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Farmer's perception of the morphological variability of *Balanites aegyptiaca* (L.) Del in Sahelo-Sudanian agrosystems in Western Niger

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Abstract

Balanites aegyptiaca (L.) is one of the priority fruit trees for rural communities in the West African Sahel and plays a multifunctional role in the daily life of the populations. However, very few studies have been done in Niger on the morphological diversity of *B. aegyptiaca* populations particularly considering farmers' perception. The main objective of this study was to identify the morphotypes of *B. aegyptiaca* populations in the southwestern part of Niger. The survey was conducted in the Dosso region. The study revealed that local communities in the study zone have extensive traditional knowledge on *B. aegyptiaca*. Forty-one (41) morphotypes were identified according to farmers' perceptions. Indeed, the local population relies on the observable variations of different parts of the plant, notably the fruits, the leaves, the taste of the fruits and the flowers to classify the morphotypes. Nevertheless, it should be noted that farmers do not combine traits from different parts of the plant to discriminate phenotypes. This poses a serious challenge in the classification of *B. aegyptiaca* by farmers, as the same morphotype can be classified differently according to the socio-professional activity of the respondent. It is therefore necessary to carry out additional molecular analyses to confirm farmers' designations.

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Introduction

Niger is a Sahelian country with very diverse ecosystems. A wide variety of spontaneous fruit plants are used for fruit, wood and various other services. The most commonly used include *Balanites aegyptiaca* L. (Del.), *Borassus aethiopum* Mart, *Vitellaria paradoxa* C. Gaertn, *Hyphaene thebaica* L. (Mart.), *Neocarya macrophylla* Sabine, *Ziziphus mauritiana* Lam, *Adansonia digitata* L., *Parkia biglobosa* Jacq, *Tamarindus indica* L., *Boscia senegalensis* (Pers.) Lam. ex Poir, *Detarium microcarpum* Guill. et Perr., *Vitex doniana* Sweet, *Vitex simplicifolia* Oliv, and *Ziziphus spina-christi* L. (Danjimo *et al.*, 2007). With global warming unequivocal and since the 1950s, many of the observed changes are unprecedented for decades or even millennia (GIEC, 2013) coupled with anthropogenic pressure which severely threatens forest resources (Taylor *et al.*, 2017) as is the case for *Balanites aegyptiaca* (Douma, 2016). Therefore, knowledge of the variability of this species is an option to better adapt sustainable management strategies in degraded ecosystems. *Balanites aegyptiaca* is a species that thrives in the Sahelian and Sudanian zone and develops on all types of soil (Dao, 1993). It is one of the priority fruit trees for rural communities in the West African Sahel and plays a multifunctional role in people's daily lives (Sagna *et al.*, 2014). Very few studies have been conducted in Niger, mainly on the socio-economic importance (Adamou, 2020) and particularly on the morphological diversity of *B. aegyptiaca* populations. The first studies on the morphological diversity of *B. aegyptiaca* are those of Habou *et al.* (2020) based on morphological descriptors of leaves and fruits in south-eastern Niger. There has been no study carried out on the variability of *B. aegyptiaca* according to farmers' perception in Niger as it was done in Chad by Abdoulaye *et al.* (2016). Thus, the main objective of this study was to enhance the knowledge of local communities on the classification and multiplication of *B. aegyptiaca* in Sudano-Sahelian agrosystems in western Niger. Specifically, the aim was to: i.) identify the criteria for identifying morphotypes according to the farmers' approach, ii.) list the morphotypes of *B. aegyptiaca* in the study area, iii.) identify the nature of propagation of *B. aegyptiaca* and the production cycle of *B. aegyptiaca* in the study area.

Materials and methods

Study zone

The study zone covered four (4) departments (Gaya, Dosso, Tibiri and Dogon-Doutchi) of the Dosso region selected to conduct the survey and data collection (Fig. 1). The choice of the Dosso region was made on the basis of the two major agro-climatic zones (the Sudanian zone and the Sudano-Sahelian zone) of the region, characterized by the scarcity of the *B. aegyptiaca* species in the south and its abundance in the north, which will serve as a point of reference for comparing the different variabilities. In each department, three villages from the same commune were selected for data collection, with the exception of the department of Gaya where the three villages came from three different communes due to the unavailability of *B. aegyptiaca* resources.

