Tracing the Tradition: Regional Differences in the Cultivation, Utilization, and Commercialization of Bitter Kola (*Garcinia kola*, Clusiaceae) in Cameroon

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Garcinia kola, known as bitter kola, is a promising multipurpose fruit tree from tropical forests in West and Central Africa. Despite the popularity of the species in folk medicine, very little is known about its management and commercialization. This knowledge might prevent unsustainable collection, overexploitation, and threats to its wild population. Thus, we investigated markets and identified three collection areas in Cameroon among 72 vendors selling bitter kola products. Among 122 purposively selected farmers, we analyzed the uses, management, and economic value of *G. kola* for rural households in these locations. We also documented the morphological characteristics of 227 trees utilized by interviewees. Knowledge of the medicinal properties of bitter kola was similar among all actors involved in the collection and commercialization of *G. kola*. However, the selected regions differed in management, plant part preferences, harvesting practices, and morphological characteristics. We suggest applying sustainable harvesting practices to support the conservation of wild-growing trees, promoting participatory domestication of the species, switching from bark collection to seed gathering, and linking farmers with promising and profitable markets.

Key Words: NTFPs, Conservation, Sustainable harvesting, Markets, Agroforestry, Domestication, Indigenous trees, Underutilized species, West Africa

Introduction

Tropical regions represent one of the richest sources of biodiversity on the planet (Jantan et al. 2015; Valli et al. 2012). Specifically, local rainforests provide various goods and services that play a crucial role in maintaining the livelihood of households. Many valuable species withdrawn from forests are of local importance and have been marginalized by researchers, breeders, and policymakers. These species represent valuable genetic resources with enormous cultural and ecological value (Padulosi et al. 2013). Non-timber forest products (NTFPs) are used particularly in less developed and rural areas in the world, where the majority of the population still depends on traditional remedies. This proves the indispensable function of medicinal plant species in the lives of local people (Cunningham 2001). Apart from

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serving as medicine, many plants also provide socioeconomic benefits through food security and income generation, particularly in periods of scarcity (IPGRI 2003; Kour et al. 2018). Due to the pressure of modern societies and globalization, traditional botanical knowledge and species have begun to disappear. Deforestation, overexploitation, and forest fragmentation are some of the main driving forces behind the declining existence and weakened diversity of traditionally utilized species because they are still in the wild or semi-domesticated phase (Kour et al. 2018; Weber et al. 2009).

Bitter kola (*Garcinia kola* Heckel, Clusiaceae) is an underutilized African indigenous tree species that grows in humid tropical forests from Sierra Leone in the west to the Democratic Republic of Congo in the east and Angola in the south (Agyili et al. 2007; IUCN 2022; Jouda et al. 2016; Onayade et al. 1998; Pérez et al. 2000; Usunomena 2012). Traditionally, the tree has been valued for its medicinal properties but has much more to offer. *G. kola* seeds, whose astringency gave the tree its vernacular name "bitter kola," represent the commercially and culturally most appreciated product, followed by bark and roots. The seeds are usually chewed raw to treat various illnesses, mainly of gastrointestinal nature, suppress inflammation, and fight symptoms of cold, sore throat, and chest pain. Traditional healers also use bitter kola to treat malaria (Adegboye et al. 2008; Ijomone et al. 2012; Onayade et al. 1998). In addition to their medicinal value, bitter kola seeds are also a very popular stimulant consumed by men for their aphrodisiac properties or simply as a snack food (Adaramoye 2010; Fondoun and Manga 2000). The bark and roots of bitter kola are renowned mainly as palm wine additives in Cameroon (Yogom et al. 2020); however, their role in traditional medicine cannot be overlooked (Jouda et al. 2016; Pérez et al. 2000; Usunomena 2012).

G. kola products represent an essential contribution to the livelihoods of many rural households. However, seed prices are volatile and vary with location and the time of year. Farmers cannot sell seeds throughout the year due to a lack of knowledge about their processing and storage (Adebisi 2004; Dah-Nouvlessounon et al. 2016). Moreover, farmers/collectors rarely sell their products directly to customers, losing a significant part of the potential price share (Ndoye 1995; Pérez et al. 2000). As pharmaceutical companies started to be interested in the species, the production of syrups, eyedrops, and herbal pastes and their concomitant distribution over the African market have increased (Adefule-Ositelu et al. 2010; Ilechie et al. 2020). Therefore, growing interest is expected to generate heightened demand for bitter kola seeds, potentially generating higher income for smallholder households. Nonetheless, combined with the invasive method of bark and root collection, the increase in exploitation may threaten tree survival, especially if one continues to rely on wild tree stands (Dadjo et al. 2020; Yogom et al. 2020). Moreover, the threat of *G. kola* extinction must also be seriously considered, because the species is categorized as "vulnerable" on the IUCN Red List (IUCN 2022; Matig et al. 2006; Termote et al. 2012).

