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Full Length Research Paper

Grain yield response of sesame (*Sesamum indicum* L.) to intra- and inter-row spacing under irrigated condition at Gode, Somali Regional State, Ethiopia

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Sesame (*Sesamum indicum* L.) is the most important oilseed crop in Ethiopia. In the present study, efforts were made to devise appropriate crop geometry to obtain improved yield. An irrigated field experiment was conducted from December, 2014 to March, 2015 at the experimental farm of Gode Polytechnic College, Gode, Somali Regional State, Ethiopia, in order to determine grain yield and yield components using factorial combinations of five intra row (5, 10, 15, 20 and 25 cm) and four inter row (30, 40, 50 and 60 cm) spacing laid down in randomized complete block design with three replications. With the increase in intra row spacing from 5 to 25 cm, plant height (cm), primary branches/plant, capsules/plant, seed yield/plant (g), 1000-seed weight (g) and grain yield (kg/ha) increased from 101.31 to 117.87, 2.01 to 3.27, 29.17 to 43.05, 3.73 to 8.38, 2.51 to 3.63 and 648 to 1114, respectively. The respective increase in these parameters with the increase in inter row spacing from 30 to 60 cm was 100.01 to 114.71, 2.46 to 3.18, 36.33 to 42.07, 5.78 to 8.20 and 3.05 to 3.54, respectively, except that grain yield increased from 1103 to 1423 at 40 cm and then declined to 1013 at 60 cm spacing. The present study suggests that 15 x 40 cm spacing would be used to maximize grain yield of moderately branching varieties such as variety Adi.

Key words: Sesame, row spacing, grain yield, *Sesamum indicum*

INTRODUCTION

Sesame (*Sesamum indicum* L.) is the most important oilseed crop in Ethiopia. It grows from sea level up to 1500 m above sea level with uniformly distributed rainfall of about 500 to 800 mm and temperature of 20-30°C under various soil conditions (Ayana, 2015). Among oilseed crops, sesame stands first in area of production and total seed production per year. It occupies about 420,495 ha (49.14% of total area allocated to oil seeds) and produces about 288,770 tons of seed (37.99% of total oilseeds production) with average yield of 0.69 tons/ha (CSA, 2015).

The low yield of sesame has been partly attributed to inappropriate plant density, planting time, and pest pressure (weeds, diseases and insect pests)

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(Gebremichael, 2011). The establishment of an adequate plant density is critical for utilization of available growth factors such as water, light, nutrients and carbon-dioxide and to maximize grain yield. Too wide spacing leads to low plant density per unit area and reduces ground cover, whereas too narrow spacing is related to intense competition between plants for growth factors (Singh et al., 2004). In general, increase in yield has been obtained with the increase in plant density to the optimum levels (Adeyemo et al., 1992; Olowe and and Busari, 1994). On the other hand, the variation in plant density has been related to the variation in the number of capsules per plant, seed yield per plant and 1000-seed weight (Rahnama and Bakhshandeh, 2006), and plant height, number of branches per plant and seed yield (Ngala et al., 2013).

In Ethiopia, sesame grows during main rainy season as well as under irrigation during off-season commonly using 5 kg/ha seed rate and 40 x 10 cm spacing (Gebremichael, 2011). Perhaps, optimum plant density for maximum yield varies depending on plant characteristics and availability of growth factors such as water and nutrients. This experiment was conducted to determine grain yield and yield components of sesame under different intra and inter row spacing under irrigation.

MATERIALS AND METHODS

A field experiment was conducted during December, 2014 to March, 2015 under irrigation on the experimental farm of Gode Polytechnic College, Gode, Somali Regional State, Ethiopia. Gode is located at 5°57' N, 43°27'E and 300 m above sea level. It receives annual average rainfall of 325 mm and the monthly average maximum and minimum temperatures of 35.38 and 22.28°C, respectively. The main rain fall occurs from March to May (total of 186 mm) and the minor rain fall occurs from October to December (total of 128 mm). On the other hand, no rainy day was recorded during the experiment duration. The soils of the experimental site at the depth of 0-30 cm is sandy clay loam (sand 48, silt 26 and clay 26%) having pH 8.30, organic matter 0.5%, total N 0.06%, available P 27.53 ppm (Olsen), exchangeable K 1.21 cmol/kg, exchangeable sodium 0.65 cmol/kg, and CEC 14.60 cmol/kg.

The treatments consisted of factorial combinations of five intra row (5, 10, 15, 20 and 25 cm) and four inter row (30, 40, 50 and 60 cm) spacing laid down in randomized complete block design with three replications. The plot size was 3 x 3 m having distance between plots and replications of 1 and 1.5 m, respectively. The seeds of commonly grown sesame variety (Adi) were drilled on December 5, 2014 and the required spacing was maintained by thinning out excess seedlings two weeks after emergence. Plots were furrow irrigated every 5-8 days from planting up to flowering and then every 10 days up to physiological maturity. Weeds were controlled with hand weeding throughout the experiment.

Days to flowering and maturity, and plant height (cm), number of primary branches and capsules per plant (average for five random plants), number of seeds per capsule (average for three random capsules per plant), 1000-seed weight (g), seed yield per plant (g) and seed yield (kg/ha) were recorded. Data were analyzed using Genstat software (VSN International, 2012).

RESULTS

Days to flowering and maturity, plant height and branches

Days to flowering and maturity, plant height and number of primary branches per plant were significantly affected by intra and inter row spacing and also increased with increasing spacing. However, they were not significantly affected by the intra and inter row spacing interaction except days to flowering. The increase in intra row spacing from 5 to 25 cm significantly increased days to flowering from 35.25 to 44.67 (26.72), days to maturity 90.50 to 105.92 (17.04%), plant height 101.31 to 117.87 (16.35%), and primary branches per plant 2.01 to 3.27 (62.69%). The respective increase in these parameters with the increase in inter row spacing from 30 to 60 cm was 36.67 to 46.33 (26.34%), 95.67 to 105.73 (10.52%), 100.01 to 114.71 (14.70%), and 2.46 to 3.18 (29.27%) (Table 1).

Capsules, 1000-seed weight, seed yield per plant and grain yield

The effect of intra and inter row spacing was significant ($P<0.01$) for capsules/plant, 1000-seed weight, seed yield/plant and grain yield. However, they were not significantly affected by intra and inter row spacing interaction except grain yield. With the increase in intra row spacing from 5 to 25 cm, capsules/plant, 1000-seed weight (g), seed yield/plant (g), and grain yield (kg/ha) increased from 29.17 to 43.05 (47.58%), 2.51 to 3.63 (44.62%), 3.73 to 8.38 (124.66%) and 648 to 1114 (71.91%). The respective increase in these parameters with the increase in inter row spacing from 30 to 60 cm was 36.33 to 42.07 (15.80%), 3.05 to 3.54 (16.07%) and 5.78 to 8.20 (41.87%) except that grain yield increased from 1103 to 1423 (29.01%) at 40 cm and then declined to 1013 (28.81%) at 60 cm spacing (Table 2).

DISCUSSION

In the present experiment, the absence of interaction of intra- and inter-row spacing for plant height and number of branches per plant has also been reported for canola (Uzun et al., 2012). Early flowering and maturity at narrow spacing observed in this study could be because depletion of nutrients at high plant densities hastens processes of flowering and maturity. This agrees with the previous reports for potato (Getachew et al., 2012) and pearl millet (Ijoyah et al., 2015). However, non-significant effect of plant density on sesame flowering and maturity (El-Naim et al., 2010) has been reported indicating that the effect of plant density on crop phenology could vary with planting material used and location.

In the present experiment, the increase in plant height

Table 1. Significance of F-ratios and mean values of days to flowering and maturity, plant height and primary branches per plant of sesame grown at five intra and four inter row spacing.

Intra row spacing (cm)	DTF	DTM	PHT	PBP
5	35.25	90.50	101.31	2.01
10	38.83	94.75	107.45	2.80
15	43.42	104.58	110.63	2.87
20	44.50	105.58	115.29	3.23
25	44.67	105.92	117.87	3.27
Mean	41.33	100.27	110.51	2.83
$LSD_{0.05}$	1.44	2.33	9.84	0.41
Inter row spacing (cm)				
30	36.67	95.67	100.01	2.46
40	39.13	97.67	110.99	2.81
50	43.20	102.00	116.33	2.88
60	46.33	105.73	114.71	3.18
Mean	41.33	100.27	110.51	2.83
$LSD_{0.05}$	1.29	2.08	8.80	0.37
F-ratio				
Intra row(4)	**	**	*	**
Inter row(3)	**	**	**	**
Intra x inter row (12)	*	ns	ns	ns
CV (%)	4.20	2.80	10.80	17.50

DTF = days to flowering, DTM = days to maturity, PHT = plant height (cm), PBP = primary branches per plant; *, ** = significant at $p<0.05$ and $p<0.01$, respectively, ns = not significant; numbers in the parenthesis are degree of freedom.