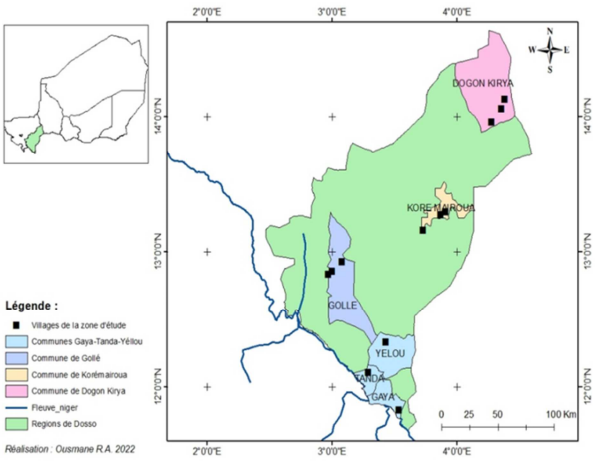

Fig. 1. Geographical location of the data collection zone in the Dosso region

Data collection

The surveys were conducted in twelve villages in the Dosso region in February 2021. In each village, a category of people with socio-professional activities including gathering, sale of fruits, traditional medicine, handicrafts, and processing of *B. aegyptiaca* fruits was targeted. The survey form is a questionnaire whose outline includes: the identity of the site and that of the respondent, the criteria for identifying morphotypes, the types of morphotypes encountered on the site and their characteristics, production, the mode of multiplication and the reproduction cycle. A quota-oriented sampling technique was used in this study. In each of these villages, ten volunteers with professional activities related to the study plant were identified to be interviewed, which will enable relevant information to be collected from the local population. If the number of people interviewed could not be reached, the number of volunteers available would be used. Seventy-six individuals were interviewed in the study area. Interviews were conducted in local languages.

Data analysis and processing

Modality frequencies

The frequencies of the modalities of the different qualitative parameters assessed were determined using the following formula $= \frac{ni}{N} * 100$: (n_i*:* number of occurence*; N: total number of* responding)

Clustering of morphotypes

A dataset with the ethnicities and the morphotypes of *B. aegyptiaca* identified in the Dosso region is used. The Hierarchical Clustering on Principal Components (HCPC) function of the 'FactoMineR' package was used to perform the hierarchical classification of *B. aegyptiaca* morphotypes. These analyses were carried out using the RStudio v 4.2.0.

Results

Identification criteria and morphotypes of B. aegyptiaca

Identification criteria of B. aegyptiaca

Ten criteria for identification of morphotypes (Table 1) were identified in the surveys. Taste of fruit (31.25%), fruit size (31.25%), leaf size (17.86%), and taste of flowers (6.25%) were the most cited criteria while criteria such as, bark color (1.79%), tree height (0.89%), wood hardness (0.89%), and the way the epicarp of the fruit opens (0.89%) were the least cited by the respondents.

Table 1. Criteria for identifying morphotypes

Identification criteria	Quote	Frequency (%)
Wood (fiber alignment)	5	4.46
Wood (hardness)	1	0.89
Bark (colour)	2	1.79
Epicarp (opening)	1	0.89
Spines (quantity / form)	5	4.46
Taste of flowers	7	6.25
Taste of fruit	35	31.25
Tree height	1	0.89
Leaf size	20	17.86
Fruit size	35	31.25
Total	112	100%

Morphotypes of B. aegyptiaca

According to the identification criteria (Table 1), 41 morphotypes are listed. The most cited morphotypes are: Sweet-fruited Balanites (14.40%), Harsh-fruited Balanites (14.40%), Large-fruited Balanites (12.76%), Small-fruited Balanites (12.76%), Broad-leaved Balanites (7.82%), and Small-leaved Balanites (7.82%). No single morphotype was cited by the entire ethnic component. The morphotypes cited by the greatest number of ethnic groups at the same time (three ethnic groups) are four (4): Harsh-fruited Balanites, Sweet-fruited Balanites, Large-fruited Balanites, and Small-fruited Balanites. There classification criteria are: taste and size of the fruits. The morphotypes cited by at least two ethnic groups are ten (10): Balanites with harsh fruits, Balanites with sweet fruits, Balanites with large fruits and Balanites with small fruits, Balanites with harsh flowers, Balanites with sweet flowers, Balanites with whitish trunk bark, Balanites with blackish trunk bark, Balanites with less hard wood, and Balanites with very hard wood.