Domestication has been recognized as a useful approach for reducing the negative effects of overexploitation (Leakey and Asaah 2011). Domestication and cultivation of bitter kola trees on farms could be sustainable solutions for both protecting the species and meeting the increasing demand for its products (Fondoun and Manga 2000). Effective domestication based on a participatory approach involving farmers and researchers might be the preferable option because this method builds on traditional knowledge and culture while promoting on-farm cultivation of the species to enhance farmers' livelihood and environmental benefits (Leakey 2019; Leakey and Simons 1997; Weber et al. 2009). However, economic value and commercialization trends and behavior data are unavailable at the household level. Moreover, information regarding the traditional medicinal knowledge and cultivation/harvesting patterns of *G. kola* is far from complete. This limits a deeper understanding of the whole range of bitter kola products and their value in different socio-ecological systems. This kind of comprehension would lay the foundation for the species' sustainable utilization, conservation, and on-farm domestication. We assume that the management and utilization of bitter kola might differ among collection areas. This might indicate regional variation in tree production characteristics, valuation of tree products, and linkages to markets. Therefore, the study aims to document and compare the (i) tree management and cultivation, (ii) use of specific plant parts, and (iii) economic value and commercialization of *G. kola* among distinct regions with different ecological, cultural, and socioeconomic environments.

Methodology

Our data collection consisted of three parts. First, we visited markets with bitter kola products in the capital city of Yaoundé to locate collection areas and understand the plant's commercialization aspects. Second, we moved to the collection areas to gather data on the utilization of bitter kola. Last, we focused on the morphological features of trees identified by farmers as commonly utilized.

Study Site Description

The identified collection places were three administrative regions in Cameroon, i.e., Southwest, Central, and South (Fig. 1). They represented the country's natural distribution range of *G. kola*, and the products were reported to have high importance to the local communities (Table 1). All three areas differed in elevation, agroecological conditions, proximity to local and regional trading hubs, and sociocultural background.

The Southwest is located in the anglophone part of the country; that is, on the border with Nigeria. Situated in a humid forest agroecological zone with monomodal rainfall, the area is classified as having a tropical monsoon climate (Am) with an average annual rainfall of 3,170 mm and a mean temperature of 24.6°C. The average measured altitude of the Southwest was 324 m.a.s.l. The other two sites, i.e., the Central and the South, belong to the francophone part of Cameroon and border Equatorial Guinea, Gabon, and the Congo Republic. Both areas belong to agroecological zone IV (humid forest with bimodal rainfall) and are dominated by hilly landscapes with average altitudes of 599 and 661 m.a.s.l., respectively. The climate is classified as tropical rainforest (Af) according to Köppen-Geiger's classification system (Kottek et al. 2006). Yaoundé, located in the Central region, is Cameroon's capital city. The average annual precipitation in that area reaches 1,540 mm, while the average annual temperature of approximately 23.2°C. The South has an average of 1,770 mm of rainfall and an average temperature of 23.4°C per year. Forest cover increased from the Central area to the South. Data in the Southwest were collected in the vicinities of Kumba, Lebialem, Mamfe, and Tombel. Sampling in the Central area was performed within Akok, Bokito, Bot-Makak, Ebogo, Lekie-Assi, and Nkenlikok. Data in the South were collected in the vicinities of Ebolowa, Kye-Ossi, Sangmelima, and Zoétélé (Climate-Data.org. 2021; Kenfack Essougong et al. 2020).

Data Collection

The market survey was conducted in 2016 with 72 traders (36 mobile and 36 stall vendors) selling bitter kola products. These traders were willing to participate in our survey and were interviewed on their knowledge of the product, commercialization practices, and consumer expectations. They also helped us understand existing market chains, including major collection areas. From there, we selected 122 farmers who utilized bitter kola trees during the fruit harvesting periods in 2018 and 2019. The selection of farmers was conducted through the purposive and convenience sampling method (Galloway 2005) (Table 1). Data on cultivation practices and product utilization were collected using a semi-structured questionnaire among those who claimed to regularly collect bitter kola products and were willing to participate in the study. Last, 227 mature fruiting trees that were indicated by the interviewed farmers were thoroughly characterized to record basic morphological characteristics. The respondents also estimated the ages of the trees. Tree girth and trunk height were measured by a sine-height method using a laser rangefinder and clinometer. The diameter at breast height (DBH) was taken at a height of 130 cm with a girthing tape, and the crown diameter was assessed by the cross method (Bragg 2014).