Table 2. Significance of F-ratios and mean values of capsules per plant, 1000-seed weight, seed yield per plant and grain yield of sesame grown at five intra and four inter row spacing.

Intra row spacing (cm)	CP	TSW	SYP	GY
5	29.17	2.51	3.73	648
10	40.03	3.27	6.75	1314
15	42.16	3.57	7.95	1404
20	42.62	3.65	8.36	1320
25	43.05	3.63	8.38	1114
Mean	39.40	3.32	7.03	1160
$LSD_{0.05}$	3.23	0.21	0.64	111.60
Inter row spacing (cm)				
30	36.33	3.05	5.78	1103
40	38.75	3.26	6.69	1423
50	40.47	3.43	7.75	1102
60	42.07	3.54	8.20	1013
Mean	39.40	3.32	7.03	1160
$LSD_{0.05}$	2.88	0.19	0.57	99.80
F-ratio				
Intra row (4)	**	**	**	**

Table 2. Contd.

Inter row (3)	**	**	**	**
Intra x inter (12)	ns	ns	ns	**
CV (%)	9.90	7.80	10.90	11.60

CP = Capsules/plant, TSW = 1000-seed weight (g), SYP = seed yield/plant (g), GY= grain yield (kg/ha); *, ** = significant at p<0.05 and p<0.01, respectively, ns = not significant; numbers in the parenthesis are degree of freedom.

with the decrease in plant density could be due to less competition for nutrients and light at wider spacing. Similar results have also been reported for canola (Uzun et al., 2012), pearl millet (Ijoyah et al., 2015) and sesame (Ngala et al., 2013; Valiki et al., 2015). As to present experiment, the increase in the number of branches and capsules per plant (El Naim et al., 2010; Noorka et al., 2011) and 1000-seed weight (Rahnama and Bakhshandeh, 2006; Jakusko et al., 2013; Jan et al., 2014) with the decrease in plant density has been reported for sesame.

The increase in seed yield per plant with the decrease in plant density could be because of an increase in number of capsules per plant and 1000-seed weight at low plant density. On the other hand, the increase in grain yield with the decrease in intra and inter row spacing could be because of the increase in the number of plants per unit area. In other words, the increase in 1000-seed weight, and number of capsules and seed yield per plant could not be able to compensate for the low number of plants per unit area under wider spacing. Similar results have also been reported for sesame (Noorka et al., 2011; Umar et al., 2012; Jakusko et al., 2013; Jan et al., 2014), canola (Uzun et al., 2012), potato (Rahemi et al., 2005) and sorghum (Miko and Manga, 2008). On the other hand, the decline in grain yield below 15 cm intra row and 40 cm inter row spacing would show intense competition for nutrients and light below optimum spacing. This agrees with the previous reports for sesame (Ngala et al., 2013).

Conclusions

The present experiment indicated that: (1) capsules and seed yield plant as well as 1000-seed weight increased with the increase in both intra and inters row spacing, (2) maximum grain yield was obtained at 15 cm intra and 40 cm inter row spacing, and (3) 15 cm intra row and 40 cm inter row spacing would be used to maximize moderately branching sesame varieties such as variety Adi under irrigated conditions.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Monitoring the implementation of *Prunus africana* (Rosaceae) management plans in Cameroon: Respect of national norms

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The Convention on International Trade in Endangered Species of Fauna and Flora (CITES) Secretariat has teamed up with the International Tropical Timber Organization (ITTO) to assist Congo basin countries in the frame of the so called "the ITTO-CITES program", to develop non-detriment findings (NDF) on *Prunus africana*, a CITES listing tree species. This paper aims to assess the way the simple management plans (SMPs) developed within the ITTO-CITES program are being implemented in the field. Data were gathered during field missions conducted from November to December 2015. Although, Cameroon has made many efforts to promote the sustainable harvesting of *P.africana*, many problems still remain in the implementation of the guidelines prescribed in SMPs. It is in the North West region where the non-respect of existing norms/standards in term of realization of exploitation inventories, the minimum exploitable diameter (MED) and sustainable harvesting techniques is largely observed. The low buying price tends to be the main cause of the non-respect of national standards by community forest managers and harvesters. There is an urgent need for the ITTO-CITES program to extend its activities on the implementation of the SMPs.

Key words: *Prunus africana*, CITES, ITTO-CITES program, norms, management plans, sustainable harvesting.

INTRODUCTION

Prunus africana (Hook.f.) Kalkman is a species of the Rosaceae family, known under its trade/pilot name as pygeum or African cherry. It is a scattered tree species, which grows well in the sub-mountain and mountain forests at an altitude of 1500 to 3000 m. In Cameroon, the plant is largely found in five regions including Adamaoua, North West, Littoral, South west and West. *P. africana* is an evergreen canopy tree, 30 m tall with thick, fissured bark and straight bole that can reach a diameter of 1.5 m. It is light demanding and responds well to cultivation (Hall et al., 2000; Vivien and Faure, 2011; Fraser et al., 1996; Tchouto, 1996). The bark is the major source of an extract used to treat benign prostatic hyperplasia, an increasingly common health problem in

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older men in the western world. Prostate-related diseases prevalence increase as men age. And as the average age of the world's population increases, the incidences of prostate diseases will increase as well, triggering a corresponding rise in demand for therapies. According to the World Cancer Research Fund International, prostate cancer is the second most common cancer in men worldwide. Around 910,000 cases of prostate cancer were recorded in 2008, accounting for approximately 14% of all new cancer cases in men (World Agroforestry Centre, 2012). The United Nations Food and Agriculture Organization (FAO) reported as far back as 1996 that the demand for the species' bark, which is used to produce treatments for prostate gland disorders, could lead to its over-exploitation (FAO, 1996). In 1997, the global need was about 4 000 tons of dried barks per year for a value of 220 millions of USD. Two hundred kilogram of dried bark yield 5 kilogram of extract (Cunningham et al., 1997). The trade in dried pygeum bark and bark extract is in the order of 3 000 to 5 000 tonnes a year (Alternative Medicine Review cit. Page, 2003) and the main sources are in Cameroon, Madagascar, Equatorial Guinea, Kenya, Uganda and Tanzania.

P. africana is classified by the World Alliance for Nature (IUCN) as vulnerable species, which led to its listing in the Appendix II of the Convention on International Trade in Endangered Species of Fauna and Flora (CITES) in 1994, becoming effective in 1995. All the countries exporting *P. africana* bark, including Cameroon, are signatories to CITES. This should ultimately mean that the bark being exported is harvested from a sustainable source. However, the reality is somewhat different and, despite the legislation, the unsustainable exploitation of *P. africana* is often well-recorded.

Prunus harvesting and exports have hence been regulated in Cameroon as "a special forest product of a particular interest" since 1994 through a system of annual based exploitation permits for dried bark. The article no. 2 of the Decision no. 0336/D/MINFOF of the 06thJuly 2006 giving the list of "special products of a particular interest" states that, these are products that are relatively less abundant in the forest or for which some additional measures are indispensable, due to the threatening caused by the non-sustainable harvesting methods used by people. The method of special permit attribution was realized, over the years, to have some weaknesses which largely contributed to the gradual depletion of the natural existing *Prunus* stock. For example, quotas and permits were issued without reference to adequate biological baseline information, the attribution of the quota of special products was not based on sound inventory of the existing stock, the harvesting was not well defined in space (specific forest area) and time, official documents settled by the forest administration were not secured, the regeneration tax set at 10 FCFA/kg(1 USD = 550 FCFA) is too small to really play its role of conservation or sustaining the resource. This situation, coupled with the onset of illegal *Prunus* bark exploitation around the country led in 2007 to the adoption of the zero quota of *P. africana* bark exportation from Cameroon by the CITES-MA.