Grouping of B. aegyptiaca morphotypes

The analysis of the results of the hierarchical principal component classification allowed the classification of *B. aegyptiaca* morphotypes into three groups based on the identification criteria of the

respondents (Fig. 2). The first group, with 35 morphotypes, outnumbered the two other groups, which each had four morphotypes (Fig. 2a). The first group is mixed and classifies morphotypes using a wide range of criteria. These criteria are based on wood fiber alignment, wood hardness, size and quantity of spines, bark colour, quantity of flowers, flower taste, epicarp and pulp structure, fruit and leaf size. The second group is made up of morphotypes of *B. aegyptiaca* with criteria such as: size and taste of fruits. The third group is composed of *B. aegyptiaca* morphotypes based on criteria of flower taste and leaf size. Depending on the zone, three groups of morphotypes can be distinguished according to the characteristics listed by the respondents: a Sudanese group and two Sahelian groups. The first group G1 does not have any specific criteria. Group G2 is characterised by the size of the leaves and group G3 is characterised by the taste of the fruits and flowers (Fig. 2b).

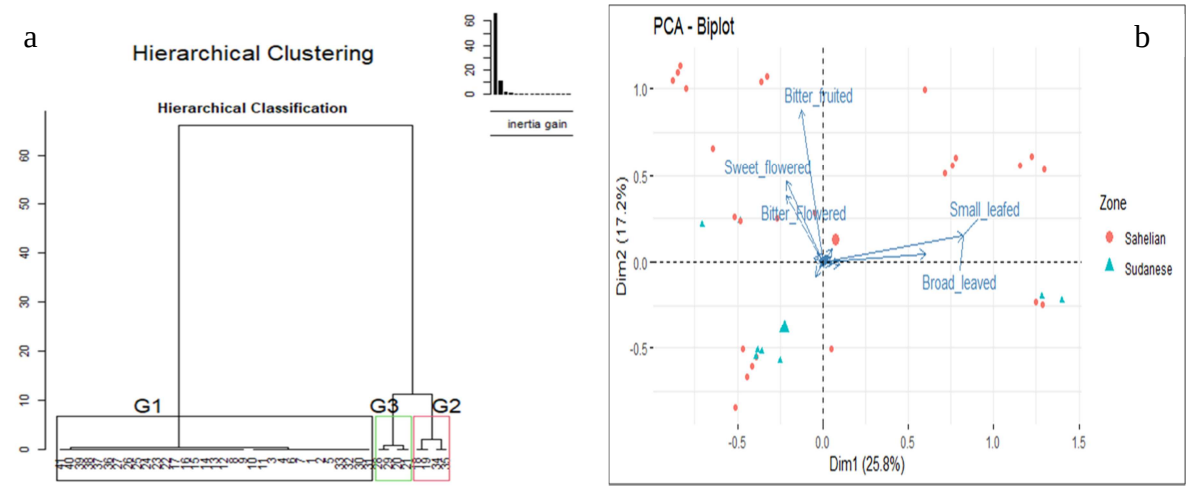

Fig. 2. Groups of *B. aegyptiaca* morphotypes according to identification criteria

Table 2. Characteristics of *B. aegyptiaca* fruits encountered in the study area

Characteristics of the fruits	Work force	Frequency (%)
Fruit shape		
Oblong	35	52.00
Round	30	45.00
Oval	2	3.00
Colour of the pulp		
Red	56	40.00
Blackish-red	15	10.71
Yellowish	4	2.86
Yellow-orange	29	20.71
Whitish	16	11.43
Greenish	20	14.29
Sweetest pulp		
Red	50	78.13
Blackish-red	7	10.94
Yellow-orange	6	9.38
Whitish	1	1.56
Respondents' preferred pulp		
Red	50	78.13
Blackish-red	7	10.94
Yellow-orange	6	9.38
Whitish	1	1.56
Colour of the almonds		
Whitish	40	58.82
Yellowish	26	38.24
Greenish	2	2.94

