel of the ripe fruits are crushed using stones in order to collect the seeds.
- skinning of the integuments: this is done by scalding at 100°C in order to rid the seeds of their integuments;
- cooking: once the integuments have been skinned, the seeds are boiled for a long period of time (approximately 6 hours), during which the cooking water is replaced several times; this is to eliminate the characteristic bitterness of *B. aegyptiaca* seeds;
- soaking: after cooking, the seeds are soaked in much water for a day where the water is also replaced several times to further eliminate the very bitter taste of the seeds. At the end of this operation, the prepared seeds are well washed and ready to be dried;
- drying: the seeds obtained from the soaking operation are less bitter. They are exposed and dried in the sun.

At the end of these different stages, the seeds (pouyadi in Fulfuldé) of *B. aegyptiaca* are ready to be consumed and marketed.

Photo 3. Final product of *B. aegyptiaca* seeds ("pouyadi")

***Used parts of Balanites aegyptiaca***

The results of the surveys show that almost all the organs of *B. aegyptiaca* are used by local residents. These include fruits, leaves, bark, roots, seeds, thorns, and wood (Figure 5). The different category uses are food (human and animal), medicinal, non-food (handicrafts, wood for service, energy) and commercial. The leaves of Balanites present (100%) usage just like its wood (100%) which are used much more than the fruits (95.88%), seeds (90.53%), roots (14.72%), thorns (6.73%), barks (2.27%). The harvesting of plant organs is carried out throughout the year, but with a predominance in the dry season. For fruits and seeds, picking is cited as the harvesting method. While for the leaves, the cutting of the branches is indicated as a method of harvesting using machetes and hooks.

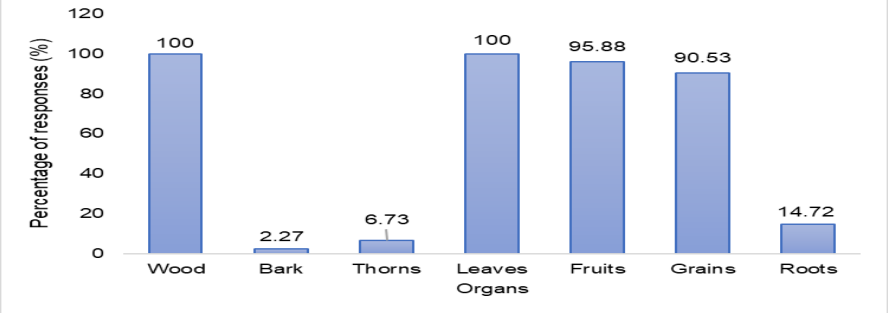


Figure 5. Use of different parts of *B. aegyptiaca*

***Marketing of B. aegyptiaca products***

The most traded *B. aegyptiaca* non-timber forest products in rural and urban markets are leaves, seeds and fruits, respectively (Table 2). The marketing of these products is mainly carried out by women in all localities. Of all the plant organs of *B. aegyptiaca*, the leaves are the most traded in the study area (71.43%). The unit of measure for selling leaves is the bowl. The selling price of a bowl varies between 50 and 100 FCFA between February and April which is the period of large quantity production and from 150 to 250 F between May and January which is the period of scarcity of *B. aegyptiaca* leaves. The seeds are the second product to be marketed in the four Sub-divisions. The unit of measurement for the seed is the glass or the bowl. The selling price of seeds varies according to the unit of measurement (glass or bowl), but also according to the nature of the seeds (raw or prepared). During the production period (March-April), the price of a glass of unprepared seed varies from 100 to 150 FCFA and a cup of seeds of the same nature costs between 1000 and 1200 FCFA in the same period.