In order for the exportation to be undergone after four years (2007-2010) of considerable economic hardship to both the local community and all the other stakeholders involved in the *Prunus* trade, several steps had to be taken by the Cameroon Government to satisfy the International Community and to meet some basic requirements such as an inventory of the existing stock, a review of the method of special permits attributions and prescribing of new sustainable methods for *Prunus* bark exploitation with the settlement of the minimum exploitable diameter (MED) at 30 cm and the prescription of 2x ¼ opposite sides harvesting. Given these challenges, a new system for the allocation of special permits for *Prunus* bark exploitation called *Prunus* Allocation Units (PAU) was adopted. The PAU grants long term exploitation rights for the exploitation of *P. africana* within a territory specified according to an inventory and subsequent Management Plan for the unit (Ingram et al., 2009). The CITES Secretariat realized the challenges that range states of the CITES listing species face implementation of CITES requirements and it has teamed up with the International Tropical Timber Organization (ITTO) to help build capacities at the country level and promote the sustainable management of tropical forests including these species. This partnership in the frame of the so called "the ITTO-CITES program" has been strengthened considerably and is currently funding national activities to assist non-detriment findings (NDFs) by developing inventory, management and silvicultural plans, setting up tracking systems, providing training, and developing training and working material. Since 2008, under the ITTO-CITES Program, ITTO has, in consultation with the CITES Secretariat, funded 25 Activities (projects) in Africa distributed as follows: Cameroon (9 activities), Congo-Brazzaville (5), Democratic Republic of Congo (5), Ghana (2) and four at regional level. The assistance of the ITTO-CITES Program to date in Cameroon on *P. africana* has focused on the development of non-detriment findings, simple management plans and resource inventories for key production regions using limited funds provided by the private sector. The lack of NDFs was identified at the earliest stages (2009) of the program's work on this species as a key factor leading to bans (in Democratic Republic of Congo and Equatorial Guinea for example) and voluntary zero quotas (in Cameroon) that gave rise to the private sector's interest in funding this work. In 2010-2011, the program funded *Prunus* management inventories in two regions in Cameroon including the North West and the South West. The management inventory was conducted with a sampling intensity of 1.11% in Mount Cameroon (South West), 3% in the 17 community forests found in the North West, 3% in the

flora sanctuary found in the North West, and 0.5% in the area out of community forests in the North West. The method used was the modified "Adaptive Clusters Sampling (ACS)". We call this method "modified ACS" since, only one circular plot was added at 100 m in each side of the rectangular plot which hosted many stems of *P. africana* (Betti et al., 2011). A prediction of the sustainable yield of *Prunus* bark was made from estimates of the natural population (number of exploitable trees), the average yield per tree (55 kg of fresh bark) and the length of time between successive debarkings (rotation) required to allow total recovery of the bark (5 to 10 years) half rotation. Those sustainable yields or annual quota were reported as follows in each regional NDF document: South West 150 tons of dried bark inside and outside the Mount Cameroon National park, North West 104 tons for community forests, 5.8 tons for Kilum-Ijim flora sanctuary, and 56.3 tons for the area out of community forests. The NDF reports also proposed specific measures to consider prior to or during harvesting of the bark which are: adoption of a rotation of 10 years or a half rotation of 5 years, dividing the useful area of each forest in five equal annual blocs (clusters) according to the rotation, conducting 100% inventory with standard methods and equation for calculating harvestable yield quotas for each cluster prior to setting annual quota and exploitation proper (this means that the real quota can differ from the estimated one), apply prescribed norms for harvesting the *Prunus* barks such as the MED (30 cm), the use of 2 x ¼ method of harvesting, harvesting only living trees, setting tracking systems (Betti et al., 2011).

This paper aims to assess the way the simple management plans developed for *Prunus* and guidelines contained in NDFs reports are being implemented in the field, the North West (Mount Oku) and the South West (Mount Cameroon) regions to be precise. The specific objective is to check the respect of national norms/ standards in the field.

MATERIALS AND METHODS

Study sites

South west region

The south west of Cameroon is composed of six divisions including: Fako, Koupé-Manengoumba, Lebialem, Manyu, Meme and Ndian. The Mount Cameroon is located, between 3°57' - 4°27' latitude North and 8°58' - 9°24' longitude East in the bottom of the Biafra bot berry in the Guinean gulf. It is up to 4095 m and covers a total area of 25 000 km², in the divisions of Fako and Mémé.

The climate is a subequatorial type, on monsoon regime with two seasons: a short dried season from December to March and a long rainy season from April to November. The average temperature is 22°C in the altitude. The relative humidity remains at 75-80% due to the influence of clouds and fogs (Ewusi et al., 1996).

The Mount Cameroon has a high diversity of plant species. From bottom to the summit of the mount, there are four main vegetation types including: the sub-mountain forest, the mountain forest, the sub-mountain meadow and the mountain meadow.

The North West region

The North West region of Cameroon is located between 5°4' and 7°15' latitude North and 9°30 and 11°15 longitude East. It covers a total area of 17 910 km². The North west region is composed of 7 divisions including: Mezam (Bamenda being the capital), Boyo (Fundong), Bui (Kumbo), Ngoketunjia (Ndop), Donga Mantung (Nkambé), Menchum (Wum) and Momo (Mbengwi). The natural Prunus inventory was conducted in the Mount Oku. The mount Oku covers two divisions in the North West region: the Boyo and the Bui divisions to be precise. The side located in the Boyo division is called "mount Ijim" and the one located in the Bui division is called "mount Kilum".

Mount Oku is up to 3011 m and belongs to the Cameroonian mountains group (White, 1983). The area is composed of a variety of landscapes including small and high mountains with high slopes and valleys. The lowest altitude is about 1169 m towards Babungo. The position of the region in the tropical area implies a humid and warm climate, which is however transformed to a temperate and warm climate on the mountains. The Oku region is characterized by two distinctive seasons including the dried season with humid and dried wins which lends from mid-November to mid-march, and the rainy season going from mid-March to mid-November. The annual rain is about 2000 mm, July and August being the most rainy months. In low levels, the highest temperature is 23°C. The water network is less dense, composed mainly of small rivers which bear in rocks in mountains and which become bigger in valleys. This gives priority to the protection of those mountains for the regulation of the water regime. There also exists a volcanic lack on the summit of the mount Oku.

The Oku vegetation is a direct consequence of the climate, topography and human activities. Following vegetation types can be found: the humid and arbustive savannahs in high altitudes, the *Pennisetum purpurum* vegetation in valleys of low drainage, and the mountain forests which cover the mounts of Nkom, Wum, Kilum and Ijim

The summit of the mount Oku is subjected to bush fires, used by "Bororos" or Foulani farmers for grazing. The Foulanic farmers are nomadic. There exists many conflicts for lands between farmers. Bush fires constitute one of the main threats for *P. africana* in the Northwest region.

The Mount Oku hosts the unique natural forest which surrounds the volcanic lack of Oku or the "Oku lack". To protect this forest which constitutes the scarce habitat of the two endemic and endangered bird species, *Tauraco bannermani* and *Platysteira laticincta*, one project entitled "the Kilum-Ijim project" was launched with the financial support of the BirdLife International in 1993. To involve local people in the conservation of the forest resources and for the maintenance of the water regime which bears from the mountains, the "Kilum-Ijim project" assisted local populations in the acquisition of community forests and planting *Prunus* trees in their farms. The project also proposed the erection of one important part of the forest in a protected area, the flora sanctuary of Kilum-Ijim to be precise. A total number of seventeen (17) community forests were created with the *Prunus* exploitation being the main goal. The simple management plans of all the 17 forests were developed. The problem is that, those simple management plans were developed without suitable *Prunus* inventories and sustainable yield set.

Methods

Data were collected from November to December 2015. Before going to the field (forest), the team of the study held several meetings with different stakeholders including the forest admini-

stration officers in the external services (regional and divisional delegates of forestry and wildlife), the representatives of Prunus production sites including the Mount Cameroon National park service and the MUTEF Community forest manager (CFM), the private sector. The team also discussed with the Program for the sustainable management of natural resources in the South West region of Cameroon (PSMNR-SWR). The PSMNR-SWR is a development program of the Government of Cameroon, co-financed by the Federal Republic of Germany through the KFW, in cooperation with GIZ. The PSMNR assisted the Mount Cameroon national park authorities to implement the management plan of the Park in collaboration with local populations.

The benefit sharing mechanisms settled in each production site, reports and official documents including field logging book and way bills were analyzed. The existence of monitoring system and the control missions to be executed by the local forest administration were also checked.

In the field, the way simple management plans dressed in 2010 - 2011 are being implemented in terms of annual plots delimitation, systematic inventories of exploitable trees in annual plots, the respect of national standards in terms of the minimum exploitable diameter and the techniques of harvesting were examined. To do this, the authors went to the first annual plot of each selected production site to collect data on diameter at breast high and to describe the techniques of harvesting of the bark used. Quantitative data were analyzed with the Microsoft EXCEL 2010 computer package.

RESULTS

Since 2011, private/trade companies in Cameroon have access to the resource (*Prunus*) in three ways including: (1) a competing process call of the PAUs, (2) community forests with approved simple management plans and quota and (3) tripartite conventions between the trade company, the State (Government), and local communities.

