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Impact of bark and foliage harvesting on fruit production of the multipurpose tree *Afzelia africana* in Burkina Faso (West Africa)

Blandine Marie Ivette Nacoulma · Anne Mette Lykke · Salifou Traoré · Brice Sinsin · Adjima Thiombiano

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Abstract In sub-Saharan Africa, extraction for daily livelihood needs often results in uncontrolled exploitation of bark and leaves of valuable medicinal and fodder trees. However, overharvesting of bark and foliage can reduce fruit production and threaten reproduction. This study evaluates the impact of combined bark and foliage harvesting on the performance of fruit production of *Afzelia africana* in Burkina Faso. We compared fruit and seed production at different harvesting intensities. Data on fruit yields were collected by stratified random sampling of 91 trees with no, low, severe, and very severe harvesting intensities. The fruit production varied with harvesting intensity, tree size and number of branches. Fruit and seed quantity and quality decreased with increasing harvesting intensity. However, no significant difference was detected between trees without and trees under low harvesting. Trees of all size classes under very severe harvesting intensity had no fruits. Under low harvesting impact, large trees had twice as many fruits as the control, whereas fruits were reduced by half to 95 % for the small trees. High harvesting intensity is an unsustainable practice that should be completely prohibited in order to ensure longterm persistence of *Afzelia africana*. Low harvesting intensity should be allowed, but only on large reproductive individuals.

Keywords Debarking · Pruning · Harvesting intensity · African mahogany · Fruit yields · Savanna trees

B. M. I. Nacoulma (✉) · S. Traoré · A. Thiombiano
Laboratory of Plant Biology and Ecology, University Ouaga 1 Professor Joseph Ki-Zerbo, 03, BP 7021, Ouagadougou, Burkina Faso
e-mail: nblandine@gmail.com

A. M. Lykke
Department of Bioscience, Aarhus University, Vejlsøvej 25, 8600 Silkeborg, Denmark

B. Sinsin
Laboratory of Applied Ecology, University of Abomey-Calavi, 01, BP 526, Cotonou, Benin

Introduction

Human well-being in sub-Saharan Africa is highly dependent on the use of natural resources (Millennium Ecosystem Assessment 2005). A variety of non-timber forest products (NTFPs) are used for satisfying rural people's daily needs such as food, medicine, fertiliser, fodder for livestock, fuel wood and income through sale at local markets (Lykke 1998; Belem et al. 2007). The most important ecosystem providing NTFPs in this region is the savanna. Over the past few decades, however, the West African savannas have been subjected to swift land-use changes due to high population growth (Wittig et al. 2007; Ouédraogo et al. 2010). Such a change has consequences for the supply of natural resources, especially for the highly exploited multipurpose trees. The harvest of NTFPs may affect physiology, vitality, survival rate, growth and reproduction of harvested individuals (Ticktin 2004) and, consequently, lead to vulnerability of the species. It has been reported that the effects of bark harvesting affected population structure, increased mortality and decreased fecundity of *Pygeum africanum* and *Prunus africana* in Cameroon and Madagascar (Stewart 2009). In the context of continued rapid land-use changes and human population growth, there is an urgent need to understand and evaluate the impact of harvesting on the reproductive performance of multipurpose trees in savanna environments in order to implement appropriate management strategies.

One of the most important multipurpose species in West Africa is *Afzelia africana* (Fabaceae-Caesalpinioideae), commonly known as African mahogany. *Afzelia africana* is a multipurpose tree that is used in agroforestry systems. The tree is valued in agroforestry systems for soil improvement because the leaves are rich in nitrogen and minerals. Furthermore, as a leguminous tree *Afzelia africana* is used for soil conservation and improvement (Orwa et al. 2009). Thus, promotion of conservation strategies for this key species may be relevant to improve agricultural yields of the sub-Sahelian region's degraded soils.

In addition, *Afzelia africana* produces high quality termite-resistant timber and wood used for construction, canoes, African drums ('djembe') and also for firewood and charcoal (Arbonnier 2002; Orwa et al. 2009). In the sub-humid zone of West Africa, *Afzelia africana* is the most commonly used multipurpose species in the traditional livestock management system and the most important source of fodder during the dry season (Ouédraogo-Koné et al. 2006). In these areas, the dry season is the most critical period for ruminant nutrition, especially in terms of quantitative and qualitative availability of grasses. During this period, tree foliage is regarded by herders and livestock owners as a rich and providential nutrient supply (Petit and Maillet 2001). For example, browsing represented about 75 % of the grazing time of cattle during this period in the sub-humid zone (Petit and Mallet 2001).