Characteristics of the fruits of B. aegyptiaca

Three main fruit shapes were recorded during the survey (Table 2): oblong (52%), round (45%), and oval (3%). Six colors were cited for *B. aegyptiaca* pulps with the highest frequencies for red (40%) and yellow-orange (20.71%) and the lowest for yellowish (2.84%) and red-blackish (10.71%). The red pulp is the sweetest (78.13%) followed by the reddish-black pulp (10.94%). The red pulp is the most preferred by the respondents (78.13%). According to the respondents, *B. aegyptiaca* kernels are whitish (58.82%), yellowish (38.24%), and rarely greenish (2.94%).

Multiplication and production campaigns of B. aegyptiaca

Multiplication

Very few people (17%) have knowledge of the practices of propagating *B. aegyptiaca* through seedlings. These seedlings are most often produced in

nurseries before being transplanted to the fields during land reclamation activities. For the rest of the respondents (83%), *B. aegyptiaca* grows in natural conditions (natural regeneration). It multiplies either by seed or by root layering. Depending on the fruiting season (Table 3), there are three types of *B. aegyptiaca*: those with a single fruiting season (42.50%), those with two fruiting seasons (42.50%), and those with continuous fruiting throughout the year (15%). Nevertheless, the respondents acknowledged the existence of Balanites that very rarely produce fruits to the point of thinking that they do not fruit. The 1st production season (November - January) is the most important for 90% of respondents.

Table 3. Frequency of propagation type and production of *B. aegyptiaca*

Multiplication/production *B. aegyptiaca*	Work force	Frequency (%)
Multiplication		
Sowing of cores (in nursery)	15	17.00
Natural regeneration	74	83.00
Annual production campaigns		
One production	51	42.50
Two productions	51	42.50
Continuous production	18	15.00
Major production campaign		
1st campaign	63	90.00
2nd campaign	5	7.00
1st campaign = 2nd campaign	2	3.00

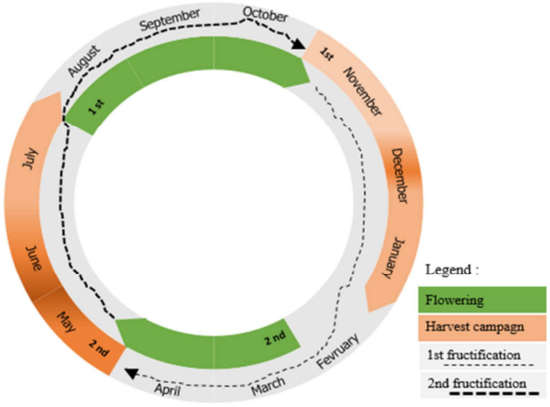

Fig. 3. Fruiting cycle of *B. aegyptiaca* in southwestern Niger according to farmers

Fruiting cycle of B. aegyptiaca

The oldest *B. aegyptiaca* plants have a double annual fruiting cycle (Fig. 3). The duration of the harvesting season varied from 1 to 3 months depending on the locality. The fruiting cycles of the older Balanites overlap. For instance, the first flowering cycle takes place from March to May and the fruit produced after fertilization will reach maturity from November to January in some localities and for some plants. Conversely, the second flowering takes place from August to October. After fertilization, the fruits will reach maturity from May to July depending on the *B. aegyptiaca* plant and the locality.

Discussion

Morphotypes and identification criteria of B. aegyptiaca

Several criteria are used to identify *B. aegyptiaca* morphotypes by the populations of the Dosso region. These criteria vary according to the socio-professional activity of the person surveyed. Some criteria are much more recurrent than others such as: fruit size, fruit and flower taste, and leaf size. Similar criteria were previously used to identify *Detarium microcarpum* morphotypes in southern Mali (Kouyaté, 2002). Based on the list of criteria drawn up, forty-one morphotypes were identified in the Dosso region. The classification criteria of *B. aegyptiaca* used by the respondents allowed the morphotypes to be grouped into three groups. It should be emphasised that this huge number of morphotypes is most often the result of a farmer characterisation according to a single criterion, rarely two at the same time to identify a morphotype. This complicates the naming of morphotypes in farming environments. Recent studies of the genetic diversity of *B. aegyptiaca* carried out in Mauritania have uncovered two distinct groups that are geographically isolated (Abdelaziz *et al.*, 2020). In addition, farmers customarily assign names to Balanites according to their specific needs, emphasizing characteristics such as leaves, flowers, fruits, wood or spines. According to the respondents, two types of fruits are most commonly used in the region. They are oblong and round. As for the colour of the pulp, the most frequently cited colours are red and yellow-orange. The most popular pulp is red. As for the colour of the almonds, they are either whitish or yellowish.