Respect of regional quota and benefit sharing mechanisms

North West region

In 2011, the Cameroon CITES management authority for flora (Ministry of Forestry and Wildlife/Directorate of Forests) was authorized to harvest a total of 280 tons of dried bark of *Prunus* in the North West (150 tons) and the South West (130) regions. The 150 tons of the North West region were approved for 12 community forests, the Kilum-Ijim flora sanctuary and the area out of the community forests. Community forests are those forests that the Government allows local communities to harvest and yield revenues. These revenues are used for implementing development projects such as building schools, dams and health structures. In the dense forest regions of Cameroon such as East, Centre, Littoral and South, community forests are often requested for timber logging. The exploitation of non-timber forest products is considered as a minor activity. But in the North West and South West regions, community forests are largely requested for the harvesting of special products mostly composed of *Prunus* barks. The activities of the 12 community forests (CFs) identified in the North West region were focused on the harvesting of *Prunus* barks. Seventh out of these CFs are found in the Bui division and 5 are found in the Boyo division. For the seventh CFs of the Bui division, local traditional authorities (rulers) together with their communities refuse to authorize the harvesting of *Prunus* bark in their forests. This was decided because of some misunderstandings that occurred on the benefit sharing mechanisms between the traditional rulers and the mayor of the city of Kumbo. In fact, the mayor of the city of Kumbo, the capital city of the Bui division, wanted to have a total control of the management of the *Prunus* barks revenues yielded from surrounding CFs. The forest administration respected that decision and has never issued the official documents including field log books and way bills to traders for the exploitation of *Prunus* barks in the Bui division. But, the study noted that, the decision was not effectively respected by some trade companies. In fact, some trade companies succeed to convince some villagers and farmers to harvest *Prunus* found in both natural forests and plantations in the Bui division. They buy some sheets of the way bills documents from the community forests of the Boyo division, to convey their products till the factory and exit port (Douala).

The only community forests authorized therefore to harvest *Prunus* in the North West are those located in the Boyo division including ANYANJUA, LAIKOM, MOULOIN, MUTEF and YANG TINIFOINBIMULO. The 2010-2011 Prunus management inventories conducted by the National Forest Development Agency (ANAFOR), the Cameroon CITES Scientific authority for flora, within the ITTO-CITES program was conducted in the North West region with an average sampling rate of 2.72% for the four community forests ranging from 1.85% at MUTEF to 3.25% at YANG. A total annual quota of 14 411.31 tons of dried bark/year was proposed for the four out the five community forests identified in the Boyo (Table 1).

For the two first harvesting years (2011 and 2012), the forest service of the Regional Delegation of Forestry and Wildlife and the Divisional Delegation of Forestry and Wildlife of the Boyo assisted local communities in managing their forests as prescribed in NDFs reports and SMPs. This assistance included: (1) training of harvesters on the national standards of harvesting, (2) the distribution of seedlings to farmers, (3) the sensitization of local people on the importance of *Prunus africana*, and (4) the delimitation of annual plots (blocs). The SMP proposes that, once the annual plot is delimitated, the CFM has to conduct the 100% inventory of exploitable trees inside the plot. During the exploitation inventory, all health *Prunus* trees with diameter at breast high ≥ 30 cm are measured, geo-referenced, tagged and recorded for exploitation. The exploitation inventory has never been conducted in any community forest of the Boyo division

Table 1. Characteristics of the four community forests inventoried in the North West region within the ITTO-CITES program in 2010.

Community forest	Total useful surface area(ha)	Proposed or previous sampling rate (%)	Real surface area surveyed (ha)	Realised sampling rate (%)	Surface area of annual plot	Annual quota (5 years half rotation)
ANYAJUA	1034	3	29	2.81	206.8	3136.45
LAIKOM	651	3	19.5	2.99	130.2	3123.37
MUTEF	595	3	11	1.85	119	5948.8
YANG TINIIFOIN BIMULO	431	3	14	3.25	86.2	2202.69
Total/or average	2 711		29	2.72	542.2	14 411.31

Table 2. Agreed benefices sharing for Prunus from the MUTEF community forest, Boyo division, north west region in 2011-2013 and 2014-2015.

S/N	Cost headings	2011-2013		2014-2015	
		FCFA/kg of fresh bark	Cost	FCFA/kg of fresh bark	Cost
1	Harvesters	60	46.2%	40	30.8%
2	Village development fund	50	38.5%	15	11.5%
3	Facilitation of community participation	20	15.4%	15	11.5%
4	The farm owner (farmer)	-	-	60	46.5
	Total	130	100%	130	100%

or in the North West region before harvesting. Since 2013, the assistance of the local forest administration has been limited to the distribution of seedlings to farmers and the sensitization of those farmers on the importance of *P. africana*. Specific activities such as the control of harvesting in the field have no longer been conducted.

The MUTEF community forest was selected in the North West for the monitoring study due to its important contribution to the divisional quota: 5 948.8 kg of dried bark/year or 12 000 kg of fresh bark/year, representing 41.3% of the total quota. This quota should be harvested in annual plots of 119 ha each for a half rotation period of 5 years. The harvesting of *Prunus* bark started in MUTEF forest in 2011 as scheduled. Once the annual plot is delimitated by the local forest services, the CFM of MUTEF engages peoples for harvesting the 12 000 kg of fresh barks attributed. The CFM said, the community does not have enough funds to support the exploitation inventories as requested. To ease the control and tracking system in the field, the forest administration reduced the number of private companies authorized to buy Prunus barks. For the MUTEF community forest, only one company was authorized to buy barks. The company pays one kilogram of the fresh bark of *Prunus* at 130 FCFA (or 0.24 USD). The benefice sharing mechanism was set as indicated in Table 2. For the period 2011-2013, the harvesters (46.2%) perceive about the average of the total revenues yielded from the selling of barks. The facilitation of the community participation or the community forest manager (CFM) has the smallest part, only 15.4% of the total revenues.

In 2013, two years after the implementation of this agreement, the harvesters complained about their salary. They said, the salary was too small as compared to the hard and dangerous work of the harvesting of *Prunus*. They requested to be paid 80.0 FCFA/kg and the CFM at 50 FCFA/kg. The reason of this was that, the authorized annual plots (bloc 3 – 5) were being located far from the

village (houses). But the CFM refused to obey. Harvesters then started debarking *Prunus* trees using un-sustainable methods. These harvesters can be distinguished in five groups according to their practices (behavior). The first group of harvesters returned in the first annual plots harvested in 2011 and 2012 to debark non-mature/exploitable trees (these are trees with diameters <30 cm). The second group of harvesters also returned back to the same previous plots and started removing one of the remaining portions of the bark (the third quarter) that was left to be harvested after five years according to the guidelines; finally, the 3 x ¼ of the tree was harvested, what is not normal. The third group of harvesters removed all the remaining bark, which are the third and the fourth quarters; they practiced a total debarking = 4 x ¼ of the tree, which is prohibited. The fourth group of harvesters started harvesting the bark of *Prunus* found in private farms, close to the village. Other harvesters (the last group) resigned, abandoned the job because of the low buying price and the hard work. In 2014, the CFM of MUTEFF wrote a letter to the Minister of Forestry and Wildlife, asking the authorization of harvesting *Prunus* barks from private farms and plantations. The reason presented in the letter was that, there was no enough *Prunus* in the blocks 4 and 5. At the same time, there were many Prunus found in private farms and plantations surrounding the community forest. The Minister accepted the request and authorized the MUTEFF community to start harvesting *Prunus* from private farms and plantations. The CFM of MUTEFF then decided to revise the benefit sharing mechanism for the period of 2014-2015 (Table 2). The farm owners (46.5%) and harvesters (30.8%) are in this order the stake holders who perceive the high amount of the funds generated by the community forest.

This new arrangement was agreed on by all parties and is the one which is working now in the MUTEFF community forest since 2014. If the buying price of *Prunus* was quite high, at least 500 FCFA/kg for example, the CFM should be able to conduct the 100% exploitation inventory in each annual plot and harvesters should continue to harvest inside the community forest without problem. In spite of the low price of the bark, the funds generated by the selling of *Prunus* have been effectively used by the CFM who contributed to the building of the MUTEFF secondary school, and to the buying of tables and chairs for the local nursery school.

Mount Cameroon

The Mt Cameroon *Prunus* Allocation Unit (PAU) includes the Mont Cameroon national park and the surrounding community forests. The 2010 *Prunus* management inventories conducted by ANAFOR in the Mt Cameroon PAU proposed an annual quota of 178 tons of dried bark inside (158 tons) and outside (20 tons) the park, for a total useful area of 22 844 ha. As a conservative measure and conscious of the status (national park) of the Mt Cameroon, the conservation service of the park together with the Regional Delegation of Forestry and Wildlife of the South West, decided to reduce that quota to 130 tons/year for the first rotation of 5 years exploitation.

The 100% *Prunus* exploitation inventories are carried out in each bloc prior for exploitation as scheduled. During the inventory, all health *Prunus* trees with diameter ≥ 30 cm are measured, geo-referenced, tagged and recorded for exploitation. Till date, the exploitation inventories are supported by the PSMNR-SW program. A total amount of 80 000 000.0 FCFA was estimated to cover the exploitation inventories on the five blocs, totalizing 32 000 ha. This gives an average cost of 2 434.0 FCFA/ha (Table 3).

Although, the authorized quota based on the previsions of the management plan was set at 1 260 tons of fresh bark/year for a 5 year rotation period, so far only about 510 tons of fresh bark of healthy exploitable was recorded in the half area of the Mount Cameroon PAU. *Prunus* regeneration is promoted through enrichment in Community Forests and Communal land, and trees planting in farms and plantations.