In order to make foliage available to the animals, tree branches are cut by herders and livestock owners, reducing the tree crown area. Being among the most used fodder tree species, *Afzelia africana* foliage is heavily harvested to feed livestock, and in many places it is the most highly preferred fodder species (Petit and Mallet 2001; Ouédraogo-Koné et al. 2006). Therefore, the species is harvested from February to July (Petit and Mallet 2001) more than one time per tree during a single dry season (Ouédraogo-Koné et al. 2006). This high preference for *Afzelia africana* by herders is due to the chemical composition and nutritive value of the foliage, which significantly affects animal performance (Ouédraogo-Koné et al. 2006). The bark is harvested and used as an important medicine to treat various diseases, including diarrhoea, coughs, gastrointestinal disorders, general pain in humans and in veterinary medicine (Arbonnier 2002; Orwa et al. 2009). *Afzelia africana* is also used for religious purposes (a fetish tree) in many regions and the bark is removed both for medicinal purposes and for sacrifices throughout the year (Gérard and Louppe 2011).

In eastern Burkina Faso, some *Afzelia africana* trees are sacred to people from the Gourmantché ethnic group, as the tree is said to protect families against diseases and provide a good harvest season. Because of their high value and status as a sacred tree, some *Afzelia africana* trees are relatively protected in certain communal areas of Burkina Faso. This protection is supported by the national protection legislation. *Afzelia africana* is listed as an endangered species on the national red list of Burkina Faso (Thiombiano et al. 2010) and has been completely protected by national legislation ("Code Forestier") since 1993. Despite this existing legislation, *Afzelia africana* is still subjected to intensive exploitation of leaves and bark.

Studies on *Afzelia africana* have revealed that the seedlings are very sensitive to fire, browsing and drought (Bationo et al. 2000, 2001; Ouédraogo et al. 2006; Gérard and Louppe 2011). It has been reported that young trees often develop poorly because of damage caused by animals such as antelopes or livestock that feed on the foliage and damage the terminal buds (Gérard and Louppe 2011). The seeds are also heavily browsed by wildlife and livestock (Orwa et al. 2009). Several ecological investigations have revealed that *Afzelia africana* faces various types of pressure, including heavy browsing, low level of regeneration in its natural habitats, uncontrolled logging and other factors such as rodents and fungi that influence population structure and dynamics in many parts of West Africa (Bationo et al. 2000; Sinsin et al. 2004; Bonou et al. 2009). A recent study demonstrated that cutting for livestock fodder and debarking for medicinal purposes are uncontrolled in eastern Burkina Faso and that harvesting negatively affects the species population structure (Nacoulma et al. 2011a).

No studies are presently available on the impact of bark and foliage harvesting on fruit production of *Afzelia africana*. The lack of data is a hindrance for drawing up an efficient management programme for *Afzelia africana* (Sinsin et al. 2004). In this study, we investigate the influence of combined bark and foliage harvesting on fruit production to understand the consequences and to give appropriate recommendations for a sustainable management of *Afzelia africana.* Based on the assumption that both bark and foliage harvesting decrease the reproductive performance of *Afzelia africana,* we addressed the following questions: (i) Does the combined bark and foliage harvesting affect fruit and seed number? (ii) Does such harvesting affect fruit and seed weight? (iii) Is there a significant correlation between tree size, number of branches and the effect of harvesting on fruit production?

Materials and methods

Study area

The study was conducted in W National Park (WNP) complex and surrounding areas in Burkina Faso, located in the Sudanian zone between lat. 11° 30′ N to 12° 22′ N and long. 1° 46′ E to 2° 23′ E. The WNP complex includes two protected hunting zones (Tapoa-Djerma and Kombongou) in addition to the national park. WNP is one of the most important transboundary Biosphere Reserves of UNESCO's Man and the Biosphere programme (MAB) between Benin, Burkina Faso and Niger in West Africa. The surrounding communal areas consist of croplands and fallows. Trees with bark and foliage harvesting were found in croplands and fallows, whereas non-harvested trees were found in the WNP and the hunting zones that are managed by prescribed fires ignited in October or November every year to mitigate the effect of accidental late fire and also to stimulate an off-season re-growth of perennial herbs for wildlife. Livestock grazing and fuel wood extractions are prohibited, whereas only exploitation of baobab (*Adansonia digitata*) fruits and straw by the neighbouring local communities is authorised and regulated.

The region has a tropical climate with a mean annual precipitation of 767 mm and annual mean temperatures between 26 and 29 °C. The length of the dry season is 6–7 months (November to April), corresponding to the starting period of the foliation, flowering and fruiting of *Afzelia africana* species (from January to April) and also to the period of fodder scarcity for livestock. The vegetation is composed of a mosaic of various types of savanna (woodland, grass-, shrub- and tree savanna) (Fontès and Guinko 1995), croplands and fallow. The human population density is approximately 16 inhabitants per km^2, dominated by the Gourmantché ethnic group, who mainly live from crop and extensive livestock farming. The livestock density (mainly cattle, sheep and goats) is approximately 50 animals per km^2 (ENEC 2003). The livestock sector is the second most important source of national income in Burkina Faso with a contribution estimated at 15 % to the GDP (MRA 2007).

Sampling design

In order to account for the different categories of bark and foliage harvesting, we collected data in different land use types (WNP, crop and fallow areas) based on the presence of *Afzelia africana.* In each land use type, we sampled 45 plots of 30 m × 30 m with a minimum distance of 200 m to each other following a stratified random sampling scheme (from March 2009 to January 2010) (Nacoulma et al. 2011b). WNP represented the non-harvested ("control") areas, whereas croplands and fallows were strongly affected by uncontrolled human activities, including various intensities of harvesting of bark and foliage. We started sampling in March when *Afzelia africana* was flowering.