Data Analysis

Data were cleaned, coded, and processed further through SPSS version 20. The Kruskal–Wallis test was applied to identify potential differences between selected collection

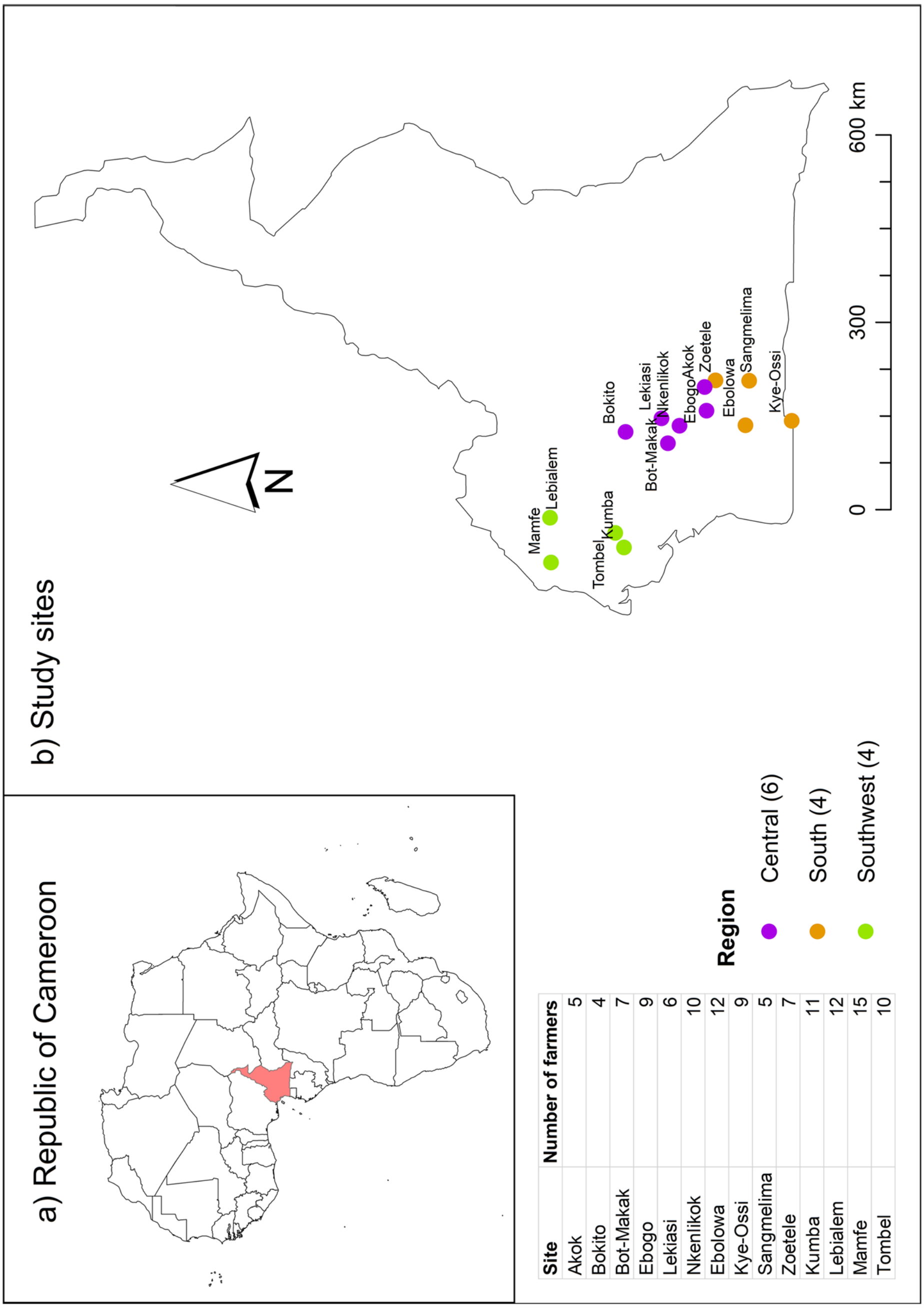

Fig. 1. Map of study sites in Southwest, Central, and South Cameroon.

Table 1. Characteristics of the study areas

Indicator	Southwest	Central	South
Farmers interviewed	48	41	33
Gender (female, % female)	4 (9%)	6 (17%)	4 (14%)
Farmer age (years)	46.04 ± 16.28	51.19 ± 14.23	46.21 ± 15.43
Farm size (ha)	6.73 ± 5.36	11.25 ± 14.00	9.02 ± 12.13
Trees characterized (number)	80	81	66
Agroecological zone	Humid forest, monomodal rainfall	Humid forest, bimodal rainfall	Humid forest, bimodal rainfall
Climate	Tropical monsoon climate	Tropical rainforest climate	Tropical rainforest climate
Altitude of our study sites (m.a.s.l.)	139-755	325-758	575-773

areas in terms of tree cultivation, morphological features and management, collectors' household characteristics, and consumption practices of bitter kola products. The specific reported use (SU) index refers to the number of times a respondent reported a specific use of a plant. The plant part value (PPV) is calculated for a particular part of a plant as the ratio between the total number of reported uses for that plant part and the total number of reported uses for the entire plant. The intraspecific use value (IUV) that allows the organization of use importance within a specific plant part was adopted from Gomez-Beloz (2002).