The participation of local communities constitutes an integral aspect of the management. A fair and equitable benefit sharing mechanism was developed and is being implemented to assist in poverty alleviation in the surrounding village communities. Exploitation inventories, harvesting, weighing and payment are done under the supervision of the Park Service and the Regional Delegation of Forestry and Wildlife with the assistance of the PSMNR-SW program. The Mont Cameroon communities association (MOCAP), a locally organized Community initiative Group (CIG) was created for the organization and monitoring of sustainable exploitation and management of *Prunus* at village level on Mount Cameroon. MOCAP regroups all villages surrounding the Mount Cameroon National Park. The trade company buys the fresh bark to MOCAP at 550 FCFA/kg, and this payment is distributed to different stakeholders/activities as illustrated in Table 4. Harvesters, field equipment and medication, appears to be the post which has the highest cost (43%). It is followed by the park management activities (20%).

The monitoring and controls are strengthened to ensure traceability and sustainability. Better coordination between central, regional and divisional Forestry Administration is ensured.

Respect of norms during harvesting

The national standards recommend that ¼ of the stem be stripped from opposite sides and leave the other sides unexploited for 5 years to permit the bark to regenerate before exploitation. This should begin at 1.3 m above the

Table 3. Clusters delimitated in the Mount Cameroon PAU and cost estimated for the exploitation inventories.

Bloc (cluster)	Surface area (ha)	Total cost estimated for the exploitation inventory (FCFA)	Cost/ha
1	3691	14 000 000	3793.01
2	3939	12 000 000	3046.458
3	6291	16 000 000	2543.316
4	12248	26 000 000	2122.796
5	6699	12 000 000	1791.312
Total	32868	80 000 000	2433.978

Table 4. Agreed benefits sharing for Prunus from the Mount Cameroon national park.

S/N	Cost headings	FCFA/kg of fresh bark	Cost (%)
1	Harvesters, fieldequipments, medication	237	43
2	Village developmentfund	88	16
3	Facilitation of community participation	38.5	7
4	Park management	110	20
5	Regeneration of Prunus trees	38.5	7
6	Transport	22	4
7	Warehouse	16.5	3
	Total	550	100

ground level and end at the first big branch. Harvesting of *Prunus* bark shall be carried out only by trained farmers/ harvesters in possession of a harvester's certificate.

Harvesters shall only debark trees that have been tagged and geo-referenced. Harvesting shall be done along ¼ strips on opposite sides of the stem up to the first big branch for trees between 30 and 50 cm DBH. The 4/8 quarters or the 3/6 quarters shall be used for all trees above 50 cm DBH. Felling of trees is prohibited. During harvesting, the order number, size and health of every tree exploited as well as the wet weight of the harvested bark shall be registered daily in a field logbook.

Boyo division

A total of 63 exploited trees were sampled in Bloc 1 of the MUTEF community forest (Table 5). Fifty six trees were found in the community forest and 7 were found in adjacent private farms. Figure 1 illustrates the distribution of the trees harvested in different diameter classes. The average diameter of trees exploited is 27.2 cm, which is less than the minimum exploitable diameter (MED) fixed by the forest administration (30 cm). A total of 46 trees, representing 73% of the total number of the trees sampled were harvested below the MED. Seventh trees were harvested below 10 cm, most of them coming from adjacent private plantations. Only 17 trees, representing 27% have attended the MED.

Harvesters in the MUTEF use two techniques of harvesting: the 2/4 opposite sides technique and the ¾ technique. The 2/4 technique was observed on 63.7% of trees while the ¾ technique was observed on 33.3% of trees. The ¾ technique may be detrimental to the survival of the resource and therefore it is not recommended according to the national standards.

Bui division

The respect of norms was examined on 38 trees sampled in one private farm of 0.25 ha in Kumbo subdivision (Table 6). The farm was set in 2002 and the first harvesting occurred in 2012, which is ten (10) years after. The distribution of trees harvested in different diameter classes is illustrated in Figure 2. The average diameter of trees exploited is 22.0 cm, which is less than the minimum exploitable diameter (MED) fixed by the forest administration (30 cm). A total of 36 trees, representing 94.7% of the total number of the trees sampled were harvested below the MED.

Only two trees were harvested using the 3 x ¼ technique. Almost all trees were harvested using the 2x1/4 opposite sides technique.

Mount Cameroon

The bloc 1 of the Mount Cameroon PAU, harvested in

Table 5. Diameters and healthy of trees sampled in the MUTEFF community forest, Boyo division, North west region of Cameroon, in 2015.

Order number of the trees	Diameter at breast high (cm)	Diameter classes	Healthy	Harvesting techniques
1	51.0	Cl50_60	Living	3x1/4
2	18.2	Cl10_20	Living	3x1/4
3	28.0	Cl20_30	Living	3x1/4
4	16.9	Cl10_20	Living	3x1/4
5	25.2	Cl20_30	Dead	3x1/4
6	32.5	Cl30_40	Living	3x1/4
7	76.4	Cl60 et +	Living	3x1/4
8	33.8	Cl30_40	Living	3x1/4
9	34.8	Cl30_40	Living	3x1/4
10	19.5	Cl10_20	Living	2 x 1/4 opposite sides
11	14.2	Cl10_20	Living	2 x 1/4 opposite sides
12	19.2	Cl10_20	Living	2 x 1/4 opposite sides
13	17.7	Cl10_20	Living	2 x 1/4 opposite sides
14	19.2	Cl10_20	Living	2 x 1/4 opposite sides
15	93.3	Cl60 et +	Living	2 x 1/4 opposite sides
16	57.3	Cl50_60	Living	2 x 1/4 opposite sides
17	17.9	Cl10_20	Living	2 x 1/4 opposite sides
18	25.5	Cl20_30	Living	2 x 1/4 opposite sides
19	10.3	Cl10_20	Living	2 x 1/4 opposite sides
20	10.4	Cl10_20	Living	2 x 1/4 opposite sides
21	3.7	Cl0_10	Living	2 x 1/4 opposite sides
22	5.2	Cl0_10	Living	2 x 1/4 opposite sides
23	6.5	Cl0_10	Living	2 x 1/4 opposite sides
24	19.0	Cl10_20	Living	2 x 1/4 opposite sides
25	33.9	Cl30_40	Living	2 x 1/4 opposite sides
26	25.4	Cl20_30	Living	2 x 1/4 opposite sides
27	14.4	Cl10_20	Living	2 x 1/4 opposite sides
28	14.8	Cl10_20	Living	2 x 1/4 opposite sides
29	7.6	Cl0_10	Living	2 x 1/4 opposite sides
30	22.5	Cl20_30	Living	2 x 1/4 opposite sides
31	13.8	Cl10_20	Living	2 x 1/4 opposite sides
32	54.1	Cl50_60	Living	2 x 1/4 opposite sides
33	10.2	Cl10_20	Living	2 x 1/4 opposite sides
34	14.0	Cl10_20	Living	2 x 1/4 opposite sides
35	33.7	Cl30_40	Living	2 x 1/4 opposite sides
36	36.8	Cl30_40	Living	2 x 1/4 opposite sides
37	22.0	Cl20_30	Living	2 x 1/4 opposite sides
38	28.0	Cl20_30	Living	2 x 1/4 opposite sides
39	24.2	Cl20_30	Living	2 x 1/4 opposite sides
40	27.1	Cl20_30	Living	2 x 1/4 opposite sides
41	12.1	Cl10_20	Living	2 x 1/4 opposite sides
42	18.8	Cl10_20	Living	2 x 1/4 opposite sides
43	27.1	Cl20_30	Living	2 x 1/4 opposite sides
44	28.2	Cl20_30	Living	2 x 1/4 opposite sides
45	12.1	Cl10_20	Living	2 x 1/4 opposite sides
46	25.2	Cl20_30	Living	2 x 1/4 opposite sides
47	24.6	Cl20_30	Living	2 x 1/4 opposite sides
48	22.0	Cl20_30	Living	2 x 1/4 opposite sides
49	22.4	Cl20_30	Living	3x1/4
50	34.6	Cl30_40	Living	3x1/4

Table 5. Contd.

51	35.7	Cl30_40	Living	3x1/4
52	27.2	Cl20_30	Living	3x1/4
53	7.0	Cl0_10	Living	3x1/4
54	6.7	Cl0_10	Living	3x1/4
55	4.8	Cl0_10	Living	3x1/4
56	44.1	Cl40_50	Living	2 x 1/4 opposite sides
57	14.2	Cl10_20	Living	3x1/4
58	11.8	Cl10_20	Living	3x1/4
59	25.2	Cl20_30	Living	2 x 1/4 opposite sides
60	41.4	Cl40_50	Living	2 x 1/4 opposite sides
61	55.4	Cl50_60	Living	3x1/4
62	14.0	Cl10_20	Dying	3x1/4
63	38.2	Cl30_40	Living	3x1/4
Mean	27.9			

Diameter classes are defined as follows: Cl10_20 = diameters comprised between 10 cm and 19 cm; Cl20_30 = diameters between 20 and 29 cm.