Inside each plot, we first recorded the different categories of bark and foliage harvesting intensities based on an adapted scale from Cunningham (2001) by an estimation of the percentage of bark and foliage harvested. The percentage of debarking was thereby defined as the percentage of outer and/or inner bark removed from the trunk of individual trees. The bark damage was estimated from the base of trunk to the first ramification. The percentage of foliage harvesting was defined as the percentage of the original crown removed, estimated by counting the number of cut branches. We used a five-level scale from the lowest to the highest levels of damage: control i.e., undamaged (0, Fig. 1a), low (1), medium (2), severe (3) and very severe (4). The low harvesting was defined by 1–25 % of the crown cut (Fig. 2b) or trunk debarked (Figs. 1b, 3b), medium harvesting was 26–50 % of the crown cut or trunk debarked, while severely foliage harvesting was 56–75 % of the crown cut or trunk debarked (Fig. 2c, 3c) and very severely harvested trees had their crown cut or trunk debarked from 76 to 100 % (Figs. 2d, 3d).

Finally, we noticed in the field: control or undamaged individuals trees (i.e., no debarking and no foliage harvesting), low (i.e., low debarking and low foliage harvesting), severe (i.e., low debarking and severe foliage harvesting) and very severe (i.e., low debarking and very severe foliage harvesting). We did not observe medium harvesting intensity (26–50 %). A total of 91 trees were sampled (30 in the WNP and 61 in communal areas) and harvesting intensity estimated; 30 undamaged individuals, 21 individuals in low harvesting intensity, 20 individuals in each of severe and very severe harvesting intensities. Then, 20–30 flowering individuals in each category were randomly selected and marked for fruit data collection. Tree characteristics were measured as the diameter at breast height (dbh), the total height and the crown diameter (North–South and East–West) of each selected individual. The diameter at breast height (dbh) of the trees was measured by the use of a diameter tape (D-tape cm). Tree height was measured with a Suunto (PM-5/360PC Clinometer (accuracy = 1/4°) using the formula $Ht = L\ [tg\ (ß_1) - tg\ (ß_2)]$, where L is distance between operator and the tree, $ß_1$ the angle of observation toward the top of the tree, and $ß_2$ the angle of observation of the foot of the tree. The crown diameter was measured using the cross-method, by measuring the lengths of longest spread from edge to edge across the crown and the longest spread perpendicular to the first cross-section through the central mass of the crown. The crown diameter is the average of these two lengths [(longest spread + longest cross-spread)/2]. Additionnaly, the total number of branches was counted. The evaluation of the quantity of fruits produced per tree was

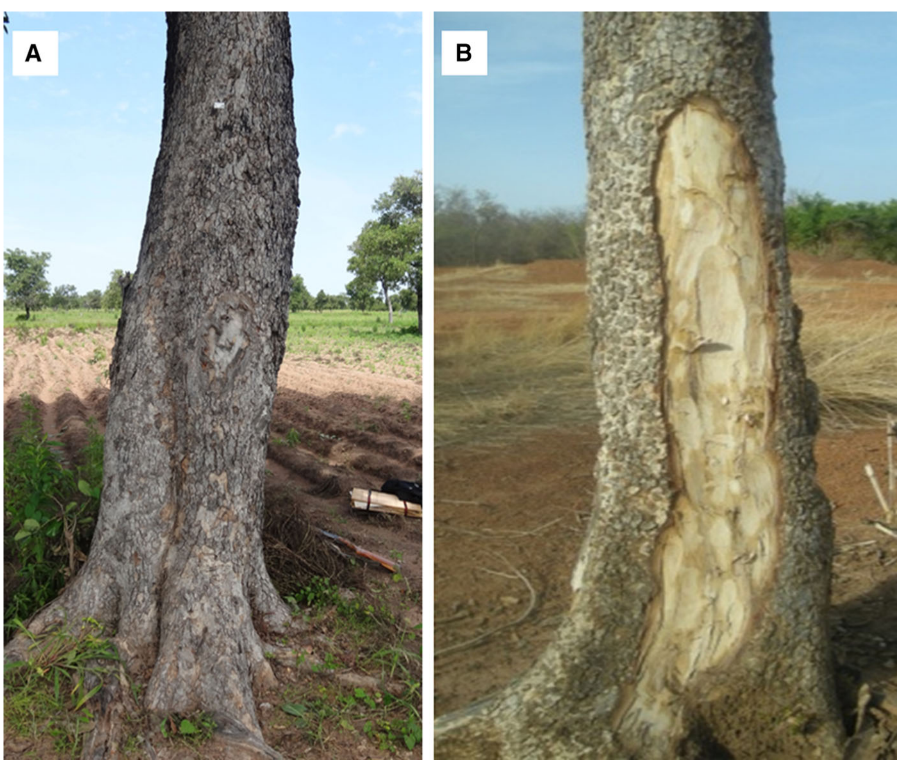

Fig. 1 The two categories of *Afzelia africana* bark harvesting (**a** undamaged tree, **b** low bark harvesting intensity)