Results

Market Survey

Mobile vendors (those without a permanent stall) were typically children who were involved in generating additional income to cover education-related expenses. One of the most commonly used measurement units in the seed trade was a 5-liter bucket. Vendors purchased seeds mainly (>50%) from wholesalers at USD 11-18 for a 5-liter bucket in the high season, and USD 27-32 in the low season when seeds became rare. Following seasonal availability, vendors further sold the seeds for USD 18-22 and USD 30-33. Farmers' prices for a 5-liter bucket of seeds decreased from USD 48 in the Southwest to 15 USD in the Central area and even USD 10 in South Cameroon. Bitter kola seeds were often sold together with other popular snacks, such as cola nut (seeds of *Cola acuminata* [P.Beauv.] Schott & Endl. and *Cola nitida* [Vent.] Schott & Endl.), jujube (fruits of *Ziziphus jujuba* Mill.), citrus fruits (*Citrus* × *aurantium* and *Citrus aurantiifolia* [Christm.] Swingle), candies, cigarettes, and toiletries. The perception of *G. kola's* healing powers was very similar among the interviewed farmers and traders. Most vendors (87%) in Yaoundé confirmed the ability of *G. kola* to heal, in particular, gastrointestinal illnesses. More than 75% of vendors also confirmed that the seeds were used as an aphrodisiac, mainly for men, representing the majority (67%) of bitter kola consumers.

Tree Management and Cultivation

Farmers in Southwest Cameroon harvested more trees than those in the other two regions ($p < 0.001$) (Table 2). The oldest trees were found in the Central part (50.98 ± 21.56), with one specimen having a reported oldest age of 120 years. In terms of DBH, trees from the South had much thicker trunks than those from the other study sites ($p < 0.001$). Differences in crown diameter were not highly significant, although slightly larger diameters occurred in the Southwest ($p = 0.012$). On average, trees were 13.9 m in height, yet no significant differences were noted among the regions ($p = 0.168$). On the other hand, a significant difference was detected in tree trunk height, with trees from the Southwest having the shortest trunks ($p < 0.001$).

TABLE 2. INDIVIDUAL TREE CHARACTERISTICS AMONG SURVEYED REGIONS

Indicator	Southwest (n=80)		Central (n=81)		South (n=66)	
	Mean ± SD	Min/Max	Mean ± SD	Min/Max	Mean ± SD	Min/Max
Trees owned by farmers (number)	23.1 ± 25.2	1/100	8.7 ± 12.1	1/60	9.4 ± 11.3	1/50
Tree age (years)	28.5 ± 16.7	7/120	51.0 ± 21.5	7/120	33.2 ± 16.8	10/120
DBH (cm)	33.9 ± 14.1	15/82	39.3 ± 14.7	14/84	86.3 ± 40.1	11/280
Crown diameter (m)	10.5 ± 2.8	4/17	9.2 ± 3.7	3/23	9.6 ± 2.9	5/18
Tree height (m)	13.6 ± 4.9	7/45	14.5 ± 4.3	6/28	13. 6 ± 3.4	7/26
Trunk height (m)	3.7 ± 2.3	1/15	5.7 ± 4.4	0/25	5.5 ± 3.3	1/16

Most bitter kola trees were retained or cultivated in agroforestry systems (47%), followed by home gardens (43%), and fewer than 10% of the utilized trees occurred in natural forest stands (Table 3). Although home gardens represent agroforestry systems, they were classified as a separate category. This classification suggests that the trees were purposively planted, which would be a significant advancement in the species' domestication. Generally, all study sites differed according to harvested places. The role of home gardens decreased along the Southwest to South gradient, being slowly replaced by collections in the wild. While 38% of trees in the Southwest were grown in home gardens, this type of cultivation site decreased significantly in both the Central and South regions (24% and 20%, respectively). In contrast, 24% of the bitter

TABLE 3. MANAGEMENT OF *G. KOLA* TREES ALONG THE SOUTHWEST-CENTRAL-SOUTH GRADIENT

Indicator	Study sites			Whole country
Growing sites (%)				
	Southwest (n=80)	Central (n=81)	South (n=66)	Total (n=227)
Harvesting period	June-August	July-September	September-November	June-November
Agroforestry system	40.0	58.6	40.7	46.8
Home gardens	60.0	34.0	35.1	43.4
Forests/wild stands	0.0	7.4	24.2	9.8
Tree management (%)				
	Southwest (n=48)	Central (n=41)	South (n=33)	Total (n=122)
Clearing/weeding	58.3	97.6	84.8	78.7
Pruning	10.4	2.4	0.0	4.9
Use of fertilizer, manure	22.9	2.4	3.0	9.8
Use of pesticides	31.3	4.9	3.0	14.7
No management	8.3	7.3	15.2	9.8
Fruit harvesting techniques and seed storage (%)				
	Southwest (n=48)	Central (n=41)	South (n=33)	Total (n=122)
Ground picking	35.4	70.7	75.8	58.2
Tree climbing/using poles	85.4	48.8	30.3	58.2
Seed storage	96.0	61.0	24.0	60.3

kola trees utilized in the South were reported from natural forest stands, compared to only 7% in the Central region and even zero in Southwest Cameroon.