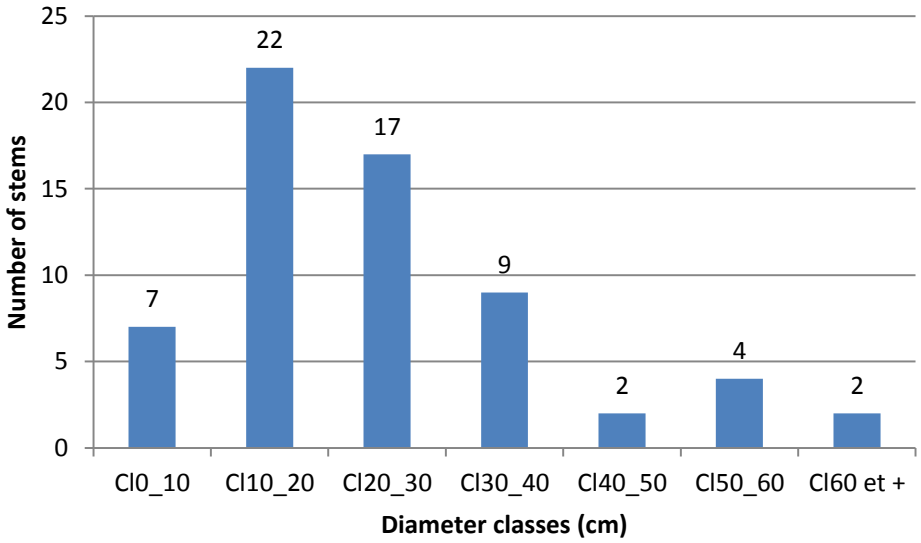

Figure 1. Distribution of *Prunus* trees harvested in different diameter classes in the bloc 1 of the MUTEF community forest, the Boyo division.

Table 6. Diameter, techniques and thickness of the bark of trees harvested in one plantation in 2012 in Kumbo, Bui division, North west region of Cameroon.

Order number of the trees	Diameter at breast high (cm)	Diameter classes	Harvesting techniques
1	16.9	Cl10_20	2x1/4 opposite side
2	28.2	Cl20_30	2x1/4 opposite side
3	21.0	Cl20_30	2x1/4 opposite side
4	16.9	Cl10_20	2x1/4 opposite side
5	6.1	Cl0_10	2x1/4 opposite side
6	18.2	Cl10_20	2x1/4 opposite side
7	6.0	Cl0_10	2x1/4 opposite side

Table 6. Contd.

8	24.3	Cl20_30	2x1/4 opposite side
9	15.4	Cl10_20	2x1/4 opposite side
10	11.7	Cl10_20	2x1/4 opposite side
11	31.7	Cl30_40	2x1/4 opposite side
12	18.5	Cl10_20	2x1/4 opposite side
13	12.8	Cl10_20	2x1/4 opposite side
14	15.9	Cl10_20	3x1/4
15	10.0	Cl10_20	3x1/4
16	22.4	Cl20_30	2x1/4 opposite side
17	31.0	Cl30_40	2x1/4 opposite side
18	27.9	Cl20_30	2x1/4 opposite side
19	18.6	Cl10_20	2x1/4 opposite side
20	25.5	Cl20_30	2x1/4 opposite side
21	25.5	Cl20_30	2x1/4 opposite side
22	23.6	Cl20_30	2x1/4 opposite side
23	22.9	Cl20_30	2x1/4 opposite side
24	26.1	Cl20_30	2x1/4 opposite side
25	23.2	Cl20_30	2x1/4 opposite side
26	36.9	Cl30_40	2x1/4 opposite side
27	26.1	Cl20_30	2x1/4 opposite side
28	41.1	Cl30_40	2x1/4 opposite side
29	24.4	Cl20_30	2x1/4 opposite side
30	18.5	Cl10_20	2x1/4 opposite side
31	19.7	Cl10_20	2x1/4 opposite side
32	27.1	Cl20_30	2x1/4 opposite side
33	18.9	Cl10_20	2x1/4 opposite side
34	18.2	Cl10_20	2x1/4 opposite side
35	25.3	Cl20_30	2x1/4 opposite side
36	28.8	Cl20_30	2x1/4 opposite side
37	29.3	Cl20_30	2x1/4 opposite side
38	22.3	Cl20_30	2x1/4 opposite side
Mean	**22.0**		

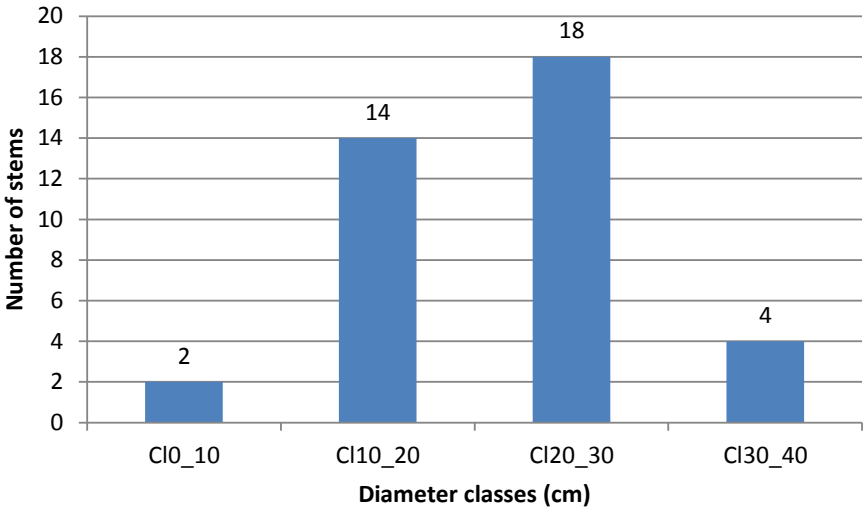

Figure 2. Distribution of Prunustrees harvested in different diameter classes in a private farm found in Kumbo, the Bui division.

2011 was chosen for this study. A total of 126 trees were sampled (Table 7).

Figure 3 illustrates the distribution of trees harvested in different diameter classes. The average diameter of trees exploited is 73.3 cm, which is higher than the 30 cm settled as the minimum limit. A total of 119 trees representing 94% were exploited with respect to the MED. Only a total of 5 harvested trees sampled representing 4% has diameter below 30 cm.

Two broad techniques of harvesting are used in the Mount Cameroon including the harvesting of the half part of the bark and the harvesting of the full bark. The harvesting of the total (full) was observed only on 1.7% of the trees sampled, while the harvesting of the half part was observed on 98.3% of trees. The technique of harvesting the half part of the bark can further be distinguished in two components including the technique of harvesting the 2 x ¼ opposite sides and the technique of harvesting the 3 x 1/6 opposite sides. The 2x1/4 opposite side appears to be the most used with 70.2%.

DISCUSSION

Generally speaking, the Cameroon Government has made many efforts to promote the sustainable harvesting of *P. africana* in the country. *Prunus* range areas are since 2009 delimitated in production forests including *Prunus* Allocation Units (PAUs) and community forests. For each production forest, the simple management plan and the annual quota are defined on a scientific basis. Trade companies have the obligation of conducting exploitation inventories prior to the harvesting in each annual plot. The MED has been fixed and sustainable harvesting techniques have been defined. Log books have been set by the forest administration to register day to day, the trees harvested with their identification number, their weight and the name of the harvester. Raw barks are being conveyed to the factory or exit points with way bills. These tools constitute the preliminary documentary tracking system which was set with the assistance of SNV, CIFOR, FAO, ICRAFT and recently ITTO and CITES through the ITTO-CITES program.

The monitoring study conducted in November to December 2015 in the North West and South West regions of Cameroon, reveals that guidelines contained in management plans and NDFs are not fully respected in the field. The degree of the implementation of the Prunus SMPs developed within the ITTO-CITES program varies from one region to another, and sometimes in the same region (North West for example), from one division to another. As noted for the timber sector and in recent studies, sometimes, management plans are well developed, but the problems resides on their implementation in the field (Betti et al., 2016; Ingram, 2014; Cunningham et al., 2014; Geldenhuys, 2004). Harvesting guidelines have been developed. These build on decades of experience (MINFOF, 2010). However, experiences strongly indicate that without adequate monitoring and control by regulatory authorities, local communities and customary rulers, guidelines and laws alone do not guarantee sustainable harvesting. This failure has been attributed to high demand for bark and the power and influence exporters and importers have in the value chain (Ingram, 2014; Cunningham et al., 2014). Based on WCMC-CITES data, Cameroon has consistently been the world's largest *Prunus* exporter, averaging 47% of total exports from 1995 to 2013. After 2004, Cameroon's share increased as other exporting countries decreased production, resulting in Cameroonian exports accounting for 65% of global exports from 2004 to 2013 (UNEP-WCMC, 2014). Pharmaceutical companies confirmed there is a continued market and demand for *Prunus* -based pharmaceuticals prescribed for benign prostatic hyperplasia which appears stable in at least four European countries(Hutchison et al., 2007; Ingram et al., 2015).