However, the price of a glass of prepared seeds varies between 200 and 300 FCFA during the production period, while the price of a bowl of prepared seeds costs between 2000 and 2500 FCFA. Very few respondents made mention of the fact that traditional oil used in cooking, cosmetic and therapeutic care can be extracted from the seeds of *B. aegyptiaca*. The fruits of *B. aegyptiaca*, sucked like candy, are also sold by farmers in various markets. For fruits, the unit of measure is fruit count, glass and bowl. On the market, four fruits of *B. aegyptiaca* are sold at 25 FCFA; a glass of fruit costs 50 FCFA and a bowl of *B. aegyptiaca* fruit is sold between 100 and 150 FCFA. According to the operators surveyed, the average annual income from the sale of all non-timber forest products of *B. aegyptiaca* varies between 20,000 and 30,000 FCFA.

Table 2. Sale of *B. aegyptiaca* products

| Nature of product | Periods | Unit of measure | Unit price (FCFA) | Wholesale price (FCFA) |
|---|---|---|---|---|
| Service wood | - | Unit | 500 to 1000 | 400 to 800 |
| Bundle of firewood | - | Bundle | 200 to 500 | 150 to 400 |
| Leaves | Production | Bowl | 50 and 100 | 25 to 75 |
| | | Bag | 2500 to 3000 | 2000 to 2500 |
| | Scarcity | Bowl | 150 to 250 | 100 to 200 |
| | | Bag | 5000 to7000 | 4000 to 5000 |
| Fruits | Production | Glass | 50 | 25 |
| | | Bowl | 100 to 150 | 50 to 100 |
| | Scarcity | Glass | 150 to 200 | 100 to 150 |
| | | Bowl | 200 to 300 | 150 to 200 |
| Raw grains | Production | Glass | 100 to 150 | 75 to 100 |
| | | Bowl | 1000 to 1200 | 800 to 1000 |
| | Scarcity | Glass | 200 to 300 | 150 to 250 |
| | | Bowl | 2000 to 2500 | 1500 to 2000 |
| Prepared grains | Production | Glass | 200 to 300 | 150 to 250 |
| | | Bowl | 2500 to 3000 | 2000 to 2500 |
| | Scarcity | Glass | 300 to 400 | 250 to 300 |
| | | Bowl | 2000 and 2500 | 1500 to 2000 |

Photo 4. Fruits of *B. aegyptiaca* on sale

***Characterization of B. aegyptiaca parks***

***Floristic composition and species richness of the parks***

Plant species are diversified in the different *B. aegyptiaca* parks. The Garawa site in Moutourwa Sub-division is the richest in taxonomic diversity, with 20 species, divided into 14 genera and 11 families (Table 3). In this park, the Mimosaceae family is the most diversified with 6 species, i.e. 30% of the total number of species on this site. It is followed by the Combretaceae family with 3 species, or 15%. For the genera, Acacia is the most diversified with 4 species, or 28.57%. Eleven (11) plant genera are monospecific in this site, i.e. 78.57%. Daiba Park located in Kalfou Sub-division is monitored with 19 species. These 19 listed species are divided into 14 genera and 10 families. The Mimosaceae family is the most diversified with 3 species, or 52.63%. Four families (Anacardiaceae, Celastraceae and Loganiaceae) are represented by a single species. The Capparis genus is the most diversified with 3 species, or 33.33%. On the other hand, *B. aegyptiaca* park of Ourosambo located in Kalfou Sub-division is the lowest in specific diversity with 9 species, divided into 7 genera and 6 families. The Capparaceae family is the most diversified with 3 species, or 33.33%. Regarding the genera, Capparis is the most diversified with 3 species, i.e. 42.85%. Four families are monospecific, i.e. 66.66%. The other parks have an intermediate specific diversity, with the number of species varying from 10 species (Doyang site) to 18 species (Toutka site).