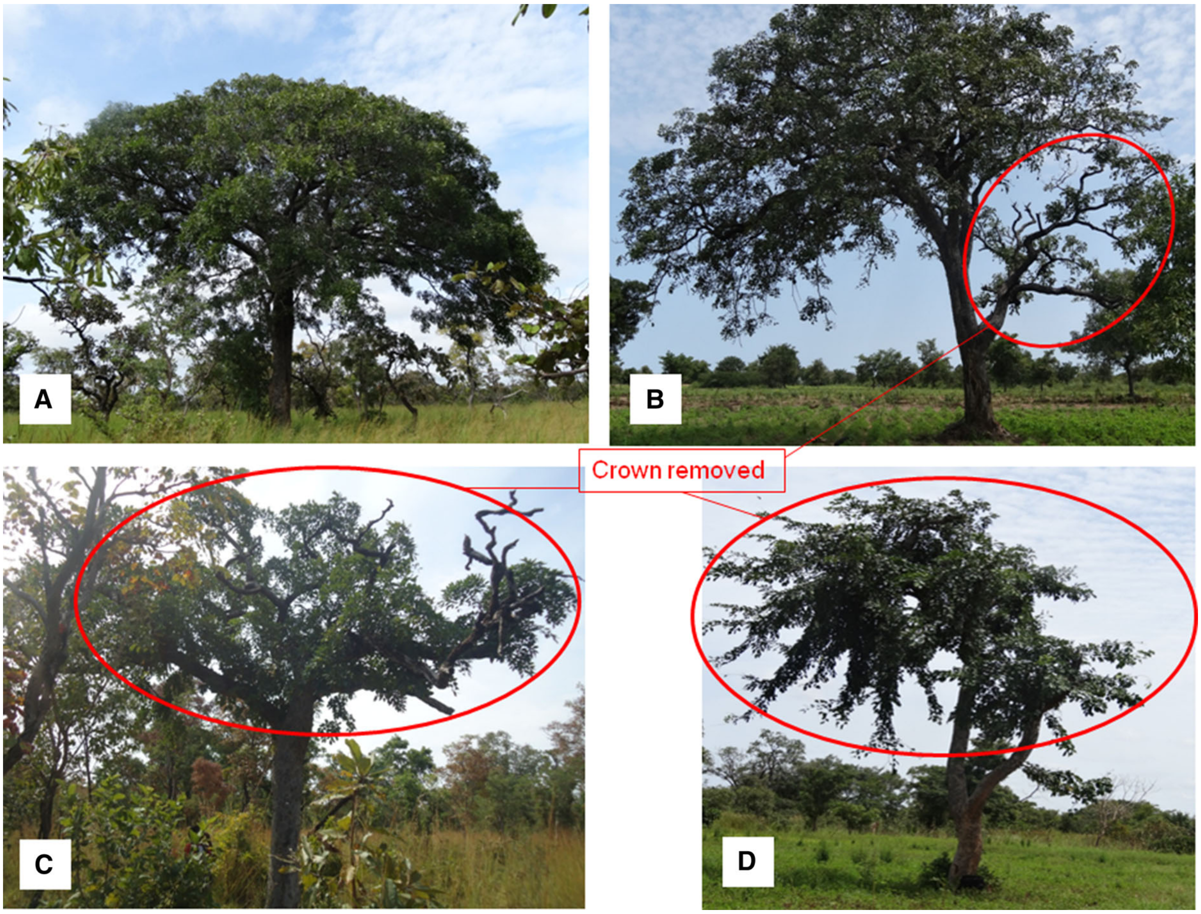

Fig. 2 The categories of *Afzelia africana* according to foliage harvesting intensity during the fruiting period (**A** undamaged tree, **B** low, **C** severe, **D** very-severe)

performed in September, when *Afzelia africana* fruiting is at peak (Ouédraogo-Koné et al. 2008; Donkpegan et al. 2014). After a visual estimation of the production, we counted the total number of fruits produced per tree for trees with less than 100 fruits. For trees with more than 100 fruits, we counted the number of fruits per branch for one-fourth of the fruit-bearing branches and extrapolated this number to the total number of fruits (Cunningham 2001). We evaluated the quality of fruits produced per tree in January, corresponding to the full maturation period (Ouédraogo-Koné et al. 2008; Donkpegan et al. 2014) when the pods turn to the mature colour, but before dehiscence. We randomly sampled three fruits per tree, but for trees with a total number of three fruits produced (i.e., in severe harvesting intensity), those fruits were systematically sampled. Each fruit was weighed directly in the field. After weighing, we broke each collected fruit and counted and weighed the total number of seeds. Then, after mixing seeds collected on one tree, we randomly selected and weighted two sets of 10 seeds per tree. To estimate fruit and seed weight we used Pesola weighing scale of 300 g (Waga Medio Line) and 50 g (Balance Light Line), respectively, both with accurate in ± 0.3 %. The reproductive performance was expressed by the number of fruits produced per tree, number of seeds per fruit and dry weight of fruits and seeds. The fruit and seed number is a measure of quantity, whereas fruit and seed weight is a measure of quality.