The task is to find ways of controlling the industry and ensuring that harvesting from production sites is kept within sustainable levels. In order to do so, research on the use and impacts of bark harvesting is urgently required (Cunningham et al., 2014; Tchouto et al., 2014; Meuer, 2007; WHINCONET, 2005; Geldenhuys, 2004).

The *Prunus* barks provided by the North West region is coming from both natural forests and private farms/plantations. In reality, the Cameroon quota does not yet include the *Prunus* barks existing in plantations. Most of those farms are still young, and the quantity of bark that can be harvested inside these farms is very small as compared to what can be obtained from natural forests. In spite of the restriction of *Prunus* harvesting in natural forests, trade companies collect the barks coming from farms. The farm monitored in Kumbo subdivision was settled in 2002, and was harvested ten years later, in 2012. This age (10 years) tend to be less than the recommended age (12 years at least) advised to ensure the efficacy of the bark. In fact, it takes 12 to 15 years for the tree to produce the bark that contains the prostate remedy's active ingredient (World Agroforestry Centre, 2012; Gachie et al., 2012).

An assumption tends to justify the use of *Prunus* from farms by the lack of sufficient stock in the natural forest, community forests, which may itself be caused by the limit method used for the estimation/calculation of the quota (Ingram et al., 2015). In theory, the possible absence or low density of *Prunus* in some annual plots (blocks 4 and 5 of MUTEF for example) of inventoried production sites is acceptable, due to the clustering feature of the species, and the type of inventories used to define the quota (estimation). *P. africana* is a scattered tree species (Ndam, 1996; Fraser et al., 1996), this means that there will be some areas of the forest where the species will be absent or less abundant. The second reason that can explain the lack of enough *Prunus* in

Table 7. Distribution of exploited trees in different diameter classes in Bloc 1 of Mount Cameroon, South west region of Cameroon.

Order number of the trees	Diameter (cm)	Diameter classes	Harvesting technique
1	120.1	Cl120_130	3x1/6
2	59.2	Cl50_60	2x1/4 opposite side
3	58.0	Cl50_60	2x1/4 opposite side
4	73.9	Cl70_80	2x1/4 opposite side
5	51.6	Cl50_60	2x1/4 opposite side
6	43.9	Cl40_50	2x1/4 opposite side
7	69.4	Cl60_70	2x1/4 opposite side
8	50.3	Cl50_60	2x1/4 opposite side
9	68.5	Cl60_70	2x1/4 opposite side
10	47.8	Cl40_50	2x1/4 opposite side
11	87.6	Cl80_90	2x1/4 opposite side
12	98.7	Cl90_100	2x1/4 opposite side
13	73.2	Cl70_80	Not harvested
14	71.7	Cl70_80	total
15	140.1	Cl140_150	3x1/6
16	73.9	Cl70_80	3x1/6
17	64.3	Cl60_70	3x1/6
18	95.2	Cl90_100	Not harvested
19	73.2	Cl70_80	2x1/4 opposite side
20	30.9	Cl30_40	Not harvested
21	111.5	Cl110_120	3x1/6
22	35.0	Cl30_40	2x1/4 opposite side
23	60.2	Cl60_70	2x1/4 opposite side
24	47.1	Cl40_50	2x1/4 opposite side
25	165.0	Cl150 et +	3x1/6
26	27.7	Cl20_30	Not harvested
27	62.7	Cl60_70	3x1/6
28	53.5	Cl50_60	2x1/4 opposite side
29	47.1	Cl40_50	3x1/6
30	325.2	Cl150 et +	3x1/6
31	109.9	Cl100_110	3x1/6
32	40.4	Cl40_50	2x1/4 opposite side
33	33.4	Cl30_40	2x1/4 opposite side
34	21.7	Cl20_30	2x1/4 opposite side
35	39.8	Cl30_40	2x1/4 opposite side
36	39.8	Cl30_40	2x1/4 opposite side
37	35.7	Cl30_40	2x1/4 opposite side
38	179.9	Cl150 et +	2x1/4 opposite side
39	37.9	Cl30_40	2x1/4 opposite side
40	49.0	Cl40_50	2x1/4 opposite side
41	56.4	Cl50_60	2x1/4 opposite side
42	43.3	Cl40_50	2x1/4 opposite side
43	63.7	Cl60_70	2x1/4 opposite side
44	58.0	Cl50_60	2x1/4 opposite side
45	52.5	Cl50_60	2x1/4 opposite side
46	72.6	Cl70_80	3x1/6
47	64.3	Cl60_70	2x1/4 opposite side
48	65.3	Cl60_70	3x1/6
49	55.1	Cl50_60	2x1/4 opposite side
50	36.3	Cl30_40	Not harvested

Table 7. Contd.

51	53.2	Cl50_60	2x1/4 opposite side
52	56.7	Cl50_60	2x1/4 opposite side
53	63.1	Cl60_70	3x1/6
54	101.9	Cl100_110	3x1/6
55	37.6	Cl30_40	2x1/4 opposite side
56	66.2	Cl60_70	2x1/4 opposite side
57	79.9	Cl70_80	3x1/6
58	54.8	Cl50_60	2x1/4 opposite side
59	97.1	Cl90_100	3x1/6
60	55.4	Cl50_60	3x1/6
61	120.1	Cl120_130	3x1/6
62	115.0	Cl110_120	2x1/4 opposite side
63	109.9	Cl100_110	2x1/4 opposite side
64	68.5	Cl60_70	2x1/4 opposite side
65	140.1	Cl140_150	3x1/6
66	58.3	Cl50_60	2x1/4 opposite side
67	119.3	Cl110_120	2x1/4 opposite side
68	16.1	Cl10_20	2x1/4 opposite side
69	56.4	Cl50_60	2x1/4 opposite side
70	135.4	Cl130_140	2x1/4 opposite side
71	78.5	Cl70_80	3x1/6
72	120.0	Cl120_130	3x1/6
73	130.0	Cl130_140	four on height (4/8)
74	73.1	Cl70_80	2x1/4 opposite side
75	56.4	Cl50_60	2x1/4 opposite side
76	61.5	Cl60_70	2x1/4 opposite side
77	61.3	Cl60_70	2x1/4 opposite side
78	16.1	Cl10_20	2x1/4 opposite side
79	37.0	Cl30_40	2x1/4 opposite side
80	66.9	Cl60_70	3x1/6
81	131.2	Cl130_140	four on height (4/8)
82	130.0	Cl130_140	four on height (4/8)
83	59.0	Cl50_60	3x1/6
84	45.0	Cl40_50	2x1/4 opposite side
85	57.4	Cl50_60	2x1/4 opposite side
86	46.0	Cl40_50	2x1/4 opposite side
87	54.9	Cl50_60	2x1/4 opposite side
88	38.0	Cl30_40	2x1/4 opposite side
89	149.7	Cl140_150	2x1/4 opposite side
90	175.2	Cl150 et +	3x1/6
91	132.2	Cl130_140	3x1/6
92	156.1	Cl150 et +	3x1/6
93	178.3	Cl150 et +	2x1/4 opposite side
94	42.8	Cl40_50	2x1/4 opposite side
95	126.0	Cl120_130	2x1/4 opposite side
96	42.7	Cl40_50	2x1/4 opposite side
97	25.5	Cl20_30	2x1/4 opposite side
98	43.4	Cl40_50	2x1/4 opposite side
99	53.6	Cl50_60	2x1/4 opposite side
100	32.0	Cl30_40	3x1/6
101	73.6	Cl70_80	2x1/4 opposite side
102	42.6	Cl40_50	2x1/4 opposite side

Table 7. Contd.