Table 3. Taxonomic diversity of *B. aegyptiaca* parks

| | Da | | LO | | Me | | Ou | | Bo | | Do | | Lu | | Ma | | Ba | | Ga | | Gr | | Zi | | Ku | | Kr | | Tc | | To | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Families** | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E | G | E |
| **Anacardiaceae** | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Annonaceae** | | | 1 | 1 | | | | | | | | | | | | | | | | | 1 | 1 | 1 | 1 | | | | | | | | |
| **Bignoniaceae** | | | | | | | | | 1 | 1 | | | 1 | 1 | | | | | | | | | | | | | | | | | | |
| **Burseraceae** | 2 | 2 | 2 | 2 | 1 | 1 | | | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 | 1 |
| **Caesalpiniaceae** | 2 | 2 | 3 | 3 | 1 | 1 | | | 1 | 1 | 1 | 1 | 2 | 2 | | | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Capparaceae** | 2 | 2 | | | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 4 | 5 | 3 | 3 | | | 2 | 4 | 2 | 5 | 3 | 2 | 3 | 5 | | | 2 | 5 | 3 | 5 |
| **Celastraceae** | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Combreaceae** | 2 | 5 | 2 | 3 | 2 | 3 | 1 | 1 | | | 1 | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 1 | 2 | | | 1 | 6 | 1 | 2 | 2 | 3 | 1 | 3 | 2 | 3 |
| **Ebenaceae** | | | 1 | 1 | 1 | 1 | | | 1 | 1 | | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Euphorbiaceae** | | | | | | | | | | | | | 1 | 1 | | | | | | | 1 | 1 | | | | | | | | | | |
| **Fabaceae** | | | | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | |
| **Loganiaceae** | 1 | 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Mimosaceae** | 1 | 3 | 1 | 4 | 1 | 3 | 1 | 2 | 1 | 3 | 1 | 4 | 1 | 3 | 1 | 4 | 1 | 1 | 1 | 3 | 3 | 6 | 2 | 4 | 1 | 3 | 1 | 1 | 1 | 3 | 1 | 3 |
| **Phyllantaceae** | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | | | | | | | |
| **Rhamnaceae** | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 2 | 1 | 2 |
| **Rubiaceae** | | | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | |
| **Sterculaceae** | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | | | | | |
| **Zygophylaceae** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **Total** | 14 | 19 | 13 | 17 | 12 | 16 | 7 | 9 | 12 | 14 | 10 | 15 | 14 | 19 | 11 | 15 | 10 | 11 | 11 | 16 | 14 | 20 | 13 | 19 | 12 | 17 | 8 | 9 | 11 | 19 | 12 | 18 |

*Da: Daiba; Lo: Lougol; Me: Meskine; Or: Ourosambo; Bo: Bogor; Do: Doyang; Read: Loubour;Ma: Maoudin; Ba: Badjava; Ga: Ganaha; Gr: Garawa; Zi: Zibou; Ku: Kurgnogno; Kr: Kurwana; Tc: Tchalogol; To: Toutka; G: Gender; E: Species.*

***Biodiversity indices of B. aegyptiaca parks***

The calculated Shannon diversity index varies between parks (Table 4). It varies from 1.77 bit in the *B. aegyptiaca* park of Ourosambo located in Kalfou Sub-division to 2.86 bit in the site of Maoudine located in Mindif Sub-division. This index is low for all parks, less than 3 bits. As for the Equitability of Pielou, it varies from 0.17 in the park of Bogor in the Sub-Division of Mindif to 0.45 in the park of Daiba in Kalfou Sub-division.

Table 4. Diversity index and equitability of Pielou in *B. aegyptiaca* parks

| Sub-Divisions | Sites | Shannon index | Equitability de Pielou |
|---|---|---|---|
| Kalfou | Daiba | 2.41 | 0.45 |
| | Lougol | 2.31 | 0.19 |
| | Meskine | 2.62 | 0.24 |
| | Ourosambo | 1.77 | 0.23 |
| Mindif | Bogor | 2.18 | 0.22 |
| | Doyang | 1.84 | 0.25 |
| | Loubour | 2.26 | 0.36 |
| | Maodine | 2.86 | 0.28 |

| | | | |
|---|---|---|---|
| Moutourwa | Badjava | 2.55 | 0.37 |
| | Ganaha | 2.20 | 0.32 |
| | Garawa | 2.14 | 0.24 |
| | Zibou | 2.50 | 0.36 |
| Pette | Kurgnogno | 2.40 | 0.27 |
| | Kurwana | 2.08 | 0.40 |
| | Tchalogol | 2.25 | 0.28 |
| | Toutka | 2.37 | 0.33 |