Data analysis

We grouped the measured trees into the six observed dbh size-classes as: 20–30, 31–40, 41–50, 51–60, 61–70, >70 cm. We tested for correlation between all

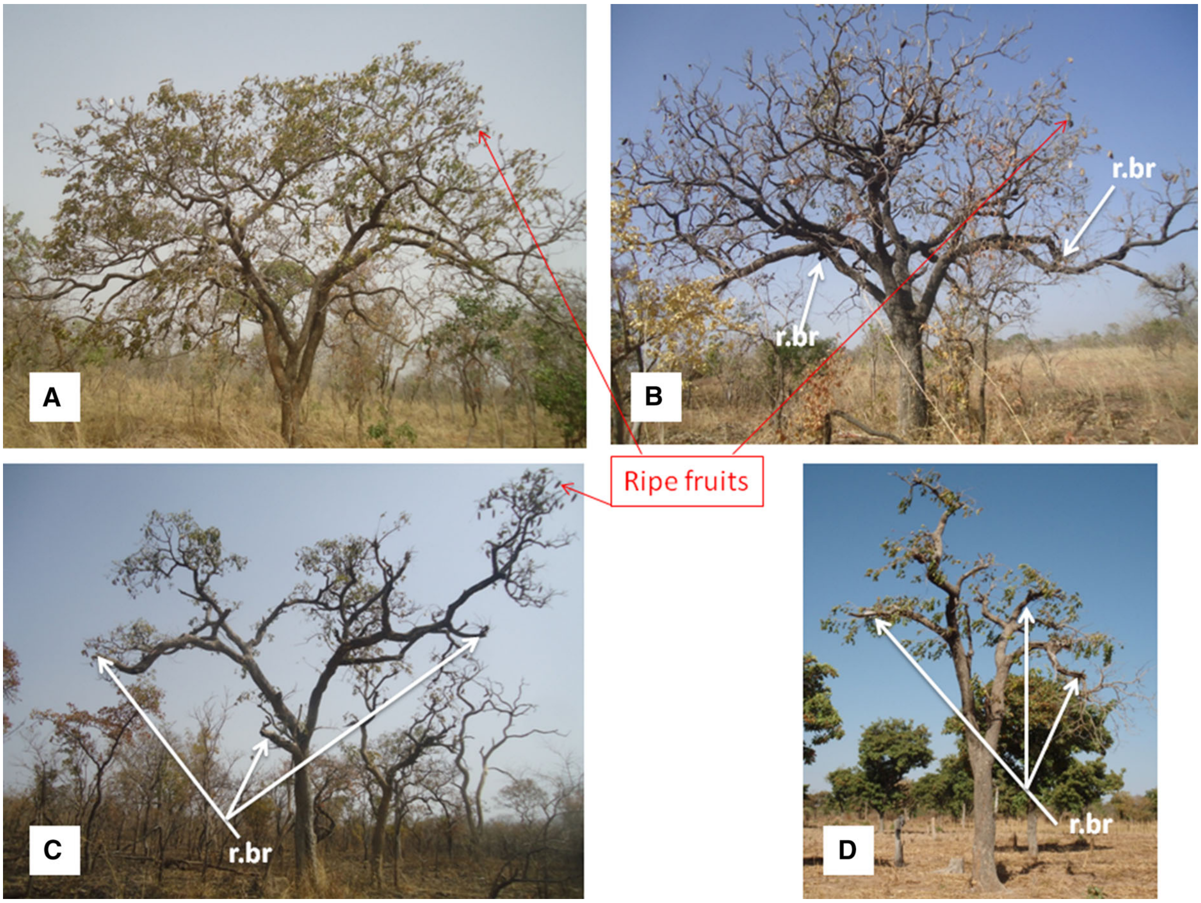

Fig. 3 Overview of the quantity of *Afzelia africana* fruits produced according to foliage harvesting: (**A** undamaged tree, **B** low, **C** severe, **D** very-severe), *r.br* removed branches

explanatory variables: dbh, height, crown diameter, number of branches and harvesting intensity. We detected high correlation between the explanatory variables dbh and height (Pearson correlation = 0.589; p = 0.000) and between number of branches and crown diameter (Pearson correlation = 0.779; p = 0.000). Then, we decided to keep the explanatory variable dbh as a measure of tree size, and number of branches was used as a measure of the crown. We tested the effect of dbh, number of branches and harvesting intensity on *Afzelia africana* fruit production (fruit and seed number and their respective weights) using Generalized linear models (GLM) with Poisson errors (logit function regression model) to account for the non-normal errors and the increasing variances with increasing mean that is associated with count data. Models were fitted using fruit number, seed number, fruit weight and seed weight as dependent variables and dbh, number of branches and harvesting intensity as explanatory variables. The intensity of harvest was treated as categorical fixed factors. We set up a model with dbh, number of branches, harvesting intensity and all two-way interactions: dbh × number of branches, dbh × harvesting intensity, number of branches × harvesting intensity and dbh × number of branches x harvesting intensity. When a significant difference was detected, a pair-wise comparison was made using Tukey's test at the 5 % level of significance. The data exploration followed the protocol described by Zuur et al. (2010). All statistical analyses were performed with the R-2.15.3 statistical software (R development Core Team 2013).