103	50.0	Cl50_60	2x1/4 opposite side
104	38.9	Cl30_40	2x1/4 opposite side
105	35.5	Cl30_40	2x1/4 opposite side
106	88.0	Cl80_90	2x1/4 opposite side
107	30.2	Cl30_40	2x1/4 opposite side
108	37.1	Cl30_40	2x1/4 opposite side
109	48.1	Cl40_50	2x1/4 opposite side
110	48.5	Cl40_50	2x1/4 opposite side
111	42.3	Cl40_50	2x1/4 opposite side
112	42.5	Cl40_50	2x1/4 opposite side
113	34.7	Cl30_40	2x1/4 opposite side
114	33.4	Cl30_40	2x1/4 opposite side
115	57.6	Cl50_60	2x1/4 opposite side
116	143.3	Cl140_150	3x1/6
117	44.5	Cl40_50	2x1/4 opposite side
118	37.6	Cl30_40	2x1/4 opposite side
119	70.1	Cl70_80	2x1/4 opposite side
120	176.4	Cl150 et +	3x1/6
121	51.0	Cl50_60	2x1/4 opposite side
122	51.4	Cl50_60	2x1/4 opposite side
123	59.9	Cl50_60	2x1/4 opposite side
124	178.3	Cl150 et +	Totaldebarking
125	98.5	Cl90_100	2x1/4 opposite side
126	61.5	Cl60_70	2x1/4 opposite side
Mean	73.3		

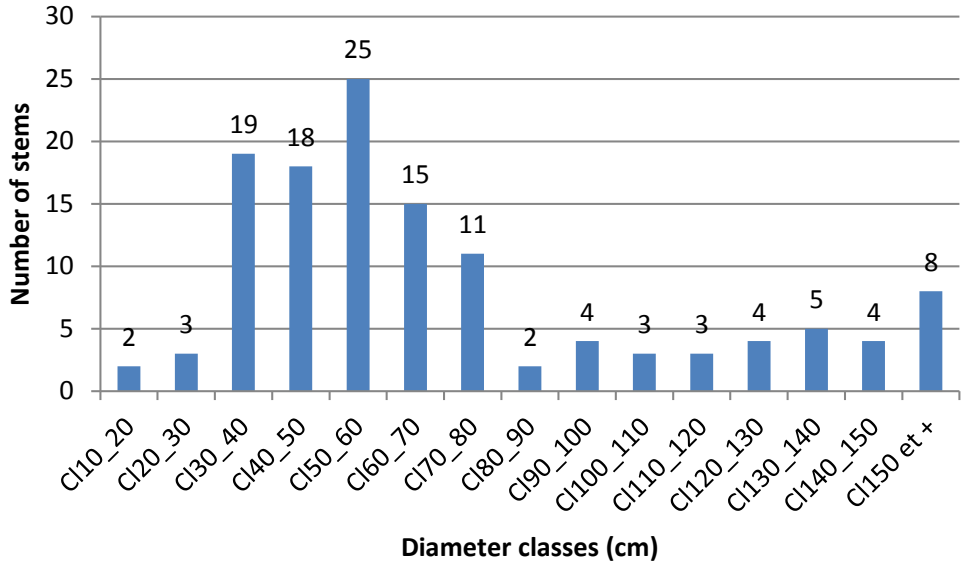

Figure 3. Distribution of Prunustrees harvested in different diameter classes in Bloc 1 of the Mount Cameroon PAU, South West region.

some plots is the type of the inventory used to define the quota. In fact, the *Prunus* quota was calculated based on management inventories. These are inventories conducted with low sampling rates (1 to 3%). The results

cannot be similar to those obtained with the systematic or exploitation inventories which are conducted at 100% of exploitable trees. The big difference observed between the estimated quota and the real quota harvested in the four first years in the Mount Cameroon PAU is due, not only to the scattering feature of *Prunus* or the sampling method used (management inventory), but mostly to the unequal delimitation of the annual plots by the local forest officers. The national standards suggest dividing the total useful area of the production site by the rotation to obtain the surface area of a single annual plot (bloc). In the case of the Mount Cameroon national park, the useful area defined during the 2010 management inventories was 22 000 ha. On this basis, a single annual plot was supposed to have about 4 400 ha. The park service decided an arbitrary delimitation of annual plots (blocs), independent of the useful area and quotas. The total surface area delimitated for the five plots is 32 800 ha, which is 1.5 times high as compared to the useful area estimated by the 2010 inventories (Betti et al., 2011). In the arbitrary delimitation, the blocs 3 and 5 are twice larger than the blocs 1 and 2. The bloc 4 is thrice higher than the blocs 1 and 2. In this context, one cannot expect an equal annual quota of 130 tons for all blocs in the Mount Cameroon. If the park service officers wanted to be rational, they should reconsider the 2010 management inventory data per delimitated blocs, limiting the quota in the lines identified in each bloc, instead of mixing all. Anyway, based on the results obtained in real *Prunus* production in different regions, it is essential that the annual quota be calculated based on the exploitation inventories which are done at 100% of exploitable trees. Data from management inventories are still important since they guide the decision of harvesting in a given production site based on the population structure and density of trees.

Some 73% of the total number of the trees sampled in the MUTEF community forest in the Boyo division and 94.7% of those sampled in the plantation surveyed in the Bui division (Kumbo) were harvested below the MED (30 cm). In Mount Cameroon, only 4% of trees sampled were harvested below the MED. If we consider an annual growth rate in diameter of 0.7 cm, it can be said that most of the trees were harvested at diameter of 23.5 cm in the Boyo and 18.5 cm in the Bui division. These results (diameter) are 1.3 times less than the authorized MED in the Boyo and the half (1/2) of the required MED in the Bui division. These findings corroborate with what was explained by the Manager of the MUTEF community forest (CFM) concerning the behavior of harvesters in reaction to the low buying price practiced in the North West region. The buyer (local trade company) in the North West buys the bark of *Prunus* at very low price, which discourage the harvesters. The buying price used by the trade company in the North West is 130 FCFA/kg of fresh bark, which is 4.23 times less than the 550 FCFA/kg practiced in the Mount Cameroon National park. As results, the local CFM do not have enough funds to support the exploitation inventories; and we assist in the overharvesting of *Prunus* trees in first blocs. In mount Cameroon, the average cost of exploitation inventories is 2 434.0 FCFA/ha. If the trade company practiced the same buying price (550 FCFA/kg) used in the Mount Cameroon in the North West (Boyo division), the CFM could use 1/3 of its part (15.4% of the total revenue yield by the bark) to support exploitation inventories without any problem and keeps the remaining funds for development projects. Also, due to the low buying price practiced in the North West, harvesters prefer over-harvesting trees harvested in the first annual plots (blocs) or in the adjacent private farms using bad techniques, than taking the risk to go far in the forest to harvest in authorized plots. Harvesters in the MUTEFF community forest do not respect national norms for the harvesting of *P. africana* in terms of the diameter and the techniques of harvesting. This problem is more crucial in the private farms where harvesters do not hesitate to debark totally some trees. These findings tend to show that the current harvesting scheme of *P. africana* in the North West region is detrimental to the survival of the resource and then to the survival of the *Prunus* trade in Cameroon.

The Cameroon CITES MA continues to grant the annual quota of 150 tons from community forest of North West in spite of the ban of harvesting in the Bui division. Finally, trade companies obtained their products from un-authorized forests (plantation/farms). This problem, coupled with the usage of false documents to convey *Prunus* barks by some traders, outlines the urgent need to settle a fair tracking system which will be able to really fix the harvesting of *Prunus* in the space. The ongoing ITTO-CITES program activities on the settlement of a tracking system using DNA to better control the origin of the barks is therefore welcome and should be extended to all PAUs in Cameroon. In general, the study noted that, it is in the North West region where harvesters do not really respect the norms of harvesting in terms of harvesting techniques and exploitable diameter. This situation is more observed in private farms/plantations where there is no control. The sustainable management of *Prunus* requires a lot of financial and technical inputs. The relatively good results recorded in the Mount Cameroon may be attributed to the financial and technical support of the Programme for the sustainable management of natural resources in the South West region of Cameroon (PSMNR-SWR).

Conclusion

Cameroon Government has made many efforts to promote the sustainable harvesting of *P. africana* in the country, but many problems still remain in the implementation of the guidelines prescribed in the NDF or SMP. The forest administration should fix the minimum buying price of *Prunus* as to avoid the destruction of the

resource in the forest. This study did not cover the Adamawa region considered as the most important in terms of the contribution in national quota (more than the half: 600 tons of dried bark). It is assumed that the same problems observed in non-control areas such as in the North West region can be observed here, and may be with very bad situation. In this region, peoples are not organized in community forests as in the North West nor in a kind of association as in Mount Cameroon with MOCAP. Villagers directly faced local trade companies who may decide to pay what they want. It is recommended that the study be extended to that region to better have a global idea of the Cameroon situation. There is an urgent need for the ITTO-CITES program to extend its activities to the implementation of the simple management plans developed. This includes: delimitation of annual plots on useful forests, conduction of exploitation inventories, setting fair tracking system, sylviculture (nurseries and plantations), training harvesters on the use of good techniques, conducting research to better refine management parameters.

Conflict of Interests

The authors have not declared any conflict of interests.

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Abbreviations

ACS, Adaptive cluster sampling; **ANAFOR,** National Forestry development Agency; **CF,** community forest; **CFM,** community forest manager; **CIG,** community initiative group; **CITES-MA,** CITES management authority; **CITES-SA,** CITES scientific authority; **DBH,** diameter at breast high; **MED,** minimum exploitable diameter; **MINFOF,** Ministry of Forestry and Wildlife; **MOCAP,** Mont Cameroon Communities Association; **NDF,** non-detriment findings; **NTFP,** non-timber forest products; **PAU,** Prunus Allocation Unit; **PSMNR-SWR,** program for the sustainable management of natural resources in the south west region of Cameroon; **SMP,** simple management plan; **USD,** United States Dollar.

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