***Vegetation structure in crown diameter classes***

The vegetation in *B. aegyptiaca* parks has an "L" structure, reflecting the dominance of individuals with a small crown diameter (figure 6). In *B. aegyptiaca* parks, plant individuals whose crown diameter is less than 1 m are the most numerous with 3852 ind/ha or 21.14% of the total population, followed by individuals with a diameter between 1 and 2 m with 3253 ind/ha or 17.85% of the total population. Individuals whose crown diameter is between 2 and 3 m come next with 2838 ind/ha or 15.57% of the total population. Plant individuals whose crown diameter is greater than 10 m are the lowest with 311 ind/ha or 1.71% of the total population. They are followed by individuals whose crown diameter is between 9 and 10 m with 447 ind/ha or 2.45% of the total park population.

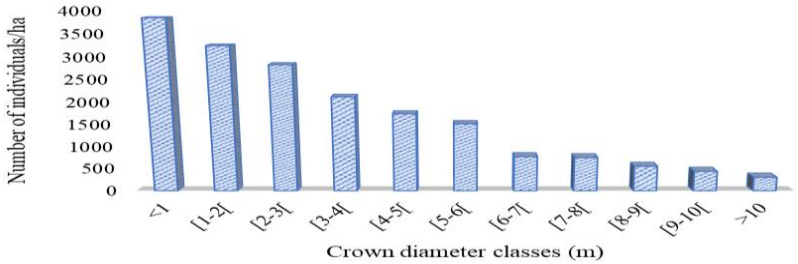


Figure 6. Proportion of individuals according to crown diameter classes

***Vegetation structure according to height classes***

Analysis of the height class structure of *B. aegyptiaca* beds gives the frequencies of individuals by height class in the study area (Figure 7). In the parks, the majority of populations of *B. aegyptiaca* have a height between 4 and 6 m with a number of individuals of 4188 ind/ha, i.e. a rate of 22.98%, followed by individuals of the class whose size varies between 6 and 8 m with a percentage of 18.51% of the population, or a number of individuals of 3373 ind/ha. Individuals from 8 to 10 m in height come next and represent 14.84% of the park population. However, 4.89% of individuals can reach an optimal height of more than 14 m, or 891 ind/ha of the total population.

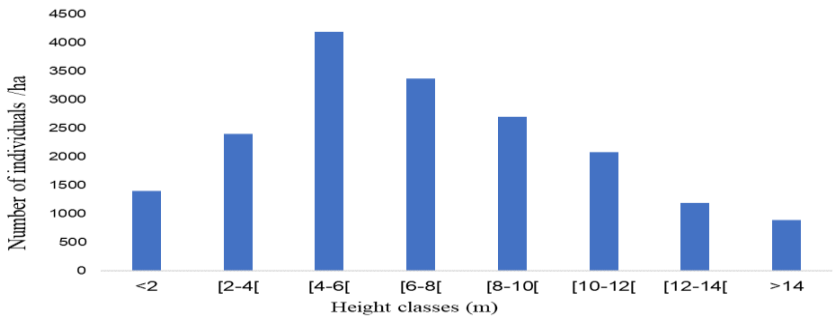


Figure 7. Proportion of individuals according to height classes

***Vegetation structure according to diameter at breast height (DBH) classes***

Figure 8 presents the distribution of individuals according to DBH. The vegetation in the parks has an "L" structure, which reflects the domination of the majority of individuals of small DBHs. Plant individuals whose DBH is less than 10 cm are the most numerous with 3676 ind/ha or 20.17% of the total population, followed by individuals with

a DBH between 10 and 20 cm with 3058 ind/ha or 16, 78% of the total population. Individuals whose DBH is between 20 and 30 cm come next with 2489 ind/ha or 13.66% of the total population. Plant individuals whose DBH is between 80 and 90 cm are the least numerous with 605 ind/ha or 3.32% of the total population.