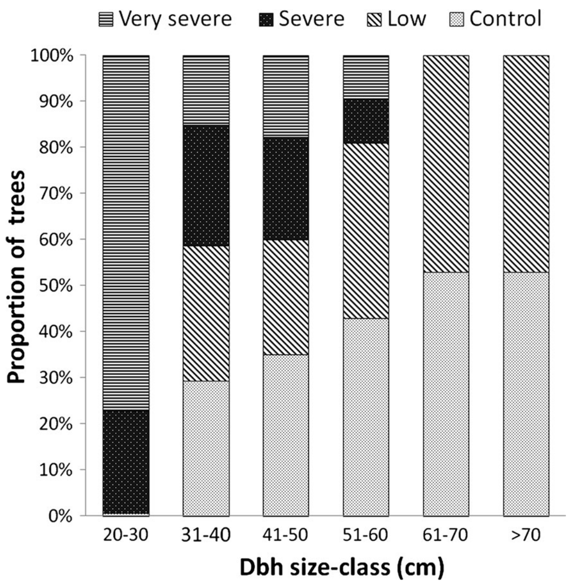

Fig. 4 Proportions of harvesting (bark and foliage) following dbh size classes

Results

Intensity of combined bark and foliage harvesting

Afzelia africana trees were harvested for foliage and bark by humans (in croplands and fallows) over all dbh size classes, but the extent of harvesting differed significantly between the size classes (Fig. 4). Trees of smaller size classes (dbh 20–30 cm) were harvested to a severe (22 % of the trees) or very severe (78 %) intensity. Trees of the medium size classes (dbh: 31–60 cm) were harvested to a low (37.5 %), severe (37.5 %) or very severe (25 %) intensity. In contrast, large trees (dbh ≥61 cm) were harvested in low intensity. Our results also revealed that trees fruited with a minimum dbh of 20 cm.

Fruit and seed production

Our results show that dbh, number of branches, harvesting intensity and all two way interactions were significant and, therefore, important factors influencing *Afzelia africana* fruit production (Table 1). The dbh and number of branches had positive effects, so trees with higher dbh produced more fruits than those with small dbh (Fig. 5), and trees with many branches produced more fruits than those with fewer branches (Fig. 6).

The effect of harvesting intensity was negative. No significant difference was found between fruit production of control and low harvesting intensity, neither between severe and very severe categories (the latter had no fruits), whereas control and low harvesting intensity differed from severe and very severe harvesting intensity (Fig. 7a).

The significant effects of dbh × number of branches, dbh × harvesting intensity, number of branches × harvesting intensity and dbh × number of branches × harvesting intensity show that the effect of harvesting intensity depended on tree size and number of branches. Under low harvesting impact, there were twice as many fruits among of large trees (51–60 cm dbh size-class) compared to the control, whereas fruits were reduced by half for the size-class 31–40 cm dbh and reduced to 95 % for the size class

Table 1 Results of GLM presenting the significant factors influencing *Afzelia africana* fruit production per tree

	Estimate	Standard error	z value	Pr(>lzl)
Intercept	4.49E + 00	1.03E − 01	43.629	<0.002
Dbh	2.97E − 02	2.13E − 03	13.94	<0.002
Number of branches	1.40E − 01	1.60E − 02	8.74	<0.002
Harvesting intensity	−5.54E − 02	2.72E − 03	−20.359	<0.002
Dbh: number of branches	8.85E − 04	2.59E − 04	3.417	0.001
Dbh: harvesting intensity	6.39E − 04	5.96E − 05	10.729	<0.002
Number of branches: harvesting intensity	5.30E − 03	4.26E − 04	12.444	<0.002
Dbh: number of branches: harvesting intensity	−6.03E − 05	8.37E − 06	−7.200	0.000

Residual deviance: 8840.9 on 84 degrees of freedom

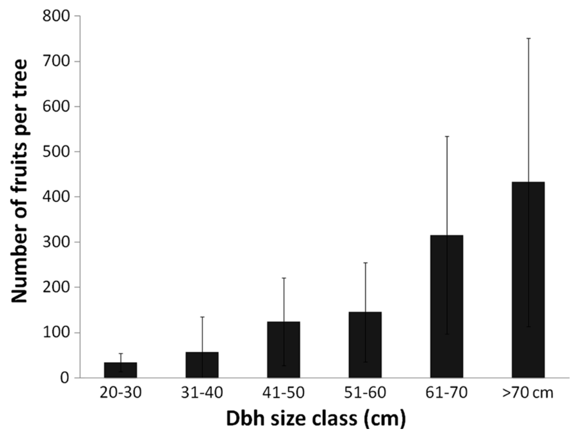

Fig. 5 Effect of dbh on fruit production, mean number of fruits per class and S.E. are shown