Since most bitter kola trees grew in cocoa agroforestry systems, 79% of farmers cited clearing and weeding around the trees while maintaining their cocoa as the most common way of managing *G. kola*. Additionally, in Southwest Cameroon, 23% of the respondents also applied fertilizer (both organic and chemical) to enhance tree growth, and 31% sprayed their trees with pesticides. Overall, only 15% of the farmers used fertilizers, while 10% of the trees were left without management. This was particularly true in the South, where 15% of the trees grew without additional inputs. Regarding fruit harvest, farmers from the South and Central areas preferred collecting fallen fruits (70% and 75% of respondents, respectively) and immediately selling or consuming the seeds without storing them for later use. In contrast, farmers in the Southwest area apply selective fruit-picking methods through climbing and harvesting poles (85% of respondents), and almost everyone practiced seed storage to preserve the harvest. In contrast, 61% of farmers in Central Cameroon and 24% in South Cameroon stored the seeds.

Based on altitude and agroecological conditions, the fruit-harvesting period generally lasts from June to November. It starts in the Southwest region, where the peak season starts in June and ends in August. It then occurs in the Central area, where the harvest is delayed for approximately one month (July to September), while September-November is the main harvesting period in the South.

Plant Parts Used

Seeds, bark, and roots were the main parts of *G. kola* collected and used by the local population (Table 4). Bark and roots were used similarly, so we merged them into one category. Leaves and twigs were rarely reported and therefore not included in further analysis. Almost all interviewees were involved in seed collection (99%). More than half (53%) mentioned

Table 4. Overall reported uses of the main bitter kola products

Plant part	Reported uses (RUs)	Plant part value (PPV)	Specific reported use	Specific use (SU)	Intraspecific use value (IUV)	Overall use value (OUV)
Seeds	181	0.71				
			Aphrodisiac	26	0.14	0.10
			Cardiovascular	1	0.01	0.004
			Food/snack	21	0.12	0.08
			Gastrointestinal	71	0.39	0.28
			Hepatoprotection	1	0.01	0.004
			Infections, injuries	6	0.03	0.02
			Neurological	1	0.01	0.004
			Respiratory	17	0.09	0.07
			Stimulant, energy boost	34	0.19	0.13
			Welcoming snack/gift	3	0.02	0.01
Bark/roots	74	0.29				
			Aphrodisiac	2	0.03	0.01
			Gastrointestinal	17	0.23	0.07
			Genito-urinary	1	0.01	0.004
			Hepatoprotection	2	0.03	0.01
			Infections, injuries	2	0.03	0.01
			Palm wine	41	0.55	0.16
			Respiratory	7	0.10	0.03
			Stimulant, energy boost	2	0.03	0.01

harvesting bark and roots, which also confirms the PPV for seeds (0.71) and bark/roots (0.29). The results show an apparent shift in the dominant use of major products, from seeds to bark and roots, along the Southwest-Central-South gradient. Seeds were then prioritized for farmers in the Southwest area, while bark and roots were primary products in the South area. Based on these results, Central Cameroon can be considered a transition zone using seeds and bark/roots along the gradient.

Concerning the mode of use, seeds were predominantly used as a medicine (69%) in all three regions. In contrast, bark and roots were primarily utilized as an additive in palm wine production (62%) and secondarily as a remedy. The most common medicinal use of seeds and bark/roots was the treatment/prevention of gastrointestinal disorders (58% and 26%, respectively). Seeds are also valued for the treatment of infections/injuries along with respiratory ailments, which were the second-most reported choice in the medicinal use of bark and roots (Table 4). Apart from their therapeutic value, seeds were also utilized as stimulants and snack food (28% and 20%, respectively). Bitter kola's popularity as a snack was mainly observed in Central Cameroon (37%), while the stimulatory aphrodisiac value was more appreciated among farmers in the South (53%). The IUV of seeds was the highest for treating gastrointestinal disorders, followed by their use as a stimulant to boost physical energy, and as a male aphrodisiac (0.39, 0.19, and 0.14, respectively).