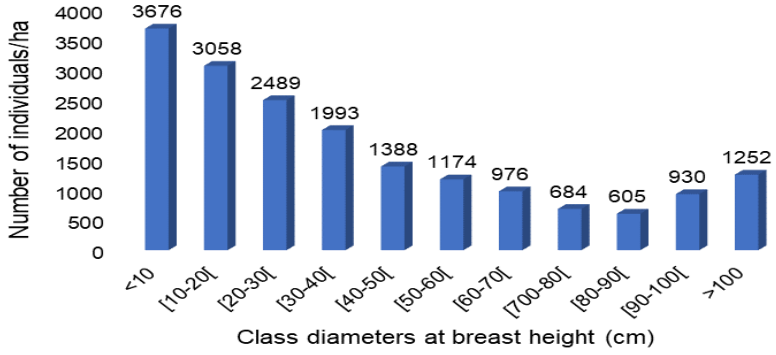


Figure 8. Proportion of individuals according to diameter classes at breast height.

**Discussion**

***Local exploitation of Balanites aegyptiaca products***

The populations of the study area know the products of *B. aegyptiaca* well since they designate them by different names from their local dialects. This knowledge of the organs of *B. aegyptiaca* by the different ethnic groups has also been reported by Abdoulaye et al. (2017) by studying the socio-economic and cultural utilities of *B. aegyptiaca* (L.) Del. (Family Zygophyllaceae) in local populations of the Ouaddaï region in Chad. The importance of knowledge of the products and their uses varies with the tribes as shown by Adamou et al. (2020) in their studies carried out on the characterization of the population of *B. aegyptiaca* (L.) Del and the perception of its socioeconomic potential in the southwestern part of Niger. Our results show that leaves (100%), fruits (98.19%) and seeds (90.06%) are the most used organs. This study has identified several areas of use of non-timber forest products of *B. aegyptiaca*, thus contributing to the development of local communities and that these products are much more used respectively in consumption (98.19%), marketing (91.67%) and as gifts (18.65%). These results are similar to those of Froumsia, 2012 and those of Abdourhamane et al. (2013) who showed that *B. aegyptiaca* products are used as food and marketed. The therapeutic properties of this species, given by the peasants and traditional healers of the study area, are presented as solutions to major ailments such as stomach aches, rheumatism and intestinal worms. Similar results were equally reported by Mamadou et al. (2017) and Habou et al. (2019) who demonstrated that the organs of *B. aegyptiaca* are used to treat nerve attacks, hemorrhoids, stomach aches, jaundice, measles, epilepsy, chronic wounds, abscesses and jaundice. The results of this study showed that *B. aegyptiaca* products like the seed are transformed into end products that are more consumable. The same results were obtained by Froumsia, 2012. Non-timber forest products from *B. aegyptiaca* play a very important role in human nutrition and are a source of income for farmers. These results confirm those of Abdourhamane et al. (2013) and Abdoulaye et al. (2017) who demonstrated that *B. aegyptiaca* plays a significant role in human and animal nutrition. According to Habou et al. (2020), *B. aegyptiaca* through its leaves and fruits compensates for food deficit during the dry season, and therefore contributes to food security of animals but also of the human population exposed to various shocks. Similarly, the results of the work of Yameogo et al. (2016) in agroforestry parks of Borassus in central western Burkina Faso and Habou et al. (2020) in central western Niger, confirm the importance of *B. aegyptiaca* products in nutrition and in providing income to farmers. The marketing of *B. aegyptiaca* products generates variable monthly and annual income for farmers. The sustainable exploitation of *B. aegyptiaca* parklands remains of great interest to its users in the Far North Region of Cameroon.

***Floristic composition and species richness of parks***

The distribution of species varies significantly within parks. The difference observed between parks could be explained by the extent of anthropic actions of the local populations on the one hand and by climatic amplitudes between the parks on the other hand. The Garawa site is the richest, located in the urban center of the Moutourwa Sub-division, thus the exploitation of natural resources (wood, NTFPs) is less accentuated and agriculture is very little practiced. On the other hand, the *B. aegyptiaca* park of Ourosambo is the poorest, located in Kalfou Sub-division is found in the bush, therefore exposed to abusive exploitation and overgrazing. Indeed, in this area, abusive