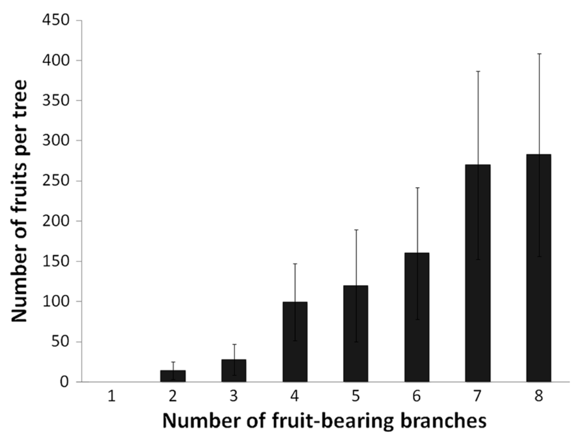

Fig. 6 Effect of number of branches on fruit production mean number of fruits per class and S.E. are shown

20–30 cm dbh (Table 2). In contrast, severe and very severe harvesting intensity effected fruit production of both large and small trees. The dbh size-class of 20–30 cm bore no fruits with severe and very severe harvesting intensity, and no trees at all bore fruits at very severe harvesting intensity.

Concerning the number of seeds produced per fruit, the dbh had no effects whereas, harvesting intensity had a negative effect ($z = -4.565$, $p = 0.005$). Trees under control and low harvesting conditions produced more seeds per fruit than severe and very severe harvested trees (no seeds) (Fig. 7b). Regardless of size class, seed production decreased with increased harvesting intensity. No difference was found between seed production under control and low intensity. Under very severe intensity did not produce any seeds.

Fruit and seed weights

Our results reveal that dbh had no effects on both fruit and seed weights whereas, the harvesting intensity was significant and, therefore, important factor influencing *Afzelia africana* fruit production. The effect of harvesting intensity on fruit weight was negative ($z = -13.828$, $p < 0.002$), i.e., weight of fruits decreased with the increasing harvesting intensity (Fig. 7c). Trees under control and low intensity pressures bore significantly heavier fruits than severely and very severely impacted trees. No significant difference was found between fruit weight in the control- and low harvesting trees, whereas the effect of low- versus severe and very severe harvesting intensities differed significantly.

The seed weight ($z = -8.731$, $p < 0.002$) decreased with the increasing harvesting intensity (Fig. 7d). No significant difference was found between seed weight under control and low harvesting intensity.

Discussion

Tree characteristics

Afzelia africana trees started fruiting at a minimum dbh of 20 cm, which is consistent with Donkpegan et al. (2014), who reported that in the genus of Afzelia generally become fertile from a size of 20 cm dbh. In addition, the positive correlation between tree size (dbh) and fruit yields has also been reported for other agroforestry trees species (Shackleton 2002; Okullo et al. 2004; Venter and Witkowski 2011; Haarmeyer et al. 2013).

Big trees produce more fruits, but the number of seeds and the weight of fruits and seeds are unrelated to tree size. Larger trees flowered and fruited copiously and more regularly compared to smaller sized trees (Okullo et al. 2004), suggesting size-specific fruiting performance.

Impact of combined bark and foliage harvesting on fruit production

Afzelia africana trees are under pressure in the eastern Burkina Faso because of bark and foliage harvesting. Our results indicated that combined bark and foliage

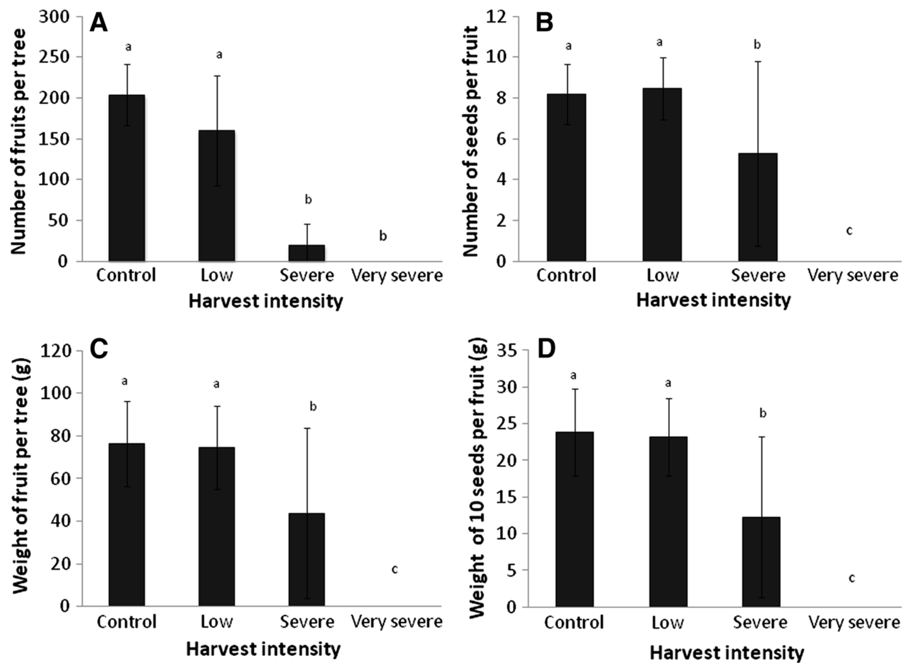

Fig. 7 Effect of harvesting intensity on *Afzelia africana* **a** fruit and **b** seed production, and **c** fruit and **d** seed weight