Bark and roots were used differently among the studied regions. In Southwest Cameroon, most respondents (77%) used these parts as medicine, while 50% followed this pattern in the Central region, and only 4% in South Cameroon. The use of bark and roots in palm wine production showed a different trend. All respondents from the South and 67% from the Central area reported this practice. At the same time, use for alcohol production was not cited in the Southwest region. The highest IUVs (Table 4) for bark and roots were calculated for palm wine production, followed by treatment of gastrointestinal and respiratory problems (0.55, 0.23, and 0.10, respectively). These values changed when computing the overall use value (OUV), especially for the bark/roots, whose importance was much lower than that of seeds. Even though the scored categories did not change, the differences in values were evident (0.28, 0.13, and 0.10 for seeds, and 0.16, 0.07, and 0.03 for bark/roots).

Discussion

Tree Management and Use

The sustainability of a species' utilization is crucial to its eventual extinction or survival in natural and on-farm environments. The overexploitation of *G. kola* in Benin has led to the disappearance of the species from its natural stands (Dadjo et al. 2020). One solution involves revising the status of the species from "vulnerable" to "near threatened" on IUCN's Red List. A more effective strategy is to promote adequate interventions for the conservation of species (Dadjo et al. 2020; Yogom et al. 2020). In our study from Cameroon, *G. kola* trees mostly occurred in agroforests in combination with various perennial cash crops, such as cocoa (*Theobroma cacao* L.), oil palm (*Elaeis guineensis* Jacq.), and robusta coffee (*Coffea canephora* Pierre ex A.Froehner). *G. kola* trees were also found in home gardens, mainly surrounded by indigenous fruit trees such as African plum (*Pachylobus edulis* G.Don), bush mango (*Irvingia gabonensis* [Aubry-Lecomte ex O'Rorke] Baill.), and cola nuts (*C. acuminata* and *C. nitida*). The gathering of *G. kola* products from natural forests was our respondents' least-cited option, providing a solid base for species conservation.

Nevertheless, we observed an evident Southwest-Central-South gradient in the management of *G. kola* trees. The intentional cultivation in agroforestry systems and home gardens in the Southwest region transitioned to collection from wild stands in the South. Additionally, *G. kola* tree management was closely related to the specific plant parts a farmer wanted to collect and use. In the Southwest, seeds were the most valued product of the tree, whereas the use of bark and roots predominated in the South. A combination of both products is operational in the Central area. Because of the appreciation of the seeds, farmers from Southwest Cameroon preferred to harvest the fruits from the tree. This technique is more labor intensive than picking fallen fruits, but ensures a higher and more stable yield by preventing the fruits from deteriorating or being stolen or eaten.

Moreover, to provide seed longevity and better off-season prices, the farmers commonly stored seeds in cold, dark places in airtight containers to prevent their oxidation. Notably, the trees from the Southwest have significantly shorter trunks and larger crowns than those from the other regions, allowing easier fruit harvesting. This indicates that preliminary tree selection based on these criteria may have already started there. Moreover, farmers from the Southwest owned more trees than those at the other study sites, indicating interest in the species and its intentional cultivation. In contrast, respondents in both the Central and South areas preferred picking fallen fruits from the ground; seed storage was not very common. This approach may significantly limit the quantities of used or traded seeds due to harvest and postharvest losses.

The problem with the preference for using bark and roots in the South and Central regions is the destructive harvesting method. Such practices were already documented in eastern Cameroon areas that are adjacent to the Central and South study sites, where two-thirds of *G. kola* trees were destroyed by stripping bark and digging up roots (Kamga et al. 2019). Even though the response to bark harvesting is species-specific, most bitter kola trees do not regenerate well after this harvesting practice (Fig. 2). In the case study from Benin, only two out of twelve studied trees were found to regenerate well after the bark harvest. Neither ring-barking nor complete trunk debarking favored sheet regrowth, eventually resulting in complete dieback of the trees. However, an alternative to debarking might be coppicing, i.e., cutting trees at a 1 m height, harvesting their bark, and letting the trees sprout new shoots (Delvaux et al. 2009, 2010). A similar management technique was already tried successfully in South Cameroon for *Garcinia lucida* Vesque, another West African medicinal tree species (Guedje et al. 2007). However, adopting these alternative and more sustainable techniques of bark harvesting is questionable. In terms of the popular palm wine drink, *G. kola* bark and roots might be also replaced by other species having the same effect of bitterness, i.e., commonly grown bitter leaf (*Gymnanthemum amygdalinum* [Delile] Sch.Bip.) (Gberikon et al. 2016).

Based on the above-mentioned studies and the experiences from South Cameroon, further research on bark harvesting practices is needed to fully understand the regeneration patterns of the species. Focusing on *G. kola* conservation, sustainable bark harvesting methods need to be addressed along with awareness of the long-term consequences of such behavior. This also assumes at least a partial shift of attention from bark to seeds, the harvest of which is not harmful to bitter kola trees. Sharing awareness of the medicinal abilities and the market potential of *G. kola* seeds may encourage farmers to protect their trees instead of causing irreversible damage to wild and cultivated populations. Combined with seedlings re-planting in the wild stands, this might be one of the approaches to preserve *G. kola* in forests.