exploitation of natural resources (timber and NWFPs) associated with agriculture which indirectly destroys the vegetation (Hamawa, 2015), leading to deforestation are very common. These practices inevitably lead to the disappearance of plant species (Tchobsala, 2003). It is for this reason that low taxonomic diversity is recorded in this site. These results are similar to those of Hamawa (2015) who observed in his study entitled ethnobotanical and ecological study of *Vepris heterophylla* (Engl.) Letouzey in the Sudano-Sahelian zone of Cameroon, highlighted that specific composition varies from one area to another depending on their geographic location. On the other hand, our results are different from those of Froumsia (2012) who inventoried 101 species, divided into 71 genera and 36 families in their study entitled impacts of anthropogenic activities on the woody cover in the forest reserve of Kalfou, Cameroon. The difference would be due to the fact that the latter conducted their study in a forest reserve while our study was carried out in environments exposed to anthropogenic activities.

Structures of the vegetation of Parks

The results of this study show that according to the classes of crown diameter, the plant individuals whose crown diameter is less than 1 m are the most numerous with 3852 ind/ha or 21.14% of the total population whereas plant individuals whose crown diameter is greater than 10 m are the lowest with 311 ind/ha or 1.71% of the total population. These results could be explained by the fact that the trees of large crowns undergo anthropic pressures because the branches of *B. aegyptiaca* are cut for livestock fodder. Our results are different from those obtained by Froumsia, 2012, studying the impacts of human activities on the woody cover in the forest reserve of Kalfou, Cameroon. This difference would be due to the fact that the latter worked in a reserve while we carried out our study in exposed and anthropized savannas. On the other hand, our results are similar to those recorded by Adamou et al. (2020), who found in their characterization study of *Balanites aegyptiaca* (L.) Del population and the perception of its socio-economic potential in the southwestern part of Niger that short crown trees are the most numerous.

Depending on the height classes, our study shows that the majority of *B. aegyptiaca* populations have a height between 4 and 6 m with number of individuals per hectare of 4188 ind/ha. These results could be explained by the pressure of overgrazing but also by the needs for service wood and firewood. Small trees are easily browsed by animals and large trees are cut down for tool making and construction. Our results are different from those of Ibrahima, 2019, who demonstrated that individuals of low height are the most numerous in his study entitled socio-economic and environmental impact of the exploitation of Minawao vegetation in Mayo-Tsanaga Division (Far North, Cameroon). This difference would be due to the disparity in study area. The latter conducted his studies in a locality hosting refugees who destroy large individuals for their survival, while our study was conducted in urban and peri-urban areas.

According to the classes of diameter at breast height (DBH), we found that the vegetation of the parks presents an "L" structure which reflects a domination of the majority of individuals of small DBH. These results could be explained by the need for service wood and firewood. Indeed, the trees of large DBH are cut by craftsmen in order to manufacture working tools such as hoe handles and mortars. Trees of this caliber are also cut for marketing but also by women for the fermentation of “bili-bili”. These results confirm those found by Haiwa, 2017, who found an “L” structure by studying the impact of deforestation on the dynamics of vegetation in the Sudano-Sahelian zone of Cameroon. According to this author, the “L” structure indicates good regeneration of young individuals. The same information was obtained by Ibrahima, (2019).

## CONCLUSION

The study of *Balanites aegyptiaca* parks provides necessary information on the exploitation of *B. aegyptiaca* products and the dendrometric parameters of this species. All the plant parts of this plant are consumed, marketed or used in the manufacture of tools and craft materials. The leaves of *B. aegyptiaca* are the most consumed and traded organ. The local populations of the Sudano-Sahelian zone have a good knowledge of the uses of the different organs of *B. aegyptiaca*. The importance of plant products and knowledge of the use of these products are the basis of overexploitation of this species. Individuals of small size and small crown diameter are the most numerous in the parks. Given the importance of *B. aegyptiaca* products for local populations, it would be wise to promote and enhance the processing of *B. aegyptiaca* products. The development of the *B. aegyptiaca* sector and the rational management of its products would allow the sustainability of this species and the development of local communities.

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