Multiplication and production campaigns of B. aegyptiaca

Several methods are available to revitalize the *B. aegyptiaca* population. In the study area, two methods are being employed. The first method involves multiplication by sowing the nuclei, which is commonly utilized by nurserymen in the premises of environmental departments and by volunteers collaborating with projects for restoration of degraded land in villages. What the population is more aware of is the multiplication of Balanites by natural regeneration through fruits that fall and germinate in optimal conditions or when they are transported to other places by animals (zoochory). The population is also aware of a second mode of multiplication of Balanites at the level of roots which emit numerous stems and some of which generate whole individuals. In very fertile areas, they claimed, the abundance of suckers around the perimeter of the *B. aegyptiaca* crown makes it difficult to plough in cereals. This is one of the reasons why most farmers prefer to have few *B. aegyptiaca* plants in their cereal fields. However, there are other propagation methods such as marcottage of Balanites (Bellefontaine *et al.*, 2005; Zida *et al.*, 2018) which the respondents do not apply to *B. aegyptiaca*.

The annual fruit production of a fruit tree is one of its most distinctive features. *B. aegyptiaca* has the ability to fruit twice a year. This phenomenon of double production system has been reported in Senegal on *B. aegyptiaca* (Dao, 1993) and *Phoenix dactylifera* (L.) in the Sahelian zone (Jahiel, Fortin & INRAN, 1990). However, there are Balanites with a single production season that coincides with the beginning of the harvest in Niger and Balanites with two annual fruitings. The second fruiting season is reserved for older trees under good environmental and climatic conditions. Very good rainfall in the current year would have a good effect on the coming year's production. The second production season takes place at the beginning of the rainy season as soon as the monsoon season starts (May - July). However, according to the respondents, a new group of Balanites has recently emerged. It is a group that fruits continuously throughout the year for a variety of reasons. Firstly, as the old-timers stated, due to climate change, rainfall has greatly varied over the last few decades. There is also the possibility of the introduction of new species of the Balanites genus through the trade of fruits among towns, or even among countries or continents. For instance, respondents stated during an interview that close friends in other countries asked them for *B. aegyptiaca* fruits. This practice could potentially contribute to the dissemination of the genus. In relation to the rate of production between seasons, most respondents claimed that the first production season is more productive in terms of fruit. Single-production Balanites plants are the most abundant as they are generally young plants. According to the respondents in Korémaïroua, there are Balanites that never bear fruit, but do flower; according to them, these are males. The availability of fruit on Balanites is very variable depending on the production season. This aspect is influenced by several parameters including the environment and the intensity of harvesting.

Conclusion

The study was carried out in the Dosso region, which has two agro-climatic zones: the Sudanian zone in the south and the Sudano-Sahelian zone in the north. According to the data collected from the respondents, *B. aegyptiaca* is very diverse. The populations rely on the observable variations of different parts of the plant, notably the fruits, leaves, and flowers to classify the morphotypes of *B. aegyptiaca*, of which there are forty-one in the Dosso region. These morphotypes are organised into three (3) groups. This study confirms that farmers in the Dosso region have ample knowledge about *B. aegyptiaca*. However, it should be noted that these populations do not combine characters from different parts of the plant to distinguish phenotypes. Furthermore, the same phenotype can be classified differently depending on the socio-professional status of the respondent. This could be explained by the low domestication of the plant in all agro-climatic zones of the region. Its basic

classification also reflects its insufficient integration into the fruit tree cultivation system, although it is very useful to the rural population and to that of the large cities, from where the products and by-products of this plant are transported and commercialized. Future investigations should focus on the socio-economic values and the agro-morphological and molecular aspects for a sustainable management of this forest species.

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