Economic Potential and Commercialization

More information on the economic aspects of bitter kola utilization is needed to increase the adoption of alternative practices among farmers. However, data on the tree's economic importance are relatively scarce. Available studies have shown that >16 tons of *G. kola* bark were traded annually from Cameroon's forest zones in the mid-1990s, representing revenues of approximately USD 7,220 (Ndoye 1995). In contrast, there is a high market potential for the seeds, as their annual production was estimated at 50 tons, equal to approximately USD 660,000 (Awono et al. 2016). Data on the selling price of *G. kola* seeds differed significantly over regions and seasons and depended on individual collectors' practices, capacities, and preferences. As stated in the results, the decline of seed commercialization from the Southwest to the South is particularly reflected in the seed price. In the Southwest, a 5-liter bucket of seeds was sold for an average of USD 48. The Central part of the country appeared as a transition zone, with an average of USD 15 paid per bucket, whereas in the South, the same quantity of seeds sold for only USD 10. This wide disparity in income generation among the regions was also confirmed by Yogom et al. (2020). There is a vast marketing gap in *G. kola* product commercialization. In Nigeria, especially in the southern parts of the

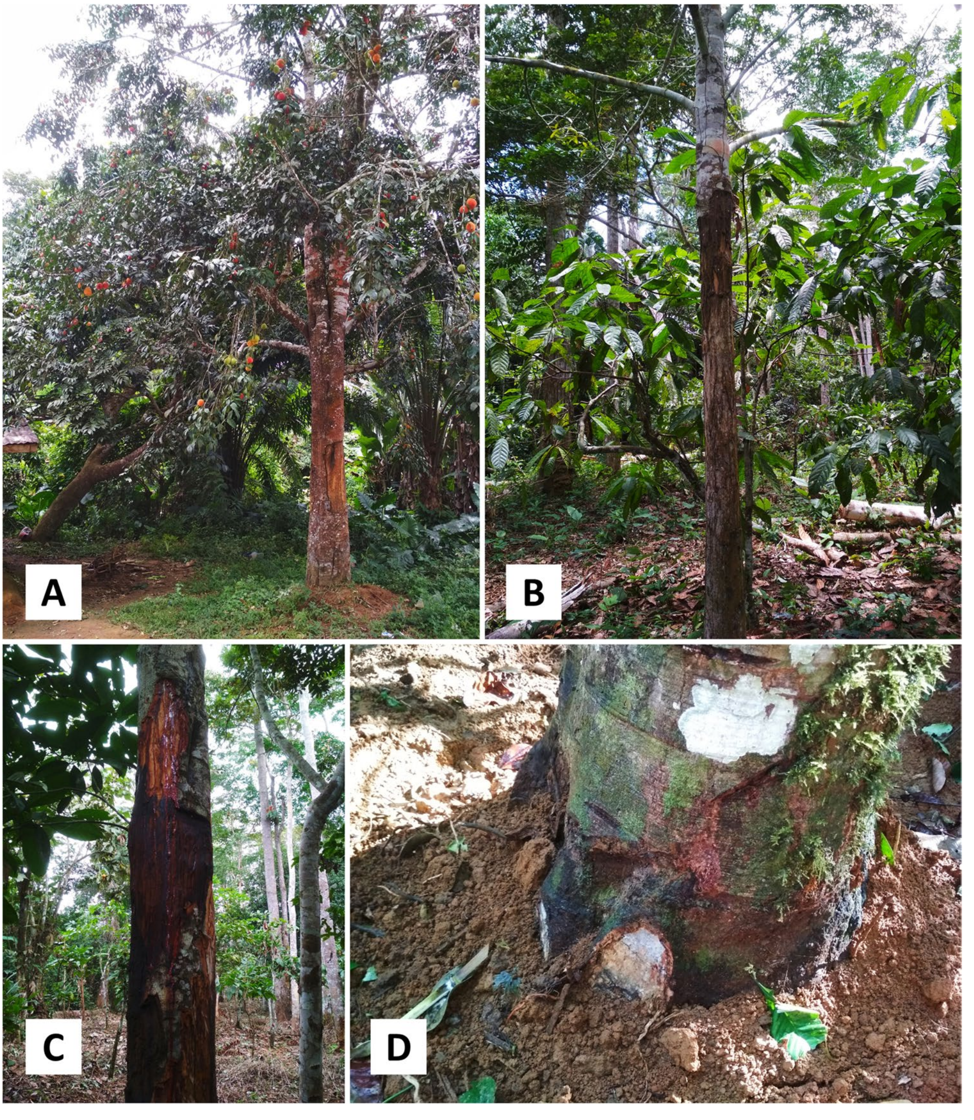

Fig. 2. *G. kola* trees damaged by unsustainable harvesting; **A**, **B.** Partial bark stripping; **C.** Trunk debarking; **D.** Signs of roots removal.