Table 2 Interaction between tree size and harvesting intensity on *Afzelia africana* fruit production per tree (mean number of fruits)

Dbh size-class (cm)	Control	Low	Severe	Very severe
20–30	100.40	4.15	0.00	0.00
31–40	156.11	61.63	12.67	0.00
41–50	199.57	185.00	45.60	0.00
51–60	109.33	242.50	11.00	0.00
61–70	464.50	470.00	18.50	0.00
>70	388.25	610.00	30.20	0.00

harvesting had a significant impact on *Afzelia africana* performance of fruit production. Similar harvesting effects on fruit and seed production (quantitatively and qualitatively) were also found for *Adansonia digitata* in Mali (Dhillion and Gustad 2004) and *Khaya senegalensis* in the Sudanian region of Benin (Gaoue and Ticktin 2008). The responses to such harvesting vary significantly with harvesting intensity.

Our results indicated that the severe intensities of harvesting decreased fruit and seed (number and weight) production. The reduction of the number of fruit and seeds is undoubtedly caused by the reduction of the number of inflorescence bearing-branches during foliage harvesting, which is specially observed to be practiced at the species flowering period (Petit and Mallet 2001; Ouédraogo-Koné et al. 2006). The removal of a significant part of the crown disrupts the balance of the roots and crown and provokes the reallocation of resources to rebuild the aboveground biomass (Ticktin 2004; Martín et al. 2015). Hence, the absence of fruit production in very -severe pruning conditions is attributed to the total decrease of photosynthesis and carbon fixation of trees (Martín et al. 2015). On the other hand, debarking creates a wound in the tree stem and exposes debarked individuals to phytopathogen agents (such as fungi), fire and desiccation. Depending on the depth of the cut, the thin layer of inner bark as well as the cambium may be removed and, hence, disturb the balance of water and nutrients transfer from leaves to roots and vice versa of the entire tree (Delvaux et al. 2009). This imbalance probably decreases the resources that would otherwise be used for fruit production to wound recovery.

Finally, the fact that harvesting, especially foliage harvesting, occurred in the dry season (March–May) may exacerbate impact on *Afzelia africana* fruit production by induced water stress during periods of high evaporation and low soil water content (Gyenge et al. 2009).

No significant difference in fruit and seed production (quality and quantity) was found between control and low harvested trees. Low foliage harvesting may provide best solar light penetration into the canopy layer. It may also increase fruit size due to less fruit competition (Boffa 1999) along the tree branch, which justified the highest fruit production (quantitatively) with less weight of large reproductive individuals in low harvesting conditions. However, the decreased fruit yields of small reproductive individuals (i.e., trees in 20–40 cm of dbh) indicates the vulnerability of such size-classes to low harvesting intensity.

Implications for conservation and sustainable management

The sustainable management of *Afzelia africana* in the study areas requires knowledge of how this socio-economically important tree species responds to the different harvesting types and intensities. In the absence of any long-term monitoring data on *Afzelia africana* fruit productivity, the results of this study (1 year data collection) could be a reference to sound the alarm about the impact of the overexploitation of the species and also to make recommendations for its sustainable use.

Our study highlights that bark and foliage harvesting occurring in the Sudanian savanna is detrimental to the performance of *Afzelia africana* fruit production. Harvesting significantly decreased the quantity and quality of fruits and seeds, which could compromise the chances of natural regeneration of this multiuse tree species in the long-term. The reduced number of fruits and seeds produced will have a short-term effect on seedling recruitment and a long-term effect on the future density of adults (Hall and Bawa 1993). This may have a remarkable effect on the seedling survival, as seedlings from large-seeded species have higher rates of survival than seedlings from small-seeded species (Moles and Westoby 2004). In fact, large-seeded species are better provided with stored reserves, which is expected to be an advantage in situations where access to water or light is limited (Westoby et al. 1996).

Our study also reveals that the severe and very -severe harvesting intensities currently practiced by local people are detrimental to *Afzelia africana* fruit production. Therefore, to secure the species and guarantee its long-term persistence in these Sudanian areas, such practices should be completely prohibited. Besides that, only low harvesting intensity, i.e., low bark and low foliage removal, should be allowed on large reproductive individuals.

Despite being protected since 1993, *Afzelia africana* is still exploited in all its ecological zones of Burkina Faso, and the species is now displaying signs of high-use pressure. However, considering the social and cultural importance of *Afzelia africana* in Gourmantché ethnic group (sacred tree), this prohibition seems difficult to implement. This suggests the importance of considering and understanding the social context of harvesting (Ghimire et al. 2008), as people are more likely to obey regulations influenced by themselves than those imposed on societies from the outside. To give a better chance for these strategies to succeed, local people, including harvesters and breeders, should also be associated with management planning.

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