country bordering Cameroon, the trade of bitter kola is as important as that of the cola nut (*C. acuminata* and *C. nitida*), thus representing one of the most profitable West African non-timber forest products (Yakubu et al. 2014). In addition to the local, national, and regional markets, there is a growing international demand for *G. kola* products, as the seeds are already commercialized in the United States and Europe (Onyekwelu and Stimm 2019). Preference for the utilization and commercialization of bitter kola seeds instead of bark and roots in Southwest Cameroon shows how existing market chains might contribute to revamping conservation efforts and sustainable harvesting techniques in the Central and particularly the South regions of the country. Commercialization of *G. kola* products is also affected by seasonality. Fewer than half of the vendors sold the seeds only at the harvest time, which leads to a discussion on the storage and processing of seeds along the chain, particularly by farmers who could decrease product price fluctuation and seasonality and provide an opportunity for producers to add more value to the product.

The Need for Domestication and Conservation

The use of *G. kola* products and their market price have been widely discussed. However, the geographical context and its potential influence on farmers' preferences remain less highlighted. Studies show that the use of seeds is much more popular in West Africa (Adebisi 2004; Codjia et al. 2018; Onyekwelu and Stimm 2019), while the use of roots and bark is more common in Central Africa (Fondoun and Manga 2000; Guedje and Fankap 2001; Matig et al. 2006). Our results confirm this geographical pattern along the Southwest-Central-South regional gradient traceable from southern Nigeria toward Gabon, Equatorial Guinea, and the Democratic Republic of the Congo. The trend reflects not only the predominant use of the particular product and its method of harvesting and commercialization, but also tree management practices, which might be detrimental to the species, as discussed above (Fig. 2).

One possible solution to preserving *G. kola* trees for future generations is conservation through a use approach based on tree domestication followed by training farmers on how to harvest tree products sustainably. In the 1990s, *G. kola* was selected by World Agroforestry (ICRAF) as one of the six priority tree species for domestication in West and Central Africa (Franzel and Kindt 2012; Tchoundjeu et al. 2006). The tree is also a target species for immediate conservation action in the sub-Saharan Forest Genetic Resources program (Sacandé and Pritchard 2004). However, to date, little has been done to speed up the domestication process. Identifying superior populations/individuals that could form the foundation for starting the species breeding process is urgently needed.

Nevertheless, *G. kola* is still an incipiently domesticated species, meaning that its current phenotypic diversity in human-selected traits varies only slightly from that of the ancestral wild populations (Clement et al. 2010; Manourova et al. 2019). Our results indicate that farmers from Southwest Cameroon might be interested in improving and domesticating *G. kola*. The species is already undergoing the first domestication steps via its intentional cultivation in home gardens and, most likely, the primary selection of the traits that interest farmers, such as large tree crowns and short trunks. To set strong fundamentals for bitter kola's potential domestication, these key morphological features identified by farmers need to be linked to actual morphological and genetic diversity (Degrande et al. 2013; Wiersberg et al. 2016). To do so, we recommend conducting a detailed study on the farmers' preferences, needs, and constraints; consumer behavior toward seed characteristics in terms of flavor, size, or shape; methods of bark and roots harvesting and their sustainability; and phenotypic screening of species and how traits are linked to a particular phenotypic feature of the tree. In addition, more research on species autecology will be necessary to create functional conservation programs including conservation through use approaches, particularly concerning different agroecological regions and socioeconomic groups.

Conclusion

Our study examined the cultivation practices, utilization, commercialization, and selected morphological characteristics of *G. kola* in Cameroon. The aim was to reflect on bitter kola's regional differences and specificity while examining its future potential and possible challenges. We discovered that tree management is closely related to specific plant parts of interest to the farmers. In the Southwest area, farmers preferred harvesting seeds, which are valued by consumers for their medicinal purposes. Also, farmers established market chains for bark and roots that are primarily used for subsistence. Additionally, Southwest farmers cultivated more trees in their farming systems. They applied advanced seed harvesting and storage techniques, which reflected a higher selling price of approximately USD 48 per 5-liter bucket of seeds compared to USD 10 in the South where the market access causes farmers to resort to bark and root exploitation as well as unsustainable harvesting practices. Bark and roots were principally intended as palm wine flavoring agents, and their collection was found to be rather invasive and unsustainable in the long term. Moreover, a reasonable share of trees in the South area was harvested from the natural forest, raising the question of the species' survival at the study site. Thus, we consider using the domestication and development of market chains as crucial strategies to support the conservation of bitter kola in Cameroon. Promoting the medicinal value of the species among the farmers might be a suitable strategy for shifting their attention from bark and roots to seeds, which are generally sustainably harvested and present a promising income opportunity if market access is supported.

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Data Availability

The data that support the findings of this study are available from the corresponding author(Vladimir Verner), upon reasonable request.

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